Analysis Procedures Manual

Version 2

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PREFACE/FOREWORD

Overview of Manual Purpose

The Analysis Procedures Manual (APM) was created to provide a comprehensive source of information regarding current methodologies, practices and procedures for conducting analysis of Oregon Department of Transportation (ODOT) plans and projects. Although this information is extensive, it is not intended to be exhaustive. For example, this manual does not fully address detailed topics such as Region safety investigations, the traffic signal approval process, or development review policies which are covered elsewhere.

The APM shall be utilized by ODOT staff as well as external consultants and contractors conducting and reviewing plans, projects and/or studies for ODOT. It also applies to work performed under ODOT Grants.

The procedures addressed in this manual have been generally organized to follow the progression of analysis conducted for a typical transportation plan or project. It begins with project scoping and data collection, proceeds through the analysis and concludes with the production of the final report. There are examples provided to "walk" the user through a process.

The APM is generally based on methodologies found in the Highway Capacity Manual (HCM). However, there are many locations in the APM, either because of limitations in the HCM or because of ODOT policies, where the APM recommends different methodologies to address these issues. Traffic analyses shall use the current edition of the HCM in effect at the start of the analysis unless otherwise specified in the APM.

While the direction provided represents recommended practices for producing consistent and accurate results, it should be recognized that every project analysis presents a unique set of opportunities and constraints. Persons applying the APM should consider relevant situation-specific factors including, but not limited to, cost, funding availability, environmental impacts, sustainability, economic development needs, community support, community vision, land use planning context, practical design, and other similar considerations as appropriate. The best alternative from a traffic analysis standpoint, may not be the best alternative for the project.

While working on various types of projects, a number of situations may arise requiring analysis methodologies not discussed in this manual. If ODOT does not have a preferred analysis methodology to offer, there are a number of technical resources available for consultation. Non-standard analysis proposals shall include thorough documentation of assumptions, methods and calculations in a methodology memorandum. Alternative methodologies must be approved by ODOT prior to analysis.

This manual is not intended to replace the need for sound engineering judgment, which must continue to be a vital part in the process of applying the methodologies to individual studies. Thorough documentation of key assumptions, decisions, and findings should be provided and archived with project files for future reference/use. Further, early and frequent collaboration between jurisdictional staff, consultants, contractors, and stakeholders involved in the analyses will help ensure that the project goals are met.

Note: All references in this manual to the Department refer to ODOT, and all references to Regions relate to ODOT Regions.

Manual Structure

Acronyms are shown in parenthesis after a term, phrase or reference is listed the first time. The acronym is used thereafter in the text.

Manuals, papers and other publication titles are italicized.

There are a number of references to web sites, web pages and web accessed documents. Many of these references are links within the document shown with blue, underlined text.

Examples are identified with a solid bar the width of the page at the beginning and end of each example.

Points that are critical for the analysis process are displayed as a box in italics with the stop sign icon.

Additional information to consider is displayed as a box in italics with the yield icon.

Manual Updates

Analysis techniques and project requirements change over time. The ability to immediately incorporate new information into this manual is essential to providing users with the most current resource possible. To accommodate expedient updating, the APM has been designed as an on-line tool, and the on-line version is the official document.

As this is an on-line document, and will not be published and distributed as a traditional publication, there is no user list for update notifications. It is the user's responsibility to verify they are using the most current version of information as their reference. Updated pages will have the change date as part of the document footer.

Please send your questions, comments and feedback to: APM@odot.state.or.us.

Manual Website

The on-line version of this document is available at:
http://www.oregon.gov/ODOT/TD/TP/pages/apm.aspx

Detailed document updates are available on the web page so that users can identify what has changed and when. Supporting information, data and tools used in this manual are available on the Planning Section Technical Analysis and Tools webpages at:http://www.oregon.gov/ODOT/TD/TP/pages/reports.aspx#Publications
http://www.oregon.gov/ODOT/TD/TP/Pages/Data.aspx
http://www.oregon.gov/ODOT/TD/TP/Pages/Tools.aspx

Periodic Training

TPAU offers some training related to this manual, generally related to new topics or methodologies. The ODOT APM User Group is a quarterly venue for training and discussion on APM procedures. Contact APM@odot.state.or.us to inquire about user group meetings or other training opportunities.

1 ODOT INFORMATION

1.1 Purpose

This chapter is an overview of ODOT, how it is organized and where transportation analysis is within the organization. This section also lists some of the typical units and groups that analysts may need to work with.

1.2 Coordinating with ODOT

The Oregon Department of Transportation (ODOT), through its various Divisions, is responsible for developing Oregon's:

- System of highways and bridges
- Bicycle and pedestrian paths
- Public transportation services
- Rail passenger and freight systems
- Driver licensing and vehicle registration programs
- Motor carrier operations, and
- Transportation safety programs

The following section describes various divisions, sections and units within ODOT that are commonly involved in decision making regarding transportation system planning, design and operations. One or more of these units may need to be contacted for input or to discuss problems and possible solutions regarding a specific project. It is preferable to begin with staff at the Region or District level.

1.2.1 Transportation Development Division

The Transportation Development Division (TDD) is the part of ODOT that:

- Facilitates long and short-term transportation planning
- Keeps statistics about transportation
- Considers transportation policy
- Conducts research to help engineers, planners and project designers
- Helps local governments with transportation through a variety of programs and services.

TDD is comprised of four sections: 1) Active Transportation, 2) Planning; 3) Research; and 4) Transportation Data.

Active Transportation Section

The Active Transportation Section is comprised of the following: 1) Economic & Financial Analysis Unit; 2) Program & Funding Services Unit; 3) Statewide Programs Unit.

The Economic and Financial Analysis Unit provides Highway Fund revenue forecasts, economic and feasibility studies, cash flow forecasting, revenue impacts, and DMV transaction analysis. In addition, the unit provides economic, financial and policy studies to determine Highway cost

allocation, tax comparisons, transportation finance, value of travel time and cost of delay estimates, and job and income generation impacts of construction projects.

The Program and Funding Services Unit of the Active Transportation Section is responsible for the development of the Statewide Transportation Improvement Program (STIP), Project Funding, Financial Plan and Project Accounting.

The Statewide Programs Unit provides educational opportunities, technical support and federal oversight to ODOT Regions, local agencies, consultants, and other transportation partners. The Unit administers the following programs including:

- Bicycle & Pedestrian Program (This includes the planning and funding/grant programs only as the designs and standards are under the Highway Division's Traffic-Roadway Section)
- Certification Program for local agencies
- ConnectOregon
- Funding Programs
- Transportation Enhancement
- Safe Routes to Schools
- Scenic Byways
- Sustainability

Planning Section

ODOT's central Planning section is comprised of four units: 1) Programs and Economic Analysis Unit; 2) Transportation Planning Unit; 3) Freight Planning Unit: and 4) Transportation Planning and Analysis Unit (TPAU). This section provides direction for long term management and improvement of Oregon's transportation system and to promote the cost-effective use of public funds through effective research, development and technology transfer.

The Programs and Economic Analysis Unit (PEAU) manages the Transportation and Growth Management Program (TGM), the State Planning and Research Program (SPR), Economic Analysis Services for the entire agency and jointly manages significant plans, initiatives, and projects. These currently include Least Cost Planning, and Tolling Policies and Rules for example. PEAU works closely with programs such as Flexible Funds, Connect Oregon, and others to help ensure planning program consistency, coordination, and implementation. There are also TGM planners based in the five ODOT Regions to lead and coordinate the TGM program.

The Transportation Planning Unit (TPU) is responsible for statewide long range planning and policy development, including creation and maintenance of the Oregon Transportation Plan and other modal plans, such as the Oregon Highway Plan. In addition, TPU is responsible for implementation of plans and policies through the preparation and dissemination of multi-modal, modal, and topic plans, policies, guidelines and administrative rules. A primary role is to provide assistance designed to help achieve statewide consistency for transportation planning products and activities. In the development of planning and implementation materials, TPU actively works with stakeholder committees and works to balance needs. They also respond to legislative requirements, including initiatives such as Least Cost Planning and greenhouse gas (GHG) reduction planning, known as the Oregon Sustainable Transportation Initiative.

In addition, each of the five ODOT Regions also has long-range planners who are familiar with the local government Transportation System Plans (TSPs) and Comprehensive Plans. They coordinate directly with City and County jurisdictions, within their respective Region, to ensure transportation impacts due to private and commercial development are sufficiently mitigated. These planners typically lead the various transportation planning efforts such as refinement plans, interchange area management plans, and transportation system plans.

The Freight Planning Unit (FPU) coordinates public-private, state-local and state-federal freight transportation investment decisions and activities on a state-wide and state-to-state basis to support goods movement and the Oregon economy. FPU is responsible for developing and implementing the Oregon Freight Plan, and supporting the integration of freight issues into the State's modal plans, corridor plans, and other planning documents and activities. They manage freight transportation studies and intermodal planning programs and projects, including highway, rail, marine, pipeline and air transportation.

The Transportation Planning Analysis Unit (TPAU) provides support and guidance for the development of corridor and urban transportation system plans, transportation model development and use of computer models to forecast transportation needs. TPAU also supports ODOT's project development process by conducting transportation analysis to aid project selection for the Statewide Transportation Improvement Program (STIP) and developing data for environmental analysis. TPAU often acts as a resource to Region Traffic Units requesting technical assistance. TPAU performs analysis and modeling for Regions 2-5. Analysis conducted in Region 1 is the responsibility of the Region 1 Traffic Section. TPAU is made up of three teams:

> The Facility Analysis and Simulation Team conducts, reviews, and provides technical support on a wide variety of studies, including transportation system plans (TSPs), refinement plans, project development, and management plans. The team also maintains the Analysis Procedure Manual.
>
> The Statewide and Urban Modeling Team works closely with jurisdictions throughout the state to develop, maintain, and apply state-of-the-art travel demand models for small urban areas, metropolitan areas, regions, counties, and statewide. The team also has developed and is maintaining a statewide travel demand model that integrates transportation, land use and economics to provide a reliable way to forecast and evaluate policies.
>
> The Systems Analysis Team is responsible for evaluating new alternative performance measures, mesoscopic tools, and system planning analysis methods. The team also does system planning analysis using the Congestion Management System (CMS) and the Highway Economic Reporting System (HERS) that decision-makers use to find cost-effective ways to manage transportation facilities that alleviate traffic congestion.

Research Section

The Research Section oversees the state's federally funded research, development and technology transfer program with particular emphasis on new technology intended to enhance the performance of Oregon's transportation systems. Major current research focuses on safety,

infrastructure repair and preservation, maintenance practices, innovative contracting and project delivery, sustainable environmental practices, and the land-use, transportation connection.

Transportation Data Section

The Transportation Data Section (TDS) collects substantial data for system inventory, volumes and crash information that can be used for the purpose of conducting traffic studies. Because much of this data is collected and processed by different units within the Department, clear and frequent communication between units regarding what is desired and what is available is critical for ensuring these resources are readily accessible. Furthermore, good communication between units will help to obtain the right data in a timely manner, which is important for maintaining project schedules. Coordinate with the appropriate ODOT department or staff as noted below.

The Crash Analysis & Reporting Unit (CARU) provides motor vehicle crash data through database creation, maintenance and quality assurance, information and reports, and limited database access. Ten years of crash data is maintained at all times. Vehicle crashes include those coded for city streets, county roads and state highways.

The GIS Unit (GISU) serves the Oregon Department of Transportation by providing geographic information products and services through the development of spatially-enabled applications, databases, mapping products, analysis, education and technical support.

Road Inventory and Classification Services (RICS) Unit collects and maintains road information necessary to classify and monitor the highways, roads, and streets within Oregon; provides mileage statistics; develops, maintains, and enhances ODOT's corporate data base known as the "Integrated Transportation Information System" (ITIS); maintains the Public Road Inventory which is a compilation of information about the status and condition of the road system in Oregon; and films and maintains the State Highway Digital Video Log. From data gathered, reports such as the Federal Highway Performance Maintenance System (HPMS) submittal and the Oregon Mileage Report are written.

The Transportation Systems Monitoring (TSM) Unit develops and maintains a system to collect and process traffic related data on Oregon's Highways. TSM provides traffic volumes, flow maps, trends, manual counts and vehicle class on state highways to Federal, State, Local, private and public constituents.

1.2.2 Highway Division

The Highway Division consists of a wide array of disciplines involved in the operations, construction and maintenance of the state's highways, bridges and other parts of the transportation system.

Traffic-Roadway Section (TRS)

This section prepares specifications, maintains standards for traffic devices and related facilities and provides design expertise in materials, operations and construction support services. TRS consists of five central units under the authority of the State Traffic Engineer:

- Roadway Engineering – This unit is responsible for roadway standards and manuals, including the Highway Design Manual. It issues design exceptions and technical bulletins related to highway design. This unit includes interchange design, value engineering and the engineering portions of the bicycle and pedestrian program.
- Office of Project Letting (OPL) – This unit is responsible for the preparation of project plans, specifications, cost estimates as well as the process of bid letting and quality assurance of project documentation.
- Geometronics – This unit consists of the maps and plan center, photogrammetry and the central units related to surveying which includes geodetic control and preparation of official survey documents.
- Traffic Engineering – This unit consists of groups that oversee signal operations, the speed zone investigations, highway safety engineering and traffic investigations. This is the unit that typically reviews and oversees State Traffic Engineer approvals.
- Traffic Standards; - This unit is responsible for project plans, specifications and standards for signs, striping, signals, illumination, traffic structures and work zones.

The State Traffic Engineer has delegated authority to approve the installation of all traffic control devices on state highways, including installation of new signals and major modifications to existing signals. All delegated authority requests for State Traffic Engineer approval should follow roughly the same process.

- Consultation with Region Traffic Unit; and
- A request sent through the Region Traffic Manager/Engineer with supporting documentation.

A list of items that require approval by the State Traffic Engineer for use on state highways can be found in the ODOT Traffic Manual.

Region Traffic Units

Region Traffic Units provide expertise to region and district staff on current traffic policies and procedures. Staff is responsible for overseeing all traffic engineering design (including signal and sign design) for Region projects. Staff actively participates as members of project development teams (PDT) to help insure traffic related issues are considered early in the process, and to provide traffic information to the team. They also act as the traffic liaison to local agencies on behalf of ODOT and can be a data source for traffic signal timing sheets and various operational investigations.

The Region Traffic Manager/Engineer may authorize standard applications and some modifications of traffic control devices that are in compliance with the principles outlined in the Manual on Uniform Traffic Control Devices (MUTCD) and applicable ODOT policies and guidelines. Items that may be authorized by the Region Traffic Manager/Engineer are listed in the ODOT Traffic Manual.

Access Management Program

The Access Management Unit (AMU) is part of the Technical Services Branch of the Highway Division. The AMU is responsible for statewide development and administration of the

Department's access management program statutes, rules, and policies.

The Access Management Unit is primarily tasked with the following:

- Training agency staff, consultants and local governments;
- Administering the approach permitting database (CHAMPS – Central Highway Approach Maintenance Permit System);
- Developing administrative rules;
- Conducting appeals procedures;
- Providing technical consultation, guidance, and training to support Region and District offices;
- Developing new program initiatives;
- Establishing statewide performance measures and customer service standards;
- Performing research and program evaluation.

In the Regions, Access Management staff implements the policies and guidelines developed by the Access Management Unit. They report to either the Region Traffic Manager or the Region Planning Manager. The Region Access Management Engineer (RAME) is the Region technical expert for access management issues. Tasks include:

- Fielding Access Management applications from private interests;
- Coordinating the Access Management Process between ODOT technical staff, the applicant, and their representatives (i.e. engineering consultants, lawyers);
- Reviewing technical data (i.e. traffic studies) submitted by the applicant, or the applicant's representative;
- Approving or denying access application requests and issuing approach permits.

Bicycle and Pedestrian Program

This program is headquartered within TRS and provides technical assistance to the Department and local officials regarding pedestrian and bicycle design, construction and maintenance. The planning and grant funding portions of the program are under the Transportation Development Division (TDD) Active Transportation Section. Regions typically participate in planning and project development to ensure that bicycle and pedestrian needs are met. They are the resource whenever bicycle or pedestrian improvements are proposed or existing facilities are affected by other proposed improvements.

Construction Section

The Construction Section administers statewide construction policies, procedures and processes and provides construction expertise and training programs. The traffic analyst may provide traffic data to the Pavement Services Unit for use in pavement design on projects.

District Maintenance Offices

The District Maintenance Offices are responsible for the on-going preservation and operation of state transportation facilities and the permitting of all activities (utility, access, miscellaneous) within the highway right of way. They are familiar with local issues and the operational and maintenance history of individual highways, and can offer valuable input during the

identification of needs and alternatives, in addition to tracking the status of existing permits. Because they are ultimately responsible for maintaining any proposed improvements, they should be consulted during the selection and design.

The Mobility Unit coordinates the construction/maintenance work zone and other restrictions that may impact freight movements as well as oversize loads. It mainly does this through the Highway Mobility Operations Manual. This guide sets project standards and minimum requirements regarding communication and coordination, vertical and horizontal clearance, bridge weight restrictions, delays, detours, staging, and design.

Region Environmental/Geo-Environmental Section

The Geo-Environmental Section is responsible for coordinating environmental regulatory compliance for all transportation improvement programs in the state which use federal funds. The section is responsible for statewide practices, standards, training, expertise, and asset management for geology, geotechnical, and environmental disciplines within ODOT. Within the Section, the Air Quality, Acoustics & Energy Program studies and mitigates the effects of transportation projects by using the environmental traffic data furnished by the traffic analyst in order to model air quality, noise and energy impacts. Region staff includes the Environmental Program Managers (EPMs) who handle the environmental issues on projects, lead the NEPA (National Environmental Policy Act) process, and manage consultants writing environmental documents.

Potential issues requiring involvement of the central or region environmental staff includes:

- Environmental justice
- Threatened and endangered species
- Wetlands
- Historic buildings
- Air quality
- Noise
- Erosion control
- Stream-bank stabilization
- Fish passage
- Storm water quality and quantity

Right of Way (ROW)

ODOT's central Right of Way Section provides expertise in real estate and other right of way matters to the Department. The ROW Section is responsible for:

- The appraisal, acquisition, and management of property acquired for public projects.
- Assisting people and businesses in relocating from the acquired rights of way.
- Administering, directing and supervising the various programs that reside in the Right of Way Section.

The five ODOT Regions each have their own Right of Way section. The Region Right of Way sections deal with the acquisition of real property and improvements necessary for the

construction and maintenance of Oregon's transportation system. They also are tasked to maximize the return on the Highway Trust Fund's real property investment through efficient management and sale of surplus property.

Roadway Engineering

The central Roadway Engineering group, which is part of the Traffic-Roadway Section (TRS), is responsible for many aspects of the project development process. Responsibilities such as the Highway Design Manual, Standard Drawings, and the Contract Plan Development Guide, which are essential to the development of projects and the preparation of Contract Plans.

Region Roadway Engineering is responsible for the design of new highways and highway features and is located in each of the region technical centers. Early consultation when evaluating potential improvements can help in identifying fatal flaws and ensure design standards can be met before recommending an alternative. The primary difference between Headquarters Roadway Engineering and Region Roadway Engineering; TRS Roadway sets ODOT highway design policies, plus issues specifications and standards for both ODOT and consultant technical staff. Region Roadway Engineering staff implements the design standards by developing plans, cost estimates and specifications for roadway project within their respective Region.

1.2.3 Other Key ODOT Divisions

Public Transit Division

Public Transit Division is the grantee for Federal Transit Authority (FTA) funds, and is responsible for state-level transit program development and management. The division is responsible for assuring the compliance requirements associated with FTA and state funds are met, even when compliance is primarily the obligation of its recipients. Public Transit provides grant management and oversight of projects and activities supported with state and federal transit funds. Technical assistance is provided on an ongoing basis to transit agencies.

Rail Division

The Rail Division has jurisdiction over railroad crossings and traffic control devices used within crossing areas. They also have exclusive legal authority over public grade crossings and provide coordination with the railroads for affected private rail crossings. The Rail Division should be contacted any time a project may have an impact directly to or within 500 feet of a railroad or rail crossing.

Traffic Safety Division

The Traffic Safety Division provides information, direct services, grants and contracts to the public and to partner agencies and organizations. More than half the funding comes from federal funds earmarked for safety programs.

1.2.4 Other Groups

The Aviation Department establishes and enforces airport planning rules, funds infrastructure improvements, and coordinates efforts to improve airport and airplane safety. When developing projects adjacent to a public or private airport, the airport's runway flight triangles must be taken into consideration, to avoid conflicts. Also, it is a mode of transportation, which should be considered by ODOT staff and consultants when developing Transportation Impact Analyses (TIA), Transportation System Plans (TSP) and other plans.

Appendix 1A – ODOT Traffic Engineering Authority

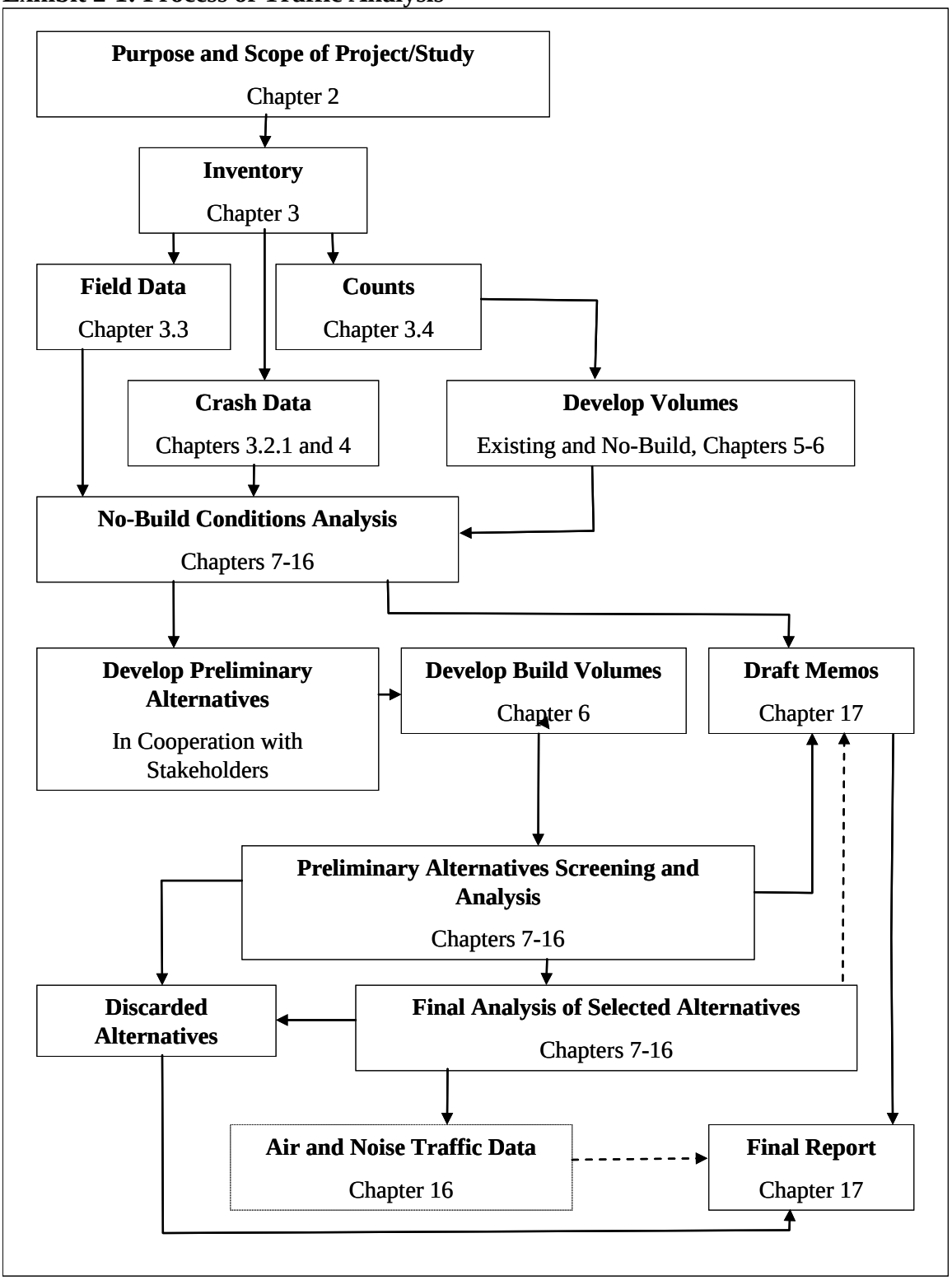
2 SCOPING PROJECTS

2.1 Purpose

The purpose of this chapter is to provide guidance to identify the various steps for scoping the analysis of a transportation study or project. The general flow of traffic analysis steps and the corresponding APM chapters are shown in Exhibit 2-1 below.

The first step is to have a thorough understanding of the work which is identified in a problem statement. The next step is to identify the appropriate level of detail and tools. The last step is to then create a scope of work for the study or project.

Exhibit 2-1: Process of Traffic Analysis



2.2 Problem Statement

2.2.1 Project Understanding

One of the most important steps in conducting analysis work is to clearly define the scope and purpose for the work. Every plan and project is unique with its own set of assumptions and applicable methodologies. There needs to be a clear understanding of what needs to be done by when and at what cost. The understanding should be conveyed through a problem statement that clearly defines the purpose and need for the work. The problem statement is the basis for either creating an analysis work plan for in-house work or for creating a scope of work for contracted work. A detailed scope of work or work plan helps to limit scope creep and lays out expectations for all parties. A problem statement template is available in Appendix 2A.

Information on geometrics, safety, volumes, past studies, prior projects, other analysis performed along with standards, guidelines, and procedures is available and should be used to gain general knowledge of the study area. There may be a project prospectus or initial planning/environmental documents available as well. The analyst should consult or coordinate with the project team to complete the problem statement. There are many useful tools and resources available on the ODOT website. Major sources are explained in Chapter 3.

2.2.2 Project Constraints

Various constraints need to be considered when the work is scoped. If any of these change during the project duration, the problem statement and scope of work should be reassessed and consequences determined. Most constraints fall into two categories. The first is project specific, given the details of what is needed. The second is the project delivery constraints related to delivery /completion date and budget for the work.

The analysis work is controlled by various project factors, issues and concerns. The following questions can focus the problem statement:

- What is the Purpose and Need for the work?
- What questions need to be answered?
- What key issues should be considered?
- What are the Goals and Objectives of the work?
- Who is the audience?
- At what level will the work need to be analyzed and evaluated?
- What types of alternatives need to be evaluated?
- What evaluation measures will be used?
- What is the overall and traffic analysis study area, if different?
- What types of useable information and tools are available and practical?

The purpose and need, goals and objectives and questions and issues typically are determined by a project team, however direction can come from statutes (ORS), rules (OAR), legislation, the Oregon Transportation Commission (OTC), ODOT management, or local jurisdiction. The level of work, types of alternatives and the evaluation measures comes from a process or project/study management team. The study area, tools and information available influence the work. For example, a study in the Portland Metro area can rely on data from “PORTAL” which has very

detailed volume information on the freeways. The rest of the state must rely on physical counts or nearby data recorders to obtain volume information. This difference can be a constraint on the project. Similar to data, the choice of performance /evaluation measures can also be a constraint. Chapter 10 provides more guidance on performance measures and their data needs.

2.2.3 Schedule, Resource, and Budget Constraints

The work is driven by a need to deliver an answer in an identified time frame with an identified resource. Questions to identify these factors include:

- What is the timeframe for the analysis work?
- What are the impacts from changes to Purpose and Need?
- What are the risks from outside sources such as other jurisdictions, stakeholders, and private citizens? For example, local concerns/issues/ politics can easily add time to a projected schedule.
- Are there outside factors or time constraints that may dictate delivery of work items? For example, crash information is needed but cannot be obtained in the specified time frame.
- What resources are available? Are they internal or external?
- Are tasks dependent on resources not within analyst's control?
- Does the project funding require certain analysis tools and procedures?
- Is the budget adequate to perform the desired analysis and data collection?
- What is the availability and quality of existing data?
- Can the work be divided? Are tasks independent of each other? Are tasks sequential or concurrent?

2.2.4 Additional Details

After the problem, schedule and budget constraints are completed, additional thought needs to be given to what likely performance measures and tools will be used in the project. A project objective will have specific evaluation criteria/measures that will require a particular performance measure which then will require a certain tool to be used. Level of detail (see Section 2.3), and constraints will determine which tools (see Section 2.4) are practical for the effort. This can be somewhat iterative, so the problem statement may need to be modified as the scope of work or internal work plan is constructed.

For example, under a project goal or objective of mobility, the evaluation measure may be travel time. This might be measured by the buffer index which would require either a travel demand model or a micro-simulation depending on the level of detail needed at a particular step in the process.

Once the steps in this section and the previous sections are completed, this will give the analyst the basis to create the scope of work analysis tasks or an internal analysis work plan.

Example 2-1 Problem Statement

The below is an example project statement which includes a summary of the field scoping conditions and the defining statement questions and constraints.

OR193 is an older congested regional highway (not a freight route) in an urban arterial corridor within the city of River City. The highway is mostly four lanes undivided (no center turn lane) with a 35 mph posted speed and an average daily traffic load that exceeds 25,000. The corridor has dense retail/service commercial development with limited right-of-way along its length. There are numerous driveways, many closely spaced, because of past uneven growth patterns. Parking and bike lanes are spotty along the length. Sidewalks are curb-tight with many poor slopes in driveway areas and sub-standard curb ramps. In addition, a number of the intersections are high-crash locations. Congestion extends through the peak hour as a significant bottleneck exists in the study area at a bridge over a local small river. The bridge is still structurally acceptable but functionally obsolete with only two lanes, no bike lanes, narrow lanes and sidewalks. The city wants revitalize the corridor with urban renewal and thus wants to improve it for all users, not just vehicles. Efforts to improve access management in the past have met with resistance from property owners. An improvement project has been listed for this location in the City's Transportation System Plan.

The project has been scoped and meets the needs for an Environmental Assessment (EA) because of the potential impacts. A draft project Purpose and Need (P&N) has been developed: "The purpose of this project is to improve multimodal mobility, increase safety, and enhance the economic development potential of the corridor." Some draft Goals and Objectives have been formed aligning with the P&N on mobility, safety, environmental, limiting natural and built-up impacts, and economic development.

The project needs to conform to practical design objectives so that the alternatives can stay within a 25-50 million dollar range. This would keep the project reasonably likely so it could be included in the next available State Transportation Improvement Plan. A travel demand model is available for the area.

Problem Constraints

- What is the Purpose and Need for the work?
    - From the draft P&N: "The purpose of this project is to improve multimodal mobility, increase safety, and enhance the economic development potential of the corridor."
- What questions need to be answered?
    - What are the base conditions to help define the project need? What are the actual congestion and safety problems? What are the future conditions? What is the impact of access management on congestion? What are the pedestrian, bike, and transit needs in the corridor? Are there cost-effective alternatives available that can address most of the issues?
- What key issues should be considered?
    - Whether to widen or to build a new vehicle and/or ped/bike bridge
    - Balancing different modal needs
    - Access management and parking impacts to properties
- What are the Goals and Objectives (G&O) of the work?
    - From draft G&O document: Mobility, safety, environmental, limiting natural and built-up impacts, and economic development.
- Who is the audience?

    - The audience is multilevel with state and local staff and stakeholders (i.e business groups, bike community, neighborhood associations, freight users) and the general public.
- At what level will the work need to be analyzed and evaluated?
    - Alternative concepts will need to be evaluated on a screening basis.
    - Once concepts are more developed into alternatives, then the alternatives can be analyzed at key locations using deterministic tools.
    - The final set of build alternatives that go into the EA (including the no-build) are analyzed in full detail including simulation, multimodal and predictive safety tools. Air & Noise traffic data will be required for the final alternatives.
- What types of alternatives need to be evaluated?
    - No-build (this is what other alternatives are measured against)
    - Possible future land use alternatives as this drives the future improvement needs (this would need to be settled first before getting into detailed analysis).
    - Couplet (new) alignments
    - Bridge replacement
    - Road diet to better accommodate other modes
    - Wider or better utilized right-of-way to improve multimodal, parking and mobility needs including bridge widening.
    - Transportation System Management (TSM)/Safety improvements including painted/raised medians, center turn lanes, improved crosswalks, and improved access management.
    - Alternative strategies such as a new ped/bike bridge, off-street parking, transportation demand management (TDM), or TSM.
- What evaluation measures will be used?
    - Ones that are applicable to this project area include: These can include: volume-to-capacity ratio (v/c), level of service (LOS), queuing, travel time, delay, emergency response time, multimodal level of service (MMLOS), ped/bike system connectivity, accessibility, duration of congestion, percent crash reduction, expected crashes, access spacing, and conflict points.
- What is the overall and traffic analysis study area, if different?
    - Land use and bridge scenarios will require a city-wide look initially to determine if any significant negative impacts exist on areas potentially outside the project limits. If these occur, and the alternatives will still be pursued, then the project limits and/or the analysis study area may need to be modified.
    - Because this is a congested area and traffic simulation will be necessary, the study area will need to go out two signalized intersections outside of the project limits (area of potential impact). The project will at least need to go a couple of block on each side of the highway to accommodate the couplet alternatives.
- What types of useable information and tools are available and practical?
    - Inventory data, some counts, analysis and modeling work done for TSP
    - A travel demand model and local modeling staff time is available.
    - Mesoscopic methods (i.e. windowing out of a model area)
    - Highway Capacity Manual (HCM) and Highway Safety Manual (HSM) methods
    - Micro-simulation

Schedule, Resource, and Budget Constraints

- What is the timeframe for the analysis work?
    - This project is going to kickoff in July, so counts will need to be obtained immediately to capture the 30th highest hour conditions.
    - The project is one of the Region's top priorities
    - Since this is an EA, the end date is somewhat unknown but is expected to last at least 36 months.
- What are the impacts from changes to Purpose and Need?
    - Likely impacts could be additional alternatives, rework of analysis which will lead to more time required to do the work.
- What are the risks from other sources such as other jurisdictions, stakeholders, and private citizens? For example, local concerns/issues/ politics can easily add time to a projected schedule.
    - Access management and parking concerns will likely cause delay or create issues with the city council/planning commission.
    - Potential issues with internal and/or outside business groups
    - Environmental/Riparian issues along the river
    - Potential additional bridge routes/alignments
- Are there outside factors or time constraints that may dictate delivery of work items? For example, crash information is needed but cannot be obtained in the specified time frame.
    - Counts will need to be obtained between July and September in order to stay on schedule.
    - Staff time to perform analysis is limited because of other legislative high-priority work. Will likely need to have help from consultant to stay on schedule.
- What resources are available? Are they internal or external?
    - Internally, there is the project lead (manager) and at least one analyst available. The EA consultant has additional analysis staff available to help out on contingency.
- Are tasks dependent on resources not within analyst's control?
    - Yes, model applications are dependent on current workload; alternatives are dependent on region designers, alternative development process is dependent on feedback from stakeholders, public open houses and the teams themselves.
- Does the project funding require certain analysis tools and procedures?
    - The project falls under NEPA requirements so full counts and inventory data will be necessary to stay consistent with land use requirements and to support the environmental analysis. In addition, the travel demand model is required to be used.
- Is the budget adequate to perform the desired analysis and data collection?
    - The budget is adequate for the data collection, and up to three detailed alternatives in the EA document.
- What is the availability and quality of existing data?
    - State inventory data is current. The TSP analysis is still usable but more counts and data will be needed for the project analysis.
- Can the work be divided? Are tasks independent of each other? Are tasks sequential or concurrent?

- Most work can be divided into concurrent tasks, but simulation work must be done sequentially from a single source to avoid inconsistencies in assumptions. Generally, no-build work must precede alternative work.

Additional Details

- Given the above mentioned evaluation measures and other issues what are the likely performance measures that will be needed?
    - Volume to capacity ratio for the state highway and level of service for the local system will be required to compare with established performance targets and standards. In addition, travel time and queuing will be needed to test the overall efficiency of alternative operations. Multimodal level of service will be used to gauge the impact of mobility alternatives on the pedestrian/bike/transit operations and vice versa.
- Likely tools to be used?
    - Analysis of the no-build and the alternatives will require the use of the travel demand model to help develop the volumes and to create high-level screening measures to test any model-usable concepts (i.e. road diet, couplet and other network changes), Tools such as Highway Capacity Manual-based software (i.e. HCS and Synchro) and the multimodal tools will be needed to develop the detailed analysis. Micro-simulation will also be needed to create the travel time measures for the detailed analysis and to create the queuing data.

2.3 Level of Detail

There are many types of analysis work done for transportation related issues. The analysis ranges from high-level policy and procedures, through subject or facility plans to specific issues, locations or improvements projects. For example, a 10-mile long facility plan should have a different level of analysis than a single intersection realignment. The analysis process can have multiple levels such as single-issue or fatal flaw screening through detailed reporting like micro-simulation.

2.3.1 Types of Work

Planning Studies

These studies are generally limited to a specific geographic area or corridor or can cover multiple topics/issues. All of these can be either rural or urban and can overlap into different elements as well as varying level of detail. In some regions, the terms “corridor”, “facility”, “refinement” all mean the same level of effort. Expressway plans are similar but deal with a certain facility type and condition reports only deal with existing or future no-build needs yet the plans may not look different from a typical refinement plan.

The key difference in plans will be what are the specific questions needing answers and the detail level needed to answer them regardless of what the plan is named. For example the I-205 corridor in a dense urban area would involve use of a regional travel demand model, dynamic

traffic assignment (DTA), and micro-simulation while the comparatively rural US395 corridor would only have an urban model in a couple locations, and use a higher segment-based analysis.

Examples of each can include:

- Statewide Policy / Plans - This work is generally of a statewide nature but can be topic specific; typically guidance or an overriding policy such as:
    - Greenhouse Gases (GHG)
    - Least Cost Planning (LCP)
    - Legislative Studies / ORS / OAR
    - Performance Measures like Alternative Mobility Standards
    - OTP and Modal Plans (OHP, Freight Plan, Rail Plan, Bike/Ped Plan)
- System Plans – these focus on:
    - Metropolitan (urbanized) areas –Regional Transportation Plan (RTP)
    - County/multiple jurisdictional – County TSP, Regional Transportation Plan.
    - City – City Transportation System Plans
- Corridor/Facility Plans – these focus on:
    - Specific highway corridor
    - Land Use (TPR-type zone change, UGB expansion)
- Refinement Plans – these focus on:
    - Topic (Road Diet or Conversion of Two-Way to One-Way)
    - Feature (IAMP),
    - Mode (Safe Routes to Schools)
    - Highway segment
    - Sub-Area

Projects

This operational analysis is limited to specific locations often with specific guidelines or parameters that influence the work. They include

- Modernization – this work covers large issues / needs that must be measured against specific data needs or standards. The intent is to bring the facility/project up to standards and/or formalize exceptions.
- Safety / Operations / Preservation – this work is specific in nature and may allow deviation from standards. For example on a facility with a high crash rate fitting a minimal left turn lane within the given right-of way may not have standard widths and tapers.
- Traffic Impact Analysis (TIA)/Traffic Impact Studies (TIS) – this work is driven by the development itself. The analysis is to determine facility adequacy, significant effects and required mitigation.
    - Transportation Planning Rule (TPR)/Zone Change –When a proposed development requires a change in land use and has a significant effect to the state facility, certain criteria must be met.
    - Conforming Use Development- When a proposed development does not fall in the TPR/Zone change, the analysis is dependent on local land use code and approach permitting
- Approach Permitting – These are for developments that do not require a TIA. This

driveway type and location considerations such as sight distance, conflict points, influence areas.

Other Procedural / Research Studies

This is analysis work in support of a specific topic or tool, such as but not limited to trip generation studies, determination of analysis factors, procedures or calculators. These studies should conform to appropriate national methods and accepted analytical processes. This work needs to be detailed out with specific deliverables and agreed to by the parties requesting and accepting the work.

2.3.2 Level of Analysis

The questions being asked and the data available can determine the level of analysis needed. This can range from policy and systemic reporting to a very detailed specific need. Resources are limited, so the level of analysis needs to be tailored to the questions.

- Rules of Thumb – Generalization based on common conditions with very little detail. Can be in tabular or checklist format or "canned." For example, when AADT exceeds 60,000 then six lanes are needed. These need to be taken into context as a general ballpark only. They may be used to help determine a starting point. Actual decisions need to be based on more detailed analysis.
- Broad Brush (a.k.a. "30,000 or 10,000 foot view") – Big picture generalized planning analysis or a preliminary estimate of a more detailed later task. This could include using daily traffic volumes (AADT's), assumed roadway geometrics, or default values. This is typically at the system or corridor level (not intersection level). Data is typically at an aggregated level.
- Screening – A mid level analysis where some plan/project specific data is available but likely not fully developed. This process is used to whittle down large number of scenarios/concepts/alternatives/options to a more reasonable number. This can include both qualitative and quantitative elements. Measures can include items such as policy/standard compliance (a.k.a. fatal flaw analysis), natural and built environmental constraints, segment demand-to-capacity ratios, and key intersection volume to capacity ratios. Context sensitivity / practical design considerations are important at this level and below. Typically in a plan or project, multiple levels of screening are used in increasing detail.
- Detailed – This is a comprehensive look a study area or topic. This uses study-specific data where the use of defaults is limited. This analysis typically furnishes detailed numbers for establishment of standards or policies or details for a specific design (i.e. storage lengths, signal progression). Actual plan or project decisions can be made from information derived from this level.

2.4 Tools

There are many tools used for transportation and planning analysis. They are a mixture of commercially developed and internally created programs serving anything from analyzing the effect of a specific policy to a specific project detail. Often a particular process becomes identified as a tool and is included for discussion purposes.

2.4.1 Individual Tool Descriptions

The following tool descriptions are not exhaustive list and mainly concentrate on the ODOT-used ones. Some of these tools are discussed in more detail in following chapters. Some of these tools could be considered a process, i.e. sub-area modeling or zonal cumulative analysis. Some tools may package together multiple tools (i.e. HCM analysis and simulation) in a suite format. Other tools and methodologies not listed here or later in the APM may be acceptable if explained and documented in a methodology memorandum and approved by ODOT. For more information or availability of these tools, please contact TPAU staff. The higher model –based tools are discussed further in the Senate Bill 1059: GHG Modeling and Analysis Tools Report: http://www.oregon.gov/ODOT/TD/TP/docs/toolkit/modelanalysistool.pdf

SWIM (StateWide Integrated Model) – This model is used for high level projects of statewide importance that involve freight movements and/or long-term economic impacts. SWIM is not designed to analyze small or isolated projects.

LUSDR (Land Use Scenario DevelopeR) – This tool is used with a travel demand model for large-scale regional planning to develop and test a range of future land-use scenarios. A single or weighted average of these scenarios can be used in system and refinement planning efforts such as TSP's and IAMP's. LUSDR can inform local jurisdictions of future land use development issues and possibilities and influence decisions on growth areas, the comprehensive plan, and the future land use patterns.

GreenSTEP (Greenhouse gas Strategic Transportation Energy Planning model) – This model is used for large-scale regional emissions planning as part of an area's Greenhouse Gas (GHG) reduction efforts. The model is used to help establish a transportation strategy for meeting greenhouse gas targets,

HERS-ST (Highway Economic Requirements System-State Version) – Typically used on a corridor-basis for determining needs (deficiencies) including capacity, geometric alignment and pavement based on identified funding thresholds. Data is available for the state highway system as the HERS-ST input datasets are created mainly from internal ODOT inventory databases and is updated yearly. Local HERS-ST data can be created if the appropriate data and resources are available. With varying levels of effort, HERS-ST can be linked to travel demand models. This produces simplified HCM segment capacities, typically in volume to capacity ratios. Like with all HCM-based tools there are no interactions between segments. Also, while some intersection data is included, HERS-ST will not produce intersection performance measures. HERS-ST can be used to produce benefit-cost ratios for different project improvements which can be used for screening alternatives or used for high-level project management decisions. It also can be used as the primary tool for determining existing and future year v/c's and needs in corridor and facility plans.

Urban Models (4-Step Travel Demand Models) – Travel Demand Models are generally built as system-level tools so detail is limited at a facility level; including basic characteristics such as number of lanes and speed limits. These models can be used as a screening tool using district travel patterns (origin-destination), demand-to-capacity ratios, percent volume differences, and high level estimates of travel times. Travel Demand Models are also used to develop future

volumes for plans and projects through post-processing methods. See the available TPAU and MPO urban model map on TPAU's website at:
http://www.oregon.gov/ODOT/TD/TP/pages/tools.aspx

IDAS – (ITS Deployment Analysis System) - This is used for integrating ITS (Intelligent Transportation System) operations into a travel demand model assignment. IDAS allows global settings of traffic signal timing, variable messaging and ramp meters in order to modify imported model assignments. IDAS is only for ITS applications only on a system basis rather than a corridor or point basis. For smaller areas, IDAS can be applied to a cut-out (window) model network. IDAS can compare multiple ITS scenarios including on a benefit-cost basis.

Dynamic Traffic Assignment (DTA) - DTA is an alternative mesoscopic method that assigns traffic across time periods so that adjacent time periods and congestion affect each other. DTA is useful when the typical peak hour traffic spreads across multiple hours. The assignment is more detailed as it incorporates basic signal timing and platoons of vehicles which allow for queuing to be modeled. DTA is a further level of effort and refinement of the model assignment between the typical travel demand model and micro-simulation. Common DTA software tools are Dynus-T and Dynameq.

Subarea modeling – This is a mesoscopic technique by cutting out a portion of a travel demand model (also called windowing) to be used separately or adding detail to a portion of a model (also called focusing). Both methods involve adding detail to the model (signal timing, smaller zones, additional centroid connectors, better refined capacities, etc). This additional detail will improve calibration between the model and field counts, possibly to the point that post-processing is very limited. Typical software for the windowing method would be VISUM.

HCS (HCM) – Highway Capacity Software is a faithful implementation of the Highway Capacity Manual methodology. These methods are point/segment based and are isolated so adjacent sections do not affect each other. This is the only source of deterministic analysis tools for freeway operations (segment, merge, diverge, and weave). HCS/HCM also considers pedestrian, bike and transit multimodal analyses. The HCS/HCM is mostly operational (high detail level) based but there are some planning-level methodologies available using mostly default values and average daily traffic volumes.

Synchro – Synchro is mainly for the operation and system optimization of signalized study area networks. Synchro is mainly focused on the analysis of signalized intersections, but can do unsignalized intersections, roundabouts, and intersection-level multimodal analysis following current HCM methodologies.

SimTraffic – SimTraffic is a micro-simulation based on the arterial portion of CORSIM and thus is best suited for simulating arterial networks. This allows system-level analysis of a study area network for queuing impacts, travel time, delay of individual vehicles as well as network wide.

VISSIM – VISSIM is a complex but comprehensive micro-simulation which can be used to model virtually any road network. VISSIM also has the capability to handle DTA and multiple modes. The software is extremely customizable but requires significant effort to calibrate and report out useable data.

Trip Generation - This process implements the ITE Trip Generation Manual procedures based on land uses and other site size and type characteristics.

SigCap – SigCap is currently used as a quick sketch-type analysis and is mainly used to develop signalized intersection LOS C values for the environmental traffic data process.

Unsig – Unsig is currently used as a quick sketch-type analysis and is mainly used to develop unsignalized intersection LOS C values for the environmental traffic data process.

EISBase – EISBase is database tool used to calculate the resulting speeds of traffic flows, based on volumes of auto and trucks, for the environmental traffic data process.

Zonal Cumulative – The Zonal Cumulative volume development process is mainly a manual three-step (generation, distribution and assignment) analysis. This involves creation of zones, uses ITE Trip Generation methodologies, external trip origin-destinations, and gravity-based distribution. Calibration is also required. The VISUM modeling software is used to streamline the assignment process.

Future Volume Tables – These show the future annual average daily traffic volumes for state highway segments based on either 20 years of historical traffic counts or travel demand model based growth trends depending on the location. These are updated annually.

Other Planning Analysis Tools – There are a number of less complex tools that can be used to evaluate a system at a relatively high level. These also can be used as part of a more detailed plan or project analysis as an alternative screening tool. Most of these are based on average daily traffic. Some examples are preliminary signal warrants (PSW), other PSW-based tools, and the capacity nomographs.

IHSDM – The IHSDM (Interactive Highway Safety Design Model) implements the HSM Part C predictive method for rural and urban highway segments. The IHSDM evaluates the effects of geometric changes on safety. The IHSDM has a very high input detail level as it requires full geometric design data (curves, grader, stationing, super-elevation, etc). This is best suited for evaluating final design alternatives.

PlanSafe – This is for comparing relative safety levels on a transportation analysis zone or district basis within a travel demand model. PlanSafe does not use HSM methods.

NCHRP Spreadsheets – These are a free download implementing the Highway Safety Manual Part C predictive safety analysis methods. These are not technically supported and may not reflect current changes/fixes in HSM procedures

HiSafe – HiSafe is a software application implementing the Highway Safety Manual Part C predictive safety analysis methods.

Crash Decoder Tool – This macro-based spreadsheet tool converts the extensive numerical codes in the typical “long-form” comprehensive PRC crash listing to words. This eliminates the need for the analyst to be familiar with the crash coding manual. The tool will also summarize and graph the crash characteristics.

2.4.2 Tool Evaluation/Selection

The second step for scoping is to determine what tools are available and can be used at particular stages in the analysis effort. Selection of the appropriate analysis procedures from this manual will often be determined by project-specific characteristics such as the type of project, the surrounding environment and land uses, availability of data and the type of traffic controls present in the field. Generally, similar types of projects will use the same analysis procedures to varying degrees. Depending on the study and the project's purpose and need, additional data may be required. For further information on project scoping and selection of traffic analysis procedures, refer to the Federal Highway Administration's (FHWA) website for the Traffic Analysis Toolbox: http://ops.fhwa.dot.gov/trafficanalysistools/

In this manual, tools are broken into two basic categories: deterministic and stochastic and two sub-categories: systemic and specific. Considering the project needs and constraints, the tool selection can greatly impact the resources and time necessary to do the analysis.

- Deterministic – These tools use a set of fixed inputs and result in a single set of outputs. These include, for example, Highway Capacity Manual procedures and the 3- or 4-Step travel demand models.
- Stochastic – These tools use a set of inputs and create multiple sets of outputs. These include, for example, micro-simulation and dynamic traffic, land use and economic assignment models. These tools are much more time-intensive for inputs, process, and analysis of outputs.
- Systemic – These tools often cover multiple points that interact / influence with each other
- Specific – These tools analyze a single location

In the sections that follow, the tools are grouped first by study type and then by analysis type, however, the tables are not exhaustive. Studies likely require more than one type and related tools over their duration. Even within these tools there is a range of uses from high-level planning to project specific. Some tools can be used for widely varying efforts depending on the questions asked. An "X" indicates the tool type in the following exhibits.

The following discussion assumes that these tools have been created, tested, and operational. If a tool is not fully updated and useable, additional time or special considerations may be needed in tool selection.

For each tool, the general data needs, staffing requirements, and time required are shown. Many tools may have a range depending on the task at hand which may be "high" for a simulation model, to "medium" for facility analysis, and to "low" for individual intersection analysis. The following exhibits attempt to reflect a relative difference between the tools and may not capture every specific circumstance.

- "High" (H) generally means obtaining large quantities of data, confidential data, data not readily available, or in the correct format. Long times to collect data or the cost of collection is also considered. These tools can require a special separate project effort to collect and clean the data or to customize the tool to the location. Use of default values is very limited. Some tools may require many staff members such as updating a travel

demand model or may require many hours from a single person, such as micro-simulation. Processes may take months or years in some cases.

- "Medium" (M) generally means data obtainable in the field or from available information/databases although it might still need conversion or cleaning. Staffing requirements will be a single to a few staff members. Time requirements are generally on the order of weeks.
- "Low" (L) generally means published data or available data in correct formats and can be immediately used. The tool may have a high use of default values. Overall data requirements are limited in total amount or elements. These tools can be used by a single staff member and time requirements are on the order of days.

Tools Grouped by Study Type

Policy Tools

Used for answering policy level questions such as for the Oregon Transportation Plan or Oregon Highway Plan. These questions can be from the legislature or upper management. Questions can be very complex, in order to determine the effects of potential policy decisions involving many diverse factors in broad areas including economics, land use and transportation. SWIM and HERS-ST are the primary tools used for this purpose.

Exhibit 2-2: Policy and Statewide Planning Tools

Tools	**Deterministic**	**Stochastic**	**Systemic**	**Specific**	**Data Needs**	**Staffing**	**Time**
	Category				**Applications**		
SWIM		X	X		H	H	H
HERS-ST	X			X	L	M	M

Statewide Planning Tools

Used for statewide or multiregional analysis studies such as the Bridge Limitation Strategy. These studies usually involve the highway network or elements such as freight movement, congestion, economic impacts of delay/detours, etc. SWIM is used for general flows including freight movements and economic impacts while HERS-ST is a segment-based tool for prioritizing/analyzing highway needs (deficiencies) and overall benefit/costs across the statewide network.

System Planning Tools

Used for regional, county or city planning studies such as Regional Transportation Plans (RTP) and Transportation System Plans (TSP). The tools cover a wide range of uses. GreenSTEP is used for greenhouse gas emissions in urbanized areas. LUSDR is used to help determine future land use allocations when there are too many unknowns to use the normal processes. The urbanized area, county and small city travel demand models are used to determine system travel patterns or behavior, to compare multiple land use and network scenarios, or can be used to develop post-processed volumes for more detailed analysis for specific locations.

PlanSafe is used on a transportation analysis zone (TAZ) or district basis to compare between network scenarios to determine relative safety levels. Historic crash analysis using the Crash Decoder Tool is needed to identify current issues as well as support the PlanSafe model if a travel demand model is available. IDAS can be used to refine vehicle assignments from travel demand models to help incorporate effects of transportation system management (TSM) and intelligent transportation systems (ITS) such as ramp metering and variable message signs. HERS-ST and IDAS can both calculate benefit/costs for alternatives. If no travel demand models exist, then a zonal cumulative or a traditional historic volume growth process may be used.

Other tools cover specific routes, segments, or locations. Multimodal analysis would be typically done for major facilities across all applicable modes using HCM methods. HERS-ST can be used for determining operational results of state highway segments or across an entire area if the data is available. Highway Capacity Manual operational or planning analysis techniques can be used to determine operational results of roadway segments for all modes. Other planning analysis tools include daily-traffic based intersection tools for determining needs or general traffic control types.

Exhibit 2-3: System Planning Tools

Tools	**Deterministic**	**Stochastic**	**Systemic**	**Specific**	**Data Needs**	**Staffing**	**Time**
	Category				**Applications**		
LUSDR		X	X		H	H	H
GreenSTEP		X	X		H	H	H
Urban Models	X		X		M	M	M
PlanSafe	X		X		M	M	M
HERS-ST	X			X	L	M	M
IDAS	X		X		M	M	L
HCS (HCM)	X			X	M	L	L
HCM Planning Analysis	X			X	L	L	L
Other Planning Analysis	X			X	L	L	L

<u>Corridor Planning Tools</u>

Used for specific highway segments, either over an entire highway or a smaller section within or between cities. Corridor plans have more detail than system plans yet lack the specific details of project refinement plans and are limited to the specific roadway in question. These tools form the full range from systemic travel demand model-based tools to intersection operational analysis to micro-simulation. Travel demand model based tools are used to compare scenarios or help screen alternatives. Some tools like dynamic traffic assignment (DTA) or IDAS are used to incorporate shifting demand or TSM/ITS into the model assignments to better match the field conditions and limit the amount of post-processing needed. If no travel demand models exist, then a zonal cumulative or a traditional historic volume growth process may be used.

Historic crash analysis is needed at the corridor planning level. Predictive crash analysis may be used on the final solutions for urban arterials and rural non-freeways. The NCHRP HSM spreadsheets and HiSafe are used to do the predictive analysis while the Crash Decoder Tool is used to simplify the historic crash analysis.

Analysis would be typically done across all applicable modes at varying levels of detail from HCM-based analysis to micro-simulation. HERS-ST or HCM planning analysis can be used for determining operational results of state highway segments along the corridor. Both HERS-ST and IDAS can be used help determine benefit/costs of alternatives. If intersection analysis is needed then any of the HCM-based methods and tools (such as HCS or Synchro) can be used. Typically, micro-simulation will not be needed in corridor plans other than in metropolitan areas. VISSIM is typically used for freeway operations, complex configurations, and/or including multimodal issues and SimTraffic is used for signalized arterial corridors.

Exhibit 2-4 shows this group.

Refinement Planning Tools

Refinement plans are more detailed than system or corridor plans, but they are limited to a specific area or highway segment. Refinement plans generally arise from system or corridor plans which identify need for more detailed analysis. Travel demand model based tools are used to compare scenarios or help screen alternatives. Some tools like dynamic traffic assignment (DTA) or IDAS are used to incorporate shifting demand or TSM/ITS into the model assignments to better match the field conditions and limit the amount of post-processing needed. The smaller scope of these plans allows sub-area (window) modeling to be done which will further reduce the post-processing need. If no travel demand models exist, then a zonal cumulative or a traditional historic volume growth process may be used.

Historic and/or predictive crash analysis is needed at the refinement planning level. The NCHRP HSM spreadsheets and HiSafe are used to do the predictive analysis on urban arterials and rural non-freeways while the Crash Decoder Tool is used to simplify the historic crash analysis. Analysis would be typically done across all applicable modes at varying levels of detail from HCM-based analysis to micro-simulation. HERS-ST or HCM/other planning analysis tools are mainly used for alternative scoping or screening. Both HERS-ST and IDAS can be used help determine benefit/costs of alternatives. Intersection-level analysis is typically needed so any of the HCM-based methods and tools (such as HCS, or Synchro) can be used. Micro-simulation (will generally be used, especially in urban or congested areas. VISSIM is typically used for freeway operations, complex configurations, and/or including multi-modal issues and SimTraffic is used for signalized arterial corridors.

Exhibit 2-4: Corridor & Refinement Planning Tools

Tools	Deterministic	Stochastic	Systemic	Specific	Data Needs	Staffing	Time
	Category				Applications		
VISSIM		X		X	H	H	H
Urban Models	X		X		M	M	M
Dynamic Traffic Assignment		X	X		M	M	M
Subarea modeling	X			X	M	M	M
SimTraffic		X		X	M	M	M
NCHRP HSM Spreadsheets	X			X	M	L	M
HERS-ST	X			X	L	M	M
IDAS	X		X		M	M	L
Synchro	X			X	M	M	L
HiSafe	X			X	M	L	L
HCS (HCM)	X			X	M	L	L
Crash Decoder Tool	X			X	L	L	L
HCM Planning Analysis	X			X	L	L	L

Project Tools

Project analysis is the most detailed of all analysis types. Project analysis can involve the full range of tools from the travel demand model to micro-simulation and may involve specialized areas such as environmental analysis. Travel demand model based tools are used to compare scenarios or help screen alternatives and are used to create post-processed design hour volumes to be used by other tools. Some tools like dynamic traffic assignment (DTA) or IDAS are used to incorporate shifting demand or TSM/ITS into the model assignments to better match the field conditions and limit the amount of post-processing needed. The smaller scope of these plans allows sub-area (window) modeling to be done which will further reduce the post-processing need. If no travel demand models exist, then a zonal cumulative or a traditional historic volume growth process may be used.

Detailed historic and/or predictive crash analysis is needed at the project level. Tools like IHSDM, the NCHRP HSM spreadsheets, and HiSafe are used to do the predictive analysis on urban arterials and rural non-freeways while the Crash Decoder Tool is used to simplify the historic crash analysis.

Analysis would be typically done across all applicable modes at varying levels of detail from HCM-based analysis to micro-simulation. HERS-ST or HCM/other planning analysis tools are mainly used for alternative scoping or screening. Both HERS-ST and IDAS can be used help determine benefit/costs of alternatives. Intersection-level analysis is usually needed so any of the HCM-based methods and tools (such as HCS or Synchro) can be used. In congested areas or where the HCM methods no longer apply then micro-simulation is required. VISSIM is typically used for freeway operations, complex configurations, and/or including multimodal issues, and SimTraffic is used for signalized arterial corridors. Some projects may involve environmental

traffic analysis for noise, air quality and energy impacts which normally requires the use of (or the equivalent of) Synchro, SigCap, Unsig, and EISbase.

Exhibit 2-5: Project Tools

Tools	**Deterministic**	**Stochastic**	**Systemic**	**Specific**	**Data Needs**	**Staffing**	**Time**
	Category				**Applications**		
VISSIM		X		X	H	H	H
IHSDM	X			X	H	M	H
Urban Models	X		X		M	M	M
Dynamic Traffic Assignment		X	X		M	M	M
Subarea modeling	X			X	M	M	M
SimTraffic		X		X	M	M	M
HERS-ST	X			X	L	M	M
IDAS	X		X		M	M	L
Synchro	X			X	M	M	L
EISBase	X			X	M	L	M
NCHRP HSM Spreadsheets	X			X	M	L	M
HCS (HCM)	X			X	M	L	L
HiSafe	X			X	M	L	L
Crash Decoder Tool	X			X	L	L	L
Trip Generation	X			X	L	L	L
HCM Planning Analysis	X			X	L	L	L
MUTCD Signal Warrant Analysis Worksheet	X			X	L	L	L
Other Planning Analysis	X			X	L	L	L
Sigcap	X			X	L	L	L
Unsig	X			X	L	L	L

Specific Analysis Elements

Volume Development Tools

These tools are used to help develop volumes to be used in the analysis at various levels of detail as warranted by the individual study. Where a travel demand model is available, model assignments can be created to help in screening and post-processing. Dynamic traffic assignment and subarea modeling techniques can be used to refine the assignment. Zonal cumulative analysis is used where a travel demand model is not available. Trip Generation is used in cumulative analysis using rates from the ITE Trip Generation manual.

Exhibit 2-6: Volume Development Tools

Tools	Deterministic	Stochastic	Systemic	Specific	Data Needs	Staffing	Time
	Category				Applications		
Zonal Cumulative	X			X	H	M	M
Urban Models	X		X		M	M	M
Dynamic Traffic Assignment		X	X		M	M	M
Subarea modeling	X			X	M	M	M
Future Volume Tables	X			X	L	L	L
Trip Generation	X			X	L	L	L

Screening Analysis Tools

Screening analysis is typically a high-level analysis used to reduce the number of scenarios/concepts/alternatives to a manageable level. Most studies will have multiple levels of screening at increasing detail levels. At the top end, travel demand model-based tools are typically used for the system impacts. Middle and lower screening levels are more detailed at the intersection level which may be using key intersection volume-to-capacity ratios, or multimodal level of services. Screening analysis in a project –level analysis will be more complex than in a system plan.

Exhibit 2-7: Screening Analysis Tools

Tools	Deterministic	Stochastic	Systemic	Specific	Data Needs	Staffing	Time
	Category				Applications		
Urban Models	X		X		M	M	M
Dynamic Traffic Assignment		X	X		M	M	M
Subarea modeling	X			X	M	M	M
HERS-ST	X			X	L	M	M
Synchro	X			X	M	M	L
HCS (HCM)	X			X	M	L	L
HCM Planning Analysis	X			X	L	L	L
Preliminary Signal Warrant Analysis Worksheet	X			X	L	L	L
Other Planning Analysis	X			X	L	L	L

Multimodal Analysis Tools

For a complete analysis of a system or a project area, a multimodal analysis is needed. Urban MPO (Metropolitan Planning Organization) models can be used to determine mode share for the base case as well as alternatives. The HCM-based multimodal level of service (MMLOS) is used to create qualitative comparisons across the auto, pedestrian, bicycle, and transit modes. HCS has all the modes and does intersections and segments while Synchro does not include transit and does only intersections. In congested areas or in areas where non-auto modes are very common mixing with vehicular traffic such as light rail, streetcar, and buses, VISSIM micro-simulation will be needed to judge the impacts of these modes on each other. VISSIM, and in some cases SimTraffic, is also needed where heavy rail modes cross roadways. Analysis of the actual modal operations requires different resources not covered in this manual, such as the Transit Capacity Quality of Service Manual (TCQSM).

Exhibit 2-8: Multimodal Analysis Tools

Tools	**Deterministic**	**Stochastic**	**Systemic**	**Specific**	**Data Needs**	**Staffing**	**Time**
	Category				**Applications**		
VISSIM		X		X	H	H	H
Urban Models	X		X		M	M	M
Synchro	X			X	M	M	L
HCS (HCM)	X			X	M	L	L

Safety Tools

Most studies will require some sort of safety analysis. At a minimum, a historic crash analysis is needed. The Crash Decoder Tool simplifies the processing and analysis of individual crash records. Historic crash data is also needed to support more-detailed predictive analysis. Travel demand model-based relative comparisons can use PlanSafe, which analyzes crashes on the TAZ level. Plans and projects can use Highway Safety Manual (HSM)-based screening methods for establishing critical crash rates within a community or predicting the number of crashes associated with changes to roadway segments or intersections. Additional HSM-based tools are available to conduct predictive analyses methods, such as the free NCHRP spreadsheets or HiSafe software. Interactive Highway Safety Design Manual (IHSDM) software allows for very detailed evaluation of safety effects of geometric design decisions and requires a project-level data collection effort to be used appropriately.

Exhibit 2-9: Safety Tools

Tools	Deterministic	Stochastic	Systemic	Specific	Data Needs	Staffing	Time
	Category				Applications		
IHSDM	X			X	H	M	H
PlanSafe	X		X		M	M	M
NCHRP HSM Spreadsheets	X			X	M	L	M
HiSafe	X			X	M	L	L
Crash Decoder Tool	X			X	L	L	L

Environmental Traffic Data Tools

Sometimes, plans and projects will require some sort of environmental analysis. This can range from high level travel demand model based efforts to very detailed traffic volume development. GreenSTEP is a model based tool that estimates greenhouse gas emissions across a metropolitan region and thus will be mainly used in the development of regional transportation plans (RTP). Development of RTP's requires an air quality conformity determination. Also some metropolitan and smaller urban areas have been (none currently are) non-attainment areas for air quality. The urban models feed data into the air quality model (MOVES) which is the tool for determining air quality conformance. Project analyses will generally involve at least a noise study with many larger projects needing air quality or energy studies. Tools such as Synchro, SigCap, Unsig, and EISbase support the creation of the environmental traffic data to be later used for environmental analysis. Simulation tools can be used to create simple system-wide deterministic measures such as fuel used and pollutant levels.

Exhibit 2-10: Environmental Traffic Data Tools

Tools	Deterministic	Stochastic	Systemic	Specific	Data Needs	Staffing	Time
	Category				Applications		
GreenSTEP		X	X		H	H	H
VISSIM		X		X	H	H	H
Urban Models	X		X		M	M	M
SimTraffic		X		X	M	M	M
Synchro	X			X	M	M	L
EISBase	X			X	M	L	M
Sigcap	X			X	L	L	L
Unsig	X			X	L	L	L

2.5 Creating a Scope of Work (SOW)

The third step for scoping is to determine the specifics for the scope of work (SOW). SOWs can be written for TSPs, Corridor/Facility Plans, Refinement Plans, IAMPs and projects. Traffic Impact Analyses/Statements (TIAs/TISs) also have a SOW, but specific criteria should be consistent with Chapter 3 of ODOT's Development Review Guidelines.

The purpose of establishing a SOW for a transportation study is to define critical parameters such as the study area boundaries, analysis requirements, data needs and the identification of specific concerns to be addressed. An effective SOW should always produce a completed study that satisfies the needs of the corresponding project.

Common elements for most types of transportation studies include:

- Background or Purpose Statement
- Objectives of the Study
- List of Work Tasks
- Identification of Deliverables
- Project Schedule
- Project Budget

It is important that the work tasks and corresponding deliverables be clearly defined and that the party responsible for completing them is identified. The distribution list for deliverables should generally include all the pertinent teams/groups and specific ODOT sections needed for review.

All ODOT analyses must have a discussion on methodologies and assumptions used. For SOWs there must be a requirement for a Methodology Memorandum clearly shown. This memorandum details out the methodologies and assumptions that are to be used in the existing and future volume development and analysis. It should include the range of analysis methodologies from identifying count locations through simulation, including any safety and multimodal analysis. This memorandum should be provided to and approved by ODOT before any analysis work is conducted. This helps to significantly reduce the amount of review by ODOT and potential re-work by the Contractor.

The SOW must require that the methodology memorandum is completed by the Contractor and reviewed by and agreed to by ODOT prior to the Contractor starting any volume development and/or analysis tasks. In the absence of a SOW requirement, the APM requires use of the same methodology memorandum. Appendix 2C contains an annotated example methodology memorandum. This example does not necessarily include all methodologies that may be applicable in a given context.

2.5.1 Traffic Scoping Considerations

Each SOW likely has specific individual issues; however, there are many common needs such as professional engineer licensing requirements and specific requirements for the state highway system. Some typical SOW traffic analysis statements are shown below.

The following lists are typical of suggested statements used in SOW's for the traffic analysis tasks and are not exhaustive. Not all of these statements will apply to a single study. These tasks may be modified as desired to fit a study's particular needs.

General

- Final versions of the Contractor's transportation analysis must be stamped by an Oregon-registered Professional Engineer (P.E.) with license being current and in good standing, with expertise in civil or traffic engineering.
- Traffic analysis must follow the Highway Capacity Manual (HCM) 2010 procedures and comply with ODOT's Analysis Procedures Manual available at http://www.oregon.gov/ODOT/TD/TP/pages/apm.aspx. Signalized intersections shall use HCM 2000 methods in order to produce intersection v/c ratios.
- Contractor shall coordinate all traffic analysis with ODOT's Transportation Planning Analysis Unit (TPAU) and Region [1-5] Traffic Section. [Coordination with local jurisdictions or groups such as MPO's , may be necessary.]
- Consultant shall obtain approval of existing and future analysis methodology from TPAU and Region [1-5] Traffic via a methodology memorandum prior to beginning analysis.
- All documents will be readable and usable in black and white [Exceptions can be specified for certain deliverables.]
- All documents must be written in plain language and use an easily understood format.
- Contractor shall review all applicable plan/past project documents to the study area
- Contractor shall allow two weeks for review of written and analysis deliverables or as agreed to by the contract administrator.
- Contractor shall furnish written and electronic documentation for all assumptions, data, calculations, and results. This includes paper and computer files (i.e. spreadsheets and analysis software files).
- Consultant shall provide any GIS layers used for inventory and graphic deliverables (i.e. volumes, Level of Traffic Stress, etc.) to both ODOT's Transportation Planning Analysis Unit (TPAU) and the Geographic Information Services Unit (GISU). [Add to end of Existing Conditions section.]

Inventory

- Counts should be broken down by type and duration as suggested in the Analysis Procedure Manual Chapter 3. For clarity, the count locations, types, durations should be identified on a map as follows:
    - Contractor (or ODOT/Agency) will provide 16-hr intersection classification traffic counts with 15-minute intervals at the morning and afternoon peak hours at the following locations:
    - Specific locations in list
    - [Note: Similar language is needed for any peak period counts or any road tube counts]
    - All counts must have at least 15-minute breakdowns from 2- 6 PM. All counts must include bicycles, pedestrians, and turning movements.
    - State highway volumes and classification information is available here:

http://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm

- Field inventory information – lane configurations, traffic controls, speeds, operational issues (queuing, unique driving behaviors, etc) will need to be obtained by the Contractor.
- If micro-simulation is desired, then Contractor shall obtain necessary calibration data.
- [Note: Use five years for projects, detailed plans (i.e. IAMP's), or roadway/study areas with low number of crashes. Three (3) to five (5) years of crash data shall be obtained from ODOT's Crash Analysis & Reporting Unit for state highways and any local roadways desired in the study area.]

Volumes

- All traffic volumes must be adjusted to reflect the 30th highest hour [Note: use the alternative standard (i.e. average volumes) if it applies to the study area].
- Areas that are covered by a travel demand model must use the model to develop future no-build and build alternative volumes.
- Contractor must submit a model request to ODOT's Transportation Planning Analysis Unit (TPAU) at least three weeks before the data is needed. The model request form is available at: http://www.oregon.gov/ODOT/TD/TP/Tools/ModelRunRequestForm.doc [Note: This is for travel demand models that TPAU has developed only.]
- All raw model numbers must be post-processed or used only in relative (percentage) comparisons.

Analysis

- Analysis locations will include at least the traffic count locations. Exact intersection analysis locations will be determined during negotiations.
- Traffic analysis must follow methods in the Highway Capacity Manual (HCM) 2010 published by the Transportation Research Board (TRB) or as agreed to by ODOT. All traffic analysis software programs used must follow Highway Capacity Manual 2010 procedures. Signalized intersections shall use HCM 2000 methods in order to produce intersection v/c ratios. Synchro/ SimTraffic is the ODOT standard software program and is the preferred format.
- Contractor shall prepare and submit a Methodology Memorandum documenting methodology and assumptions to be used for existing conditions (i.e. seasonal factors used), future conditions (i.e. volume development/post-processing methodology), and alternative analysis (i.e. peak hour factors, analysis parameters, calibration, etc) to TPAU and Region [1-5] Traffic Section. Consultant shall obtain approval of methodology from TPAU and Region [1-5] Traffic Section prior to beginning analysis. Consultant shall obtain approval of analysis and conclusions from TPAU and Region [1-5] Traffic Section prior to submitting Draft Tech Memos.
- [Note: for existing conditions] Contractor shall obtain the past five years of crash data from Agency's Crash Data & Reporting Unit for both state and non-state roadways and perform crash analysis. Contractor's data for state highways shall include locations of Safety Priority Index System (SPIS). If the local agency or region has established a critical crash rate for intersections or if each intersection type within the study area includes a minimum of 5 study intersections, Contractor shall use the Highway Safety Manual Part B Network Screening Critical Crash Rate method for intersections to compare intersection crash rates to a critical rate. Each reference population used in the critical crash rate method must have at least 5 (five) sites. If this is not met, intersection crash rates need to be compared with the published 90th percentile rates (See ODOT Analysis Procedure Manual Chapter 4).
- If the local agency or region has established a critical crash rate for segments or if each segment type within the study area includes a minimum of 5 study segments, Contractor shall use the Highway Safety Manual Part B Network Screening Critical Crash Rate method for segments to compare segment crash rates to a critical rate. If fewer than 5 segments exist for a segment type, segment data must be compared with the official published crash rates (ODOT Crash Tables – Table II) for similar facilities [Does not apply to urban areas]. Segments must be homogenous in number of lanes, area type, and volume.
- For intersections that exceed the identified critical crash rate and/or the published 90th percentile rate, crash patterns, evaluation of causes and potential countermeasures must be identified for each site. Consultant shall map locations of these safety issue areas and the Safety Priority Index System sites. Consultant shall utilize the Crash Data and MMLOS/LTS to identify potential countermeasures and safety improvement alternatives.
- For segments that exceed the identified critical crash rate or published crash rate and intersections that exceed the identified critical crash rate, analysis of crash patterns, identification of contributing factors, and potential countermeasures need to be completed. Contractor shall map locations of these safety issue areas and the SPIS sites.
- [Add to the above before the last sentence for projects and detailed refinement

plans/IAMPs]. Contractor shall perform HSM Part C predictive analysis for all screened locations exceeding segment or critical rates for the existing conditions.

- [Note: Future safety for TSP's, similar detail level plan, and project development screening] For each alternative developed to specifically address a safety concern, Contractor shall summarize safety impacts of each design. Contractor shall use the Crash Modification Factors (CMF) in the HSM Part D and/or the FHWA CMF Clearinghouse to indicate the potential crash reduction for each safety alternative or countermeasure. ODOT guidance on the CMF Clearinghouse is available here: http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/pages/crash_mod_factors.aspx . The ODOT CMF standard is to only use CMF's with a quality rating of 3 stars or better.
- [Note: Future safety for projects or detailed refinement plans/IAMP's] For each alternative developed to specifically address a safety concern, Contractor shall summarize safety impacts of each design using HSM Part C predictive methods. Full predictive analysis should only be completed on and reported out on the final alternatives (including the future no-build) to be included in the [plan/project].
- Consultant shall conduct a qualitative ("Good, Fair, Poor") multimodal assessment for the Project Area collectors and above as per APM Chapter 14. The assessment analysis must include bicycle, pedestrian, and transit (if applicable) operations.
- Consultant shall conduct Level of Traffic Stress (LTS) analysis for all roadways in the Project Area as per APM Chapter 14. As much as possible, data should be obtained from current aerial photography and (TSP) roadway inventories before field data collection. Bicycle LTS will be evaluated and results graphically displayed for the existing conditions.
- Contractor shall conduct a high level MMLOS analysis for [indicate roadways to be studied] in the study area. MMLOS analysis must include vehicle, transit, bicycle, and pedestrian operations. Pedestrian analysis should not include the effective width of sidewalk data and calculations but rather assume a clear sidewalk width for each side of each segment. Bike analysis should use the link-level analysis only. Transit analysis should use as much general or average data from available transit district information as possible.
- Traffic analysis at ODOT intersections must be consistent with ODOT's Analysis Procedures Manual (APM) available on the internet at http://www.oregon.gov/ODOT/TD/TP/pages/apm.aspx
- Traffic analysis at non-state intersections needs to be compatible with ODOT procedures and must follow standard engineering procedures and practices.
- ODOT may approve a different or additional intersection analysis method prior to use when the different method can be justified for local and ODOT facilities. Contractor must provide documentation fully explaining the issue and the reasons for the proposed change. Contractor must obtain approval before use.
- Operational targets for state facilities should include the volume to capacity (V/C) ratio. Existing conditions and future no-build must be compared to the Oregon Highway Plan (OHP) v/c targets. Build alternative v/c's are to be compared with ODOT's Highway Design Manual v/c's. Standards for non-state facilities can be v/c and level-of-service (LOS) or a combination of v/c and LOS, depending on the local standards.
- Other performance measures may be required which can include queuing, MMLOS,

simulation-based MOE's, etc. All secondary performance measures shall be included in the methodology memorandum.

- Simulation to determine queues or other measures of effectiveness should be used if v/c's exceed 0.70 and simulation shall be used if v/c's are equal to or exceed 0.90. Simulation shall also be used if existing conditions show congested conditions, (i.e. intersection queuing backs into adjacent intersections/connections) or if Agency requires it.
- If simulation is desired to obtain 95th percentile queue lengths or other measures of effectiveness, then the simulation shall be calibrated following procedures in Chapter 16 of the Analysis Procedure Manual.
- Areas with complex freeway geometry/operations, transit operations (bus, light rail, etc), railroad pre-emption, require simulation and shall follow the VISSIM Protocol available at: http://www.oregon.gov/ODOT/TD/TP/pages/apm.aspx

Air/Noise/Energy Traffic Data

- Air/Noise/Energy traffic data must be obtained and reported as in the Analysis Procedure Manual Chapter 17 or as agreed upon by Agency.

Coordination with other Work Areas

- If rail facilities are within the study area, coordination with the ODOT Rail Division is required.
- If the study area is adjacent to an airport or includes any overlay zones then coordination with the Department of Aviation is necessary.
- If studied facilities are formally recognized freight routes, then compliance with ORS 366.215 "Reduction in Capacity" may be needed if alternative concepts could potentially restrict the roadway width (i.e. curb extensions, medians, etc).

2.5.2 Developing Work Plans

Once a SOW has been determined, a detailed internal workplan that outlines the analysis tasks and timelines should be developed. This will help the analyst determine the analysis process necessary to achieve the SOW deliverables. For internal ODOT-only studies, where SOW's are not developed, then a detailed workplan is required. This is typically developed by the project analyst and should be updated as needed. The workplan tasks should be developed to line up with the Sample Analysis Process Reviewer Checklist.

Exhibit 2-1 shows the typical traffic analysis work flow.

The work plan must include the project title, highway name and number, and a purpose statement to identify the project objectives. This work plan must be consistent with the overall project schedule and should be submitted to the project leader for review of timelines. This document will help explain to the project leader/contract administrator analysis and staffing/resource needs and timelines. At the very least, this will start conversation about project expectations. Delays or additional work requests will extend the timelines. The work plan should be updated as the study proceeds especially if major changes occur. A revision date should be on the first page of the work plan. A typical analysis will include most, but not necessarily all, of the following tasks. The tasks are not necessary linear, some may be concurrent or overlap while others provide feedback to other tasks.

The following example tasks assume a typical plan or modernization/safety project. This would need to be modified to fit any specific study.

- **Task 1 – Project Identification and Understanding**
  The purpose of this task is for the analyst to have an understanding to have a purpose and need of the study, the parameters and constraints that influence it, the questions that need to be answered, and to define the level of analysis and tools to be used.

  The methodology of this task should include the following which impact the analysis:
  - Study purpose and need and goals and objectives
  - Identify any prior relevant plans (i.e. TSP's, refinement plans), analysis (i.e. prior/adjacent projects, traffic impact analyses) that need to be considered in the study area
  - Identify any concurrent project or planning efforts in or adjacent to study area. This will require coordination (i.e. data, timelines, project progress etc) between these efforts.
  - Identify any new data needs (such as need to update a travel demand model)
  - Identify any constraints or issues that may affect the project (i.e funding, natural or built environment, politics).

  Task deliverables includes a summary of any prior or current studies in or adjacent to the study area with issues, constraints, and impacts to the analysis discussed. A traffic analysis methodology memorandum may be appropriate if the work needs to be coordinated with multiple staff and or studies.

- **Task 2 – Transportation System Inventory**
  The purpose of this task is to review existing data and collect additional inventory data for the study area. Note: Allow 6-8 weeks from date of request for counts requested from ODOT.

  The methodology for this task should specify the following:
  - Count Request – This should include count locations, types and durations and any other special considerations. Refer to Chapter 3.
  - Field inventory data needed including, but not limited to the suggestions in Chapter 3.
  - Office inventory data needed including, but not limited to:
    - 3-5 Year crash information for roadways through study area
    - Available inventory data
    - Pertinent map/aerial photograph of area for figures
    - Roadway functional class, designations and planning information
    - State and local performance measures
  - If simulation, multimodal analysis, or predictive crash analysis will be needed then more extensive inventory data will be required.
  - Other optional inventory data that may be needed, depending on project.

  Task deliverables include inventory information, project area map and photo for use in

the following tasks.

- **Task 3 – Develop No-Build (Existing and Future) Design Hour Volumes**
  The purpose of this task is to develop base year, build year and future year no- build design hour volumes (30th highest or other alternative standard). Occasionally, other interim years may be needed such as air quality or project phasing (short-term fixes) issues. The base year is the year of the study, or when most of the data was gathered. The build year is the year that has the day of opening of the project. Generally, the build year is one year (for small projects like intersections) to two or more years (for large projects like interchanges) from the let date shown on the project prospectus. The future (design) year is typically 20 years from the build year. For example, a 2015 interchange project with a let date in 2019 would have a base year of 2012, a build/opening year of 2021 and a future/design year of 2041.

  The methodology for this task is to use the manual count data to obtain the existing/base 30th highest hour volumes (30HV) using historical and seasonal adjustments in Chapter 5. A single system peak hour must be used with volume balancing as appropriate. .

  The future volume development methodology should be described, whether by historical trends, cumulative analysis, or with a transportation model (see Chapter 6).

  Task deliverables include the figures/worksheets showing the traffic volume development process and the balanced base 30 HV and future no-build volumes on figures in the technical memoranda for the existing and the future no-build conditions.

- **Task 4 – Analysis of No-Build Transportation System**
  The purpose of this task is to evaluate no-build system conditions for the base, build and future years. This may help identify any deficiencies related to the study purpose and need.

  The methodology for this task should use the base year, build year and future year data developed in Task 2 along with current Highway Capacity Manual (HCM)-based analysis software to evaluate the system by performing the following:
  - Use crash data from Task 1 and perform a safety analysis following procedures in Chapter 4. This needs to include a Highway Safety Manual Part B network screening process of locations before doing more detailed safety analysis. This should cover intersections and segments and use historical and predictive methodologies as appropriate.
  - Operational analysis including preliminary signal warrants , turn lane criteria, access/street spacing, and signal progression should be covered (see Chapters X, Y, and Z)
  - Evaluate the volume to capacity (v/c) and level of service (LOS) or other performance measures as appropriate by jurisdiction for the study area for intersections, merge/diverge/weaving sections, freeway mainlines and highway segments.
  - Perform multimodal evaluation (such as HCM 2010 MMLOS) across the pedestrian, bicycle and transit modes.

- Micro-simulation modeling may be needed if there are multiple signals involved or congested conditions exist. All simulations shall be calibrated according to APM methods. Simulation outputs should at least include 95th percentile queues, travel times, speeds, and overall hours of delay. Remember to allow the additional time (least a month) to calibrate the existing condition simulation model.
- Turn bay storage lengths will be compared to the 95th percentile no-build queues. Blocking of turn bays and upstream intersections must be noted if microsimulation is performed.

The task deliverable is a technical memorandum which includes the safety and operational analysis including the various performance measures. If simulation is used, then a calibration report will be required.

- **Task 5 – Evaluate Preliminary Alternatives (Screening)**

The purpose of this task is to work with the project team to develop and screen the preliminary alternatives.

The methodology for this task is to review goals and objectives with the team considering identified needs, and evaluate each preliminary alternative by comparing operations at major intersections or other agreed upon key location(s) for the appropriate years. Travel demand models can also be used to screen alternatives effectively if the alternatives have the potential to change traffic patterns beyond the local area. Travel demand model screening can include relative volume comparisons and link demand-to-capacity (d/c) ratios. The future no-build alternative needs to be included in the analysis as the baseline that the preliminary alternatives are compared against.

Any comparisons using HCM-based v/c's need to use the current Highway Design Manual (HDM) v/c's. Travel demand model-based link d/c's have different methodology and cannot be directly compared to the HDM v/c's. Travel demand model-based screening criteria should be based on relative comparisons. Comparisons may also need to be made to local jurisdiction operational standards which could be LOS, v/c or delay based.

The task deliverable is a technical memorandum, with the screening criteria and results shown for each alternative. A summary comparison table that shows how the alternatives and the future no-build alternative perform against the screening-level criteria and each other must be included. Recommendations for keeping or dropping alternatives based on traffic analysis considerations should be included.

Note: Post-memo project team decisions on alternatives should be documented in the next technical memorandum on build alternatives and needs to be documented for the alternatives considered but dismissed section of the final memo/narrative.

- **Task 6 – Evaluate Build Alternatives**

The purpose of this task is to work with the project team to develop and completely evaluate the detailed alternatives that satisfy the future transportation needs for this project. All tasks need consider timelines per alternative. Ideally, no more than three detailed alternative analyses are performed. Too many full–detail alternatives will result

in excessive time or budget requirements.

The methodology for this task is:

- Develop build and future year Design Hour Volumes (DHVs) for each of the final alternatives. Either distribute the no-build volumes on the build alternatives, or create new build volumes for each alternative if currently diverting traffic that would return with the new alternative is sufficient to invalidate the use of the no-build volumes.
- Operational considerations such as preliminary signal warrants, functional area, and turn lanes will be evaluated.
- Evaluate the v/c and LOS and other performance measures for the study area for intersections, merge/diverge/weaving sections, freeway mainlines and highway segments.
- Perform a predictive safety analysis if appropriate following procedures in Chapter 4.
- Perform multimodal evaluations across the pedestrian, bicycle and transit modes.
- Microsimulation of build conditions including determining turn bay storage lengths using the 95th percentile build queues and blocking of turn bays and upstream intersections.
- The output build v/c's must be compared with the HDM design v/c's for state facilities. Non-state v/c or LOS need to be compared with the appropriate local operational performance measure standard.
- Work with TRS/Region Traffic if new signals or changes to existing signals are involved. A progression analysis for the study area is needed if more than one signal is included in the alternative.
- Determine if access, intersection and interchange spacing meets or improves over current conditions in the OHP spacing requirements.

The task deliverables include a technical memorandum with volumes, v/c, LOS, queues, safety, multimodal, and other measures of efficiency shown on diagrams for each alternative, a summary comparison of the alternatives (including a table) and how they fared against the evaluation criteria and each other. Also, the design storage lengths and other geometric details need to be forwarded onto the appropriate design staff, either ODOT or consultant.

- **Task 7 – Environmental (Air/Noise/Energy) Traffic Data (If Needed)**
  The purpose of this task is to produce environmental traffic data for the no-build and build alternatives. The base year and no-build future year environmental traffic data can be started immediately after the Task 3 volumes are completed. The build alternative environmental traffic data should not be started until the final build alternatives are selected. Note: need to make sure that the data collection efforts properly support this task (i.e. ADT creation-capable classification counts).

  This includes the base year, build year and future volumes. Larger projects may also require the creation of short-term future year (10 year) data. The analyst should contact the air/noise/energy specialist(s) who will be using this information before beginning this task to ensure the correct information is provided. Air quality and energy data may or may not be needed. There may be some differences in data requirements from project to project, depending on the needs of the user of the data.

The methodology for this task uses the balanced hourly volumes, the average daily traffic (ADT), and the LOS C volume thresholds. The average daily traffic volumes will need to be developed and balanced for all needed years. The LOS C volumes will also need to be developed. This volume data, in addition to truck classification data, is needed for the base, build and future years to compute the environmental traffic data. The LOS C volumes (representational of the noise hour which is the maximum number of vehicles moving at the maximum speed) are only needed for noise analysis. Use the TruckSum summary spreadsheets and the EISBase program. Work with the noise consultant to confirm years and data results requirements. In congested areas, air quality data might be needed, which involves intersection LOS and number of stopping vehicles on each approach. Energy data may be needed on large projects of regional significance (environmental impact statements) which involves vehicles miles traveled.

The task deliverables include the environmental traffic data for the base, build and future years delivered to the air/noise/energy consultant(s). Diagrams are also required as the identification/location key for the data.

- **Task 8 –Traffic Analysis Narrative/Final Technical Memorandum**
  The purpose of this task is to prepare the written documentation of the project analysis. This will assist the project team in making the preferred alternative selection. For large or complex projects a full narrative report is required. For smaller projects such as single intersection safety or operational projects can be documented with a final technical memorandum.

  The narrative/memo should draw from, summarize, and discuss information from all of the previous technical memoranda and any other analyses into a stand-alone document. Draft and final versions will need to be produced. In addition, the final narrative/memo needs to have an engineer's stamp as it is a document of record for the traffic analysis. The narrative/memo will document all of the selected and dismissed alternatives and may or may not make any recommendations.

2.5.3 Typical Task Times

Every project is different so actual task times can be quite different depending on project complexity, actual staff time available or overall project schedule (i.e. fast-tracked) to name some of the factors involved. Timelines should be defined by number of weeks required to complete each task. Target completion dates for each task should be established but should allow for overall analyst workload. For example, the timeline may show three weeks to complete the task if 100% of time was available, but if only 25% of time is available then the target date should be 12 weeks out. The final task timelines are negotiated with the project leader depending on the resources involved. Actual task timeline totals will depend on the overall size of the project, how many different years are analyzed, and number of alternatives/options to be analyzed.

Here are some general guidelines for typical studies:

Project Understanding/Scoping

- Allow at least two weeks to develop work plan, identify issues, constraints and impacts to analysis in review of existing/current plans and projects.

Counts/Inventory

- Allow six to eight weeks for counts to be completed and processed
- Allow at least two weeks if crash data is to be requested from the Crash Analysis and Reporting Unit
- Count timing – can add many months if the data collection window is passed

Volume Development

- Allow a month to create the existing 30th highest hour volumes
- Time to update a travel demand model if needed (6 -12 months or more)
- Allow three weeks for model application requests to be completed
- Allow a month to create the future no-build volumes (including all interim years)
- Allow about two weeks to create volumes for each alternative

Analysis

- Allow at least four weeks to perform and report on alternative screening analysis. This will depend on number of alternatives and how many levels of screening to do (i.e. travel demand model relative comparisons followed by key intersection v/c's).
- Allow two weeks for analysis of each build alternative

Simulation

- Allow one to six weeks for simulation model construction/error checking (depends on software)
- Simulation calibration – SimTraffic (two weeks to a month); Vissim (one month +)?
- Allow one week per alternative for simulation results

Environmental Traffic Data

- Allow one to two weeks to setup link diagrams, spreadsheets, etc
- For smaller projects allow one to two weeks per existing, no-build future and alternatives (three to six weeks total)
- For larger projects allow four weeks per existing, no-build future and alternatives (12 weeks total).
- Allow one to two weeks for review of data (dependent on reviewer's schedule).

Documentation/Review

- Allow three weeks to write and review tech memos
- Allow a week for a reviewer to review the draft tech memos/ narrative (dependent on reviewer's schedule).
- Allow four to six weeks to write and review draft narrative; two to three weeks for final publication
- Allow one to two weeks for completed deliverable review and comment

2.5.4 Reviewing Analysis Work

Often times an analyst may be required to review work conducted by others, whether it was performed within the Department or by a consultant. All traffic analysis work (either done internally by ODOT staff or by a consultant) must be reviewed by an Oregon-registered civil or traffic engineer. At a minimum, this can be a peer review if both the analyst and reviewer are Oregon-registered civil or traffic engineers. The reviewer should be the analyst's lead worker/supervisor as they should be involved in the flow of the work. If the analyst is not registered, then the reviewer must be the lead worker/supervisor who is registered as they must be familiar with the work as the professional responsibility falls under them. Work performed by a non-registered consultant analyst must be reviewed by their registered lead worker/supervisor prior to submission to ODOT for review.

The review parameters such as who the reviewers are, what is going to be reviewed, and what level of detail the review will be must be documented before the review starts. At least one week should be allowed for the review of memos and reports. Individual review of analysis methodology, work in-progress, figures, etc should be completed in two or three days or less.

The following section provides general guidance for reviewing traffic analysis that can be applied to any type of analysis project. Specific guidance for the review of TISs can be found in ODOT's Development Review Guidelines.

2.5.5 Purpose of the Review

The reviewer should know what the purpose of the review is as this establishes what the review needs to cover. Some considerations include:

- Audience – is this only for internal, technical staff or is this to be included as part of a public document like a traffic study or guideline?
- Completeness – is this a rough draft to start a process or a discussion or is this to report analysis, discussions or decisions?
- Full Documentation – are there short-cuts taken like referring to other past memos/reports/projects? Note that report readers may not have access to the other reports. Reports should stand alone. For example, just stating that "US 101 in the project has an OHP mobility standard v/c ratio of 0.85 in Tillamook", leaves out the missing classification information which includes items like what is the highway classification; expressway, freight route, or Special Transportation Area designations, etc.
- Accuracy - need to verify things like OHP/HDM standards, speeds, lane configurations and traffic control
- Consistency - thinking "outside the box" may be good in some cases, but it should not carry through freely to documentation as readers are looking for specific types of information and having to sort through pages of data can be difficult.

2.5.6 Organization and General Format

The report should be set up for the specific (target) audience, using words and sentences (word size and sentence length) appropriately with acronyms defined and used minimally. Most readers need some sort of organization, so thoughts should be grouped linearly (i.e. time, location, or

process) or grouped by topic (i.e. safety, configuration/geometrics, policies/standards, procedures, and findings/conclusions).

The report should have good readability. Color does not always copy well as graphics may just turn into multiple impossible to differentiate shades of gray. Graphics should use patterns to distinguish different features as much as possible. Typeface size for general text should be at least a 12 point (or larger) and should be limited to standard fonts with few "extras" (i.e. Times New Roman, Georgia, Arial, Verdana). Footnotes in text, tables or figures should not be any smaller than 8 point. Remember that clarity dissolves with copying and not all programs use all fonts.

The format should be appropriate, so there should be "white space" instead of continuous lines of text. Paragraphs after paragraphs of text lead to low readability. Tables are better but can be complex especially if multiple variables are involved. Tables should make data easy to read by making comparisons and failing values should be emphasized (bolded, shaded, etc).

Drawings and figures are better than long-winded description paragraphs, but some text is still needed to point out or explain to the reader the important features, issues, key locations, etc. Numbers should be noted and balanced appropriately (i.e. future volumes rounded and not to the exact amount; or not losing traffic between ramps on a freeway). Information should be limited to about three layers on a single diagram (i.e. street names, classification, and volumes).

2.5.7 Checking Information

A reviewer does not have to check every fact and figure, but should cover major sections and areas that would affect the results of the work. Some of these areas are:

- Study Area - When reviewing analysis conducted by others, knowledge of the study area is typically beneficial. The reviewer should first examine all study area mapping and photographs available and visit the physical site, if practical to do so.
- Roadway Classification and Jurisdiction - This establishes what type of road it is and who controls it. This will determine what overall performance measure to use (state or local) and the specific value.
- Analysis Methods and Processes – The document should state its purpose and need as that establishes the level of detail needed in the analysis, the answers that are needed and what the expected results are. Review the methodology memorandum to make sure that the assumptions and parameters to be used in the existing conditions, future conditions and the alternatives is appropriate for the level of detail of the work. As long as the work follows the memorandum, then the rest of the review is streamlined for both sides. Any disagreements need to be taken care of before analysis work is started to minimize rework and issues later. Keep in mind assumptions made by the analyst performing the work can have a significant effect on analysis results, even if specific analysis procedures are followed correctly.
- Data - With any type of technical analysis the proper collection and processing of data is critical to obtaining accurate results. Before reviewing the analysis itself, verify the data used is appropriate for the analysis conducted. Consider things such when was the data collected, type of data used, and whether any processing of data (e.g., volume balancing) was conducted correctly.

- Appropriate Factors – This means checking that the count data was correctly obtained and correctly seasonally adjusted to the 30th highest hour (or other applicable alternative standard). Are seasonal adjustments less than 30%? Are all the counts adjusted to a common base year? Are other analysis parameters correct such as the peak hour factor?
- Spot Checks – The reviewer should do a few quick checks by pulling the cited data and verifying correctness. With the given data, can the reviewer reproduce the seasonal and growth adjustments? Or can they follow the methodology used in a volume development or future post-processing spreadsheet? The calculations performed in the analysis should be checked for computational errors, and procedures used must be appropriate for the given situation and in compliance with accepted ODOT practices. Knowledge of the study area, prevailing traffic conditions and accepted ODOT analysis procedures will aid the reviewer in determining which assumptions are appropriate, and which are not.
- Correct Processes – Make sure that what is reported was analyzed with the correct program. For example, queue lengths in congested systems should be from a system micro-simulation program (SimTraffic), not just the program (Synchro). Also, make sure that methodologies cited in a scope of work, workplan, or a methodology memorandum, are being followed.
- Correct Targets/Standards – Once the adequacy of the analysis has been verified, compare the results to ODOT's adopted performance measures. Check any proposed mitigation against ODOT's design standards. Often times the review process will require coordination with other units within ODOT that have specific expertise in, or authority over, certain elements of the design or approval of the mitigation proposed.
- Reasonableness - In addition to technical accuracy, the results of the analysis must be evaluated using a "reasonableness" test. The reviewer should compare the subject data, such as the traffic volume counts, lane configurations and traffic controls, and determine whether the conclusions and recommendations of the study are reasonable. This type of test often helps pinpoint sources of error in analysis, and may reveal questions likely to arise when the project is presented to the public.
- Addressing Errors - When sources of error are detected in the analysis, the reviewer should not only note the error itself, but acknowledge the significance of the error to the results of the analysis. There may be times when correcting the error would require a substantial amount of work, but the results of the corrected analysis would not be significantly different and the recommendations of the study would remain unchanged. Noting the significance of the error ahead of time will enable ODOT to determine whether correction is necessary or cost-effective.

2.5.8 Documentation

For a typical report, there should be documentation of the following:

- Study area map
- Methods and assumptions
- Applicable polices, standards, background conditions
- Local street and highway system including (pedestrian, bicycle, and transit modes)
- Data and inventory summary as well as source(s) of the information
- Traffic volumes (segments and/or intersections)
- Volume development – raw counts, system peak hour, adjustment factors, unbalanced

volumes, base year, build (opening) year, future years

- Trip patterns/distributions
- Lane configurations
- Land use and zoning maps
- Circulation routes
- Existing or proposed scenarios/concepts
- Existing or proposed alignments/alternatives
- Existing & future no-build and build alternative analysis
- Summaries as appropriate
- Conclusions and recommendations
- Technical data included in appendices with electronic files available upon request

Missing sections or other errors/issues found should be addressed in a comment memo or Email, so the reviewer's comments can be documented as well. Page, section and/or line number should be identified for easy reference. Many times the team/project or planning lead will be consolidating comment from a number of reviews.

Appendix 2A – Problem Statement Worksheet

Appendix 2B – Sample Analysis Process Reviewer Checklist

Appendix 2C – Sample Methodology Memorandum

3 TRANSPORTATION SYSTEM INVENTORY

3.1 Purpose

Before any analysis can begin, data for the study area must be collected from the field or other available in-office sources. This chapter provides guidance in the selection criteria and collection methods of appropriate inventory data types for use in transportation analysis. Inventory data is the foundation that all other later decisions are based on, so it is important that the scope of the data collection is appropriate and adequate to support the needs/outcomes of the plan or project.

3.2 Office Data Resources

There is a wide range of data sources that can be obtained prior to the field investigation. Gathering this information gives the analyst a "feel" of the study area and what level of data is available, what may need to be verified versus gathered.

3.2.1 Crash Data

Crash data can come from a variety of sources, and is useful for identifying problem areas of the highway experiencing an above-average frequency of crashes or reoccurring crash patterns. The analysis procedures that use this data are described in following chapters, while the data itself is described below.

Sources of Crash Data

The following describes sources of crash related data and information. Tools available for the analyst to use in crash analysis are discussed in Chapter 4.

Oregon Motor Vehicle Traffic Crash Database

ODOT's Crash Analysis and Reporting (CAR) Unit provides the official motor vehicle crash data through database creation, maintenance and quality assurance, information and reports and limited database access. Crash data since 1985 is maintained at all times. Vehicle crashes include those coded for city streets, county roads and state highways. The CAR Unit website offers a variety of publications containing information on monthly and annual crash summaries.

Although there are other sources of information, such as police departments, local groups that collect information, and anecdotal information, the ODOT CAR Unit data is the standard source. Oftentimes these other sources include reporting calls, not the actual investigation/report, and groups often include near-misses and/or don't have all the facts, so the report is erroneous. The CAR data has the checks and balances built into the data collection that matches "both sides of the reports" for a crash, treating all areas the same so comparisons can be made. This is also the database used to calculate all the comparison rates published in the crash rate books.

The CAR Unit obtains documentation of reported crashes from DMV and other sources which

they use to code the crash database. It should be noted that not all crashes are reportable, not all those that should be reported are reported, many of those reportable are filed out by citizens with attendant limitations on data accuracy, and even those law enforcement reported may have issues with accuracy. The documentation provided to the CAR Unit can range from being very thorough to very limited and can include conflicting or incorrect information. The documentation is carefully checked and may be corrected before being coded. Crash codes are defined in the ODOT Traffic Crash Analysis and Code manual, available on the TransData Crash Data webpage. For detailed information about the coding process contact the CAR Unit.

Depending on the level of analysis needed, there are various reports that can be obtained. It should be noted that even though this database often represents the most current data available, data for a given year is typically not available until at least 6 months into the following year.

Detailed information for individual crashes can also be obtained by contacting the CAR Unit and specifying the segment of highway (roadway) and time period of interest. Because crashes are reported by specific points, an issue may be located just outside of the analysis area. Therefore, the area of requested crash data should always be greater than the area of analysis. The additional distance should be enough to catch the character of the road such as the adjacent blocks in an urban setting and a quarter to half mile in a rural setting.

Crash data is always available from the CAR unit and should be obtained through them for complex, controversial or legal situations since they are the official reporting source. For most analysis efforts, using the on-line reports is sufficient. Crash data is available on both state highways and local roads on the ODOT Internal Crash Reports website or the External Crash Reports website.

Crash data is requested by state highway number and milepoint for specific years. Local road crashes are available at the above websites by clicking on the Local Roads tab.

Crash information is categorized first by county, then city and finally by street name. Selecting the summary detail will bring up the entire length of the roadway. The summary is only useful when the entire roadway in within the study area. If only a portion of the street is desired, the data needs to be obtained from the comprehensive report (PRC). The analyst will need to review the report and select the appropriate crashes to summarize for use in the analysis.

While several years of data may be available for any given roadway segment, it is common practice to analyze only the most recent, complete three to five (3-5) years of data as factors such as traffic volumes, environmental conditions and roadway characteristics may change with time. Three years of data gives a minimal picture and is the minimum analysis period for a safety analysis, while the five year listing gives a more desirable view. Roadways with a small number of crashes should be looked at through a five year period to get a better representative sample. In some circumstances even a longer period may be reviewed. Also, remember that the crash databases are regularly updated to include more recent data, so care should be taken to select the correct timeframe(s).

Safety Priority Index System

The Safety Priority Index System (SPIS) is a method developed by ODOT in 1986 to flag potential safety issues on state highways. Major revisions have occurred from the original process. The SPIS score is based on three years of crash data, and considers crash frequency, crash rate and crash severity. ODOT bases its SPIS on 0.10-mile segments to account for variances in how crash locations are reported. To become a SPIS site, a location must meet one of the following criteria:

- Three or more crashes have occurred at the same location over the previous three years.
- One or more fatal crashes have occurred at the same location over the previous three years.

The use of this information is discussed in the Safety Chapter (4) and the documentation on how the SPIS is calculated can be found at the Safety Priority Index System website. Any SPIS listing can be obtained by ODOT staff. Non-ODOT analysts can obtain the SPIS listing by contacting ODOT Region Traffic personnel. Top 5% and 10% sites need to be included in any crash analysis of a study area.

SPIS-All Roads (Internal Use Only)
The program is a tool internal to ODOT which is a variation of the standard SPIS program. SPIS-All Roads contains crash data for local roads as well as the state highway. It allows the data to be filtered based on specific fields and then have the SPIS calculation reported.

TransGIS Mapping Tool

TransGIS is a web mapping tool designed for users of every skill level. It presents many data levels in an interactive map format in multi-level views. This mapping tool provides more detailed information on many types of safety, volume and crash data on a state map. The user can choose the information that is displayed, and can zoom into the map to increase detail as well as display city and county maps behind this data. Extensive work with individual layers may be required in the generic TransGIS application, to obtain all necessary information about a study segment. A decoded crash layer is available

For external access to the newer TransGIS 2.0 follow the link and click on “New TransGIS 2.0”

The ODOT GIS Unit may be able to produce custom maps or applications in some cases, depending on the nature of the request and work priorities. GIS maps or web applications may be possible, as well as additions to TransGIS. A web application is a custom TransGIS website with pre-defined layers. GIS software is not required. The user can zoom in/out and turn layers on/off as desired. The application may be permanent or temporary, as needed for the duration of the project. Examples are located on the GIS Unit Applications Webpage.

All requests for mapping products are submitted to the ODOT GIS Unit (GISU) from ODOT staff. Consultants may initiate a request through ODOT staff. Requests should be clearly defined prior to submittal to avoid re-work. Contact the GIS Unit for further information. Custom

mapping requests need to use the GIS Project Request form which is available by contacting the GISU.

Crash (Collision) Diagrams

Crash diagrams are typically used to evaluate operational and safety projects, not analytical ones. The typical project and planning analysis would not require this level of detail. The CAR Unit can create a crash diagram that depicts the crashes on a given roadway section. Depending on the size of area requested and the number of crashes in the requested area, this can be time consuming. For more information, refer to the ODOT Safety Investigation Manual available on the ODOT Highway Safety webpage.

Crash Rate Tables

Crash Rate Tables have been published annually by the CAR Unit since 1948. Tables in the front of the book list statewide crash rates for several categories of the State Highway System. More tables list the crash rates for selected sections of each state highway, as well as a rural/urban break out. Additional tables list intersection crash data and fatal crash data. These tables are discussed further in the Safety chapter and are available on the CAR Publications webpage.

3.2.2 Roadway Data

ODOT maintains a wide variety of roadway characteristic and features data in Transviewer which is available on the ODOT Transviewer webpage.

TransGIS including the newer TransGIS 2.0 is available on the ODOT Internal TransGIS website or the External TransGIS website.

These sites are also available on the Consultant Portal under the Data and Reports section on the ODOT Internet site.

This data includes and is not limited to:

- Roadway alignment – horizontal and vertical (grades)
- Roadway cross-sectional data – lane, shoulder and median widths
- Roadway features – pavement type, number of lanes, speed limits
- Roadway details – structures, connections, mile points and equations
- Segment Vehicle Classifications and Characteristics
- Summarized Traffic Information

Other data sources are also available through the above links. They include:

- Digital Video log
- Traffic Count Information
- Functional Classifications
- Highway Classifications including freight routes, scenic byways
- Operations and Performance Standards including spacing and mobility
- Design Standards
- ODOT generated maps

Additional Data that should be located includes:

Transit Information

The following information is likely needed from the local transit authority

- Transit vehicle characteristics
- Route specifics such as paths, schedules, dwell time, headway
- Passenger boarding/alighting and occupancy data
- Transit specific control and timings

Traffic Signal Timing Sheets

Traffic signal timing sheets are needed when creating analysis files. The best source of current information for state highways is through the Region Traffic Engineer. Occasionally, the local jurisdiction will be responsible for the signal timing, so they are the source of that data along with any local signalized intersections of interest.

Traffic Plan Sheets (If available)

An analyst should obtain information related of the roadway and traffic control for the intersections of interest. Specific details such as the detector layouts and striping sheets are available for many areas. Digital PDF copies of signing, striping and signal plans are available at the FileNet Workplace website. This file sharing site is searchable. You can obtain this information by logging in as a guest.

Other useful information

Information such as zoning and local classification maps needs to come from local jurisdictions. Private entities may have aerial photos also available. Although on-line data sources such as NAVTEQ, Google and Bing may yield useful (scalable) information, they can also contain information that is not very current and may not be consistent between overhead and street/driver views. Street names often differ from the official names. Information from these sources needs to be verified.

3.2.3 Reports and Tools

Transportation Planning On-line Database (TPOD)

This is a map-based, graphical tool for locating planning studies within a specific area. This may include but is not limited to Transportation System Plans (TSP), refinement plans, Interchange Area Management Plans (IAMP) and others that may have factors that significantly impact the study. For example, a TSP may include alternative mobility standards, local jurisdiction's operational standards, fiscally constrained project list and many more. Because this tool is only updated periodically, the most recent reports likely are not included in the data. Contact the region planning manager to verify.

Features Attributes and Conditions – Statewide Transportation Improvement Program (FACS-STIP)
This is an ODOT Asset Management database in both listing and map-based forms. Information includes data such as sidewalks, bike facilities, ADA facilities, access locations, and some traffic features. This is an evolving database that is being continually expanded as data is collected. The tool is available at:

In addition to gathering data from TPOD and other on-line databases, the analyst should determine / locate other studies that may have bearing within the study area, including previous (related) studies, Safety Investigations, and Traffic Impact Studies (TIS). The analyst should contact local jurisdictions, the Region Traffic Manager, the Region Access Management Engineer (RAME) and the Region Planning Manager to locate any of this work.

3.3 Field Inventory

Specific data related to field conditions that may affect traffic safety and operations shall be collected directly during a visit to the area. In addition, inventory data collected through other sources such as previously conducted studies or databases maintained by the road authority should be field verified. There is no substitute for a field visit as an analyst cannot get a good feel for the project area otherwise. This is a check of other data sources (such as aerial photos) for accuracy. Notes, photographs and/or video should be taken of the project area in addition to the inventory data to reference, and possibly include, as graphical elements in the final report. The most common types of field data needed are discussed below.

3.3.1 Geometric Data

Geometric data is the physical characteristics of the facility, typically including:

- Street names
- Segment lengths
- Lane/shoulder/median widths
- Lane configurations
- Storage bay and ramp taper lengths
- Acceleration and Deceleration lane lengths and tapers
- Storage bay lengths (from stop-bar to start of taper)
- Bike/multi-use facility locations and dimension
- Parking locations and dimensions
- Raised medians/pedestrian refuges/islands locations and dimensions
- Location of stop/yield bar, intersection guidelines (dashes)
- Pedestrian facilities (type, condition, location) including crosswalks dimensions (length and width)
- Intersection and access spacing
- Access type, location, width and land use served

3.3.2 Operational Data

Operational data describes the characteristics of traffic control and flow, and typically includes:

- Speed limits
- Saturation flow, speed and travel time studies
- Intersection controls (signalized, stop-controlled, yield, merge, etc.)
- Signal characteristics (timed, actuated, split-phased, protected left turns, etc.)
- Signing (especially turn prohibitions)
- Parking signing, striping, and maneuver frequency
- Pedestrian crossings including at crosswalks and improper (jay-walking) frequency of use
- Transit stop locations and amenities
- Rail crossing locations, train frequency and duration of blockages
- Intersection sight distance

3.3.3 Field Observation Data

Observations related to travel patterns and driver behavior. This can include:

- Perceived or actual operational problems
- Length and duration of queues
- Driver behavior for lane choice, turn paths, upstream and downstream movements or maneuvers, left turn "sneaker" (left turn drivers that turn enter and depart the intersection during the yellow or red intervals)
- Pedestrian, Bicycle or other user behavior including actual travel paths
- Evidence of crashes such as glass on the shoulder, tire marks on curbs or medians
- Tire wear on pavements
- Damaged or worn physical features

3.3.4 Simulation-Specific Data

In addition to the geometric and operational field data, additional simulation specific data is needed if a project requires simulation. Simulation-specific data typically may include:

- Number of detectors, length, and distances from stop bar or crosswalk
- Turning speeds and radii (if unusual geometrics or conditions exist)
- Free-Flow speeds on ramps, highway segments, or on intersection discharge legs approaches (can be collected using road tubes or speed guns)
- Floating car travel times and average speeds
- Important travel patterns (OD Data), Example: ~75% of traffic exiting the mall makes left at Main Street
- Lane Use
    - Details of user specific lanes (e.g. Heavy Occupancy Vehicle (HOV), truck/bike/bus)

    - Use of the shoulder or median to move around blockage points or due to driver confusion/disregard
    - Lane-change positioning lengths or landmarks where vehicles tend to position themselves in a lane to make an upcoming turn or merge
    - Freeway/arterial guide sign locations (for lane change distances)
    - Noticeable lane imbalance issues (some lanes used more heavily than others) and causes (i.e. lane drops, multiple turn lanes, closely spaced intersections/accesses, etc.)
    - If more than one lane is available to turn into from an approach, indicate the lane that turning vehicles align into (left or right alignment) regardless if the movement is legally proper or not.
- List the approximate average and maximum queues for each lane
- If upstream intersections or bays are blocked by congestion from the observed intersection, what percentage of the site visit hour did blocking occur <5%, 10%, 25%, 50%?
- Arrival type for each approach (i.e. are the vehicles arriving in a platoon, if so, are they arriving on red or green?)

3.3.5 Safety-Specific Data

Additional data beyond the general geometric, operational, and observation data may be needed to support Highway Safety Manual (HSM) techniques (See Section 4.4.4). Safety-specific data may include:

- Fixed object density and average distance offsets
- Intersection skew angle
- Presence/absence of centerline rumble strips, lighting, red-light cameras, and automatic speed enforcement
- Number of schools, bus stops and alcohol-selling establishments within 1000’ of an intersection.

3.3.6 Field Data Collection Requirements

For studies not needing simulation, the field inventory data is recommended as it can help the analysis.

For projects requiring simulation, the simulation specific field data and counts MUST be collected at a time representing the analysis time period (the 30th highest hour) as closely as possible. The simulation calibration data should be obtained by the analyst conducting/ overseeing the simulation work. This effort should occur during the vehicle count collection if feasible. See the Simulation Chapter for guidance and instruction on calibrating simulations.

With some project areas, it is impractical to obtain all counts and inventory on a single day representing the 30th highest hour. When this happens, the counts and field inventory at the primary locations should be on days that closely represent the 30th highest hour. If it is not possible, then short sample counts should occur during the field inventory collection to factor the off-peak counts to the day the study area was visited. Factor the counts for seasonal influences

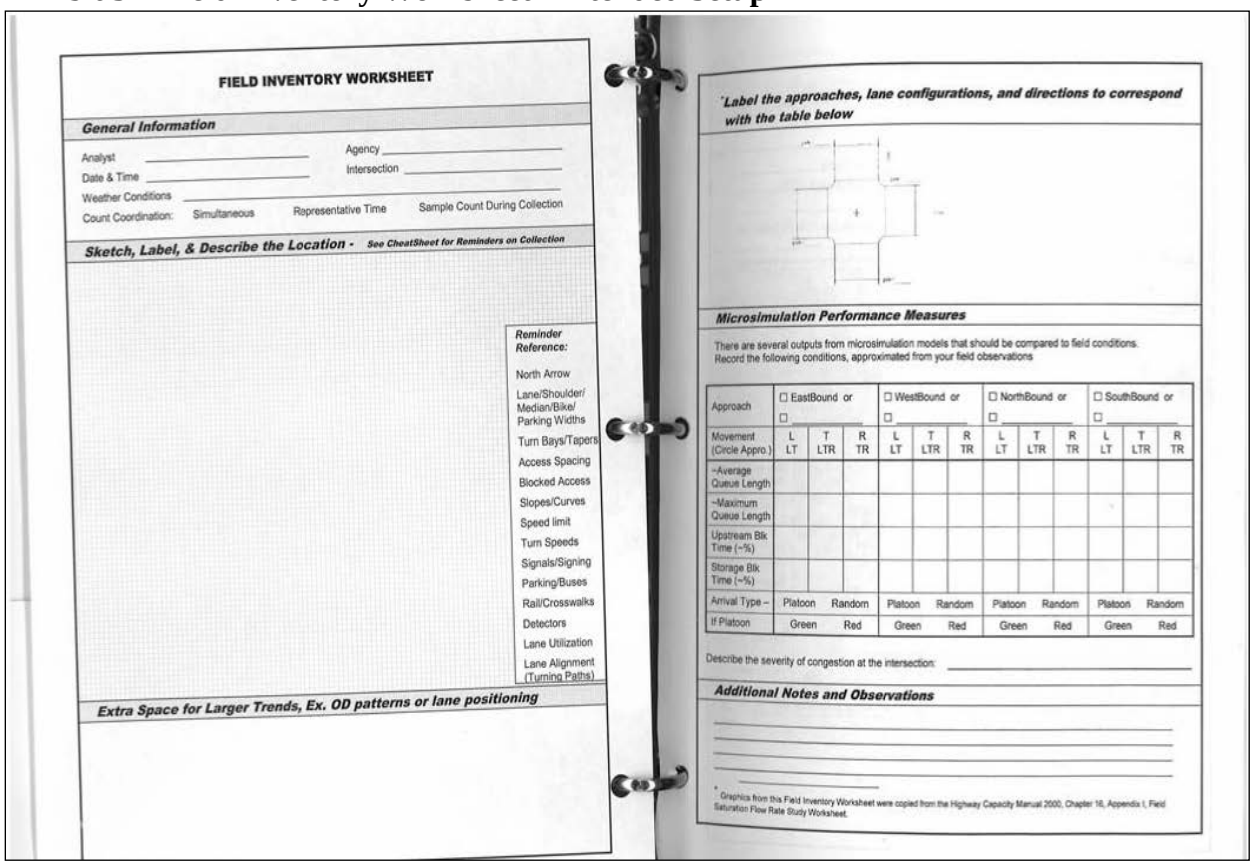
(described in Chapter 5). If this is the case and simulation is required for the study, use the seasonal factor methodology to determine if the vehicle count day is representative of the 30th highest hour.

If the study's primary counts occurred at a time that is more than 10% different than the 30th highest hour period (considering seasonal trend type) then short duration sample counts need to occur during the field collection time to calibrate the "existing conditions" model. The counts need to be at critical locations (high volumes, bottlenecks, unusual conditions) to assist with representing the traffic flows. These rules are established to help ensure that calibration volumes 1) are near the 30th highest hour and 2) represent conditions that have been witnessed in the field.

3.3.7 Field Inventory Worksheet

The Field Inventory Worksheet has been designed by the Transportation Planning Analysis Unit (TPAU) to be generic enough to aid in the collection of field data for all studies. The Field Inventory Worksheet, Exhibit 3-1, assists the field data collection process. The worksheet is an example of how to organize/document the information. It shows much of the suggested information, but it should be customized according the study's needs. The worksheet can be used for projects where just geometry and observational data is required or for projects requiring simulation where all the data listed above should be addressed. Exhibit 3-1 shows a completed worksheet for a simulation project. Note that the worksheet may be printed multiple times for a given project area. The collection of worksheets can be placed in a three-ring binder providing a hard writing surface. A worksheet can be used for each intersection or area of interest in the study and all copies can be neatly organized in a single project binder.

Exhibit 3-1 Field Inventory Worksheet - Intended Setup



FIELD INVENTORY WORKSHEET

General Information

Analyst _____ Agency _____

Date & Time _____ Intersection _____

Weather Conditions _____

Count Coordination: Simultaneous Representative Time Sample Count During Collection

Sketch, Label, & Describe the Location - *See CheatSheet for Reminders on Collection*

Reminder Reference:

North Arrow
Lane/Shoulder/ Median/Bike/ Parking Widths
Turn Bays/Tapers
Access Spacing
Blocked Access
Slopes/Curves
Speed limit
Turn Speeds
Signals/Signing
Parking/Buses
Rail/Crosswalks
Detectors
Lane Utilization
Lane Alignment (Turning Paths)

Extra Space for Larger Trends, Ex. OD patterns or lane positioning

Label the approaches, lane configurations, and directions to correspond with the table below

Microsimulation Performance Measures

There are several outputs from microsimulation models that should be compared to field conditions. Record the following conditions, approximated from your field observations

Approach	☐ EastBound or ☐ _____			☐ WestBound or ☐ _____			☐ NorthBound or ☐ _____			☐ SouthBound or ☐ _____		
Movement (Circle Appro.)	L LT	T LTR	R TR	L LT	T LTR	R TR	L LT	T LTR	R TR	L LT	T LTR	R TR
~Average Queue Length												
~Maximum Queue Length												
Upstream Blk Time (~%)												
Storage Blk Time (~%)												
Arrival Type –	Platoon		Random	Platoon		Random	Platoon		Random	Platoon		Random
If Platoon	Green		Red	Green		Red	Green		Red	Green		Red

Describe the severity of congestion at the intersection: _____

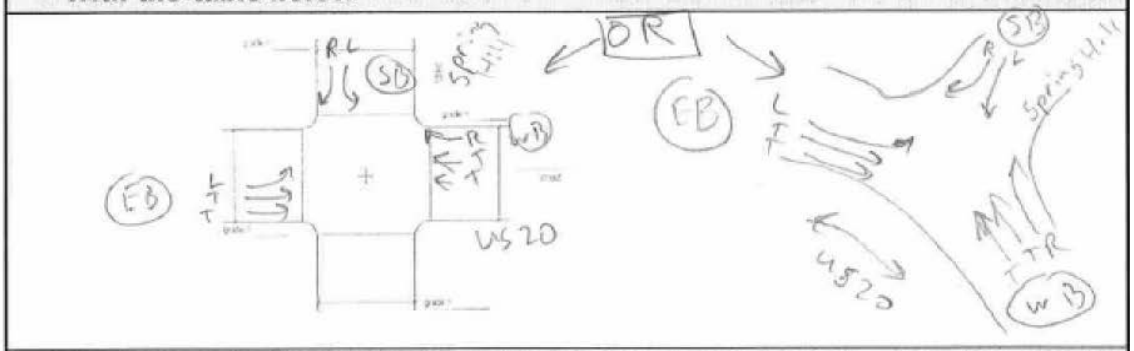
Additional Notes and Observations

_____

* Graphics from this Field Inventory Worksheet were copied from the Highway Capacity Manual 2000, Chapter 16, Appendix I, Field Saturation Flow Rate Study Worksheet.

Exhibit 3-2 Completed Example Field Inventory Worksheet

Label the approaches, lane configurations, and directions to correspond with the table below



Microsimulation Performance Measures

There are several outputs from microsimulation models that should be compared to field conditions. Record the following conditions, approximated from your field observations

Approach	☑ EastBound or ☐			☑ WestBound or ☐			☐ NorthBound or ☐			☑ SouthBound or ☐		
Movement (Circle Appro.)	(L) LT	(T) LTR	R TR	L LT	(T) LTR	(R) TR	L LT	T LTR	R TR	(L) LT	T LTR	(R) TR
~Average Queue Length	50	150			200	50				200		50
~Maximum Queue Length	150	400			Back to Bridge	400				300		300
Upstream Blk Time (~%)												
Storage Blk Time (~%)					5%					25%		<5%
Arrival Type –	(Platoon)	Random		(Platoon)	Random		Platoon	Random		Platoon	(Random)	
If Platoon	(Green)	Red		(Green)	Red		Green	Red		Green	Red	

Describe the severity of congestion at the intersection: Little to no congestion most of the hour, except pk 5 min

Additional Notes and Observations

This Collection seemed to represent a peak hour/season and commuter driving characteristics. This data should be applicable to counts taken on days representing the 30th highest hour for this area.

* Graphics from this Field Inventory Worksheet were copied from the Highway Capacity Manual 2000, Chapter 16, Appendix I, Field Saturation Flow Rate Study Worksheet.

3.4 Vehicle Count Surveys

The data collected from vehicle count surveys is used in nearly all types of analysis procedures,

and can include information regarding volumes of vehicles, types of vehicles, vehicle speeds and directions of vehicle flow. When such information is needed, the analyst must determine the appropriate time and method of data collection to obtain the desired results.

How many counts of what type is dependent on the context of the plan or project goals and objectives. For outsourced projects and plans, a draft scope/work plan with a completed objective section is critical for efficient use of time, money and data for all involved parties. The level of count detail required will be dictated by the level of detail in the plan or project. For example, Transportation System Plans (TSP) will be less detailed than a TSP Refinement Plan.

3.4.1 Vehicle Count Types and Durations

Intersection Classification Counts

Intersection classification counts provide vital information for project development. They provide peak hourly volumes (PHV), Average Daily Traffic (ADT) and vehicle classifications such as cars, pickups, buses and trucks for each approach and movement. Additionally, the K-factor (percent of ADT in the peak hour) and the D-factor (percent of traffic in a single direction) can be derived from the intersection count data. These are then used to convert PHV to ADT. For further explanation of traffic volume characteristics, refer to the Highway Capacity Manual (HCM) – Part I: Overview.

Intersection classification counts are typically 16-hours in duration, so average daily traffic (ADT) and other relationships can be created. These counts are used at signalized intersections, intersections that may become signalized, and other important major intersections, such as interchange ramp terminals. A 16-hour count is needed when requirements exist such as multiple peak periods, truck classifications, signal warrants, pavement design, air quality and/or noise studies in environmental documents. Sixteen–hour counts can also be easily used for other purposes such as pavement design (see Chapter 6) or other plans or projects. The average cost of an ODOT-performed 16-hour Full Federal Manual Classification Count is approximately $\$1,100_{(2012\ costs)}$. This cost is dependent on the complexity of the intersection, whether or not it's a high-volume intersection, and other special requirements including travel.

Intersection classification counts group 13 different types of vehicles, pedestrians and bicycles. Refer to the Federal Highway Administration (FHWA) vehicle classification descriptions in Chapter 6 and in the Environmental Traffic Data Chapter. Classification counts can either be done manually in the field or by use of video cameras. ODOT typically uses video cameras as it does not require the presence of a field technician throughout the duration of the count, may have less influence on driver behavior in some situations, allows for more flexibility in scheduling and processing counts, and provides a database that can be easily revisited if more information is desired at a later time or if an error in the count is detected. Data is recorded in the field and is then sent to the Transportation Systems Monitoring (TSM) Unit for processing.

Passenger and other two-axle vehicles are tabulated both with and without trailers. The number of axles for single-unit trucks and for all single, double and triple trailer trucks is recorded along with buses and motorcycles.

A number will be given to each count so that it can be accessed easily. A hardcopy will be stored in TSM's files. Counts are sent to the requestor either electronically as a spreadsheet file or hardcopy by mail. The first page of the ODOT intersection count provides a sketch of the intersection counted, the date, location, count number and the ADT for each movement. The second page provides a summary of movements broken down into 1-hour increments. Some intersection counts will break the peak periods into 15-minute intervals instead of 1-hour intervals. Specify 15-minute count intervals for any period when peak hour factors are needed. The rest of the pages show individual turning movements with the vehicle classifications, a summary of the bicycle and pedestrian counts (if originally requested) and a summary of the movement volumes. Sample Count Request and Sample ODOT Counts have been included in Appendix 3B – Sample Count Request and Sample ODOT Counts.

Peak Period Counts

Peak period counts capture the individual vehicle movements at a location. These counts are typically used to capture the in/out turning movements at driveway accesses or to count all movements at minor or unsignalized intersections that are not being considered for signalization. Generally, separate truck percentages are not available. Use of turning movement counts are limited to counting in a single peak period. Typical peak periods are morning (6:00 AM – 9:00 AM), mid-day (11:00 AM – 1:00 PM), and evening (3:00 PM – 6:00 PM). A three-hour count is a typical duration to capture the peak hour. A four-hour afternoon peak period count can be obtained to capture both school and commuter peaks. Truck peak hours could be any hour outside of the typical commuter peaks so are unlikely to be captured by a peak period count. For count durations of more than four hours or when more than one peak period is needed, it is more practical to collect a 16-hour count. Count durations less than three hours make it difficult to capture the peak hour and should be avoided unless previous counts clearly identify the system peak hour in which case shorter duration counts may be acceptable. Typical ODOT count costs are variable depending on travel, duration, and other specifics, but are in the 600_{(2012\ costs)}$ range.

Peak period counts should not be used to create daily traffic volumes (ADT) in most cases. Exceptions would be volumes to support HSM analyses and preliminary signal warrants where sufficient 12+ hour counts are available to calculate K-factors to be applied to the peak period counts. Air/noise traffic data production must use longer duration counts. See Chapter 5 for more information.

Road Tube Counts

Road tube counts are often employed when the details provided by intersection counts are not needed, impractical given the data needs, when certain additional data is needed that would best be collected by tubes, such as roadway speed (Section 3.5.2), or available gaps in traffic. These count individual vehicles only or can be setup to capture vehicle classifications. These counts are used to capture mid-block volumes on streets and for segment volumes on most highways and interchange ramps. Road tubes are subject to vandalism or damage, and should not be done where vehicles may stop on the tube (in congested areas or near intersections) or cross the tube at an angle (near intersections or driveways) because under or over-counting may occur. Tubes are

also susceptible to be damaged on roadways with speeds at or above 40 mph, and for employee safety reasons, cannot be placed on high-volume expressways and freeways. It is also not recommended to use road tubes during winter months (November 1st – April 1st), due to the use of studded tires, which have been shown to destroy hose tubes, even at slower city speeds. Road tube counts are typically done in a 48-hour format so an entire 24-hour period can be obtained. A 7-day count can also be done if daily fluctuations over a week are necessary to be captured and are only done on roadway segments. Typical ODOT road tube count costs are around $200(2012 costs).

3.4.2 Other Sources of Traffic Data Information

Frequently, existing or alternative count sources are overlooked so these should be reviewed before completing the initial count list. This can, in some cases, substantially reduce the number of new counts, save on data collection costs, and cut down the number of Scope of Work (SOW) review iterations. When searching for older traffic counts, generally the counts should only be a few years old (3-5). The longer period may be acceptable when there is little to no change in volumes or when developing a preliminary analysis. When counts are older than three years, growth rates may not reflect the growth when much change is occurring. The further the count is being interpolated, the more likely for error to be introduced. See Chapter 6 for information on forecasting.

Transportation System Monitoring (TSM) Unit Data

- **Previously Collected Counts**

  Besides obtaining new counts there are some other sources of count information which may be used to reduce the overall new count requirement needs. ODOT has a large quantity of traffic volume data and previously collected counts. Before any new counts are ordered, the Transportation System Monitoring (TSM) Unit should be contacted to determine if any previous usable counts are available for the study area.

  In general, counts in the study area should be three years old or less. Older counts between three and five years old can sometimes be used if they are the correct type and no significant changes, such as new roads or developments, have occurred to influence traffic flows. A newer count may not accurately represent the traffic flows on a roadway section even if less than the three years old if recent development has occurred within or near the study area since the count was taken.

  If you have the specific count identifier of a previous count, the count can be requested from the TSM data analyst who can send either an electronic or hardcopy version of the count.

  Typically, internal ODOT staff can access prior counts through the Traffic Count Management Program (TCM). This program requires approval from TSM to obtain access to the program. Also, some vendors maintain and sell traffic data from a compiled database.

- **Transportation Volume Table (TVT) and Highway Performance Monitoring**

System (HPMS) Count Sites

The 48-hour tube counts used for the development of the TVT and at HPMS sample sites are available from TSM. These counts are collected in 15-minute intervals at a minimum. Some TVT and all HPMS counts have vehicle classification information as well. (Note: Volumes listed in the TVT are for a single point, not the entire segment).

- **State Highway Vehicle Classification Data**

State Highway vehicle classification information is available through the TSM Unit's Internet Traffic Volumes and Vehicle Classification webpage. Exhibit 3-3 shows an example excerpt of the State Highway Vehicle Classification Report. This report is also the source of information for highway segments Average Annual Daily Traffic (AADT). With this information, the daily and hourly volumes can be obtained along with truck classifications which will substantially reduce the need for 48-hour road tube counts. Vehicle classes 4 through 13 are considered trucks for most applications, including Pavement Design and HCM analysis. However, class 3 vehicles may be considered light trucks in some software.

Note that volumes listed in the State Highway Vehicle Classification report are for segments, as shown in Exhibit 3-3. A beginning mile point is shown for the starting point of each segment. Volumes listed in the Transportation Volume Tables (TVT) are for individual points, as shown in Exhibit 3-4. The mile point shown is where the traffic count was taken.

Exhibit 3-3 Excerpt from State Highway Vehicle Classification Report

Traffic Volumes and Vehicle Classification

Effective Date 12/31/2011 *Highway #: 033 CORVALLIS-NEWPORT Hwy*

Beginning Mile Point	Roadway	Mileage Type	Overlap Code	Dir Code	AADT Volume	AADT 20 YR Volume	ATR Count	Design Hour Factor	Ton Mileage Factor
0.00	1			E	14900	0	N	11.0	6.4

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
Vehicle Class Percentage	0.66	50.35	43.04	0.73	1.90	0.75	0.21	0.27	1.12	0.82	0.02	0.04	0.09
Volume	98	7502	6413	109	283	112	31	40	167	122	3	6	13

Beginning Mile Point	Roadway	Mileage Type	Overlap Code	Dir Code	AADT Volume	AADT 20 YR Volume	ATR Count	Design Hour Factor	Ton Mileage Factor
0.05	1			E	13000	0	N	11.0	6.4

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
Vehicle Class Percentage	0.66	50.35	43.04	0.73	1.90	0.75	0.21	0.27	1.12	0.82	0.02	0.04	0.09
Volume	86	6546	5595	95	247	98	27	35	146	107	3	5	12

Exhibit 3-4 Excerpt from Transportation Volume Tables

		CORVALLIS-NEWPORT HIGHWAY NO. 33
		Milepoint indicates distance from Oregon Coast Highway (US101), in Newport
		On Olive Street
0.04	*15400*	0.04 mile east of Oregon Coast Highway (US101)
0.07	*13400*	0.02 mile east of Avery Street
0.30	*16000*	0.02 mile west of Eads Street
0.34	*14000*	0.02 mile east of Eads Street

- **Automatic Traffic Recorders/Automatic Vehicle Classifiers (ATR/AVC) Sites**

  ATR and AVC sites record bidirectional volumes on an ongoing basis and can be used as substitutes for classification and regular road tube counts. ATR sites only include bidirectional volumes, but to understand vehicle classifications, every ATR site is also counted with a 24-hour classification count every three years which is available from the TSM Unit. AVCs continually classify data so classification data will be available throughout a given year at these locations. AVCs are gradually replacing ATRs so eventually all recorder sites will have classification abilities. ATR/AVC "Critical Hour" listings are also available which breakdown a year's worth of data down to the hour level so a 30 Hour Volume (HV) can be easily obtained at that location.

- **Ramp Volume Diagrams**

  While 16-hour counts at an interchange ramp terminal are preferable, the ramp volume diagrams in the Transportation Volume Tables and on the TSM Unit webpage can be used to substitute if a count is not available and intersection turn movements or intersection operations are not desired. Many of the interchange ramp volumes have 48-hour tube counts that were used to create these volumes, so an analyst should check for their availability. These counts are taken on a 3-year schedule. Free-flow ramp volumes (i.e. between two Interstate highways) can be obtained from the diagrams if a 48-hour tube count is not available or practical. The TVT ramp volumes are balanced and may not represent the actual count volumes. Contact the TSM Unit directly if the actual count is needed.

Other Jurisdiction's Counting Programs

In addition, some counties and larger cities may have traffic counting programs in place. The TSM Unit webpage also has links to many of these jurisdiction's Internet traffic data pages on the Traffic Counting Program webpage.

These counts are typically daily volumes and can be used to supplement the local system and can reduce the need for 48-hour road tube counts. Sometimes intersection counts are available, but differing classification breakdowns and durations from ODOT standards can make these difficult to use except for a source for local peak period counts.

Traffic Signal Controller Counts

The new Model-2070 and earlier Model-170 traffic signal controllers have the ability to store loop or video detection information that can be downloaded at a later date. This data is attractive to the end user as there are a large number of usable installations available. Controller count data is primarily used by Region signal timers, when preparing field refinements to signal timing plans. For traffic analysis, controller counts are useful in determining trends between weekday and weekend traffic, or in establishing relationships for side streets (i.e. seasonal adjustments). It is imperative to have a copy of the loop detector diagram for the specific intersection, when deciphering both Model-2070 and Model-170 controller count data. The Model-2070 controller stores the data in up to 32 columns or bins, depending on the complexity of the intersection, with two loops per detector phase (standard). However, field modifications may differ from the "as-built" plans, which is why a current detector diagram is necessary. The most recent detector diagrams can be obtained from the various Region Tech Centers.

Special Vehicle Counts (short duration)

Frequently on projects, there is a need to collect additional peak hour data for driveways, for a check count, or other overlooked spot. Sometimes these counts are done for specific purposes such as capturing headways, weaving movements, or saturation flow rates for simulation calibration. These counts typically are collected by the project analyst rather than region or consultant counting staff. Counts longer than an hour or in many locations should be done by region staff, TSM staff or traffic count contractors.

These counts can be manually tabulated in case of a number of small adjacent driveway counts, or use of a video camera or electronic count board. Video cameras can be useful assuming that a good vantage point is available that will provide a clear view of all movements being counted. When using video cameras to collect count surveys, be sure to have an adequately charged battery and large enough media to collect the amount of data needed.

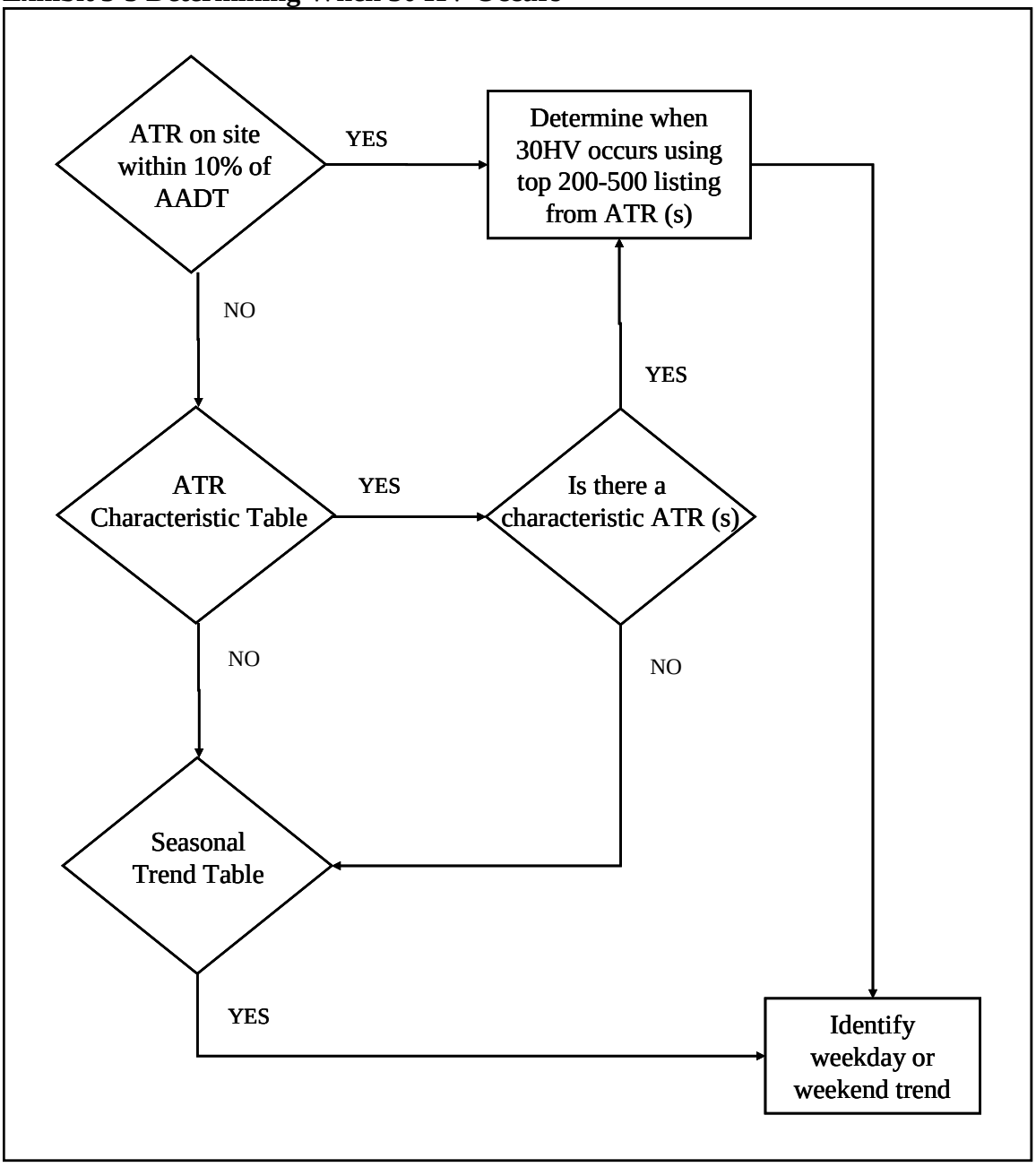
Typically, when counts are not done by video, some sort of handheld electronic count device is used. One of these is the JAMAR board which has been used by ODOT in the past to collect counts. Limitations of the JAMAR boards prevent using these to do a full 13-class count. However, the boards can be used for volume-only or limited class counts. These counters are necessary for saturation flow data capture or other simulation/ operational data (see the Simulation Chapter). The JAMAR traffic count is in raw form which can be downloaded to a text file through the use of the serial cable and a communications program. Detailed instructions for this process are available on the Planning Section Technical Analysis and Tools webpage.

3.4.3 Vehicle Count Periods

For most traffic studies, the 30th highest hour volumes (30 HV) should be used to represent future volumes. It is recommended a top 200- to 500-hour count listing (Critical Hour) of the ATR(s) is obtained from the Transportation Systems Monitoring Unit. The 30 HV at the ATR(s) will be included in the list so that it will be possible to determine when the 30 HV occurs during the day and in the week. Manual counts can then be timed for the period when the 30 HV will likely occur, minimizing seasonal adjustments. Exhibit 3-5 illustrates the general process for

identifying when the 30 HV occurs. Refer to Chapter 5 for detailed guidance on each of these steps.

Exhibit 3-5 Determining When 30 HV Occurs



To get a typical traffic mix of the 30 HV for the analysis, the counts should be taken as close to the likely 30th highest hour as possible. This typically requires collecting counts on a weekday afternoon in most larger urban areas, but may include weekends for high recreation areas (the coast or Central Oregon), or areas experiencing lunch hour peaks or high reverse direction flows during the day. Where capturing school trips is important, counts need to be taken when school is in session. In some cases two sets of counts may be needed, during months when school is in

session as well as during the summer. In fully developed portions of Metropolitan Planning Organization (MPO) areas, the 30th highest hour is generally assumed to be represented by the typical weekday evening commuter peak hour. Outside of fully developed MPO areas, a seasonal adjustment will be required to convert the counts to 30 HV. For access management, the peak hour is defined as the highest one-hour volume during a typical or average week in urban areas, and the 30th highest hourly volume on rural roadways.

Seasonal adjustments should not be more than 30% because the traffic flow characteristics are most likely NOT represented by the count information. A seasonal adjustment greater than 30% indicates that the count was taken at the wrong time of year. Turn movement patterns may be so different they cannot be adequately represented by a seasonal adjustment. Count timing is critical especially if the project/plan SOW will not be complete until after October. Please refer to Existing Volume Development (Chapter 5) or contact TPAU for advice.

Counting Considerations to Minimize Seasonal Adjustments

- Coastal or summer recreational areas should be counted during the traditional summer period (Memorial Day to Labor Day). Outside of coastal/recreational areas, most areas can be counted from March to October. Larger MPO areas or commuter-based corridors can be counted most months, but should generally avoid December to February as these are the lowest traveled months, have a number of holidays, and have the most weather-related problems. Winter recreation areas (i.e. Mt. Hood area) should be counted in the December to February timeframe to capture the peak periods. Recreational areas (or routes that travel to or between recreational areas) may require counting on the weekends.
- If alternate periods/volume thresholds other than the typical summer/ or 30 HV like what would be used to create an alternate mobility standard, then counts need to be taken in those alternate periods so resulting seasonal factors do not exceed 30%. This might mean for certain efforts, multiple sets of count data may be required. For example, a summer recreational area that uses a non-summer standard, counts should be obtained in the non-summer (Oct-Apr) period. For areas that use an annual average, counts should be obtained in Sep-Oct and/or Apr-May periods. Winter or winter-summer recreational areas will be a variation/combination of the methods.
- Road tube count placement is limited to the April to October period because of studded tire damage potential.
- In general, days potentially influenced by state or federal holidays or other significant events (such as local festivals, sporting events, hunting season, etc.) that may alter normal traffic patterns should be avoided.
- Counts that may be influenced by nearby construction projects may be affected and such counts should be thoroughly investigated and may require adjustments.
- It is also common to avoid Monday and Friday counts when weekday data is desired, as the trip characteristics on these days generally differ from the remainder of the week.
- Consideration should be given to the presence of generators such as schools/colleges/universities because of the enrollment and events (such as spring break) can vary greatly through the year. Consideration should also be given to major employers or attractions such as regional shopping centers that experience significant peaks in generated trips that may or may not occur during the other peaks because of shift

changes or event scheduling. Note: The City of Corvallis requires that counts occur when Oregon State University (OSU) is in session because of the large percentage of the population related to school being in session.

- In agricultural areas, truck traffic may be highly seasonal and have a substantial impact on the system. Counts may have to be timed carefully to balance the overall peak months with the harvest periods.
- In the Portland Metro area, while infrequent, there may be times when additional data must be collected to capture the 2nd hour, needed to evaluate the adopted 2-hour Oregon Highway Plan (OHP) mobility target. This is generally only necessary when the mobility target for the second hour of the peak period is lower than the mobility target for the first hour of the peak period and the analysis shows the first hour does not meet its target, but satisfies the target for the second hour.

Counting Considerations for Congested Conditions

Counting under congested conditions (i.e. Portland Metro area) requires some additional considerations as there may be places that the actual demand is queued up and unable to flow smoothly through the system. Volumes are being reflected on the ground while demand is being reflected in the form of unserved queues (cannot pass through in a single signal cycle over a 15-minute period at least) . In this case, a typical count would only measure the discharge flow through the intersection versus what would like to use the intersection. This could lead to an underestimation of demand especially under a build alternative condition. Both volume and demand should be quantified in the analysis in order to help inform the analyst on volume development steps and following analyses.

If there is a suspicion that counts may not reflect true demand...

Step 1: Check existing tube counts or automatic traffic recorders for any peak hour “M” effect where the shoulder hours on each side of the peak hour/period are higher than the peak hour/period or the shoulder hours share the same capacity as the peak hour. If this is the case, demand has likely exceeded capacity.

Step 2: Check existing manual turning movement counts to see if the 15-minute shoulder intervals of the estimated peak hour/period are higher than the peak hour/intervals.

Step 3: If easily available, check private sector vehicle probe data such as TomTom or Inrix data to see if the corridor experiences speeds lower than the posted speed for more than one hour.

Step 4: Do a field visit or have video taken to verify whether vehicles can be served before ordering counts.

Step 5: Consider collecting counts upstream from the desired count location where the roadway is not oversaturated if congestion is observed in the field, video, and/or by counts. When counting upstream, consider counting side streets between the unsaturated count location and the desire count location that may have traffic leave or enter the roadway.

Other considerations:

- If traffic is heavily favoring a single lane more than others, lane by lane utilization counts or field observations are needed. For example, this can easily occur in one lane of a dual

left turn lane because of an immediate lane drop or heavy turn movement downstream. Lane utilization counts should also be considered where a through lane is reduced downstream from a traffic signal.

- Locations need to be noted where queue spillback occurs from turn lanes blocking through lanes or vice versa. This may require additional counts upstream or field observations.

3.4.4 Vehicle Count Locations

Vehicle count locations should be identified in the project work plan/SOW, and should be determined based on the needs of the subject plan or project. For example, planning efforts that are expected to generate potential highway projects within three years will require more detailed counts than a standalone or long-range plans, such as TSPs.

For planning projects it is important to correspond with the local jurisdiction and TPAU/Region Traffic to make sure that count needs cover the system to be analyzed at the appropriate level of detail and address issues. The grant/project manager should meet with TPAU/Region Traffic staff to discuss traffic count requirements after the objective section of the SOW (or project prospectus) is completed as this section provides the context for the plan/project. For Transportation Growth Management (TGM) grants, it is usually more efficient to arrange a meeting with the appropriate TPAU/region staff to go over multiple studies at once. For construction projects, the project team or at least the region traffic engineer/manager, the environmental lead, and/or project leader should be consulted.

While differences of opinion may exist on the number and type of counts versus the available budget, remember that the ultimate goal will be to have enough data to analyze and answer the questions, address the needs, evaluate alternatives, and cover the level of detail in the plan/project as described by the project objectives and the local jurisdiction(s). Staff will need to come to an agreement whether the data collection budget and/or the number/type of counts need to change.

The following plan/project-specific count location guidelines do not cover every possibility or combination of elements, but are intended to help generate a reasonable starting point for discussion. The location guidelines are generally laid out in an increasing level of detail.

County Transportation System Plan (TSP)

The arterial and major collector system needs to be documented (counted). It is generally unnecessary to count lower functional class roads as these usually carry very little traffic, and possibly are unpaved unless the county government wants a specific roadway included because of operational issues. Analysis at the County level is more system-based with a higher emphasis on ADT rather than peak hour and many of the analysis tools require ADT as an input.

- Need to have at least ADT-level count coverage of the arterial and major collectors. Acceptable previously taken counts may exist at the state or local level.
- Major arterial intersections with other arterial and major collector intersections should be

counted where operational issues exist. State highway segments (between major intersections) should use the TSM Unit's vehicle classification data to capture volumes and truck classifications.

- The TSM Unit's ramp volume diagrams (where available) should be used to capture any free-flow ramp connections.
- County arterials and major collectors should have at least a 48-hour classification tube count performed so truck traffic can be captured and ADT can be calculated.
- Peak period counts should be obtained at signalized intersections, unsignalized highway to highway junctions, and county arterial – highway intersections. If this is a TSP Update, refer to the old TSP to help identify the critical intersections that should be counted.

City Transportation System Plan (TSP)

The arterial and collector system needs to be documented (counted). It is generally unnecessary to count lower functional classes unless the roadway is area-significant, provides an alternate path for trips to bypass congested areas (as in a parallel local street), or the local government has previously identified operational issues. Analysis at the City level is more centered on the peak periods and individual facilities/intersections which require more detail.

- Need to have at least ADT-level count coverage of the arterial and collectors. Acceptable previously taken counts may exist at the state or local level.
- Major cities (> 50,000 pop,) generally need to have at least the arterial system counted.
- Medium cities (10,000 – 49,999 pop.) generally need to have the arterial and representative/significant collectors counted.
- Small cities (<10,000 pop.) generally need to have the arterial and significant collectors counted.
- Major arterial intersections with other arterial and significant collector intersections should be counted. Peak period counts should be obtained at minor arterial/collector signalized intersections, unsignalized highway to highway junctions, city arterial – highway intersections, and major private development accesses (i.e. regional shopping mall). If this is a TSP Update, refer to the old TSP to help identify the critical intersections that may need to be re-evaluated.
- Significant collectors extend across the city for a considerable distance, are a direct route, or extend outside the city.
- If multiple signals exist, it may not be necessary to have a count at every one, but a reasonable representation of the system needs to be counted.
- Bracketing peak period counts with 16-hour counts is an acceptable practice. Each major roadway should have truck traffic captured on it in at least one location.
- Sixteen-hour counts should be obtained at interchange ramp terminals and signalized major arterial intersections. If tube classification counts are available to provide ADT and truck volumes on each leg, then shorter duration counts can be used. The TSM Unit's ramp volume diagrams (where available) should be used to capture any free-flow ramp connections.
- State highway segments (between major intersections) should use the TSM Unit's vehicle classification data to capture volumes and truck classifications.
- City arterials and collectors should have at least a 48-hour tube count performed so ADT

can be calculated. Larger cities may already have this count data.

- If detailed refinement plans and/or actual highway projects are expected out of the TSP within three years and plan to use the TSP data, then the counted major intersections should be 16-hour counts with the lesser unsignalized intersections or access points using peak period counts.

Interchange Area Management Plan (IAMP)

The roadway system needs to be counted within at least a half-mile radius of the interchange. Analysis at the IAMP level can be close to a project-level of detail (see project section) depending on whether it is standalone or not. If the IAMP is part of a project, then the IAMP should be using the project counts and volumes and no new counts should be necessary unless the counts are very old (greater than three to five years old) or development patterns in the area have changed. It may be necessary to obtain a few "check counts" to see if volumes are substantially different before replacing all or most of the counts. If the IAMP is a standalone plan but it is anticipated that a project may occur within three years, then the IAMP needs a project-level count request. If the IAMP is a standalone plan but no project is anticipated within three years:

- Major arterial intersections with other arterial and major collector/collector intersections should be counted.
- Sixteen-hour counts should be obtained at the ramp terminal intersections, other arterial/arterial intersections, or unsignalized intersections that may need to be signalized.
- Peak period counts should be obtained at other existing signalized and unsignalized intersections and unsignalized intersections.
- 48-hour road tube counts may be necessary to support HSM safety analyses.
- If multiple signals exist, it is unnecessary to have 16-hour counts at every one. Bracketing peak period counts with 16-hour counts is an acceptable practice. Each major roadway should have truck traffic captured on it in at least one location.
- Most, if not all, driveway accesses should be counted with peak period counts as many of these will be rerouted to new connections.
- State highway segments (between major intersections) should use the TSM Unit's vehicle classification data to capture volumes and truck classifications.
- The TSM Unit's ramp volume diagrams (where available) should be used to capture any free-flow ramp connections.

Refinement, Management or Facility Plans

The arterial and collector system needs to be counted within the defined study area limits. It is generally not necessary to count lower functional classes unless the roadway is area-significant, provides an alternate path for trips to bypass congested areas (as in a parallel local street), or the local government has previously identified operational issues. If it is anticipated that a project may occur within three years, then a project-level count request is needed. If no project is anticipated within three years:

- Major arterial intersections with other arterial and major collector/collector intersections should be counted.

- Facilities parallel to the subject arterial should be counted.
- Longer roadway sections without intersections should use road tube counts.
- Sixteen-hour counts should be obtained at signalized intersections and major unsignalized intersections (i.e., ramp terminals, four-way stops) to capture truck traffic or where larger scale improvements may be needed.
- Bracketing peak period counts with 16-hour counts is an acceptable practice. Each major roadway should have truck traffic captured on it in at least one location.
- Unsignalized intersections or major accesses should be counted with peak period counts.
- 48-hour road tube counts may be necessary to support HSM safety analyses.
- If an Interstate Highway or statewide expressway exists in the study area, the mainline shall be counted by direction between interchanges in addition to any interchange ramp terminals. Road tube counts may be necessary to capture movements on ramps or connections.

Local Street Network (LSN) or Downtown Plan

These kinds of plans are generally trying to identify new roadway or multimodal connections to control congestion on the state highway or make limited improvements in the downtown area. The arterial and collector system need to be counted. It is generally not necessary to count lower functional classes unless the roadway is the only access to a neighborhood, provides an alternate path for trips to bypass congested areas (as in a parallel local street), or the local government has previously identified operational issues. Larger numbers of peak period counts may be necessary with a few 16-hour counts at major intersections.

- Major arterial intersections with other arterial and collector intersections should be counted.
- Sixteen-hour counts should be obtained at signalized intersections and major unsignalized intersections (i.e., ramp terminals, four-way stops) to capture truck traffic or where larger scale improvements may be needed.
- If multiple signals exist, it is unnecessary to have 16-hour counts at each one. Each major roadway should have truck traffic captured on it in at least one location.
- Unsignalized intersections or major accesses should be counted with peak period counts.
- 48-hour road tube counts may be necessary to support HSM safety analyses.
- Bracketing peak period counts with 16-hour counts is an acceptable practice. Each major roadway should have truck traffic captured on it in at least one location.
- State highway segments (between major intersections) should use the TSM Unit’s vehicle classification data to capture volumes and truck classifications.
- The TSM Unit’s ramp volume diagrams should be used to capture any free-flow ramp connections.

Pedestrian or Trail Plans

Generally, counts are only needed if the state highway system will be affected by removing or narrowing through travel lanes or if new crossings are to be added. Count requirements in the lane reduction areas should follow the LSN/Downtown Plan recommendations above.

Plans with proposed mid-block trail crossings of state highways or local arterials should have a 48-hour classification road tube count performed at the crossing location. For plans with existing pedestrian crossings (formally defined or not) where the number of crossing pedestrians is desired, the crossing count should be replaced with a 16-hour video classification count with bike and pedestrians requested.

Pedestrian and/or bicycle counts are more adversely affected by weather conditions than vehicle counts, and are recommended to be taken when pedestrians and/or bikes are anticipated, such as not in the winter in many cases, or during school-in-session periods if near a school/college/university.

Traffic Impact Studies (TIS)

For TISs, the analysis area and study intersections are typically selected from estimates of anticipated impacts from added traffic based on site trip generation and distribution, and existing intersection operations. Count requests need to be developed with the guidance of the Region Access Management Engineer or appropriate region staff and the Development Review Guidelines.

- Sixteen-hour counts should be obtained at major unsignalized intersections (i.e., ramp terminals, four-way stops) to capture truck traffic; obtain the basis for signal warrants, or where larger scale improvements may be needed.
- Signalized intersections may use a 16-hour count or a peak period count depending on the particular study area.
- If multiple signals exist, it may not be necessary to have 16-hour counts at each one. Bracketing peak period counts with 16-hour counts is an acceptable practice. Each major roadway should have truck traffic captured on it in at least one location.
- Unsignalized intersections and accesses should be counted with peak period counts.
- 48-hour road tube counts may be necessary to support HSM safety analyses.
- The Interstate/expressway/highway mainline shall be counted by direction in addition to any interchange ramp terminals. Road tube counts may be necessary to capture movements on ramps or connections.

Construction Projects

For most other project types (modernization, safety, operations, etc) the analysis area and study intersections are selected by considering the problem that is being addressed by the project and the information that is required to fully assess the problem and propose appropriate solutions. Project analysis is needed to support roadway and intersection control improvements, pavement and bridge design, air quality, and noise mitigation. Larger projects, especially those with required environmental studies (such as noise and air quality) may require multiple full 16-hour classification counts.

- Sixteen-hour classification counts should be obtained at signalized intersections and major unsignalized intersections (i.e., ramp terminals, four-way stops) to capture truck traffic or where larger scale improvements may be needed.

- Truck classification data must be captured on each roadway segment in the study area.
- Minor unsignalized intersections and accesses should be counted with peak period counts.
- 48-hour road tube counts may be necessary to support HSM safety analyses.
- Significant driveway accesses should be counted as many of these will be rerouted to new connections.
- If an Interstate Highway or grade-separated highway exists in the study area, the mainline must be counted by direction between interchanges in addition to any interchange ramp terminals. Road tube counts may be necessary to capture movements on ramps or connections.

3.4.5 ODOT Internal Count Request Process

When ordering counts, the request must contain the name of the contact person (requestor), the person to whom the data will be sent, the locations, time periods, dates, types of counts and collection methods must be clearly communicated to those conducting the counts. Count requests should group different count types (classification, peak period, road tube) separately for clarity. The count request should also list any special requests, count intervals, count time windows (start and finish dates), and a charge number (Expenditure Account (EA) for internal counts). A couple examples of a special request would be counting only on a specific day or counting certain intersections or elements of intersections at the same time. Because of staffing restrictions, classification counts for 2012 and beyond will not have pedestrian and bikes counted by default. Pedestrians and bike counts will need to be specifically requested.

A map showing the count locations, durations and other special requirements should also be provided to help eliminate misunderstandings since often times the text is separated from the map. Please keep in mind that the field counting staff usually only has the map in hand so all pertinent information (count locations, durations, types, intervals, and special requests) needs to be on the map. A Sample Count Request including map have been included in Appendix 3B – Sample Count Request and Sample ODOT Counts.

When ordering intersection counts, be sure to specify the duration and type for each location. Fifteen-minute intervals must be specified for at least the standard morning, noon and evening peak periods in 16-hour counts. Peak period counts should be done in 15-minute intervals. It is not required, but very helpful if 48-hour road tube counts are counted in 15-minute intervals as well.

Specify the latest acceptable date by which the count is needed for analysis. Keep in mind, based on scheduling and staff limitations, that it can take at least five weeks from the date of the request date to get the count scheduled (not including weather restrictions) and then another three to four weeks to have the count processed, recorded and distributed. Therefore, counts need to be requested about nine weeks ahead (or more if weather is a factor) of when they will be needed for the analysis work.

All count requests should have copies sent to both the Region Traffic Manager and to the TSM unit to alert them that they are requested and need to be scheduled. Either TSM or the region

staff will have the counts performed (in-house or with contractors) and should assure that the data is processed into an ODOT format before being released to the requestor. The TSM Unit needs know what counts are available so staff resources can be allocated. The TSM Unit coordinates the counting schedules of all Region traffic counting staff. Coordinating with the TSM Unit in the loop allows for these counts to be added to ensure the count databases are properly maintained, which can avoid unnecessary duplication and limit counting needs by others and minimize delays. ADT –capable counts performed by third parties or consultants are also encouraged to be submitted to the TSM Unit to be added to the database.

3.4.6 Using the Traffic Count Management (TCM) Program (ODOT Employees Only)

TCM is a program maintained by the TSM Unit and available for installation on ODOT staff computers. It contains recent counts (2008 forward) conducted throughout the state of Oregon. Counts performed by the TSM Unit and counts provided to the TSM Unit are entered into the program. It is important to contact the TSM Unit if you are unable to find counts in your study area or to determine if there are existing counts that have not been processed.

There are many different count types and each requires TCM to generate a different report. TCM must be installed on a computer and an individual user name and password is required. Contact the TSM Unit for access. The Traffic Count Management (TCM) Program Count Report Guide, included in Appendix 3C – Traffic Count Management (TCM) Program Count Report Guide, provides step-by-step instructions on how to obtain traffic count information from TCM in the correct format for the most common types of counts used by the analyst. This includes intersection counts, ATR/AVC sites, TruckSum, and tube (machine) counts.

3.4.7 Count Validation

Once counts are completed and processed and are available to the analyst , the counts should be checked to make sure that everything is furnished as requested. This includes count days, time periods, 15-minute intervals, movements, and classification requirements. Missing data, intersection approaches, etc should be reported back to the TSM Unit and the appropriate region for recounting (if possible) or reprocessing (in case of a video count) as soon as possible. Do not wait until all of the counts are completed to perform these checks.

Check the counts for any “red flags.” Do the values look okay? Counts have had approaches mis-labeled, or wrong orientations (i.e.flipped east to west but also can be west to north) .

As counts are being assembled for volume development, additional issues may arise between adjacent counts. Compare these counts with previous counts with adding in factored historical/seasonal growth; they should be similar if nothing has changed in the field between the counts. If adjacent or a whole section of counts appear to be very low or high, then verify that no incidents (road closures on the subject or adjacent roadways, crashes, bad weather, or scheduled events nearby) occurred while the count was in progress. If the count is 18 months or older then crash data records can be checked. Recent counts may require more investigation (contact TSM Unit, Region traffic units, local maintenance districts, or traffic operation centers).

3.5 Travel Time, Speed and Other Data Collection

3.5.1 Travel Time

Travel time surveys measure the duration of time taken for a vehicle to travel from one point to another along a designated route, and are often used to quantify congestion over a corridor. The data collected from travel time surveys works well with statistical analysis, and the results are often more easily understood by the public than other methods used for measuring congestion.

Data Collection

One common method used for this data collection uses a "floating car." The elapsed time is measured from a car driven along the designated route maintaining an average travel speed relative to other cars on the road. Other methods include vehicle or license plate matching and the use of various intelligent transportation system technologies. Travel time data is collected at the beginning and end of a designated route, and can be collected between predetermined points along the route as well, depending on the level of information desired. Travel time can also be calculated from Inrix speed data using the average speed and segment length (see section on Speed below).

When collecting travel time data, all measurements should be taken under good weather conditions and during a time representative of the period of interest for the study. Except when collecting the data for simulation calibration, it is good to distribute the travel time runs over several days and over multiple weeks that are representative. To have an accurate representation of the field conditions for simulation calibration, travel times need to be taken at the same time as the operational field data collection.

It is recommended that a minimum of 10 travel time runs be collected in each direction for each hour to be simulated (and each lane where lane imbalances occur) for both freeways and arterials. The 10 travel time runs should be collected during the same time as other data collection if possible but can be collected over multiple days if necessary. The travel time runs can also be a combination of the floating car and Bluetooth data methods. For VISSIM simulations, refer to Section 3.5 in the VISSIM Protocol.

Floating Car Data Collection with GPS

Floating car travel time runs are conducted using a handheld GPS device that records vehicle location, speed, and direction of travel every 1 to 5 seconds. This method allows the actual roadway conditions to be analyzed as the data returned from the probe vehicles will reflect the periods of congestion and free-flow speeds experienced by other motorists. The floating car technique requires the driver to mimic or match the speed of the traffic stream for a given roadway. However, it may be difficult for test drivers to mirror the actions of the traffic stream as drivers often revert to their own driving habits instead of staying with the majority of traffic. When designing a floating car study, the goal is to have a large enough sample which is optimally spaced for the purpose of capturing variability within the traffic stream. Some things to consider:

1. Route selection

    a. Try to include as many key intersections, segments as necessary
2. The number of floating car "probes" and the area (route) covered per run
    a. In general, increasing the number of probes sampled during the run and/or reducing the area size will increase the resolution of the samples.
3. Lane position of probe car
    a. Results are provided in fine enough detail to determine speeds based on lanes occupied. It may be difficult for the driver to determine which lane most closely represents the average vehicle speed.
4. Weather, Tree cover and %trucks along route.
    a. High instances of either will lead to signal disruption and loss of data points.
5. Start the routes at least 15 minutes ahead of recording period
    a. Establishing the route prior to the recording time minimizes driver route errors
6. Driver Notes are helpful (see Exhibit 3-5 Determining When 30 HV Occurs).
    a. Record queue position at intersections
    b. Lane position

Exhibit 3-6 Example of Notes

I hit lots of reds on OR99E. There were only a couple instances where I hit greens along the cooridor.
I was in the inside lane on OR99E and the outside lane on I5. I used the inside lane going northeastbound on OR99E to position myself in the appropriate ramp lane, but also because the curbside lane delayed at driveways (Especially at Killdeer) as people turned into the shopping center. I used the inside lane going southwestbound on OR99E to position myself for a quick turnaround at Ermine Drive and to avoid delays due to right-turning traffic. I remained in the right hand lane on I5 for all but (2) loops. The ramps are closely spaced. As long as I was following multiple vehicles, I did not feel disadvantaged by sitting in the right hand lane. During (2) loops, I was behind a semi-truck and followed other vehicles around the slow moving truck.

The queues were no more than 10 cars-
The longest queues existed for the inside lane southwestbound OR99E at Albany/Airport Road and both lanes for northeastbound OR99E at Waverly

4:30-4:45 loop - I didn't turn left at the appropriate location- this will show in the GPS
5:10-5:20 loop - stuck behind a Hay truck turning left from Century Drive to Old Salem Road at the Murder Creek Interchange
- no reds on OR99E
5:20-5:33 - Used the left lane going NB on I5 to go around a semi
5:33-5:39 - Used left lane going SB on I5 to go around a semi

Upon completion of the of the floating car runs, the data is downloaded to an ArcGIS shapefile format for cleaning and analysis (see Exhibit 3-7). It is typical that some data cleaning will be required such as removing outliers and converting the speed to MPH. This is easily done in ArcGIS.

Exhibit 3-7 Data format

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	LATITUDE	LONGITUDE	ALTITUDE	EASTING	NORTHING	UTCDATE	UTCTIME	SOG	COG	MAG_VAR	SATS_USED	HPE	VPE	EPE	HDOP	VDOP	PDOP	QUALITY	DIFF_AGE	DIFF_ID	DEPTH	DEPTH_OFF	WATERTEMP
2	44.9486862720	-123.0151426399	25.062	-123.015	44.949	3/31/2011	221953	51.7	95.3	298.0	4	0.0	0.0	0.0	2.4	5.1	5.7	1			0.0	0.0	0.0
3	44.9486749269	-123.0149701418	25.319	-123.015	44.949	3/31/2011	221954	47.1	95.2	302.2	5	0.0	0.0	0.0	2.4	5.1	5.7	1			0.0	0.0	0.0
4	44.9486585704	-123.0146570282	25.515	-123.015	44.949	3/31/2011	221956	40.7	92.8	328.3	5	0.0	0.0	6.4	2.4	5.1	5.7	1			0.0	0.0	0.0
5	44.9486549742	-123.0145250729	25.643	-123.015	44.949	3/31/2011	221957	34.6	91.7	340.9	5	0.0	0.0	6.4	2.4	5.1	5.7	1			0.0	0.0	0.0
6	44.9486544290	-123.0143104926	25.720	-123.014	44.949	3/31/2011	221959	25.2	89.0	359.1	5	0.0	0.0	6.4	2.4	5.1	5.7	1			0.0	0.0	0.0
7	44.9486555250	-123.0142312615	25.765	-123.014	44.949	3/31/2011	222000	19.9	88.6	0.0	5	0.0	0.0	6.4	2.4	5.1	5.7	1			0.0	0.0	0.0
8	44.9486582178	-123.0141097766	25.944	-123.014	44.949	3/31/2011	222002	14.5	88.5	358.5	5	0.0	0.0	6.4	2.4	5.1	5.7	1			0.0	0.0	0.0
9	44.9486774096	-123.0140094421	31.027	-123.014	44.949	3/31/2011	222004	12.8	74.7	32.7	5	0.0	0.0	6.4	1.8	3.3	3.8	1			0.0	0.0	0.0
10	44.9487257761	-123.0139409302	31.848	-123.014	44.949	3/31/2011	222005	7.0	94.3	346.9	6	0.0	0.0	6.4	4.3	3.3	5.4	1			0.0	0.0	0.0
11	44.9486807570	-123.0139490074	31.053	-123.014	44.949	3/31/2011	222007	2.1	41.2	2.4	5	0.0	0.0	7.4	1.8	3.3	3.8	1			0.0	0.0	0.0
12	44.9487274773	-123.0139084054	31.876	-123.014	44.949	3/31/2011	222008	0.6	174.7	350.5	6	0.0	0.0	7.4	4.3	3.3	5.4	1			0.0	0.0	0.0
13	44.9486788817	-123.0139464597	30.948	-123.014	44.949	3/31/2011	222010	0.1	89.7	354.2	6	0.0	0.0	7.4	1.8	3.3	3.8	1			0.0	0.0	0.0
14	44.9486784519	-123.0139470807	30.861	-123.014	44.949	3/31/2011	222012	0.0	172.9	353.5	6	0.0	0.0	6.1	1.8	3.3	3.8	1			0.0	0.0	0.0
15	44.9486785752	-123.0139470839	30.843	-123.014	44.949	3/31/2011	222013	0.0	302.1	353.5	6	0.0	0.0	6.1	1.8	3.3	3.8	1			0.0	0.0	0.0
16	44.9486787955	-123.0139472568	30.763	-123.014	44.949	3/31/2011	222015	0.1	41.1	354.5	6	0.0	0.0	6.1	1.8	3.3	3.8	1			0.0	0.0	0.0
17	44.9486787737	-123.0139475311	30.690	-123.014	44.949	3/31/2011	222017	0.1	221.8	353.0	6	0.0	0.0	6.1	1.8	3.3	3.8	1			0.0	0.0	0.0
18	44.9486787242	-123.0139477957	30.640	-123.014	44.949	3/31/2011	222018	0.0	348.0	353.9	6	0.0	0.0	6.1	1.8	3.3	3.8	1			0.0	0.0	0.0
19	44.9486786977	-123.0139478861	30.656	-123.014	44.949	3/31/2011	222020	0.1	24.6	354.4	6	0.0	0.0	6.1	1.8	3.3	3.8	1			0.0	0.0	0.0
20	44.9486784582	-123.0139481406	30.636	-123.014	44.949	3/31/2011	222021	0.1	253.1	353.0	6	0.0	0.0	6.1	1.8	3.3	3.8	1			0.0	0.0	0.0
21	44.9486782224	-123.0139486691	30.538	-123.014	44.949	3/31/2011	222023	0.1	187.9	353.3	6	0.0	0.0	6.1	1.8	3.3	3.8	1			0.0	0.0	0.0
22	44.9486782015	-123.0139487914	30.514	-123.014	44.949	3/31/2011	222025	0.1	261.9	352.4	6	0.0	0.0	6.1	1.8	3.3	3.8	1			0.0	0.0	0.0

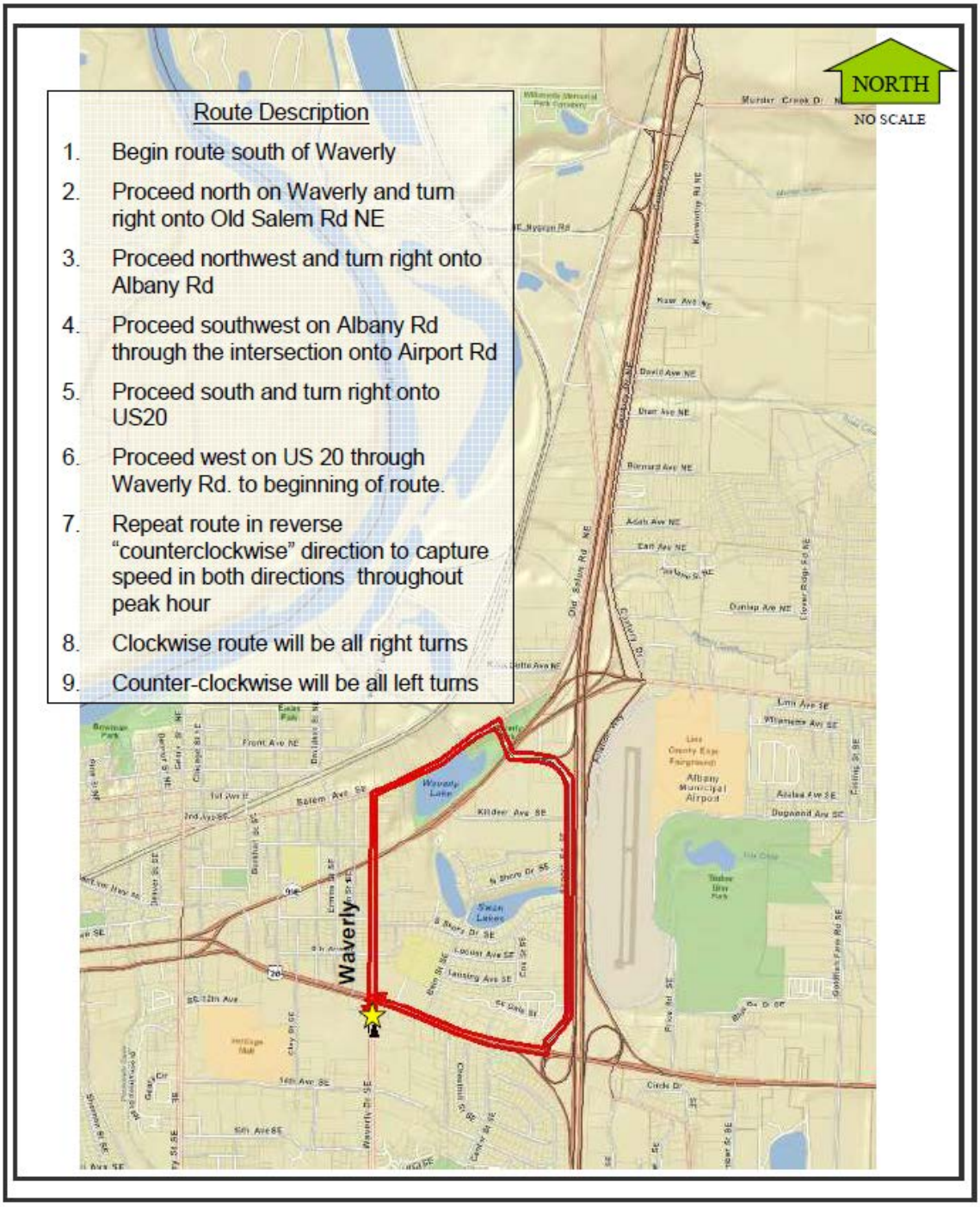
Example 3-1 Floating Car Data Collection with GPS

For a project in Albany, travel time data is needed for calibration of a simulation model for the Existing Year. See Chapter 15 for calibration procedures.

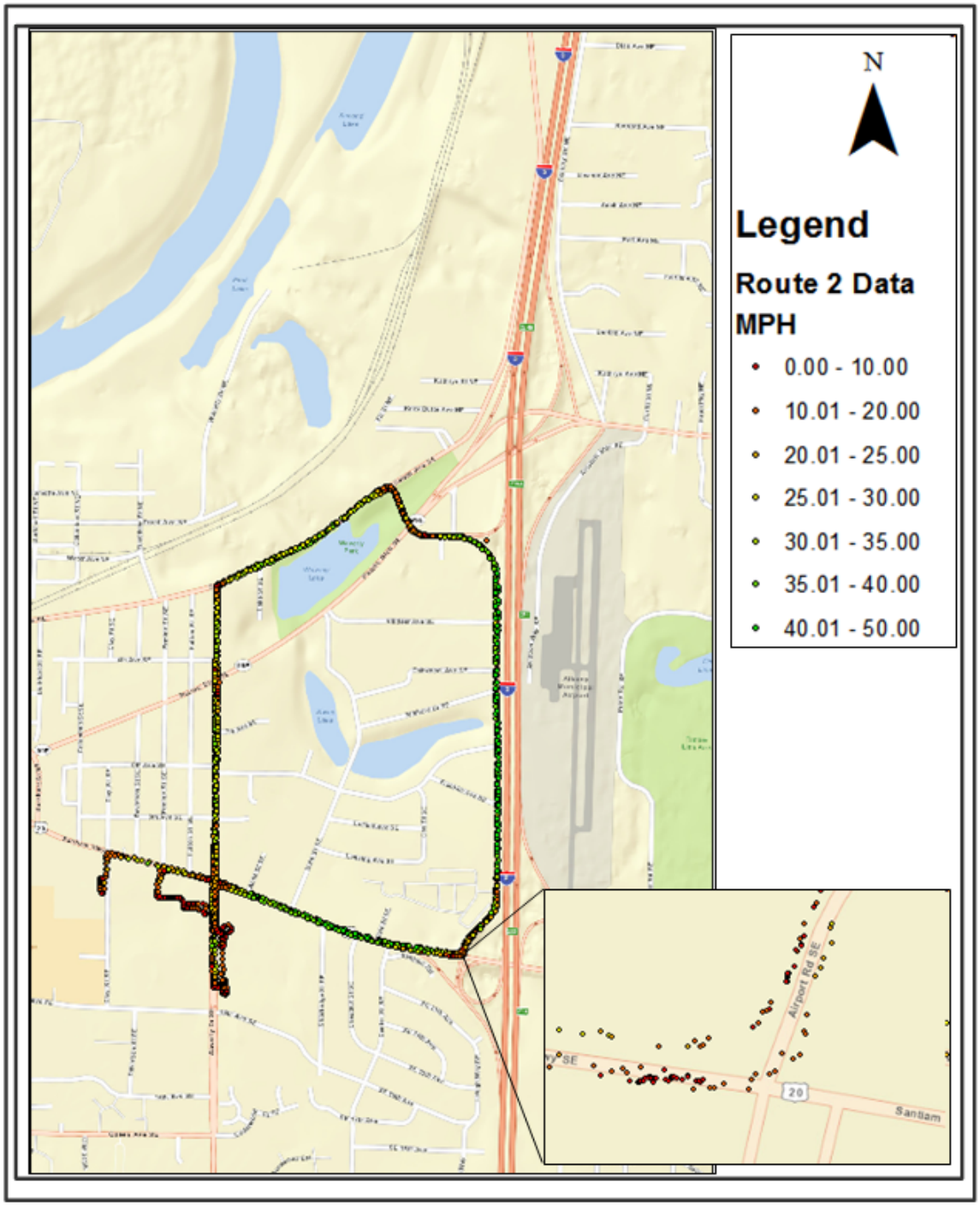
Floating car data was collected on March 31st 2010 in the peak hour between 4:45 PM and 5:45 PM. Three vehicles were equipped with GPS units and each assigned a separate travel route. In order to represent the most likely driving conditions drivers were asked to travel according to their best judgment of the traffic stream's speed and collect as many full routes as possible during the data collection period.

Average speeds along the routes were recorded in the GPS tracklog where time/location points set to record at 1 second intervals. A greater interval period could be used in other applications such as for a rural corridor. At each 1 second interval, the GPS recorded the coordinate location, the date and time the data point was recorded and the instantaneous speed of the vehicle. Instantaneous speed and travel times along each route were averaged over the total number of completed runs and summarized based on link segments from the SYNCHRO network. The figures below display the floating car data collection route and output results. The table below summarizes the results of the data collection.

Floating Car Data Collection, Route 2



Floating Car Data Output Results



Route 2 Floating Car and SimTraffic Data Comparison

Roadway	Section	Floating Car Data Collection		SimTraffic Calibration	
US20	BETWEEN SANTIAM INTERCHANGE RAMP TERMINALS (EB)	Speed (mph)	24	Speed (mph)	11
		Travel Time (s)	29	Travel Time (s)	59
US20	BETWEEN SANTIAM I5 NB RAMP TERMINAL / SPICER DR SE / US20 AND PRICE RD SE	Speed (mph)	39	Speed (mph)	27
		Travel Time (s)	14	Travel Time (s)	22
US20	BETWEEN PRICE RD SE AND TIMBER ST SE	Speed (mph)	46	Speed (mph)	37
		Travel Time (s)	13	Travel Time (s)	17
US20	BETWEEN TIMBER ST SE AND GOLDFISH FARM RD SE	Speed (mph)	35	Speed (mph)	32
		Travel Time (s)	28	Travel Time (s)	28
US20	BETWEEN GOLDFISH FARM RD SE AND TIMBER ST SE	Speed (mph)	45	Speed (mph)	36
		Travel Time (s)	22	Travel Time (s)	25
US20	BETWEEN TIMBER ST SE AND PRICE RD SE	Speed (mph)	46	Speed (mph)	36
		Travel Time (s)	14	Travel Time (s)	17
US20	BETWEEN PRICE RD SE AND SANTIAM I5 NB SLIP ON-RAMP	Speed (mph)	42	Speed (mph)	28
		Travel Time (s)	5	Travel Time (s)	5
US20	BETWEEN I5 NB SLIP ON-RAMP AND SANTIAM I5 NB RAMP TERMINAL / SPICER RD SE	Speed (mph)	12	Speed (mph)	10
		Travel Time (s)	27	Travel Time (s)	41
US20	BETWEEN SANTIAM INTERCHANGE RAMP TERMINALS (WB)	Speed (mph)	13	Speed (mph)	10
		Travel Time (s)	53	Travel Time (s)	69
US20	BETWEEN SANTIAM I5 SB RAMP TERMINAL AND CENTER ST SE	Speed (mph)	35	Speed (mph)	27
		Travel Time (s)	13	Travel Time (s)	20
US20	BETWEEN CENTER ST SE AND BAIN ST SE	Speed (mph)	38	Speed (mph)	40
		Travel Time (s)	19	Travel Time (s)	33
US20	BETWEEM BAIN ST SE AND WAVERLY DR SE	Speed (mph)	14	Speed (mph)	7
		Travel Time (s)	42	Travel Time (s)	69
US20	BETWEEN WAVERLY DR SE AND BAIN ST SE	Speed (mph)	32	Speed (mph)	29
		Travel Time (s)	17	Travel Time (s)	18
US20	BETWEEN BAIN ST SE AND CENTER ST SE	Speed (mph)	36	Speed (mph)	35
		Travel Time (s)	19	Travel Time (s)	20
US20	BETWEEN CENTER ST SE AND SANTIAM I5 SB SLIP ON-RAMP	Speed (mph)	19	Speed (mph)	25
		Travel Time (s)	9	Travel Time (s)	8
US20	BETWEEN SANTAIM I5 SB SLIP ON-RAMP AND AIRPORT RD SE / SANTIAM I5 SB RAMP TERMINAL	Speed (mph)	6	Speed (mph)	6
		Travel Time (s)	53	Travel Time (s)	49

Bluetooth

Bluetooth uses probe vehicles. Probe vehicle techniques involve direct measurement of travel

time (along a route or point to point) using data from a portion of the vehicle stream. Probe measure technology (cell phone triangulation or GPS location tracking) is based on collecting vehicle ID data and timestamps of vehicles passing a roadside reader device and checking against the last reader passed to determine the travel time between reader locations. Many computers, car radios, navigation devices, PDA's, cell phones, headsets and other personal devices are Bluetooth enabled to allow wireless communication between devices. Both types of probe technologies provide direct travel time output. Bluetooth-based travel time measurement involves identifying and matching the MAC address of blue-tooth enabled devices. This can be used to measure arterial travel time, average running speed, and OD patterns of travelers (see sections below).

There have been several recent studies evaluating the effectiveness of the bluetooth device matching method compared to ground truck data. The results indicate that blue tooth is capable of reproducing floating car data, while providing a significantly higher number of data points than the floating car method.

3.5.2 Speed

Speed data is used in multiple areas of analysis. There are measured and calculated speeds. A measured speed is a direct "point" measurement obtained with the use of equipment such as road tubes, Radar, or Lidar. A calculated speed is derived from a combination of a time and distance information (i.e. travel time over a specific length segment).

Measured Speed

One of the easiest ways to obtain a measured speed is through the use of road tubes with vehicle classifying counter. This method can only be used for free-flow non-congested segments where tubes can be safely placed, outside the influence of any intersections causing platooning effects. Collection of tube count data is restrained by weather and installation issues and needs to be coordinated with count program staff. Another method to obtain a measured speed is through the use of hand-held speed devices such as Radar/Lidar. See the Speed Zone Investigations Manual for procedures for measuring speeds with these devices.

Measured speeds can be used to calculate segment speeds and headways. A measured speed may also be needed to determine/verify a specific segment speed such as a turning speed around a "non-standard" radius or corner for the purpose of simulation.

Speed data can also be obtained from fee-based private sources, such as Inrix. Inrix is a private-sector provider of travel time and speed data at the link level worldwide with over 400 different sources of input data (mobile, fleet, in-pavement, etc). Inrix speed is based on GPS observations from fleets of probe vehicles (mostly commercial) which capture speed along major roadway segments. Average speed is available for every hour of the year. The travel time is calculated from the average speed and segment length.

ODOT has purchased an Inrix historical archive of real time data covering the state of Oregon.

The historical data is a comprehensive database of speed statistics by day of the week. In rural or smaller urban areas, data coverage is generally limited to state highways (which have the most probe vehicles). Larger urban areas are more likely to include data on non-state facilities.

ODOT has also purchased Inrix Analytics, a web-based tool which facilitates data extraction and reporting. The Analytics Tool is available at www.inrixtraffic.us. The Analytics Tools uses historical 1-minute or 5-minute bins of real-time data with TMC, speeds, travel times and quality scores. Quality scores indicate whether the data is based on real-time, average, or reference speeds (30, 20, or 10 respectively). Scores of "30" also have a confidence value (0-100) which indicates consistency with itself, the average, and overall trends.

Public agencies within Oregon can freely use the data for planning and analysis. ODOT can authorize contractors to do the same on ODOT's behalf. Some limitations are that Inrix data cannot be merged or averaged with competitor's data (i.e. Tom-Tom) and that Inrix must be given credit when the data is used. Contact the ODOT ITS Unit for more information on data availability.

Calculated Speed

Calculated speeds are obtained from sources that furnish point or vehicle identification with a time stamp so data matching can yield a time between known points to determine an average speed. Data may be obtained from vehicle detection equipment, historic data or private sector sources. Common uses for calculated speeds are for calibration and validation of simulation models and creation of performance measures.

Floating car and MAC address matched travel time data can be converted into "running speed", segment or corridor travel speeds as long as distances are available.

3.5.3 Other Data Collection

Origin-Destination (O-D) Surveys

These surveys obtain route information that a vehicle takes between specific points. Project complexity can range from simple, such as a weave study, to medium focusing on select paths within a project/study area, to complex such as a city-wide network. The number of "interview" stations adds complexity to the process.

- Direct Interview - This process entails stopping a sample of vehicles to ask specific data collection such as point of beginning and ending, trip purpose, route choice, etc. Sometimes these are viewed as disruptive and invading privacy. These are very expensive (labor and traffic control) and require Oregon Transportation Commission (OTC) approval for state highways because of impacts to the traffic flows.
- License Plate Surveys – This process uses in-person or recorder images of vehicle identification (license plates) to obtain routing information without the stops associated with a direct interview process. This method can be expensive and labor intensive to match the data inputs. The more stations that are recorded, the more complex the process.

- Mail Survey – This process uses a sampling method to deliver/receive route information from driver input. This method requires a large distribution of requests to get a valid sampling of information. It can have accuracy (driver reporting), privacy and timeliness issues.
- MAC Address Reader (Bluetooth) - This process uses roadside detectors (portable or permanent) to record an identifying signature of an electronic device. Using multiple detectors, the device can be tracked to a specific route. To alleviate privacy issues, only a minimal amount of characters needed to uniquely specify a device is recorded. The electronic files of data can be matched using software programs, thus reducing labor costs.

Saturation Flow Rate Studies

The saturation flow rate is a critical component in signalized intersection analysis. It is defined as the flow in vehicles per hour accommodated by a lane group assuming that the green phase is displayed 100 percent of the time. Saturation flow rate data is collected on an ongoing basis. Oregon saturation flow studies done to date show that the HCM 2010 value of 1750 passenger cars per hour of green per lane is appropriate for small urban areas.

Except in larger urban areas, field conditions generally do not allow the HCM saturation flow study procedures in Chapter 31 of the 2010 HCM to be met. A roadway approach may not have long enough queues during the study or intersection spacing may be so tight that long enough queues without gaps are not possible. In these cases, a default ideal unadjusted saturation flow is determined as follows:

- Outside of the Portland, Salem and Eugene MPO urban areas the unadjusted saturation flow rate is 1750 passenger cars per hour of green per lane (pcphgl).
- Inside the Portland, Salem and Eugene MPO urban growth boundaries an unadjusted saturation flow rate of 1900 pcphgl may be used, unless one or more of the following conditions is present, in which case 1750 pcphgl shall be used. Conditions indicating use of lower base saturation flow rate inside urban growth boundaries:

    - On-street parking
    - Greater than 5% trucks
    - Roadways intersect at severe skew angle (i.e., greater than 20 degrees off perpendicular)
    - One or more driveway approach(es) with a combined volume in excess of 5 vph, are present downstream of the intersection within the functional area (see Chapter 4) or upstream within the length of the standing queue
    - Poor signal spacing or observed queue spillbacks between signals during the peak hour
    - Less than 12-foot travel lanes

The ideal (unadjusted) saturation flow rate is converted to an actual flow rate by applying adjustment factors to account for the influence of lane widths, heavy vehicles, approach grades, on-street parking, frequent bus stoppages (3-4 or more per hour per direction) in the

intersection vicinity or roadway segment, area type, lane utilization, turning movements and bicycle and pedestrian conflicts. Theoretically, once adjusted, the result would be equivalent to the field measured value.

Field Measurements of Saturation Flow Rates

When an analyst desires a verification of the saturation flow (conditions are outside the default conditions above or a need for simulation), an investigation should be performed. The field measurement of the saturation flow rate shall be in accordance with methodology described in Chapter 31 of the 2010 Highway Capacity Manual (*HCM*) and submitted on the *HCM* Field Saturation Flow Rate Field Study Worksheet(s).

The measurement is performed by recording the following data for each signal cycle and each desired lane. In order for a cycle to be used, it needs to have a minimum of 8 vehicles in the stopped queue at the start of green. First record the number of vehicles in the stopped queue when the signal turns green. Then record the elapsed time elapsed between when the front axle of the fourth vehicle in queue crosses the stop line and when the front axle of the last vehicle in queue crosses the stop line. Finally record the end of green. These values are used to calculate the average saturation flow headway per vehicle. Signal cycles with events such as downstream queues blocking the flow of traffic or presence of emergency vehicles should be discarded. A minimum of 15 signal cycles with a minimum of 8 vehicles in the stopped queue is needed to obtain a statistically significant value.

$$\text{Saturation Headway} = \frac{\text{(Time of last stopped vehicle - Time of 4th vehicle)}}{\text{(Vehicle position of last vehicle - 4)}}$$

$$\text{Saturation Flow} = \frac{\text{3600 s/h}}{\text{saturation headway}}$$

In order to facilitate this process, a Saturation Flow Rate Data Collection Form and a Saturation Flow Rate Calculator tool have been developed. The data collection form is arranged as one row per cycle. For each cycle, the analyst records the time of the 4th vehicle, time of last stopped vehicle, number of stopped vehicles and time at end of green. Once collected, the data from the form are directly entered into the calculator office form tab. If more than 25 cycles of data have been collected, additional cycles can be added to the calculator by pressing the “Add 25 More Cycles” button.

Once the analyst has input the field data, click the “Calculate Sat Flow” button. The calculator automatically checks to ensure there are at least 15 cycles with 8 or more vehicles in queue. Cycles with less than 8 vehicles in queue are ignored. For more specifics on the tool see the Instructions tab.

Field measured saturation flow rates are preferred over estimation and do not require further modification. Using default values and adjustment factors will not produce more accurate results. If possible, saturation flow rates should be collected at no less than one major intersection on each main study area roadway. When using these values in analysis be sure to set all of the

adjustment factors to 1.0.

Once the field saturated flow rate is obtained, the ideal (unadjusted) saturation flow rate should be back-calculated by applying adjustment factors to account for the influence of lane widths, heavy vehicles, approach grades, on-street parking, bus stops, area type, lane utilization, turning movements and bicycle and pedestrian conflicts. Heavy vehicles, parking maneuvers, turning movements, and bicycle and pedestrian conflicts must be collected during the same period as the field saturation flow study to be able to back- calculate an accurate value.

TPAU has a limited database of saturation flow rates. To find out if specific saturation flow rates are available for a specific site/area, contact TPAU analysts. Copies of saturation flow rate studies should be sent to TPAU for inclusion in appropriate studies such as verification of default values. Coordinate data collection and verification with TPAU so any acceptable saturation flow studies can be included in the database.

Appendix 3A – Field Inventory Worksheet

Appendix 3B – Sample Count Request and Sample ODOT Counts

Appendix 3C – Traffic Count Management (TCM) Program Count Report Guide

Appendix 3D – Saturation Flow Rate Data Collection Form

4 SAFETY

4.1 Purpose and Overview

The purpose of this document is to provide guidance on safety analysis procedures for specific transportation planning and project development applications with a safety component. All planning and project development efforts need to be individually scoped as there are a number of different tools and techniques that can be applied. APM Section 4.1.2 identifies the recommended safety analysis procedures for common planning and project development applications.

The primary goal of any safety analysis presented in this chapter is to promote a proactive approach to reducing the frequency of fatal and serious injury (Injury-A) crashes. This is consistent with the Oregon Transportation Plan (OTP) that states "it is the policy of the State of Oregon to continually improve the safety and security of all modes and transportation facilities for system users including operators, passengers, pedestrians, recipients of goods and services, and property owners." The Oregon Transportation Safety Action Plan implements the OTP policy.

The first edition of the Highway Safety Manual (HSM) provides the technical foundation for many of the procedures discussed in this chapter. However, this chapter does not replicate the entire guidance of the HSM, and the reader is encouraged to consult the HSM directly where appropriate. The HSM is published by the American Association of State Highway and Transportation Officials (AASHTO) with support from the Federal Highway Administration (FHWA), the Institute of Transportation Engineers (ITE), and the Transportation Research Board (TRB) Highway Safety Performance Committee (ANB25).

The HSM is a national guide—and the first of its kind—providing science-based methods, procedures, and measures that integrate quantitative estimates of crash frequency and severity into roadway planning, evaluation, and project development. Prior to the HSM, crash analysis for planning and project development was typically limited to simple evaluations of crash data and somewhat subjective analysis. Evaluations of future safety performance were primarily limited to meeting design standards, with few options for comparing alternatives. In contrast, the tools in the HSM allow safety to become a meaningful performance measure that can be implemented at any stage of the transportation decision-making process.

As stated in the HSM, it is neither intended to be, nor does it establish, a legal standard of care for users or professionals.

> STOP
>
> HSM methodologies are provided to assist agencies in their effort to integrate safety into their decision-making processes, but are not intended to be a substitute for the exercise of sound engineering judgment. No standard of conduct or any duty toward the public or any person shall be created or imposed by the publication and use or nonuse of the HSM. The HSM does not supersede publications such as the MUTCD, the AASHTO Green Book, or other AASHTO and agency guidelines, manuals and policies.

HSM screening tools provide a robust methodology for objectively evaluating historical crash data based on frequency, severity, collision type, and other crash characteristics. The screening tools identify locations with the highest potential for reducing the frequency and severity of crashes and, by identifying factors contributing to the crashes, help choose effective potential countermeasures. Screening tools are discussed in APM Section 4.3.

The HSM Predictive Method is the first comprehensive model for estimating the frequency and severity of crashes based on traffic, roadway, and roadside characteristics. Predictive analysis can be applied to quantify the safety impact of design alternatives and forecast scenarios, using the understandable language of crash frequency and severity. Predictive analysis can also be applied in conjunction with historical data analysis to overcome statistical limitations inherent in historical data analysis. Predictive tools are discussed in APM Section 4.4.

The HSM framework also provides local agencies a methodology to expand on the foundation of the HSM by calibrating to local conditions and developing custom safety performance functions (SPFs). ODOT's webpage on the HSM includes information on completed and future research projects.

The APM does not address ODOT highway safety program procedures or traffic operations-level safety analysis. This includes road safety audits, collision diagrams, detailed safety investigations, and benefit-cost analyses. Contact the Traffic-Roadway Section for procedures related to those programs.

4.1.1 Statewide Crash Rate References

Statewide average crash rates are used in the critical crash rate analysis method and are useful resources for informal discussions of crash frequency.

The Oregon State Highway Crash Rate Tables are published annually by the ODOT CAR Unit. Crash Rate Table II shows statewide average crash rates for each of the last five years, by urban and rural area and by roadway classifications for state highways. These crash rates are based on overall crash frequency and total vehicle miles traveled on mainline state highways. Federal functional classifications can be found on the ODOT Federal Functional Classification (FC) webpage.

Exhibit 4-1 shows intersection crash rates by land type and traffic control, based on a 2011 assessment of data from 2003-2007. The crash rates here are based only on crashes that occurred at an intersection or because of an intersection and are given as a rate per million vehicles entering the intersection [million entering vehicles (MEV)].

Intersection crash rates also need to be compared to the published statewide 90th percentile intersection crash rates in Exhibit 4-1. Any rates close to or over the 90th percentile rates need to be flagged for further analysis. The intersection crash rate is calculated by the following formula:

$$Intersection\ Crash\ Rate\ per\ MEV = \frac{Annual\ Number\ of\ Crashes\ x\ 10^6}{(AADT)x\ (365\ days/year)}$$

The values shown in Exhibit 4-1 represent the 90th percentile crash rates from a study of 500 intersections in Oregon. The crash rates are grouped by rural/urban, signalized/unsignalized, and three-leg/four-leg intersections. Intersections with crash rates that exceed the 90th percentile values shown in the table should be flagged for further analysis. For more information on crash rates and using this table, see Section 4.3.4 Critical Crash Rate.

Exhibit 4-1: Intersection Crash Rates per MEV by Land Type and Traffic Control

	Rural				Urban			
	3SG	**3ST**	**4SG**	**4ST**	**3SG**	**3ST**	**4SG**	**4ST**
No. of Intersections	7	115	20	60	55	77	106	60
Mean Crash Rate	**0.226**	**0.196**	**0.324**	**0.434**	**0.275**	**0.131**	**0.477**	**0.198**
Median Crash Rate	0.163	0.092	0.320	0.267	0.252	0.105	0.420	0.145
Standard Deviation	0.185	0.314	0.223	0.534	0.155	0.121	0.273	0.176
Coefficient of Variation	0.819	1.602	0.688	1.230	0.564	0.924	0.572	0.889
90th Percentile Rate	**0.464**	**0.475**	**0.579**	**1.080**	**0.509**	**0.293**	**0.860**	**0.408**

Source: Assessment of Statewide Intersection Safety Performance, FHWA-OR-RD-18, Portland State University and Oregon State University, June 2011, Table 4.1, p. 47.

Note: Traffic control types include 3SG (three-leg signalized), 3ST (three-leg minor stop-control), 4SG (four-leg signalized), 4ST (four-leg minor stop-control).

4.1.2 Tools and Procedures by Application Type

Safety analysis tools should be specified during the scoping process. Model scoping language is provided in APM Chapter 2. In order to facilitate scoping of tools, this section describes the recommended safety analysis tools and procedures for common application types as shown in Exhibit 4-2. Safety analysis tools are identified in order of increasing level of effort in the chart going from left to right. Plan or project level of detail is shown in increasing level of detail in the chart going from top to bottom. Best practice/recommended methods are shown with closed circles, while open circles identify optional or supplemental methods.

Exhibit 4-2: Applicability of Safety Analysis Tools by Plan or Project Type

Level of Effort +

Details +

Plan or Project Type	Other Methods			Highway Safety Manual (HSM) Methods					Other Tools
					Statistical Crash Data Screening		Predictive Methods		
	State Crash Rate	SPIS	Queue	CMFs	Critical Crash Rate	Excess Proportion of Specific Crash Types	Net Change in Predicted Crash Frequency or Predicted Crashes	Excess Expected Crash Frequency	PlanSafe
System Plans (TSP, RTP etc.)	○	●		●	●	●			○
MMA's	●	●	●	○	○	○			
Facility Plan	○	○	○	○	○	○	●	●	
Development Review	○	○	○	○	○	○	●	●	
NEPA / Project Development	○	○	○	○	○	○	●	●	

● Best practice or recommended method
○ Supplemental methods

The tools and procedures recommended here describe the crash analysis appropriate for the scope and scale of typical applications. A balanced approach to safety analysis should also consider queues, sight distances, safe and convenient crossing opportunities, and other safety-related techniques where appropriate for the application context.

- All Applications:
  - Safety Priority Index System (SPIS) – Identify top 5% or 10% locations from the most recent three (3) SPIS Site listings
- RTPs, Transportation System Plans (TSPs) and High-Level Corridor Plans:
  - Critical Crash Rate – required
  - Excess Proportion of Specific Crash Types – required
  - Crash rate comparison – minimum requirement when other methods can't be applied. Compare intersection crash rates to the 90th percentile crash rates (Exhibit 4-1) and segment crash rates to Table II in the CARS crash rates tables.
  - PLANSAFE – optional, system-wide predictive method. Recommended if there are regional transportation network changes proposed or if there is an expectation of significant demographic changes.
  - Crash Modification Factors (CMFs) – Optional. Use to estimate potential crash reduction of alternatives.
- Multimodal Mixed-Use Areas (MMAs)

    - MMAs are governed by OARs which require that public safety is not compromised. The primary safety analysis methods recommended for MMAs are the OAR requirements:
        - If the area has a crash rate above statewide averages. Crash rates are generally considered on the mainline and the crossroad.
        - If the area includes a top 10% SPIS site
        - If existing or future traffic queues will create a safety concern on the mainline highway exit
    - The new safety analysis options could provide additional value for MMA analysis.
    - The Critical Crash Rate could be a complement to crash rates as described in the OARs.
    - Excess Proportion of Specific Crash Types can be used to identify crash patterns and multimodal safety concerns.
    - The HSM Predictive Method can also be used to evaluate an MMA location and identify mitigation needs before an MMA is granted, or could be incorporated into guidelines for evaluating plan amendments within MMAs.
- Facility Plans/Refinement Plans:
    - HSM Predictive Method – required if valid model exists
        - Excess Expected Crash Frequency – use for existing conditions evaluation
        - Net Change in Predicted Crash Frequency – use for alternatives evaluation
    - If no valid model exists:
        - Use Critical Crash Rate, Excess Proportion of Specific Crash Types, and statewide crash rate comparisons for existing conditions
        - Use CMFs for alternatives evaluation
- Development Review:
    - HSM Predictive Method – recommended if valid model exists
        - Excess Expected Crash Frequency – use for existing conditions evaluation
        - Net Change in Predicted Crash Frequency – use for alternatives evaluation
    - If no valid model exists:
        - Use Critical Crash Rate, Excess Proportion of Specific Crash Types, and statewide crash rate comparisons for existing conditions
        - Use CMFs for alternatives evaluation
- Project Development / National Environmental Policy Act (NEPA) Work:
    - HSM Predictive Method – required if valid model exists
        - Excess Expected Crash Frequency – use for existing conditions evaluation
        - Net Change in Predicted Crash Frequency – use for alternatives evaluation
    - If no valid model exists:
        - Use Critical Crash Rate, Excess Proportion of Specific Crash Types, and statewide crash rate comparisons for existing conditions
        - Use CMFs for alternatives evaluation
- Countermeasure Development:
    - Using site characteristics and analysis results, identify contributing factors
    - Document Crash Modification Factor(s)
    - Perform additional geometric safety assessments, as applicable:
        - Intersection functional area

- Sight distance
- Conflict points
- Access management

4.2 Crash Data

Crashes are used as the basis of safety analysis presented in this chapter. Crash frequency (number of crashes per year) and crash severity (rating based on most severe injury sustained in a crash) are fundamental indicators of the "safety" of a roadway.

Observed crash data provides information for describing and analyzing crash frequency and severity for historical time periods. Predictive methods proactively estimate crash frequency and severity for situations where observed crash data are not available, such as for future conditions. This chapter focuses on analysis of "objective" safety, which is based on quantitative measures that are independent of the observer. Objective safety is not directly experienced by a traveler, unless he or she is involved in a crash. In contrast, analysis of "subjective" safety involves the perception of how safe a person feels while using the transportation system. An assessment of subjective safety for the same location may vary between observers, and techniques for assessing the subjective safety of a location are not covered in this chapter. Subjective safety is an important component of many design and policy decisions. A person's choice of mode and route is strongly affected by how safe and comfortable the mode and route feels.

4.2.1 ODOT Crash Data Sources

The ODOT Crash Analysis and Reporting Unit (ODOT CAR) maintains a statewide crash record database that includes all reported crashes involving a motor vehicle on public roads. These data are collected by the Department of Motor Vehicles from police and driver reports then provided to ODOT CAR for quality assurance, standardization, and distribution. ODOT CAR produces a variety of publications annually that summarize crashes throughout the state of Oregon.

Crash data only includes reported crashes to the Department of Motor Vehicles (DMV). Many crashes are not reported because they fall under the $1,500 reporting threshold or are just not reported (i.e., single vehicle incident, or on tribal lands). Errors can still occur in the coded crash records so it is important to carefully review and note any anomalies. Reporting errors on officer reports and DMV forms and officer reports such as crash location are common and while the crash reporting technicians attempt to reconcile them, sometimes data are not available or is incomplete. This is why sometimes perceived crash issues from local residents differ from available crash data. See Chapter 3 for more information.

The Crash Data System provides analysts access to detailed crash reports for a custom study area and time period. The Crash Data System can be accessed online on the Internet through ODOT's Unified Access Gateway and ODOT's Intranet site.

The Crash Data System provides tools for querying crash data by jurisdiction, location, and time.

Crash data formatting and querying is different for state highways, city streets (non-state roads within city limits), and county roads (non-state roads outside city limits). Crash data can be downloaded in print-formatted or spreadsheet-formatted reports. Report download options include:

- **Summary by Year CDS150:** A general summary of crashes for the queried location, displayed by year, collision type, and generalized severity (fatal, nonfatal injury, property damage only).
- **Crash Location CDS390:** A detail report with a single line of data for each crash, including location, date, collision type, injury severity, and contributing factors.
- **Comprehensive (PRC) CDS380:** A detail report with at least three lines of data for each crash, including a row for every vehicle and participant in the crash. Summary includes location, date, collision type, injury severity, contributing factors, and more.

Data extracts are also available, providing unformatted full access to records for every crash, vehicle, and participant individually. Data extracts are available as a comma-delineated text document or as an Access database. The Access database includes code definitions and pre-defined report queries, making it a valuable resource for analysts familiar with database software.

The Comprehensive (PRC) CDS380 report or data extracts are recommended for use with the analysis procedures listed here, as these are the only formats that include the full injury severity scale (KABCO) and identify crashes involving pedestrians or bicyclists. The summary reports identify crashes involving pedestrians, but not bicyclists, and only include severity as fatal, nonfatal injury, or property damage. Summary reports may not include sufficient information for all analysis methods described in this chapter.

The crash data reports are heavily code-based and use of the Statewide Crash Data System Motor Vehicle Traffic Crash Analysis and Code Manual is required for a full understanding of the crash data. This manual and the online help documents provide additional important information about the crash data and reports and are available through the ODOT CAR Publications page or from within the Crash Data System.

Crash data are geocoded with latitude and longitude coordinate values. This allows for easy display on a map using a Geographic Information System (GIS) such as ArcMap, QGIS, or other online tools. If crash data are mapped using coordinate values, care should be taken to identify any records with the “Unlocatable_Flag” indicating that the coordinates are nonspecific default values.

Caution should be exercised when identifying actual crash locations from reported data. Crashes may be reported at the nearest integer milepoint or intersection even if they occurred hundreds of feet away. Crash data should be checked for discrepancies, such as where a crash occurred on a curve but where the reported location is a straightaway section.

4.2.2 Crash Characteristics, Trends, and Patterns

Crash analysis involves identifying trends and patterns on facilities. Analyzed crash types or severities may be all crashes or a more specific subset of crashes, such as fatal and serious injury crashes. These trends can then be used to identify applicable countermeasures for future mitigation. For guidance on performing a detailed on-site investigation and diagnosis of a safety trend, refer to the ODOT Safety Investigations Manual.

ODOT crash data includes many characteristics that can be used to identify trends and patterns. The analysis methods in this chapter primarily use the following characteristics:

- **Crash Location:** Geographical crash location is described by milepoint, distance to nearest intersection, and latitude and longitude coordinates.
- **Intersection-Related:** Crashes are identified as located at an intersection or related to the functioning of an intersection.
- **Driveway-Related:** Crashes are identified that are related to the use of a driveway.
- **Severity**: Crash severity is equal to the most serious injury sustained by anyone involved in the crash, based on the on-scene assessment (but which may not align with final medical determination of injuries). Severity is ranked on the KABCO scale:
    - K – Fatal injury, an injury that results in death
    - A – Incapacitating injury, a nonfatal injury that prevents the person from walking, driving, or doing activities they were capable of before the injury
    - B – Non-incapacitating evident injury, an injury that is evident to observers at the scene of the crash
    - C – Possible Injury, an injury or claim of an injury that is not evident to observers at the scene of the crash
    - O – No injury, also described as Property Damage Only (PDO)
- **Collision Type:** This field describes the intended movements of the vehicle(s) at the time of collision. Crashes are coded as one of the following collision types:
    - Angle – Vehicles collided while traveling on crossing or perpendicular paths, such as would occur if a vehicle ran a red light and crashed into a vehicle traveling on the crossing roadway
    - Head-On – Vehicles collided while traveling in opposite directions, their forward movement impeded while attempting to occupy a location simultaneously
    - Rear-End –Vehicles collided while traveling in the same direction, with one vehicle hitting the rear end of the second vehicle
    - Sideswipe-Meeting –Vehicles collided while traveling in opposite directions, with the side of at least one vehicle involved
    - Sideswipe-Overtaking – Vehicles collided while traveling in the same direction, with the side of at least one vehicle involved
    - Turning Movement – Collision involved one or more vehicles turning, originally traveling on parallel paths
    - Parking Maneuver – Collision involved one or more vehicles entering or leaving a parked position. Parking begins when a vehicle first exits the traffic lane and ends when a vehicle resumes travel in the traffic lane.

    - Backing – Collision involving one vehicle backing in a traffic lane that struck another vehicle also in a traffic lane, does not include parking maneuvers
    - Fixed-Object or Other-Object – Collision where one vehicle struck a fixed object or other object (identified in the event field) on or off the roadway
    - Pedestrian – A collision where the first harmful event was an impact between a vehicle in traffic and a pedestrian. Does not include crashes where pedestrians are injured subsequent to the first impact, in which case pedestrians are coded as supplemental events to the crash.
    - Miscellaneous Collision – Any crash that does not fall into the other collision type categories, including collisions with animals
    - Non-Collision – Crash involved only one vehicle and is not classifiable as any other collision, for example, a roll-over
- **Bicyclist Involvement:** This information is contained in "Crash Type" field, separate from the "Collision Type" field described above. Bicyclist involvement is designated with the "Pedalcyclist" description.

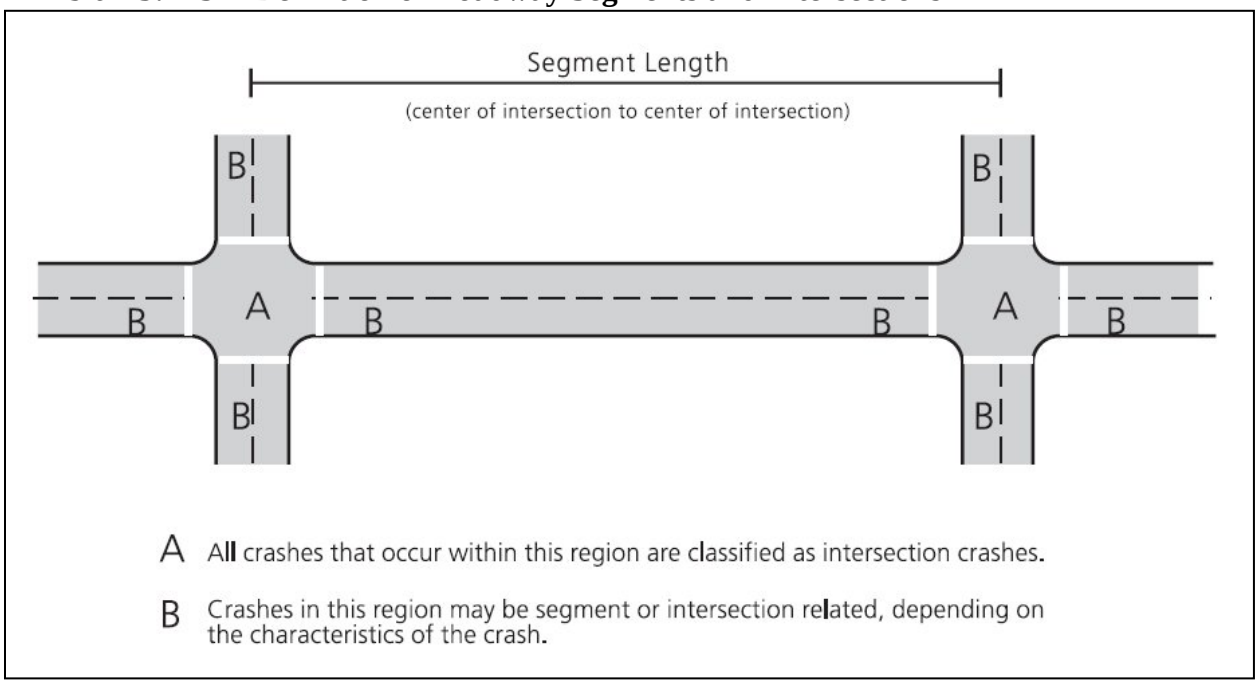
The crash data includes a wealth of other characteristics that may be of interest to the analyst, including direction of travel, lighting, weather and road conditions, work zones, vehicle and occupant details, use of alcohol and other drugs, use of safety restraints, cell phone use, speeding, and other contributing causes and events prior to the crash.

4.2.3 Assigning Crashes to Intersections and Segments

The safety analysis methods in this chapter require that each crash be uniquely assigned to an analysis site. Often this requires determining if the crash was intersection-related or roadway segment-related. The location and characteristics of the crash can be used to help determine the proper assignment for the crash.

Crashes that occur within an intersection are assigned to that intersection, as are crashes that occur on the intersection legs and are intersection-related in character. All crashes that are not assigned to an intersection are assigned to a segment. Exhibit 4-3 illustrates this concept. All crashes that occur in the "A" regions are intersection crashes. Crashes that occur in the "B" sections may be assigned to an intersection or the roadway segment on which they occur, depending on their characteristics.

Exhibit 4-3: HSM Definition of Roadway Segments and Intersections



Source: HSM Part C, Appendix A, Figure A-1

ODOT crash records include a field called "Intersection Related" that indicates a crash was related to an intersection, even though the crash was not coded as occurring at the intersection. (Note this field is not used for crashes coded as occurring at the intersection.) However, it may be that not all intersection-related crashes are identified with this field. The analyst should examine crashes near an intersection to determine if they have characteristics consistent with an intersection-related crash. For instance, rear-end collisions on an intersection approach are likely intersection-related. Conversely, run-off-the-road crashes or turning crashes near a driveway are likely segment-related. An understanding of the intersection's functional area (see APM Section 4.8.1) is also useful for assigning crashes to intersections and segments. The analyst also needs to observe operations in the field as part of the assessment, for example extent of queuing in determining intersection related crashes (see Chapter 3 for data collection procedures).

When performing both segment-based and intersection-based analyses, care should be taken to not double-count crashes. It is good practice to add a field identifying the analysis site to which each crash was assigned when including crash records in a project report.

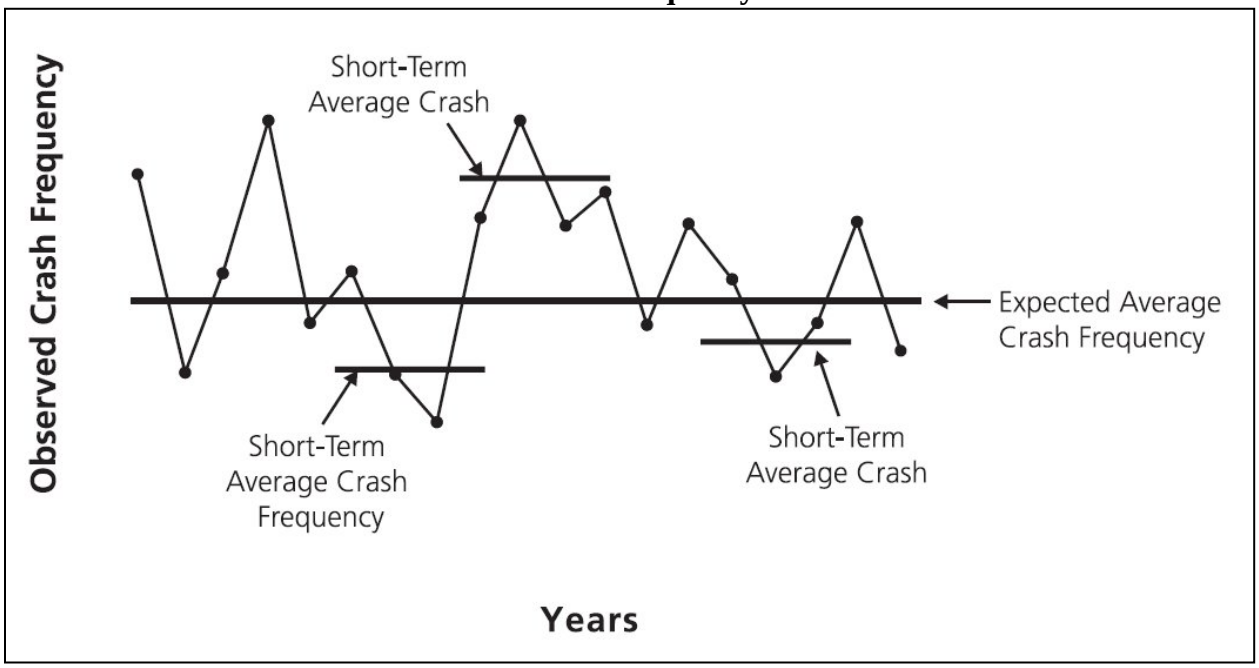
It should be noted that there may be more than one roadway segment analysis site between adjacent intersections, depending on roadway conditions. Segmenting, the process of dividing the study area into homogeneous analysis sites, is discussed in APM Sections 4.3.3 and 0.

Further information on assigning crashes to intersections and segments can be found in the HSM Part C, Appendix A, Section A.2.3.

4.2.4 Regression-to-the-Mean

Crashes are rare and random events, in that they represent a very small proportion of all events occurring on the transportation system and are partially influenced by factors that are unpredictable. As such, there is a natural variability in crash frequency at any specific location that should be considered when doing a crash analysis. This natural variation means that short-term crash frequencies using samples of one to five years of data may vary significantly from the long-term average crash frequency. Exhibit 4-4 illustrates this phenomenon. It is difficult to tell if the short-term sample represents a high, average, or low point in the natural variation of the crash frequency.

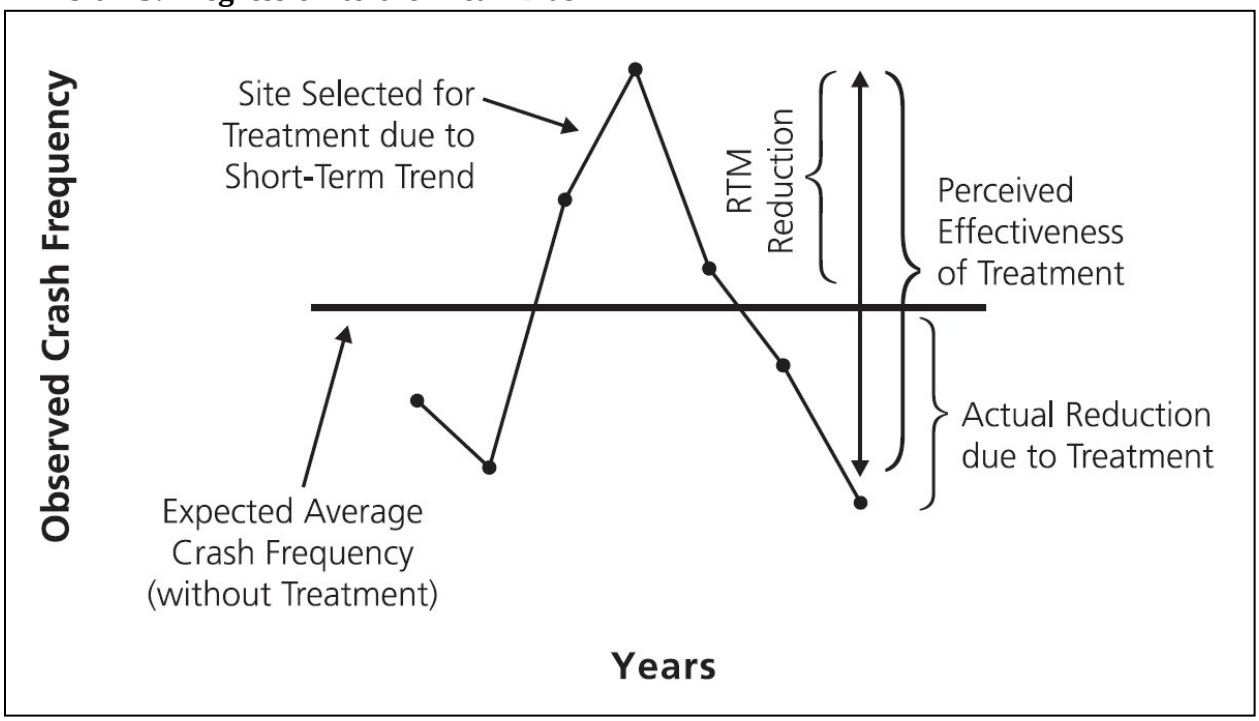
Exhibit 4-4: Variation of Short-Term Crash Frequency



Source: HSM Part A, Chapter 3, Figure 3-4

When a relatively high crash frequency is observed using a short-term sample, it is statistically probable that the next observation of that location will have a lower crash frequency. Similarly, when a low crash frequency is observed, it is likely that subsequent observations will be higher. This phenomenon is known as regression-to-the-mean (RTM), and is illustrated in Exhibit 4-5.

Exhibit 4-5: Regression-to-the-Mean Bias



Source: HSM Part A, Chapter 3, Figure 3-5

In a safety analysis, the effects of RTM can lead to a selection bias that prioritizes and evaluates countermeasures based on short-term trends. This may obscure locations with a higher expected average crash frequency or make it difficult to determine the actual reduction in expected average crash frequency due to a countermeasure.

Using a long-term sample is a way to account for RTM, and it is recommended that five years of crash data be used whenever possible. The predictive method described in this chapter uses statistical models to estimate the expected average crash frequency for a location with specific characteristics. Another way to account for RTM is to combine the predictive method with crash data [known as the Empirical-Bayes (EB) Method].

The analyst should be mindful of variations in conditions that may need to be accounted for when using multiple years of crash data—such as traffic volume changes, geometric and control changes, or disruptions due to construction. The predictive method is performed on a year-by-year basis, reflecting variations in conditions. When using screening methods, care should be taken to not include data from times with fundamentally different conditions.

4.2.5 Tools for Summarizing Crash Data

Crash Decoder Tool

The Crash Decoder Tool is an Excel-based spreadsheet with macros that uses the Comprehensive (PRC) CDS380 crash report (in Excel format) and the Excel look-up tables to translate the information. Once the sheet has decoded the information, filters can be applied to the data set to

investigate specific locations or issues. This tool also allows the analyst to create crash graphs that are helpful in both analysis and reporting. This tool can be used on all roadways. It is available on the ODOT Highway Safety Webpage.

Crash Graphing Tool (ODOT Employees Only)

The Crash Graphing Tool summarizes crash information of the "Direction" listing (in an Excel format) report from the State Highway Crash Reports and presents the information in standard graphs and charts. This report only analyzes state highways. Only ODOT employees can access this internal tool by contacting Information Services.

Crash Summary Database (ODOT Employees Only)

The Crash Summary Database, produced annually since 1990, is useful to generate quick summary reports that are often sufficient to answer questions when there is not time to do a detailed analysis. This software must be installed by an Information Services field technician. The crash summary database is a product of the most current Safety Priority Index System (SPIS) run so it uses the same three years of data. The crash summary gives an estimated crash rate based on the number of crashes, the average of the AADTs at the beginning and ending mile points of the segment and the numeric difference in the same mile points. This summary does not account for interruptions in the mile point distance (equations) or variation in the volumes when crossing multiple segments. The output reports only an estimated value along with the highest and number of SPIS sites within the section. It should not be used to report a formal crash rate unless all of the above items have been accounted for.

4.2.6 What Data to Report

When reporting the results of a crash analysis the narrative should describe the data and assumptions used, trends observed in the data, and the results of any crash analysis performed. Special consideration should be given to characterizing fatal and injury-A crashes and crashes involving transit, pedestrians, and bicyclists. The appendix should include data sufficient to reproduce the analysis, including the complete crash records used.

Try to use words like "more crashes than expected," "over-representation of crashes," "requires more investigation," or "will likely reduce crashes" when speaking about safety review locations. These words are more defensible because they are based on quantitative data and analysis. Avoid using subjective or qualitative words like "problem," "hazard," "unsafe," etc.

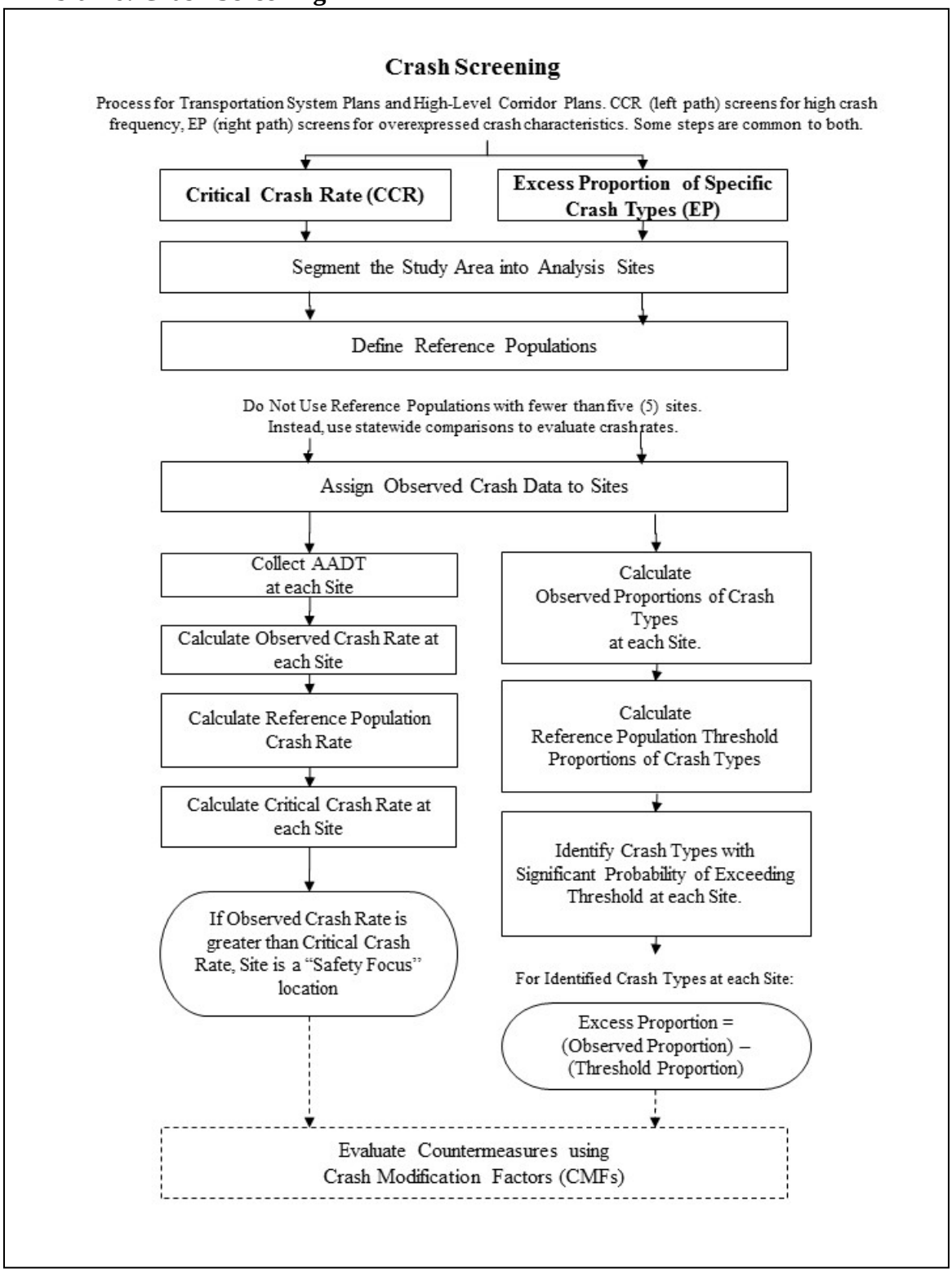
- Crash Analysis Narrative
    - Data sources
    - Years of analysis
    - Assumptions used, including reference population descriptions
    - General crash trends and traffic conditions
    - Description of fatal, injury-A, transit, pedestrian, and bicycle crashes
- Crash Analysis Results Summary (as applicable)
    - Crash frequency per year at each study location by severity and by collision type

    - Crash rates and critical crash rates, including comparisons to statewide averages
    - Locations exceeding critical crash rates
    - Locations with an excess proportion of specific crash types
    - Excess expected average crash frequency
    - Predicted average crash frequency
    - PLANSAFE results
- Appendix (as applicable)
    - Crash records, including the corresponding study location assigned to each
    - Reference population statistics and descriptions
    - AADT values used for each study location
    - Unabridged critical crash rate results
    - Unabridged excess proportion of specific crash type results
    - Predictive method characteristics and results

4.3 Screening Methods

Screening methods are used to quickly characterize observed crash data from a large study area using a minimum of extra data. The results are used to identify a smaller set of locations that can then be analyzed in more detail. The HSM discusses network screening in more detail in Part B, Chapter 4. Screening methods are recommended for use with large-scale planning efforts such as Transportation System Plans (TSPs) and refinement plans. The flow chart in Exhibit 4-6 gives an overview of the process for crash data screening.

Exhibit 4-6: Crash Screening



4.3.1 Safety Priority Index System (SPIS)

Recommended Uses	All project types
Data Required	None
More Information	Safety Priority Index System website

The SPIS is an analysis tool used by ODOT that provides an automated method of screening and ranking of state highway segments. SPIS All-Roads covers all local roadways that have traffic volume data available in addition to state highways (typically these include all functionally classed public roads in Oregon). SPIS incorporates crash rate, frequency and severity components to generate a single index to compare a roadway or intersection. Each annual SPIS list uses crash data from the three most recent available years.

Locations with the top 5% and 10% are determined for each year of data and reported as locations for further investigation. Detailed documentation on SPIS can be found on the Safety Priority Index System website.

As part of a complete safety analysis, the analyst needs to identify and report any top 5% sites in the study area along with a summary of crash trend information that may contribute to the SPIS score. Overlapping segments should be reported as one group using only the highest SPIS score. The analyst should identify relevant improvements and/or countermeasures and whether any interim roadway or operational changes have taken place since the data were collected. Identified SPIS sites may differ from those highlighted using the previously identified in HSM screening methods due to differences in methodology.

The top 5% SPIS ranking requires the Region Traffic offices to conduct a safety investigation each year to determine if there is an appropriate safety improvement fix to the problem. Contact the Region Traffic office to obtain any applicable safety investigations performed in the study area. The SPIS ranking can be determined by contacting the appropriate Region Traffic office for assistance or on the SPIS webpage.

4.3.2 Oregon Adjustable Safety Index System (OASIS) (ODOT Employees Only)

OASIS was developed as an online safety analysis tool that is capable of performing “SPIS-like” safety analysis while allowing users to vary the settings, crash conditions, and scoring formula. Parameters and filters that can be modified in OASIS include:

- Crash Years
- Segment Length
- Segment Qualifier (minimum crash history required for inclusion in analysis)
- Road Jurisdiction
- Collision Type
- Light Condition
- Road Surface Condition
- Work Zone Involved

- Speed Involved
- Alcohol or Drugs Involved
- Pedestrian or Bike Involved
- Truck Involved
- Deer or Elk Involved
- Cell Phone Involved
- Scoring Formula and Weighting

The OASIS tool allows the user to quickly create a statewide custom safety analyses, for example, examining only crashes involving pedestrians and bicyclists. This program is available only to Traffic Roadway staff and ODOT Region Staff.

4.3.3 Reference Populations

Recommended Uses	Critical Crash Rate and Excess Proportions of Specific Crash Types
Data Required	Crash frequency for target crash types of interest Site characteristics such as: Land Use (Rural/Urban) Geometry (Number of through lanes, intersection legs, etc.) Traffic Control (Signalized, two-way stop control, etc.) AADT Traffic Volumes
More Information	HSM Part B, Chapter 4, Section 4.2.2

Reference populations are central to the HSM screening methods presented in this chapter. Reference populations are groups of study sites (such as intersections or roadway segments) that have similar characteristics and serve as a comparison for evaluating safety performance.

Reference populations represent the typical safety performance for a specific type of study site. The safety performance of an individual study site is compared to the average safety performance of a reference population, using either the Critical Crash Rate method or the Excess Proportion of Specific Crash Types method to establish a performance standard specific to the study site and reference population.

Potential characteristics that can be used to define reference populations include:

- Traffic control (e.g., signalized, two-way or four-way stop control, yield control, roundabout)
- Number of approaches (e.g., three-leg or four-leg intersections)
- Cross-section (e.g., number of through lanes and/or turning lanes)
- Functional classification (e.g., arterial, collector, local)
- Adjacent land use (e.g., urban, suburban, rural)
- Traffic volume ranges [e.g., total entering volume (TEV), peak hour volume, average annual daily traffic (AADT)]
- Terrain (e.g., flat, rolling, mountainous)
- Access density (e.g., driveway and intersection spacing)

- Median type and/or width
- Operating or posted speed

Defining characteristics for a reference population will vary depending on the amount of detail known about each study site, the size of the network to be screened, and the focus of the safety analysis. Each reference population must contain at least five sites to be statistically valid.

Reference populations may be composed of “internal” or “external” sites, or a combination of both. Internal sites are locations being studied for the safety analysis; external sites are locations not being studied for the safety analysis.

For example, a city TSP may be screening the safety performance of a variety of intersections within the city. An internal reference population might be composed of four-way stop-controlled intersections being screened in the city. An external reference population might be composed of four-way stop-controlled intersections from similar adjacent cities.

Internal reference populations are the minimum requirement for network screening. Since all data are being collected for the project, there is no need to gather extra data. Internal reference populations are best for prioritizing locations within a study area or for identifying outliers within a study area.

External reference populations may be used when it is desired to assess statewide safety performance conditions to assess statewide safety performance, use the mean crash rate from Exhibit 4-1.

When reporting screening results, clearly identify the reference populations used.

4.3.4 Critical Crash Rate

Recommended Uses	Transportation System Plans and Corridor Plans May be used for existing conditions assessment in development review or project development when predictive methods are unavailable
Data Required	Crash frequency by severity AADT traffic volumes Reference populations
More Information	HSM Part B, Chapter 4, Section 4.4.2.5

Crash rates describe crash frequency in relation to traffic volume. Crash rates at intersections are typically given in units of crashes per million entering vehicles (crashes/MEV). Crash rates for segments are typically given in units of crashes per million vehicle miles traveled [crashes/million vehicle miles traveled (MVMT)]. It is recommended that Annual Average Daily Traffic (AADT) values be used in calculating crash rates. APM Section 5.7 contains procedures for calculating AADT. If AADT data are not available, Average Daily Traffic (ADT) can be substituted.

The Critical Crash Rate analysis method evaluates each study site’s crash rate compared to the

average crash rate of that site's reference population. Study sites with significantly higher crash rates (exceeding the Critical Crash Rate) are identified for further analysis.

The Critical Crash Rate method evaluates the overall magnitude of the observed crash rate for one target crash type at a time. Two variations on Critical Crash Rate are commonly used, one evaluating total crash rate and one evaluating the crash rate considering only fatal and injury-A severity crashes.

The Critical Crash Rate method does not allow for estimates of future safety performance and cannot be used for evaluating alternatives. This method does not address RTM, so short time periods (less than three years) should not be used. Crash rates also do not account for the non-linearity of crash frequency with respect to traffic volumes. Analysts should be aware that crash rates may be reduced simply by an increase in traffic volumes alone. A reduction in crash rate at higher traffic volumes is often the expected roadway behavior and does not indicate a fundamental change in underlying safety performance. The predictive methods discussed in APM Section 0 can address all three of these limitations.

A spreadsheet is available from the safety analysis tools section of the ODOT Transportation Development Planning Technical Tools website that automates much of the Critical Crash Rate calculations.

The general procedure for network screening using the Critical Crash Rate method is as follows:

1. Identify analysis sites and assign observed crashes (see APM Section 4.2.3)
2. For each analysis site, using the target crash frequency and AADT traffic volume calculate the crash rate (or observed crash rate) on a MEV basis
3. Establish reference populations and calculate the average crash rate for each reference population
4. Choose the desired statistical significance level (95% is recommended)
5. For each analysis site, calculate the reference population critical crash rate. This value is unique for each analysis site and is a function of the reference population average crash rate, traffic volume at the site, and the desired statistical significance.
6. For each analysis site, calculate the statewide comparison critical crash rate. This value is unique for each analysis site and is a function of the mean crash rate from Exhibit 4-1, traffic volume at the site, and the desired statistical significance.
7. Identify any sites where the observed crash rate is greater than the calculated reference population critical crash rates
8. Identify any sites where the observed crash rate is greater than the calculated statewide comparison critical crash rates
9. Identify any sites where the observed crash rate is greater than the published statewide comparison rates. Intersections should also be compared with the 90th percentile rates in Exhibit 4-1. Segments should also be compared with the average rates in Crash Rate Table II.

This process is repeated for each area of interest. The analysis should be done using a critical crash rate based on total crashes. An additional suggested analysis is to use a critical crash rate based on only fatal and injury-A severity crashes. If multiple sets of reference populations are

being used (e.g., internal and external), the process is repeated for each set of reference populations.

The process is generally the same for intersections and for segments. Intersection critical crash rate analysis should use only crashes associated with intersections and segment critical crash rate analysis should use only crashes associated with segments (see APM Section 4.2.3).

For intersections and segments, the crash rate is derived using different measures of traffic exposure. For intersections, crash rates are derived using Million Entering Vehicles (MEV), while segments are derived using Million Vehicle Miles Traveled (MVMT).

$$MEV = \frac{AADT \times 365 \times n}{1{,}000{,}000}$$

$$MEV = Million\ \ Entering\ \ Vehicles$$

$$n = Number\ of\ \ Years$$

$$MVMT = \frac{AADT \times L \times 365 \times n}{1{,}000{,}000}$$

$$MVMT = Million\, Vehicle - Miles\ of\ \ Travel$$

$$L = Segment\ \ Length$$

$$n = Number\ of\ \ Years$$

Segments also must be divided into sites that are similar in character, as described in APM Section 4.3.3 on reference populations. Segment boundaries should be placed where the reference population changes, at intersections that have observed crashes, and at other logical breakpoints in order for segments not to exceed two or three miles in length. For some very long corridors such as in rural eastern Oregon, segments could be up to five miles in length. Segments should ideally be close to one mile in length. For urban areas, obtaining one mile segments is difficult, however the majority of urban crashes are intersection related. Short sections less than a half mile in length typically skew the crash rates and should be avoided.

However, it may not be possible to avoid short segments in which case the length should be normalized to a mile and the rate recalculated. This recalculated rate would be compared to Table II to see if it still exceeds. For example, if a 0.25 mi segment had a crash rate of 8.0 crashes per MVMT, then the normalized rate would be 8.0 crashes per MVMT x 0.25 mile = 2.0 crashes per MVMT.

For segments on milepointed highways, length may be calculated based on Begin and End Milepoint. All crashes (both intersection and non-intersection) are included in a Table II-based segment crash analysis. Segment lengths need to be adjusted if they contain a milepoint equation. Milepoint equations can be found from the Equations and Milepoint Range Report.

When reporting the results of this method, include the following for each target crash type:

- Crash frequency for each analysis site
- AADT (or ADT) traffic volume for each analysis site
- Reference population characteristics and summary statistics
- Observed crash rate for each analysis site
- Critical crash rate for each analysis site
- Sites identified as exceeding their critical crash rate

For this method to be statistically valid, there needs to be at least five to ten sites in each reference population. If there are fewer than five sites available to create a reference population, these methods do not apply (since there are not enough sites to screen). This method may also produce small crash rate variances that may overlook sites with a significant crash problem. Also, the sites within the study area reference populations may have different variances when compared to similar sites statewide. To minimize these issues, crash rates should also be compared to published statewide crash rates as described below. The Critical Crash Rate method can also be used for a statewide comparison by replacing the reference population average crash rate with the appropriate mean crash rate from Exhibit 4-1.

Segment crash rates should be compared to the appropriate average crash rate from the Oregon State Highway Crash Rate Tables, annually published by the ODOT CAR Unit. In this document, crash rates for given segments of all state highways are calculated and listed for each of the last five years.

Crash Rate Table II is the primary table used in segment crash rate analysis. It shows statewide average crash rates for each of the last five years, by urban and rural area, and by roadway classification. Federal functional classifications can be found on the ODOT Federal Functional Classification (FC) webpage.

The following examples illustrate the calculation of MEV, segment crash rates, and the calculation of Critical Crash Rates for intersections and segments.

Example 4-1: Segment Crash Rate Calculation and Comparison

A 1.6-mile principal highway segment in a rural area has experienced 22 reported crashes over the last three years. The segment AADT from the State Highway Vehicle Classification Data Report is 23,000.

$$\text{Rate} = \frac{\text{Number of Crashes X } 1{,}000{,}000}{\text{Length (in miles) X AADT X (Yrs X 365)}}$$

$$= \frac{22 \text{ X } 1{,}000{,}000}{1.6 \text{ X } 23{,}000 \text{ X } 3\text{Yrs X } 365}$$

$$= 0.55 \text{ Crashes per Million Vehicle Miles (MVM)}$$

As shown in the table below, the statewide average crash rates are:

2005	0.67
2006	0.69
2007	0.68
Average	0.68

The segment crash rate of 0.55 is less than the average statewide rate of 0.68.

Statewide Crash Rate Table

TABLE II: FIVE-YEAR COMPARISON OF STATE HIGHWAY CRASH RATES

Table II presents a comparison of state highway crash rates for the past five years, for urban and rural areas, by functional classification. Mileage is shown for the current data year only.

See Table IV for information on official highway mileage and VMT data.

JURISDICTION AND FUNCTIONAL CLASSIFICATION	MILES*	2007 Rate	2006 Rate	2005 Rate	2004 Rate	2003 Rate
TOTAL STATE HWY SYSTEM	**7,455.23**	**0.85**	**0.85**	**0.87**	**0.79**	**0.98**
Interstate Freeways	729.57	0.38	0.39	0.41	0.38	0.42
Other Fwys/Expressways	52.26	0.73	0.78	0.80	0.78	0.87
Non-Freeways (combined)	6,673.40	1.27	1.26	1.25	1.13	1.45
Other Principal Arterials	3,281.04	1.28	1.29	1.28	1.16	1.52
Minor Arterials	1,964.61	1.20	1.14	1.14	1.02	1.20
Urban Collectors	8.69	1.10	0.68	1.19	1.23	2.08
Rural Major Collectors	1,382.20	1.25	1.11	1.14	0.93	1.25
Rural Minor Collectors	36.86	0.64	0.66	1.30	0.32	1.30
Rural Local	0.00	0.00	16.52	4.23	2.68	8.06
Rural Areas	**6,414.01**	**0.58**	**0.58**	**0.59**	**0.51**	**0.59**
Interstate Freeways	539.37	0.28	0.29	0.31	0.25	0.26
Non-Freeways (combined)	5,874.64	0.79	0.77	0.77	0.68	0.80
Other Principal Arterials	2,658.39	0.68	0.69	0.67	0.61	0.71
Minor Arterials	1,839.04	0.99	0.93	0.98	0.83	0.97
Rural Major Collectors	1,340.60	1.24	1.08	1.10	0.92	1.20
Rural Minor Collectors	36.61	0.69	0.36	1.40	0.35	1.40
Rural Local	0.00	0.00	16.52	4.23	2.68	8.06

* Couplet and Roadway 3 data are included. Frontage road and connection data are excluded.

A segment crash rate that exceeds the statewide average crash rate may be an indication that further investigation is necessary, although it is possible that upon further investigation it may be determined that no improvements are necessary. Likewise, cost-effective improvements to reduce crashes could still be identified even with a segment crash rate lower than the statewide average.

Example 4-2: Million Entering Vehicles (MEV)

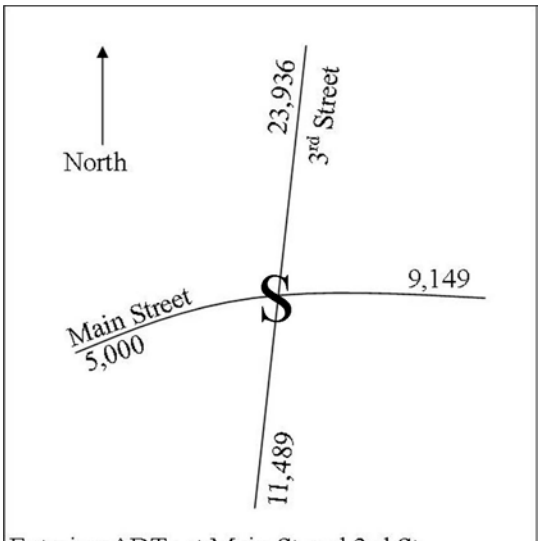
As a part of an urban street modernization project, a safety analysis needs to be done for Main St. This street is a congested urban corridor with a mixture of unsignalized and signalized intersections with varying numbers of lanes.

Traffic counts were taken at each intersection and crashes for the previous five years have been

compiled. In order to calculate the HSM Critical Crash Rate the total MEV is needed for each intersection.

Data Needs

Directional count data are needed for each leg of each intersection. If ADT-capable counts are not available and the best data available are the Traffic Volume Tables (TVT) or a non-directional tubular count, a 50/50 directional split can be assumed. For the intersection of Main St. and 3rd St., ADTs entering the intersection from each leg were developed and are shown in the diagram below. See Chapter 5 for the process to develop directional ADTs.



Entering ADTs at Main St and 3rd St

Step 1: Adjustment of ADTs to AADTs

The ADTs entering the intersection need to be converted to AADTs. See Chapter 5 for the process to develop the appropriate adjustment factors. Note: If using the TVT for volumes, this step does not apply. The volumes in the TVT have already been adjusted to AADT. In this case move directly to Step 2.

$$AADT = ADT \times Adjustment\ \ Factor*$$

$$Entering\ \ AADTs\ at\ Main\ Street\ and\ 3rd\ \ Street$$

$$AADT_{North} = 23936 \times 0.94 = 22500$$

$$AADT_{South} = 11489 \times 0.94 = 10800$$

$$AADT_{East} = 9149 \times 0.94 = 8600$$

$$AADT_{West} = 5000 \times 0.94 = 4700$$

* See Chapter 5 for steps to calculate the adjustment factor.

Step 2: Million Entering Vehicles (MEV)

$$Total\ Entering\ AADT = \sum Entering\ \ AADTs$$

$$Total\ Entering\ AADT_{Main\ Street\ at\ 3rd\ Street} = 22500 + 10800 + 8600 + 4700 = 46{,}600$$

$$MEV = \frac{Total\ Entering\ AADT \times 365 \times n}{1{,}000{,}000}$$

$$AADT = Annual\,Average\,Daily\,Traffic$$

$$n = Number\ of\ \ Years$$

$$MEV_{Main\ Street\ at\ 3rd\ Street} = \frac{46{,}600 \times 365 \times 5}{1{,}000{,}000} = 85.0MEV$$

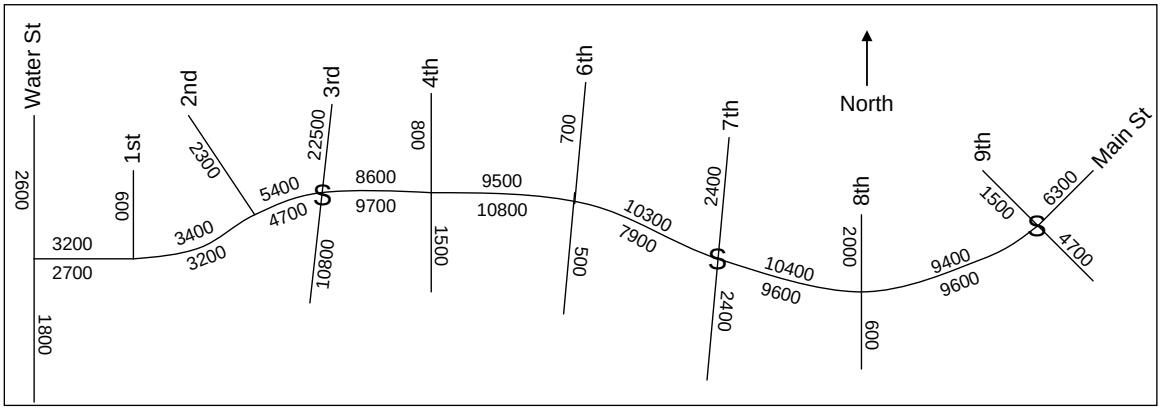
Example 4-3: HSM Critical Rate for Intersections with Internal Reference Population

As part of an urban street modernization project corridor plan, a safety analysis needs to be done for Main St. This street is a congested urban corridor with a mixture of unsignalized and signalized intersections with varying numbers of lanes.

The project engineer has created existing year average daily traffic (ADT) volumes from available intersection counts. The ADT counts were converted into AADT (an average value for 2005-2009 using appropriate seasonal factors and annual growth factors), which are shown as daily total entering volumes in the figure below. In addition, intersection crash data for the past five years are shown in the table below. Crash data are summarized by year and by severity. A critical crash rate analysis will be performed considering all crashes and considering Fatal plus Injury-A crashes as the target crash type.

Data Needs

<u>Existing Year Annual Average Daily Entering Traffic Volumes</u>



Intersection Crashes Per Year

Intersection	Type	Year					Total
		2005	2006	2007	2008	2009	
Water St.	Unsignalized	2	1	0	1	2	6
1st St.	Unsignalized	0	0	0	0	0	0
2nd St.	Unsignalized	0	0	0	0	1	1
3rd St.	Signalized	6	8	5	6	4	29
4th St.	Unsignalized	0	0	0	1	1	2
6th St.	Unsignalized	6	2	3	2	1	14
7th St.	Signalized	3	1	2	6	3	15
8th St.	Unsignalized	0	0	2	3	0	5
9th St.	Signalized	3	6	2	0	1	12
Total		**20**	**18**	**14**	**19**	**13**	**84**

Intersection Crashes By Severity

Intersection	Type	Severity					Total
		Fatal	Inj. A	Inj. B	Inj. C	PDO	
Water St.	Unsignalized	0	2	0	1	3	6
1st St.	Unsignalized	0	0	0	0	0	0
2nd St.	Unsignalized	0	0	0	0	1	1
3rd St.	Signalized	0	3	5	9	12	29
4th St.	Unsignalized	0	0	0	0	2	2
6th St.	Unsignalized	0	5	1	3	5	14
7th St.	Signalized	0	1	1	4	9	15
8th St.	Unsignalized	0	0	1	1	3	5
9th St.	Signalized	0	1	3	3	5	12
Total		**0**	**12**	**11**	**21**	**40**	**84**

The HSM Critical Rate screening method will be used to determine the intersections with the greatest need.

Note: All sample calculations given at the intersection of Water St. and Main St.

Step 1: At each intersection, calculate the volume on a Million Entering Vehicle (MEV) basis

$$(1) \quad MEV = \frac{AADT \times 365 \times n}{1{,}000{,}000}$$

$$MEV = Million \;\; Entering \;\; Vehicles$$

$$n = Number \; of \; Years$$

$$MEV = \frac{7{,}600 \times 365 \times 5}{1{,}000{,}000} = 13.9 \; MEV$$

Step 2: Calculate the crash rate at each intersection

$$(2) \quad R = \frac{Crash \; Total}{MEV_n}$$

$$R = Observed \; Crash \; Rate$$

Crash rate for all crashes

$$R = \frac{6}{13.9} = 0.43 \frac{Crashes}{MEV}$$

Crash rate for Fatal and Injury-A target crash type

$$R_{FA} \frac{2}{13.9} = 0.14 \frac{Fatal + A \, Crashes}{MEV}$$

Intersection	Daily Volume	MEV (1)	Crash Total	F+A Crash Total	Crash Rate (2)	F+A Crash Rate (2)
Water St.	7,600	13.9	6	2	0.43	0.14
1st St.	6,700	12.2	0	0	0.00	0.00
2nd St.	10,900	19.9	1	0	0.05	0.00
3rd St.	46,600	85.0	29	3	0.34	0.04
4th St.	21,500	39.2	2	0	0.05	0.00
6th St.	22,300	40.7	14	5	0.34	0.12
7th St.	23,100	42.2	15	1	0.36	0.02
8th St.	19,800	36.1	5	0	0.14	0.00
9th St.	22,100	40.3	12	1	0.30	0.02

Step 3: Calculate the average crash per population

(3a) Divide the intersections into varying populations (groups) based on operational (i.e., unsignalized/signalized/roundabouts) or geometric (i.e., three-leg/four-leg) differences. Only one reference population of sufficient size exists for this example. Six intersections fall under the unsignalized type (Type 1) reference population. There are not enough three-leg or four-leg unsignalized intersections to further subdivide the reference populations. The critical rate method cannot be used for the signalized intersections (Type 2) since there are only three in the reference population. TPAU will be contacted to propose adding external reference sites to the signalized reference population (not included in this example).

$$(3b)\ R_a = \frac{\sum_{i=1}(N_{obs,i})}{\sum_{i=1}(MEV_i)}$$

$R_a = Average\ crash\ rate\ \ for\ reference\ \ population\ a$

$R_{FA(a)} = Average\ Fatal + A\ \ crash\ rate\ \ for\ reference\ \ population\ a$

Average Crash Rate for Unsignalized Intersections reference population:

$$R_1 = \frac{6+0+1+2+14+5}{13.9+12.2+19.9+39.2+40.7+36.1}$$

$$= 0.17\,\frac{Crashes}{MEV}$$

Average Fatal + Injury-a Crash rate for Unsignalized Intersections reference population:

$$R_{FA(1)} = \frac{2+0+0+0+5+0}{13.9+12.2+19.9+39.2+40.7+36.1}$$

$$= 0.04\,\frac{Crashes}{MEV}$$

Equation (3b) is a reduced version of Equation 4-10 found in the 1st edition Highway Safety Manual, Volume 1, Chapter 4.

Step 4: Calculate a critical crash rate for each intersection

$$(4)\quad R_c = R_a + Confidence\ Level \times \sqrt{\frac{R_a}{MEV_n} + \frac{1}{2 \times MEV_n}}$$

$R_c = Critical\ crash\ rate$

$R_a = Weighted\ average\ crash\ rate\ \ for\ reference\ \ population$

Critical crash rate for all crashes

$$R_C = 0.17 + 1.645 \times \sqrt{\frac{0.17}{13.9} + \frac{1}{2 \times 13.9}} = 0.39\,\frac{Crashes}{MEV}$$

Critical crash rate for Fatal + Injury-A crashes

$$R_{FA(C)} = 0.04 + 1.645 \times \sqrt{\frac{0.04}{13.9}} + \frac{1}{2 \times 13.9} = 0.17 \frac{F + A \ \ Crashes}{MEV}$$

Table 4-9 in the HSM (page 4-36) gives P-levels to correspond to differing confidence levels. Typical use would be 95% confidence (P=1.645).

Intersection	Intersection Population Type (3a)	Crash Rate (2)	Critical Crash Rate (4)	Over Critical (5)
Water St.	1	0.43	0.39	Over
1st St.	1	0.00	0.41	Under
2nd St.	1	0.05	0.35	Under
4th St.	1	0.05	0.29	Under
6th St.	1	0.34	0.29	Over
8th St.	1	0.14	0.30	Under

Intersection	Intersection Population Type (3a)	F+A Crash Rate (2)	F+A Critical Crash Rate (4)	Over F+A Critical (5)
Water St.	1	0.14	0.17	Under
1st St.	1	0.00	0.18	Under
2nd St.	1	0.00	0.14	Under
4th St.	1	0.00	0.11	Under
6th St.	1	0.12	0.11	Over
8th St.	1	0.00	0.11	Under

Step 5: Compare observed crash rate with critical crash rate

Compare the critical crash rate with the crash rate for each intersection. Any intersection with a crash rate that exceeds its critical rate should be flagged for further review.

In the above example, the following intersections were flagged for further analysis:

- Water St. and Main St.
- 6th St. and Main St.

Step 6: Compare observed crash rate with statewide 90th percentile rates (Exhibit 4-1)
The crash rates at all study intersections (including those without a reference population) are compared to the statewide 90th percentile crash rates for urban three-leg minor stop-controlled (U3ST), urban four-leg minor stop-controlled (U4ST), and urban four-leg signalized (U4SG) intersections.

Intersection	Intersection Population Type	Observed Crash Rate	Statewide 90th Percentile Crash Rate
Water St.	U3ST	0.43	0.293
1st St.	U3ST	0.00	0.293
2nd St.	U3ST	0.05	0.293
3rd St.	U4SG	0.34	0.860
4th St.	U4ST	0.05	0.408
6th St.	U4ST	0.34	0.408
7th St.	U4SG	0.36	0.860
8th St.	U4ST	0.14	0.408
9th St.	U4SG	0.30	0.860

In the above example, the following intersection was flagged for further analysis:

- Water St. and Main St.

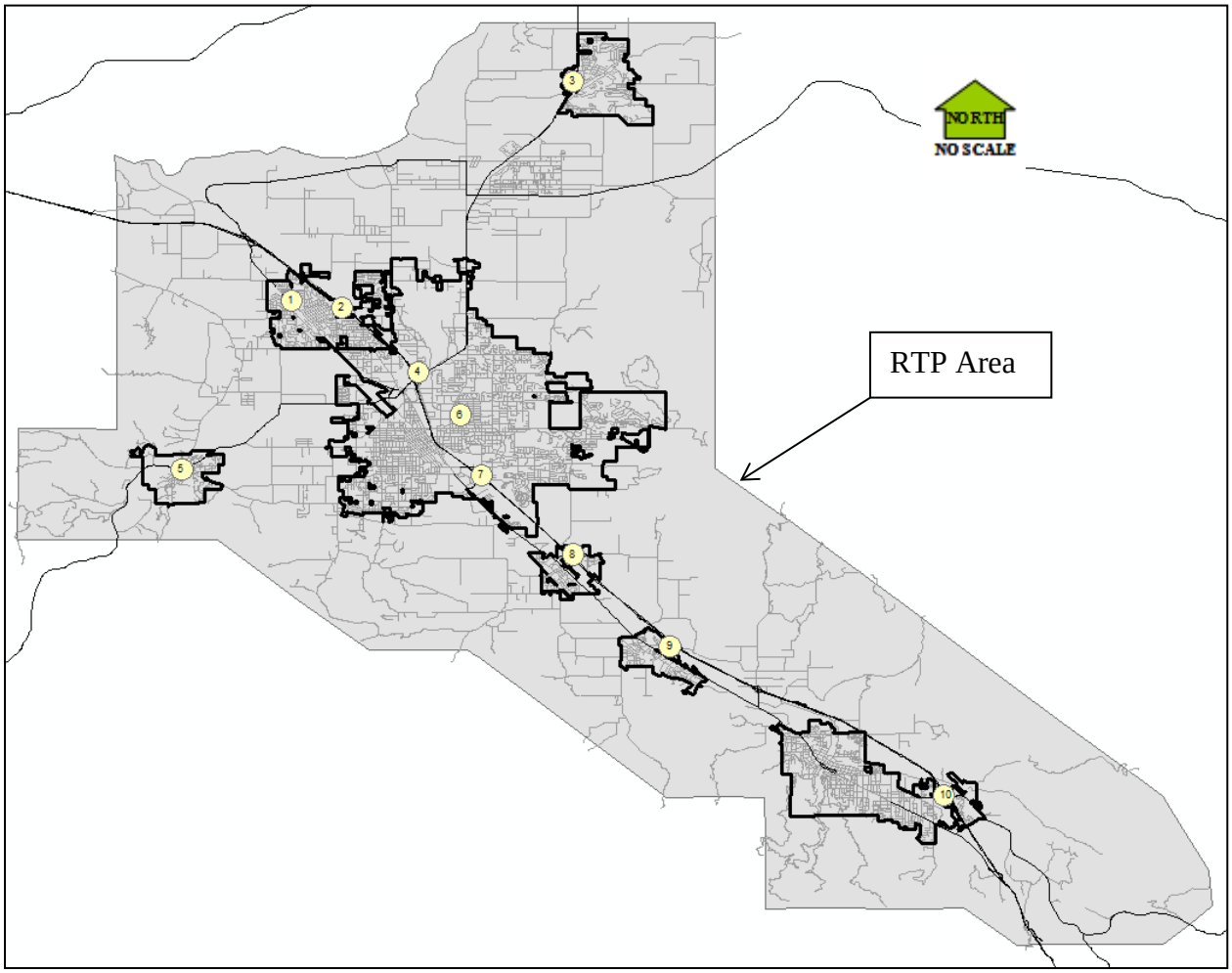
Step 7: Conclusions
From the analysis, the intersections of Main St. and Water St. and Main St. and 6th St. exceed the critical rate. Main St. and 6th St. also exceeds the Fatal plus Injury-A critical rate, and the statewide 90th percentile crash rate. These intersections are "safety focus" locations that need to be reviewed in more depth. At a minimum, crashes and patterns need to be identified and potential countermeasures indicated. More in-depth HSM predictive analysis could be done for the existing conditions and any later future conditions, which could also include finding the most cost-effective countermeasures.

Example 4-4: HSM Critical Rate for Intersections with Statewide Reference Population

As part of an RTP update, screening level statewide comparative safety analysis is to be performed on ten urban four-leg signalized intersections within the RTP area. The goal of this analysis is to identify intersections that have crash rates above other similar intersection types statewide. This analysis will consider all crash types and severities.
The project engineer has created existing year average daily traffic (ADT) volumes from available intersection counts and converted into AADT (total entering volumes). In addition, intersection crash data for the past five years are shown in the table below. Crash data are summarized by year and by severity.

Data Needs

Existing Year Annual Average Daily Entering Traffic Volumes



Intersection Crashes Per Year

Intersection	Type	Year					Total
		2010	2011	2012	2013	2014	
1	Signalized	5	5	3	4	2	19
2	Signalized	4	3	5	4	2	18
3	Signalized	1	1	2	1	1	6
4	Signalized	4	1	1	5	5	16
5	Signalized	4	1	1	4	2	12
6	Signalized	3	3	4	3	3	16
7	Signalized	1	1	1	1	5	9
8	Signalized	4	1	4	5	4	18
9	Signalized	3	1	2	5	1	12
10	Signalized	1	4	1	2	1	9
Total		30	21	24	34	26	135

The HSM Critical Rate screening method will be used to determine the intersections with the greatest need.

Note: All sample calculations given for Intersection #1

Step 1: At each intersection, calculate the volume on a Million Entering Vehicle (MEV) basis

$$(1) \quad MEV = \frac{AADT \times 365 \times n}{1{,}000{,}000}$$

$$MEV = Million \;\; Entering \;\; Vehicles$$

$$n = Number \; of \; Years$$

$$MEV = \frac{9{,}700 \times 365 \times 5}{1{,}000{,}000} = 17.7 \; MEV$$

Step 2: Calculate the crash rate at each intersection

$$(2) \quad R = \frac{Crash\ Total}{MEV_n}$$

$$R = Observed \; Crash \; Rate$$

Crash rate for all crashes

$$R = \frac{19}{17.7} = 1.07 \; \frac{Crashes}{MEV}$$

Intersection	Daily Volume	MEV (1)	Crash Total	Crash Rate (2)
1	9,700	17.7	19	1.07
2	19,700	36.0	18	0.50
3	12,400	22.6	6	0.27
4	12,300	22.4	16	0.71
5	11,000	20.1	12	0.60
6	16,600	30.3	16	0.53
7	11,500	21.0	9	0.43
8	8,000	14.6	18	1.23
9	8,600	15.7	12	0.76
10	11,500	21.0	9	0.43

Step 3: Calculate the average crash per population

(3a) Because this is a statewide comparison, use the mean crash rate for Urban 4SG intersections from Exhibit 4-1.

Exhibit 4-1: Intersection Crash Rates per MEV by Land Type and Traffic Control

	Rural				Urban			
	3SG	3ST	4SG	4ST	3SG	3ST	4SG	4ST
No. of Intersections	7	115	20	60	55	77	106	60
Mean Crash Rate	**0.226**	**0.196**	**0.324**	**0.434**	**0.275**	**0.131**	**0.477**	**0.198**
Median Crash Rate	0.163	0.092	0.320	0.267	0.252	0.105	0.420	0.145
Standard Deviation	0.185	0.314	0.223	0.534	0.155	0.121	0.273	0.176
Coefficient of Variation	0.819	1.602	0.688	1.230	0.564	0.924	0.572	0.889
90th Percentile Rate	**0.464**	**0.475**	**0.579**	**1.080**	**0.509**	**0.293**	**0.860**	**0.408**

Source: Assessment Of Statewide Intersection Safety Performance, FHWA-OR-RD-18, Portland State University and Oregon State University, June 2011, Table 4.1, p. 47.

Note: Traffic control types include 3SG (three-leg signalized), 3ST (three-leg minor stop-control), 4SG (four-leg signalized), 4ST (four-leg minor stop-control).

Step 4: Calculate a critical crash rate for each intersection

$$(4) \quad R_c = R_a + Confidence\ Level \times \sqrt{\frac{R_a}{MEV_n} + \frac{1}{2 \times MEV_n}}$$

$R_c = Critical\ crash\ rate$

$R_a = Weighted\ average\ crash\ rate\ \ for\ reference\ population$

Critical crash rate for all crashes

$$R_C = 0.477 + 1.645 \times \sqrt{\frac{0.477}{17.7} + \frac{1}{2 \times 17.7}} = 0.78\ \frac{Crashes}{MEV}$$

Table 4-9 in the HSM (page 4-36) gives P-levels to correspond to differing confidence levels. Typical use would be 95% confidence (P=1.645).

Intersection	Intersection Population Type (3a)	Crash Rate (2)	Critical Crash Rate (4)	Over Critical (5)
1	Signalized	**1.07**	**0.78**	**Over**
2	Signalized	0.50	0.68	Under
3	Signalized	0.27	0.74	Under
4	Signalized	0.71	0.74	Under
5	Signalized	0.60	0.76	Under
6	Signalized	0.53	0.70	Under
7	Signalized	0.43	0.75	Under
8	Signalized	**1.23**	**0.81**	**Over**
9	Signalized	0.76	0.80	Under
10	Signalized	0.43	0.75	Under

Step 5: Compare observed crash rate with critical crash rate
Compare the critical crash rate with the crash rate for each intersection. Any intersection with a crash rate that exceeds its critical rate should be flagged for further review. In the above example, intersections #1 and #8 were flagged for further analysis.

Step 6: Compare observed crash rate with statewide 90th percentile rates (Exhibit 4-1)
The crash rates at all study intersections (including those without a reference population) are compared to the statewide 90th percentile crash rates for urban three-leg minor stop-controlled (U3ST), urban four-leg minor stop-controlled (U4ST), and urban four-leg signalized (U4SG) intersections.

Intersection	Intersection Population Type	Observed Crash Rate	Statewide 90th Percentile Crash Rate
1	U4SG	**1.07**	**0.860**
2	U4SG	0.50	0.860
3	U4SG	0.27	0.860
4	U4SG	0.71	0.860
5	U4SG	0.60	0.860
6	U4SG	0.53	0.860
7	U4SG	0.43	0.860
8	U4SG	**1.23**	**0.860**
9	U4SG	0.76	0.860
10	U4SG	0.43	0.860

In the above example, intersections #1 and #8 are flagged for further analysis.

Step 7: Conclusions
From the analysis, intersections #1 and #8 exceed the critical rate based on a statewide comparison as well as the statewide 90th percentile crash rate. These intersections are "safety focus" locations that need to be reviewed in more depth. At a minimum, crashes and patterns need to be identified and potential countermeasures indicated. More in-depth HSM predictive analysis could be done for the existing conditions and any later future conditions, which could also include finding the most cost-effective countermeasures.

Example 4-5: Critical Crash Rate for Segments

A screening level safety analysis is to be performed on North Santiam Highway, a rural state highway corridor. The route is approximately 80 miles in length and has both level and rolling terrain . It contains multilane, two-lane, passing and climbing lane sections. It is desired to identify segments for further safety analysis. The Critical Crash Rate method will be applied to segments within the corridor. The study area is shown below.

Study Area

All sample calculations given are for the reference population 4-lane highway, and for Segment 5.

Step 1: Obtain comprehensive (PRC) crash report in Excel format for corridor
Five years of crash data should be obtained using the PRC crash report, available for both state highways and local roads on the ODOT Internal Crash Reports website or the External Crash Reports website. The PRC report contains multiple records per crash. Only the crash level record (first record) is needed. The vehicle and participant level records should be filtered out so that only the crash level record remains for each crash.

Step 2: Filter out urban areas and rural intersections
The PRC report identifies intersection crashes using the RD_CHAR_SHORT_DESC field. Filter out these crashes. Intersection crashes can generally be assumed to be any that are at an intersection with at least one crash, plus 0.01 miles on either side of the intersection milepoint, as well as any coded as intersection-related. Segments are subdivided at intersections with at least one crash. Intersections with no crashes can be included within segments. The intersections with crashes can be analyzed separately using the Intersection Critical Rate method described previously.

Step 3: Obtain AADTs from the State Highway Vehicle Classification Report
For state highways, AADTs are obtained from the State Highway Vehicle Classification Report. For non-state highways, AADTs will need to be calculated following procedures in Chapter 5.

Step 4: Segmenting
Segments are developed based on reference populations. Segment boundaries should be placed where the reference population changes, at intersections that have crashes, and at other logical breakpoints in order for segments not to exceed two or three miles in length. For some very long corridors such as in rural eastern Oregon, segments could be up to five miles in length.

A variety of potential reference populations could be considered, including:

- Urban/rural
- Freeways/arterials
- Number of travel lanes (2, 3, 4, 5, etc.)
- Divided/undivided
- Presence of auxiliary lanes (passing lanes, climbing lanes)
- Terrain (level, rolling and mountainous)
- Geographic area or elevation
- AADT level

Data sources for determining reference population boundaries include TransGIS, Transviewer, the digital video log, and the State Highway Vehicle Classification Report.
At least five segments are needed for each reference population. If there are enough segments, it

may be possible to have subgroupings, such as initially by number of lanes and then by terrain. It may also be desirable to separately analyze more than one reference population. This may help to further identify crash trends. Specific types of crashes could be examined as well, such as those involving snow and ice or fatal and injury crashes.

Freeway reference populations could include basic freeway lane sections, weave sections, and ramp merge or diverge sections.

Each segment is assigned a Begin and End Milepoint. Segment lengths need to be adjusted if they contain a milepoint equation. Milepoint equations can be found from the Equations and Milepoint Range Report.

Step 5: Identify the number of crashes in each segment
Each segment is assigned the total number of crashes within that segment. This process can be automated using the PRC crash data from Step 1 as a lookup table to sum the number of crashes in each segment between begin and end milepoints.

In this example, five segments were identified within the reference population of four-lane divided highway segments, as show in the following table.

Segment	Reference Population Type	Begin Milepoint	End Milepoint	5-Year Crash Total	AADT	Crash Rate
1	4 Lane Divided	4.10	6.84	21	24400	0.17
2	4 Lane Divided	6.88	8.89	7	19100	0.10
3	4 Lane Divided	8.93	11.53	8	19100	0.09
4	4 Lane Divided	11.54	13.23	8	13100	0.20
5	4 Lane Divided	13.24	13.80	5	8900	0.55

Step 6: Calculate the crash rate for each segment
The remaining steps can be automated using the Critical Rate Calculator. It is convenient if the data previously developed is formatted to paste directly into the calculator input cells.

(1) $$MVMT = \frac{AADT \times L \times 365 \times n}{1{,}000{,}000}$$

$$MVMT = Million\ Vehicle - Miles\ of\ Travel$$

$$L = Segment\ Length$$

$$n = Number\ of\ Years$$

$$R = Crash\ Rate = \frac{Number\ of\ Crashes}{MVMT}$$

The MVMT for Segment 5 is calculated as follows:

$$MVMT = \frac{8900 \times (13.80 - 13.24) \times 365 \times 5}{1{,}000{,}000} = 9.10$$

The crash rate for Segment 5 is calculated as follows:

$$R = \frac{5}{9.10} = 0.55$$

Step 7: Calculate the average crash rate for each reference population

$$(2)\ R_a = \frac{\sum_{i=1}(N_{obs,i})}{\sum_{i=1}(MVMT_i)}$$

$$R_a = Average\ segment\ crash\ rate\ \ for\ reference\ population\ a$$

For the reference population of four-lane divided highway segments, the average crash rate is calculated as follows:

$$R_1 = \frac{21+7+8+8+5}{122.01+70.06+90.63+40.40+9.10}$$

$$= 0.15\ Crashes / MVMT$$

Step 8: Calculate a critical crash rate for each segment

$$(3)\quad R_c = R_a + Confidence\ Level \times \sqrt{\frac{R_a}{MVMT_n} + \frac{1}{2 \times MVMT_n}}$$

$$R_c = Critical\ crash\ rate$$

$$R_a = Weighted\ average\ crash\ rate\ \ for\ reference\ population$$

The segment 5 critical crash rate is calculated as follows:

$$R_C = 0.15 + 1.645 \times \sqrt{\frac{0.15}{9.10} + \frac{1}{2 \times 9.10}} = 0.41\ Crashes / MVMT$$

Step 9: Compare observed crash rate with critical crash rate

Segments can be ranked and prioritized by the amount the segment crash rate exceeds its critical rate. Mapping the safety priority locations may be desirable for visualization.

Segments identified for further analysis can then be analyzed in more detail by identifying specific crash types, causes, and locations within the segment. For example, for a climbing lane segment, each portion of the climbing lane can be examined—the uphill, crest, and downhill sides.

For Segment 5, the observed crash rate is 0.55, which exceeds Segment 5's critical crash rate of 0.41.

Step 10: Conclusions

From the analysis, Segment 5 exceeds the critical rate and is a "safety focus" location that needs to be reviewed in more detail. At a minimum, crashes and patterns need to be identified and potential countermeasures indicated. More in-depth HSM predictive analysis could be done for the existing conditions and any later future conditions, which could also include finding the most cost-effective countermeasures. A variation of this method could be to calculate fatal and injury-only crash rates. This could help to identify segments with potential crash severity issues.

4.3.5 Excess Proportion of Specific Crash Types

Recommended Uses	Transportation System Plans and Corridor Plans May be used for existing conditions assessment in development review or project development when predictive methods are unavailable
Data Required	Crash frequency by collision type, and pedestrian and bicyclist involvement Reference populations
More Information	HSM Part B, Chapter 4, Section 4.4.2.10.

STOP The example in HSM Section 4.4.2.9 has a number of errors and the APM spreadsheet should be followed instead.

The Excess Proportion of Specific Crash Types method quantifies the extent to which a specific crash type (the target crash type) is overrepresented at an analysis site, compared to the average representation within a reference population. Sites with significant overrepresentation are "safety focus" locations identified for further analysis. Since it does not require traffic volumes, it is well suited to large-scale regional analysis.

This analysis method can be used to assess any number of target crash types simultaneously. Analysis of collision type, pedestrian involvement, and bicyclist involvement are required. The analyst is encouraged to additionally include other crash characteristics that may be relevant to the project.

The Excess Proportion of Specific Crash Types analysis does not consider the overall frequency or rate of crashes, instead it considers only the types of crashes observed. It is useful for identifying locations that may benefit from targeted countermeasures. This method is best used in conjunction with Critical Crash Rate, as the two methods have complementary strengths and weaknesses.

This method does not allow for estimates of future safety performance and cannot be used for evaluating alternatives.

This method is generally unaffected by RTM. However, the analysis may be of limited usefulness for small study areas having low crash frequencies of the target crash type. For this method to be statistically valid, there needs to be at least five sites in each reference population. In addition, a minimum of two of those sites must have two or more observed crashes of the target crash type. It is preferred to have more than the minimum number of sites.

While the methodology will work with only two sites, caution should be exercised where there are fewer than 5 sites meeting the criteria. If this is an issue and the study area is a portion of an urban area, expanding the study area for this methodology to include the entire urban area should be considered. Also, expanding the number of years of crash records should be considered as long as no significant changes occurred within that timeframe that may have affected crash history.

A spreadsheet is available under safety analysis tools on the ODOT Transportation Development Planning Technical Tools webpage that automates much of the Excess Proportion of Specific Crash Types analysis. The analyst can provide input data in a summary table manually or can use automated extraction macros to analyze a PRC comprehensive crash summary report directly from ODOT. If the automated method is used, the results should be reviewed to ensure that all intersection-related crashes have been included, even those not identified as such in the records. The analyst must clean and format the results as described in the instructions tab before use.

Using the automated process still requires cleaning of the data as described in the instructions for the spreadsheet. The cleaning becomes more time consuming when using local roadways.

The general procedure for network screening using the Excess Proportion of Specific Crash Types method is as follows:

1. Identify analysis sites and assign observed crashes (see APM Section 4.2.3)
2. For each analysis site, determine the total crash frequency and the crash frequency for the target crash type
3. For each analysis site, calculate the proportion of total crashes for the target crash type. This is the number of target crashes divided by the number of total crashes (the observed proportion)
4. Establish reference populations and calculate the proportion of total crashes for the target crash type for each reference population (the threshold proportion)
5. Calculate the sample variance and “alpha” and “beta” parameters for the target crash type for each reference population
6. Using these results, at each site calculate the probability of the observed proportion exceeding the threshold proportion
7. Select the limiting probability for the analysis. Only sites with a probability over this limiting probability will be further evaluated. The recommended minimum value is 60%, but higher values can be used to limit the number of sites to a reasonable study size. The limiting probability can be interpreted as the likelihood that the expected long-term observed proportion actually exceeds the expected long-term threshold proportion.
8. For all sites that exceed the limiting probability, calculate the excess proportion of the target crash type by subtracting the threshold proportion from the observed proportion.

This process is repeated for each target crash type. If multiple sets of reference populations are being used (e.g., internal and external), the process is repeated for each set of reference populations.

Results can be used to help diagnose crash trends at each analysis site. For each target crash type, the greater the excess proportion, the greater the likelihood that the site will benefit from a countermeasure that addresses that crash type.

When reporting the results of this method, the following should be included:

- Crash frequency of each target crash type at each analysis site
- Reference population characteristics and summary statistics
- Limiting probability used
- Excess proportion of each target crash type at each analysis site

Example 4-6: HSM Excess Proportions at Intersections

As a part of a corridor safety project, a safety analysis needs to be completed for 25 intersections along Salem Highway (#072). The focus of this study is to increase safety by reducing angle crashes. The project is to reduce crashes at five intersections along the corridor. There are no ADT-capable counts along the corridor and the budget does not allow for taking any new counts. Crashes occurring along the corridor are examined, and those that are determined to be intersection crashes (see APM Section 4.2.3) are summarized by intersection and crash characteristics. The analyst also has the option of importing the length of the highway in question using the spreadsheet to summarize the data. Using the PRC data requires a cleaning process to take place after the data is pulled.

General & Site Information	
Analyst:	LJP
Agency/Company:	ODOT
Date:	1/7/16
Project Name:	APM Example 4-6
Highway Number and Name:	072 Salem Hwy
Mile Points:	All
Crash Years Pulled:	2008-2011

Calculate Probability

Intersection Crash Data						
			Type of Crash			
MP	Reference Pop	Street 1	Street 2	Angle	Rear	Total
1.54	4SG	Salem Parkway	Verda Ln NE	5	14	22
3.16	4SG	Broadway St NE	Salem Parkway	13	17	36
3.55	3ST	Hickory St NE	Liberty St NE	1	0	2
3.56	3ST	Commercial St NE	Hickory St NE	4	0	5
3.57	3SG	Commercial St NE	Pine St NE	3	3	8
3.62	3SG	Liberty St NE	Pine St NE	18	2	20
3.73	3ST	Grove St NE	Liberty St NE	2	1	5
4.24	3ST	Commercial St NE	Hood St NE	7	3	13
4.30	3ST	Commercial St NE	Gaines St NE	2	8	10
4.36	3SG	Commercial St NE	Market St NE	5	13	24
4.79	3SG	Commercial St NE	Union St NE	14	3	22
4.84	3ST	Front St Parkway NE	Union St NE	5	3	13
4.85	3SG	Commercial St NE	Marion St NE	3	8	42
5.39	3SG	Commercial St NE	Ferry St SE	20	7	33
5.43	3SG	Commercial St NE	Trade St SE	8	6	31
5.47	3SG	Ferry St SE	Liberty St SE	8	3	19
5.52	3SG	Liberty St SE	Trade St SE	10	3	18
5.65	3SG	Church St SE	Ferry St SE	5	8	18
5.69	3SG	Church St SE	Trade St SE	3	1	7
5.93	4SG	Pringle Creek Parkway	Winter St NE	3	6	13
6.20	4SG	Pringle Creek Parkway	12th St SE	4	10	18
6.77	3SG	Mission St SE	17th St SE	1	23	33
7.52	4SG	Mission St SE	25th St SE	2	50	60
7.92	4SG	Mission St SE	Turner Rd SE	3	36	51
8.26	3SG	Hawthorne Ave SE	Mission St SE	3	68	84

Step 1: Organize Sites into Reference Populations

Intersections are divided into reference populations by traffic control and number of intersection legs (see APM Section 4.3.3). Reference populations are identified by the analyst during the initial steps of the spreadsheet. Each intersection is then placed into a reference population. Use of the digital video log, aerial photos and other electronic sources is suggested for placing intersections into reference population.

The next 6 steps are all done within the spreadsheet. Once the sites have been organized, the spreadsheet can calculate the following steps.

Step 2: Calculate Observed Proportions

$$p_i = \frac{N_{observed,i}}{N_{observed,i(total)}}$$

Where: P_i= Observed proportion at site i

$N_{observed,i}$= number of observed target crashes at i

$N_{observed,i(total)}$= Total number of crashes at i

Step 3: Calculate a Threshold Proportion

$$p*_i = \frac{\sum N_{observed,i}}{\sum N_{observed,i(total)}}$$

Where: P_i= Threshold proportion

$\Sigma N_{observed,i}$= Sum of observed target crash frequency within the population

$\Sigma N_{observed,i(total)}$= Sum of total observed crash frequency within population

Step 4: Calculate Sample Variance[1]

$$Var(X/Y) = \frac{E^2(x)}{E^2(y)}\left[\frac{Var(X)}{E^2(X)} + \frac{Var(Y)}{E^2(Y)} - 2\frac{Cov(X,Y)}{E(X)E(Y)}\right]$$

Where:

$E(X) =$ Mean number of target crashes.

$E(Y) =$ Mean number of total crashes

$Cov(X,Y) =$ using the Excel Covariance function (COVARIANCE.S)

$Var(x) =$ using the Excel Variance function (VAR.S)

$Var(Y) =$ use the Excel Variance function (VAR.S)

If the number of sites with more than two type 'i' crashes is not greater than one, the variance is zero. There are also rare instances where the variance is calculated to be zero. If the variance is zero, the probability cannot be calculated because there is nothing to compare.

Step 5: Calculate the Alpha and Beta Parameters

$$\alpha = \frac{\overline{p*_i}^2 - \overline{p*_i}^3 - s^2\left(\overline{p*_i}^2\right)}{Var(N)}$$

$$\beta = \frac{\alpha}{\overline{p_i^*}} - \alpha$$

Where:

$n_{sites} =$ Total number of sites being analyzed

$p*_i =$ Threshold proportion

$p_i =$ Observed proportion

$Var(N) = s^2$

Step 6: Use the Excel Function to Calculate the Beta Distribution

$$p\left(\frac{p_i > p_i^*}{N_{observed,i}, N_{observed,i(total)}}\right) = 1 - betadist(p_i^*, \alpha + N_{observed,i}, \beta + N_{observed,i\ (total)} - N_{observed,i}$$

[1] This replaces Equation 4-20 in HSM 1st Edition 2010, which was found to have a number of errors.

$$Where:$$

$p^*_i =$ Threshold proportion

$p_i =$ Observed proportion

$N_{observed(total)} =$ Total number of crashes for site i

$N_{observed,i} =$ Observed target crashes for site i

The resulting number is the probability of a specific crash type being greater than the long-term expected proportion of that crash type at the specified intersection type.

Steps 7 and 8: Choose Limiting Probability and Calculate the Excess Proportion

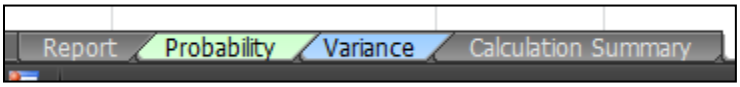
$$p_{diff} = p_i - p^*_i$$

$$Where:$$

$$p^*_i = Threshold \quad proportion$$

$$p_i = Observed \quad proportion$$

The spreadsheet first calculates the probability of each crash type exceeding a threshold proportion. . The calculated probability can be interpreted as the likelihood that the long-term expected proportion of a crash type at the intersection is greater than the threshold proportion. In order to calculate the excess proportion the analyst must use engineering judgement to set the limiting probability. According to the HSM "the selection of a limiting probability can vary depending on the probabilities of each specific crash type exceeding a threshold proportion. If many sites have a high probability the limiting probability can be set higher." The default limiting probability of the spreadsheet is 90% but is adjustable. The excess proportion that is calculated is simply the difference in the observed crash proportion and the threshold proportion for the reference population. The data output and a short explanation of the output for this example is shown here. The spreadsheet places the output onto the Probability tab. If the analyst chooses, they can use the "Create Report" button to create a printer friendly summary of the intersections with an excess proportion.



Steps 9: Interpreting Results

The Report Tab summarizes those intersections with a probability greater than the set limiting probability. It separates out each crash type and sorts each crash type by descending Excess Proportion. According to the HSM, the greater the excess proportion, "the greater the likelihood that the site will benefit from a countermeasure targeted at the collision type under consideration."

General & Site Informaiton

Analyst:	LJP	Highway Number and Name:	072, Old Salem Hwy
Agency/Company:	ODOT	Mile Points:	All
Date:	1/26/2016	Crash Years Pulled:	2008-2011
Project Name:	APM Example 4-6	Limiting Probability:	0.9

Notes

Angle Crashes

MP	RefPop	Street 1	Street 2	Probability	Excess Proportion
3.62	3SG	Liberty St NE	Pine St NE	1.00	0.62
4.79	3SG	Commercial St NE	Union St NE	1.00	0.36
5.39	3SG	Commercial St NE	Ferry St SE	1.00	0.32
5.52	3SG	Liberty St SE	Trade St SE	0.99	0.27
3.16	4SG	Broadway St NE	Salem Parkway	1.00	0.21
5.47	3SG	Ferry St SE	Liberty St SE	0.90	0.14

Rear Crashes

MP	RefPop	Street 1	Street 2	Probability	Excess Proportion
4.3	3ST	Commercial St NE	Gaines St NE	1.00	0.49
8.26	3SG	Hawthorne Ave SE	Mission St SE	1.00	0.40
6.77	3SG	Mission St SE	17th St SE	1.00	0.28
7.52	4SG	Mission St SE	25th St SE	1.00	0.17

MP	RefPop	Street 1	Street 2	Probabilit	Excess Proportion

Fix Crashes

MP	RefPop	Street1	Street2	Probability	Excess Proportion
6.2	4SG	Pringle Creek Park	12th St SE	0.97	0.08
5.43	3SG	Commercial St NE	Trade St SE	0.95	0.06
4.85	3SG	Commercial St NE	Marion St NE	0.92	0.04
3.16	4SG	Broadway St NE	Salem Parkway	0.93	0.02

Head Crashes

MP	RefPop	Street1	Street2	Probability	Excess Proportion
5.43	3SG	Commercial St NE	Trade St SE	1.00	0.04
4.85	3SG	Commercial St NE	Marion St NE	1.00	0.02

NonCol Crashes

MP	RefPop	Street1	Street2	Probability	Excess Proportion
5.43	3SG	Commercial St NE	Trade St SE	0.93	0.06
4.85	3SG	Commercial St NE	Marion St NE	0.95	0.06

SS-M Crashes

MP	RefPop	Street1	Street2	Probability	Excess Proportion
4.85	3SG	Commercial St NE	Marion St NE	1.00	0.07
5.47	3SG	Ferry St SE	Liberty St SE	1.00	0.06
5.43	3SG	Commercial St NE	Trade St SE	1.00	0.05
4.79	3SG	Commercial St NE	Union St NE	1.00	0.04
6.77	3SG	Mission St SE	17th St SE	1.00	0.04
4.36	3SG	Commercial St NE	Market St NE	1.00	0.03

Turn Crashes

MP	RefPop	Street1	Street2	Probability	Excess Proportion
3.57	3SG	Commercial St NE	Pine St NE	0.92	0.17
5.93	4SG	Pringle Creek Park	Winter St NE	0.94	0.11
4.85	3SG	Commercial St NE	Marion St NE	0.91	0.04

Page 1

Using the Liberty Street and Trade Street intersection, the 0.274 means that there are 27% more observed angle crashes than the calculated threshold for three-leg stop-controlled intersections in this population.

Angle Crashes

MP	RefPop	Street 1	Street 2	Probability	Excess Proportion
3.62	3SG	Liberty St NE	Pine St NE	1.000	0.619
4.79	3SG	Commercial St NE	Union St NE	1.000	0.355
5.39	3SG	Commercial St NE	Ferry St SE	1.000	0.325
5.52	3SG	Liberty St SE	Trade St SE	0.992	0.274
3.16	4SG	Broadway St NE	Salem Parkway	0.998	0.211
5.47	3SG	Ferry St SE	Liberty St SE	0.901	0.140

For this population of intersections, a total of 6 intersections have a greater than 90% chance of having a greater proportion of angle crashes than expected. Intersections with a probability greater than the limiting probability (default of 90%) and an excess proportion of at least 0.10 or a probability greater than the limiting probability and flagged by either the Critical Rate or the SPIS top 10% need to be further investigated.

In looking at the probability of 0.992, this means that there's a 99.2% chance that the long term expected proportion of angle crashes at Liberty St SE and Trade St SE will be greater than the long term expected proportion of angle crashes at 3-legged Signal-Controlled intersections when

compared to the rest of this population of intersections. Then the 0.274 in the excess proportion column implies the "the likelihood that the site will benefit from a countermeasure targeted at the collision type under consideration." (HSM 4-58) The greater the excess proportion the greater the likelihood.

Turn Crashes					
MP	RefPop	Street1	Street2	Probability	Excess Proportion
3.57	3SG	Commercial St NE	Pine St NE	0.92	0.17
5.93	4SG	Pringle Creek Park	Winter St NE	0.94	0.11
4.85	3SG	Commercial St NE	Marion St NE	0.91	0.04

The spreadsheet will automatically grey out intersections with an excess proportion of less than 0.10. Unless these intersections are flagged by either the Critical Rate calculation or the SPIS 10% they may dropped from further investigation. Use engineering judgement to determine if there are other factors at the greyed out intersections to determine if they need to be further investigated.

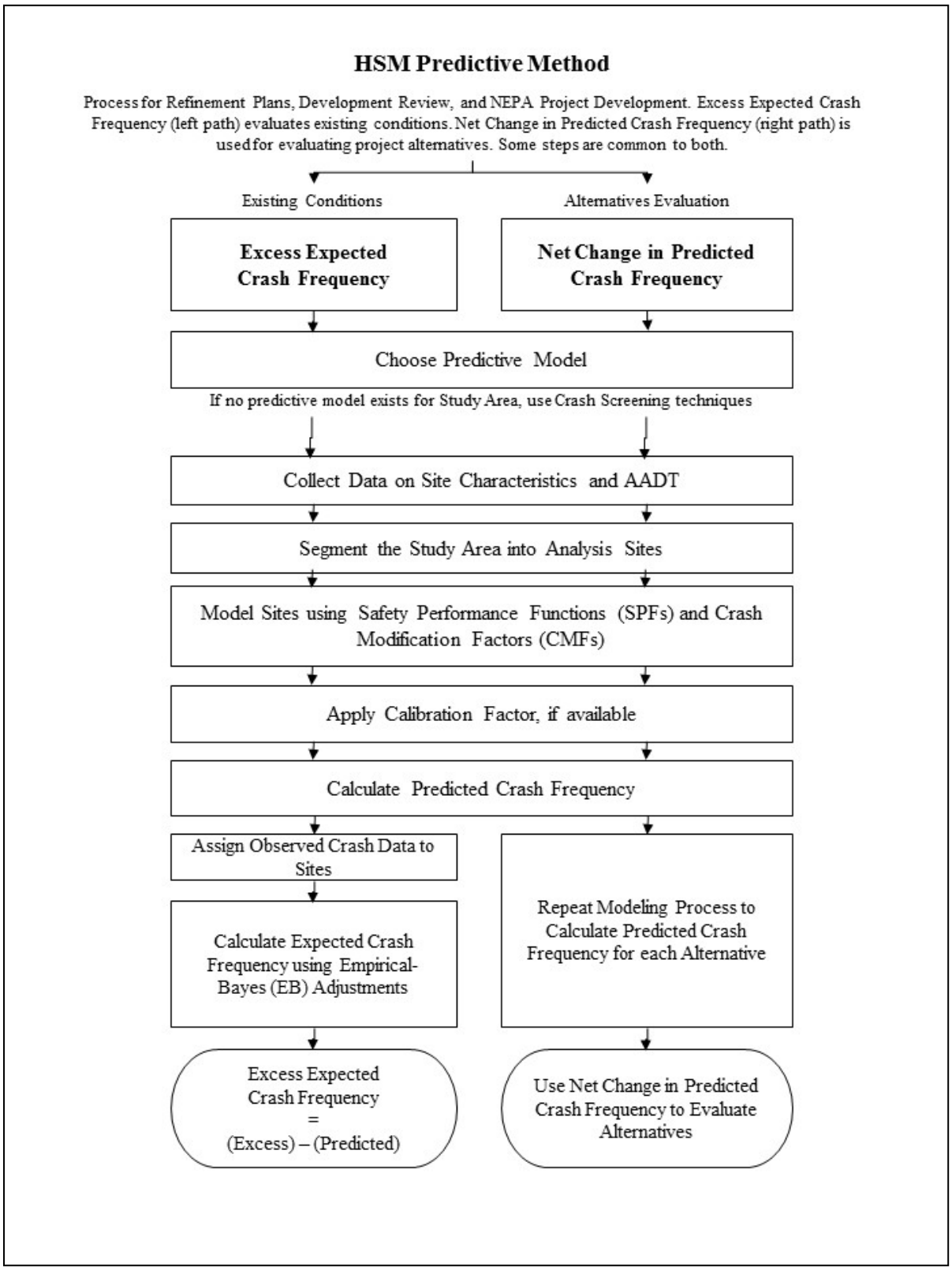
4.4 Predictive Methods

Predictive methods are used for detailed assessment of safety performance at the segment or intersection level. These methods are based on models developed for predicting crash frequency based on geometric and operational characteristics. The results are used to evaluate existing, future and alternative conditions. The HSM discusses predictive methods in more detail in Part C. Predictive methods are recommended for use with more detailed efforts such as Facility Plans, Development Review and Project Development.

Recommended Uses	Facility Plans, Development Review, and Project Development
Data Required	Crash frequency by severity, collision type, and pedestrian and bicyclist involvement [if using the Empirical Bayes (EB) Method] AADT traffic volumes for major and minor roads Pedestrian and bicyclist volumes or estimates Traffic control information Geometric design and roadway details Data requirements vary by predictive model and are discussed in APM Section 4.4.6. Complete HSM Part C data requirements can be found in HSM Part C, Sections 10.4, 11.4, and 12.4
More Information	HSM Part C, Chapters 10-12 ISATe User Manual PLANSAFE User Manual

The flow chart in Exhibit 4-7 gives an overview of the process for HSM Predictive Method.

Exhibit 4-7: HSM Predictive Method



The HSM has introduced a new way of evaluating safety performance of a roadway segment

and/or intersections using substantive safety. This new predictive method, detailed in Part C of the HSM, was created from extensive research and analysis rather than relying on design standards (also known as nominal safety). The overall method estimates crashes per year and severity, depending on specific local conditions.

Predictive methods do not require observed crash data to derive quantitative safety evaluations, and therefore can be used with future scenarios or design alternatives that do not yet exist. This allows for a rigorous quantitative safety analysis in circumstances where it was previously impossible, such as development review or National Environmental Policy Act (NEPA) project development. Predictive methods also allow for a fine-grained safety analysis of locations without need of a reference population, which is beneficial for detailed corridor studies where an established safety concern exists.

The HSM predictive equation is located in HSM Section C.4 but is generalized to:
Predicted Crashes =

Safety Performance Function x Crash Modification Factor(s) x Calibration Factor

The HSM makes a distinction between the crashes based only on characteristics (Predicted Crashes) versus characteristics plus local crash history (Expected Crashes). Predicted Crash Frequency is based on the geometric design, traffic control and traffic volumes of the local conditions. The Expected Crash Frequency is the combination of the predicted crash frequency with the historical crash frequency (using the Empirical-Bayes methods).

Expected Crashes =
(EB Weighting Factor x Predicted Crashes) + [(1- EB Weighting Factor) x Observed Crashes]

The generalized process for the predictive method is as follows:

1. Divide the study area into homogenous analysis sites, called “segmentation,” for intersections and roadway segments
2. Choose an appropriate predictive model for each site
3. Gather AADT or ADT traffic volumes, roadway characteristics, and traffic control features for each site
4. Characterize each site using SPFs and CMFs from Part C of the HSM
5. Apply calibration coefficients, if available
6. Calculate predicted crashes
7. If using Empirical Bayes (EB) method, assign crashes to sites and calculate expected crashes

This process is then repeated for each alternative to be evaluated. APM Section 0 describes the HSM Predictive Method process in more detail.

Because predictive methods have very specific methodology requirements and are under frequent revision, it is recommended that the analyst consult the appropriate source documentation (including published updates and errata) before beginning a predictive analysis.

The SPFs, CMFs, and calibration coefficients used for a predictive analysis are collectively referred to as the predictive model. Predictive models are specific to a particular type of roadway and require substantial research effort to produce. The HSM provides a methodology for jurisdictions interested in developing local predictive models.

4.4.1 Available Predictive Models and Current Limitations

Predictive models are available to analyze the following types of roadways:

- Rural two-way, two-lane roads (HSM Part C Chapter 10)
- Rural multilane highways (HSM Part C Chapter 11)
- Urban and suburban arterials (HSM Part C Chapter 12)
- Freeways, interchanges, and ramp terminals (ISATe / HSM Supplemental Chapters 18 and 19)

However, the predictive models mentioned above cannot be used in the following situations:

- Highways or arterials with six or more through lanes
- Rural freeways with eight or more through lanes
- Urban freeways with ten or more through lanes
- Interchange designs other than diagonal or partial clover (Parclo)
- Single-point urban, crossing/diverging diamond, or continuous flow interchanges
- Freeway ramp terminals on a one-way street, metered entrance, or roundabout
- All-way stop intersections
- Yield-control intersections
- Rural three-leg signalized intersections

ODOT is in the process of developing additional predictive models for:

- Access management (SPR 720)
- Roundabouts (SPR 733)
- Improved SPFs for signalized intersections (SPR 756)

When predictive models are not available or cannot be used for a location, the analyst should use the screening methods described in APM Section 4.3 and other techniques described in APM Section 4.8 to describe the existing conditions. The effect of potential countermeasures can be estimated using CMFs as described in APM Section 4.6.

If the predictive method can be applied to all but a small portion of the study area, it is acceptable to implement the predictive method where available. In this case, the narrative should explain the reasoning and expected impact of the omission and omitted locations should be clearly identified.

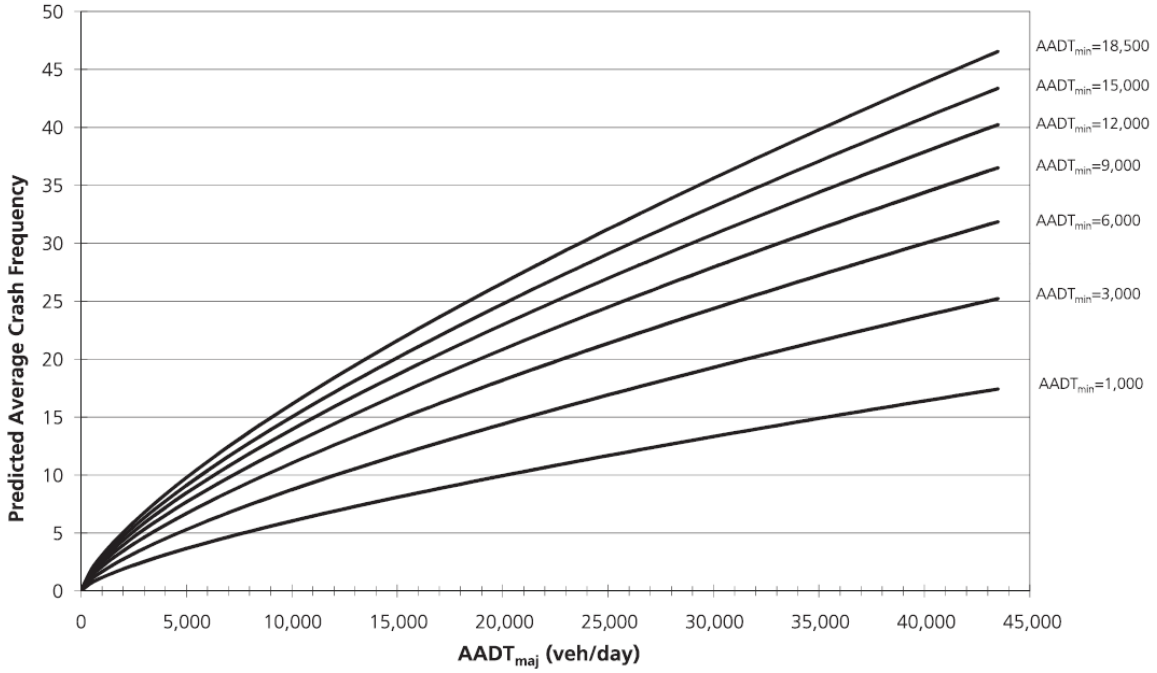
4.4.2 Safety Performance Functions (SPFs)

SPFs are developed using empirical research and regression models. SPFs predict crash frequency for a "base condition" roadway as a function of traffic volume. A unique SPF is developed for significant base condition variations, such as rural multilane highway segments or urban four-leg signalized intersections. CMFs adjust these predictions to account for differences from the SPF base conditions.

SPFs account for the fundamental non-linearity of crash frequency with respect to traffic volumes. An example of a non-linear SPF plot is shown in Exhibit 4-8. Crash rates alone do not capture the non-linearity of crash frequency with respect to traffic volumes. Analysts should be aware that crash rates may be reduced simply by an increase in traffic volumes alone. A reduction in crash rate at higher traffic volumes is often the expected roadway behavior, and does not indicate a fundamental change in underlying safety performance.

For example, consider the function in Exhibit 4-8 for a minor AADT of 1,000 vehicles/day (the bottom curve). At a major AADT of 8,000 vehicles/day, the predicted average crash frequency is approximately five crashes per year. This is a crash rate of 1.52 crashes per MEV. At a major AADT of 35,000 vehicles/day, the predicted average crash frequency is approximately 15 crashes per year. This is a crash rate of 1.14 crashes per MEV. Although the crash rate is lower in the second case, it is due to expected roadway behavior and not a change in underlying safety performance.

Exhibit 4-8: Rural Multilane SPF Four-leg Signalized Intersections (4SG)*



**Source: Fig 11-7 on p 11-23 in Ch. 11 of Volume 2, Part C, 1st Edition HSM*

4.4.3 Crash Modification Factors (CMFs)

CMFs describe the effect of specific treatments on the estimated crash frequency. In the HSM predictive method, CMFs adjust the "base condition" prediction of an SPF to account for additional characteristics of the local site. HSM predictive models require specific CMFs (from HSM Part C) that must be included in the model and developed in conjunction with the SPF. The required CMFs are further described in the HSM chapters for each predictive model and are included in the model spreadsheets or other computational tools.

In general, a CMF is multiplied with the crash frequency predicted by the SPF to account for any change in predicted crashes from the base condition. A CMF greater than 1.0 implies an increase in crashes, while a CMF less than 1.0 would have a decrease in crashes. A CMF equal to 1.0 means no change is expected.

For example a base model SPF may have four-foot shoulders but the actual site has eight-foot shoulders. In this example, one would expect a crash reduction because the roadway has a wider shoulder, so the CMF should be less than one. The actual value of the CMF will vary depending on facility type.

CMFs can also be used to estimate the effects of countermeasures or changes in conditions on observed crash frequency, independent from predictive models. CMFs for general use are included in the HSM Part D and CMF Clearinghouse, among other sources. These CMFs are based on independent research and are reviewed and approved by the HSM Task Force. There is a considerably wider selection of CMFs that can be used this way.

CMFs are an active area of research, and the best available CMF for a situation may change frequently. See APM Section 4.6 Countermeasure Selection and Evaluation for further information on selecting and applying CMFs to evaluate countermeasure effectiveness.

Part C CMFs were developed in conjunction with the model development and are unique to the HSM Predictive Method.

CMFs in Part C should only be used with Part C SPFs and the HSM Predictive Method.

The term crash reduction factor (CRF) was part of the early discussions of predictive crash methods (and is still frequently used in other literature) but was dropped in preference to the modification factors. CRFs relate to CMFs in the following way (see Section 4.6 for more information on CRFs):

CMF = 1- (CRF/100), so a CMF of 0.2 is a CRF of 80%.

4.4.4 Local Calibration Coefficients

Calibration coefficients are developed locally by comparing predictive results to locally observed results. These adjust the prediction to account for differences in geography, crash reporting, enforcement policy, and driver behavior between the general models provided in the HSM and the location of application. Oregon calibration coefficients are not yet available for all predictive models. In cases where a state- or region-specific SPF has been produced, calibration coefficients are not applied.

In Oregon, crash reporting is a driver responsibility with some enhancement for enforcement. This means that it is more likely to have a police report if there was a serious injury than for a crash involving property damage only. Oregon's required reporting threshold is typically higher than many other states (at $1,500) so many minor crashes are not reported and do not show up in the crash data. Because of these reporting requirements, Oregon conditions data should not be directly related to national averages or adjacent states (i.e., Washington), which have different reporting thresholds.

ODOT has created Oregon calibration factors for the HSM Part C models in the report, *Calibrating The Future Highway Safety Manual Predictive Methods For Oregon State Highways*. This report covers the Rural Two-Lane models, Rural Multilane models, and Urban/Suburban Arterial models for both segments and intersections. The ODOT Driveway Safety models do not require calibration, because they were developed using local Oregon data. PLANSAFE does not require calibration by the analyst, because the program self-calibrates using provided data. Enhanced Interchange Safety Analysis Tool (ISATe) is not currently calibrated for Oregon conditions and must be reported uncalibrated, as described below.

The locally-derived calibration factors listed in Exhibit 4-9 adjust total predicted crash frequencies to a value that is representative of Oregon conditions. Predicted crashes are multiplied by the calibration factor to determine the calibrated predicted crashes. For example, if an uncalibrated model estimated 10 predicted crashes per year and had a local calibration factor of 0.50, the locally-calibrated result would be five predicted crashes per year.

Exhibit 4-9: Locally-Derived Oregon HSM Calibration Factors

Facility Type		Calibration Factor
Segments		
Rural Two-Lane		
R2	2-lane undivided	0.74
Rural Multilane		
MRU	Undivided	0.37
MRD	Divided	0.77
Urban/Suburban Arterials		
U2U	2-lane undivided	0.62
U3T	3-lane with TWLTL	0.81
U4D	4-lane divided	1.41 / 0.64 *
U4U	4-lane undivided	0.63
U5T	5-lane with TWLTL	0.64
Intersections		
Rural Two-Lane		
R3ST	3-leg, minor stop	0.31
R4ST	4-leg, minor stop	0.31
R4SG	4-leg, signalized	0.45
Rural Multilane		
MR3ST	3-leg, minor stop	0.15
MR4ST	4-leg, minor stop	0.39
MR4SG	4-leg, signalized	0.15
Urban and Suburban Arterials		
U3ST	3-leg, minor stop	0.35
U4ST	4-leg, signalized	0.45
U3SG	3-leg, signalized	0.73
U4SG	4-leg, signalized	1.05

* Value of 1.41 based on small sample size and geometric designs no longer used. Value of 0.64 should be used for all future new designs.

Source: Calibrating The Future Highway Safety Manual Predictive Methods For Oregon State Highways

Additional locally derived severity and crash type distributions are included in the calibration report linked to the above table. The best way to ensure that all appropriate Oregon calibration factors are accounted for is to use or refer to the HSM Spreadsheets that are pre-filled with Oregon calibration factors. These spreadsheets include tables with all recommended locally derived calibration factors and distributions, and are described in APM Section 4.4.13 below.

Where an Oregon calibration factor does not exist, the results of the predictive analysis should only be used for relative comparisons such as net difference in predicted crashes or percent

change in predicted crashes. Uncalibrated predicted crashes should be identified as such and reported separately from calibrated predicted crashes or expected crashes.

4.4.5 Excess Expected Crash Frequency using Empirical Bayes (EB) Adjustments to Include Historical Crash Data

The HSM makes a distinction between the crashes based only on characteristics (predicted crashes) versus characteristics plus local crash history (expected crashes). Predicted crash frequency is based on the geometric design, traffic control and traffic volumes of the local conditions. The expected crash frequency is the combination of the predicted crash frequency with the historical crash frequency (using the EB Method). The benefit of the EB method is that it accounts for the RTM error, which is the natural fluctuation of crashes that occurs over the years independent of the contributing factors the analysis is trying to review. The EB method results in a more reliable estimate of crash frequency, while still accounting for unique site characteristics that influence safety but are not included in the predictive models.

The EB method requires a calibrated prediction model (with overdispersion factor) and substantial similarity between the analysis period for which crash data exists and the analysis period being used for the predictive method.

EB Method Can Be Used	EB Method Cannot Be Used
• Existing Conditions • Future conditions with traffic volume changes only • Future conditions with minor geometric changes (i.e., wider shoulders) or addition of turn or passing lanes.	• Uncalibrated predictive models, such as ISATe • Where no crash data from any time period is available • Future conditions with entirely new roadways where none existed before • Future conditions modifying existing roadways that include major alignment changes, the addition of through lanes, or a change in traffic control devices

The EB method can be performed at a site-specific level or a project level. Site-specific EB adjustments are done for each analysis site and require the analyst to associate each crash with a specific site. Project EB corrections are done using crash data aggregated over all analysis sites and do not require crashes to be associated with a specific site. The site-specific EB method is preferred and should be used in most situations, since crash data available through ODOT is geocoded and can be associated with specific analysis sites.

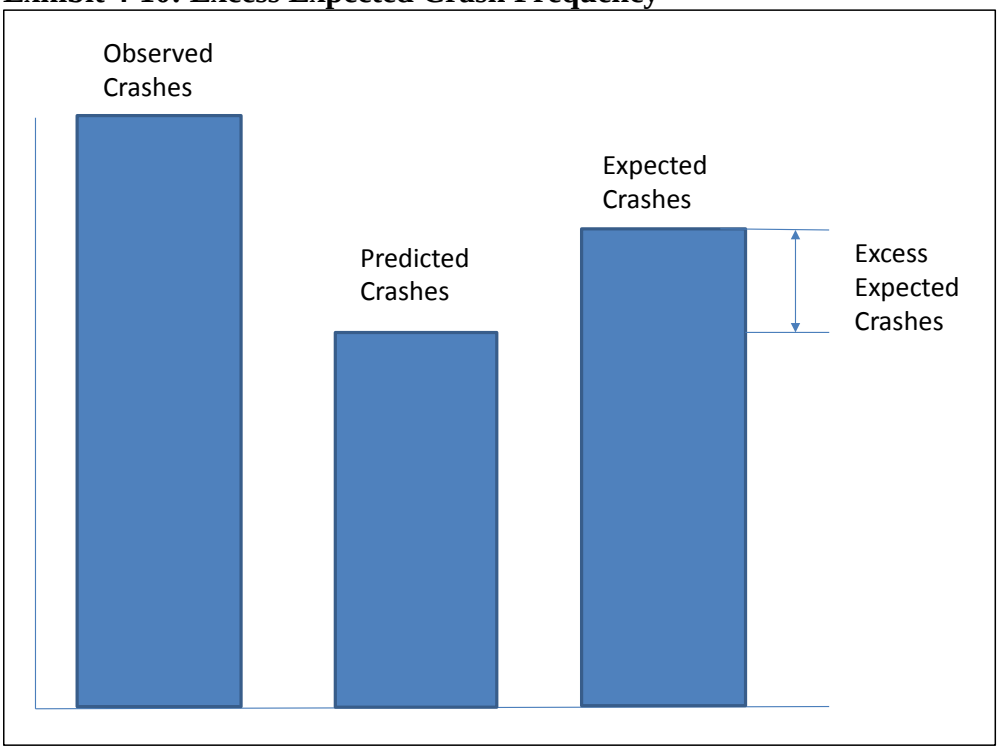
When the EB method is performed, the result is an expected crashes value. This value is reported using the “Excess Expected Average Crash Frequency,” defined as:

Excess Expected Average Crash Frequency = Expected Crashes – Predicted Crashes

An example of Excess Expected Average Crash Frequency is illustrated in Exhibit 4-10. In this example, Excess Expected Crash Frequency is a positive number, meaning the long term average crash frequency at this site is greater than for comparable sites. The site should be investigated further for potential safety countermeasures. In other cases, Excess Expected Crash Frequency may be a negative value, meaning the long term average crash frequency at the site is less than

for comparable sites.

Exhibit 4-10: Excess Expected Crash Frequency



APM Section 4.2.3 contains guidance for assigning observed crashes to an analysis site and determining if they are intersection-related or roadway segment-related.

Instructions and examples for using the EB method are provided in the HSM Part C, Appendix A, Section A.2.

4.4.6 Net Change in Expected or Predicted Crashes

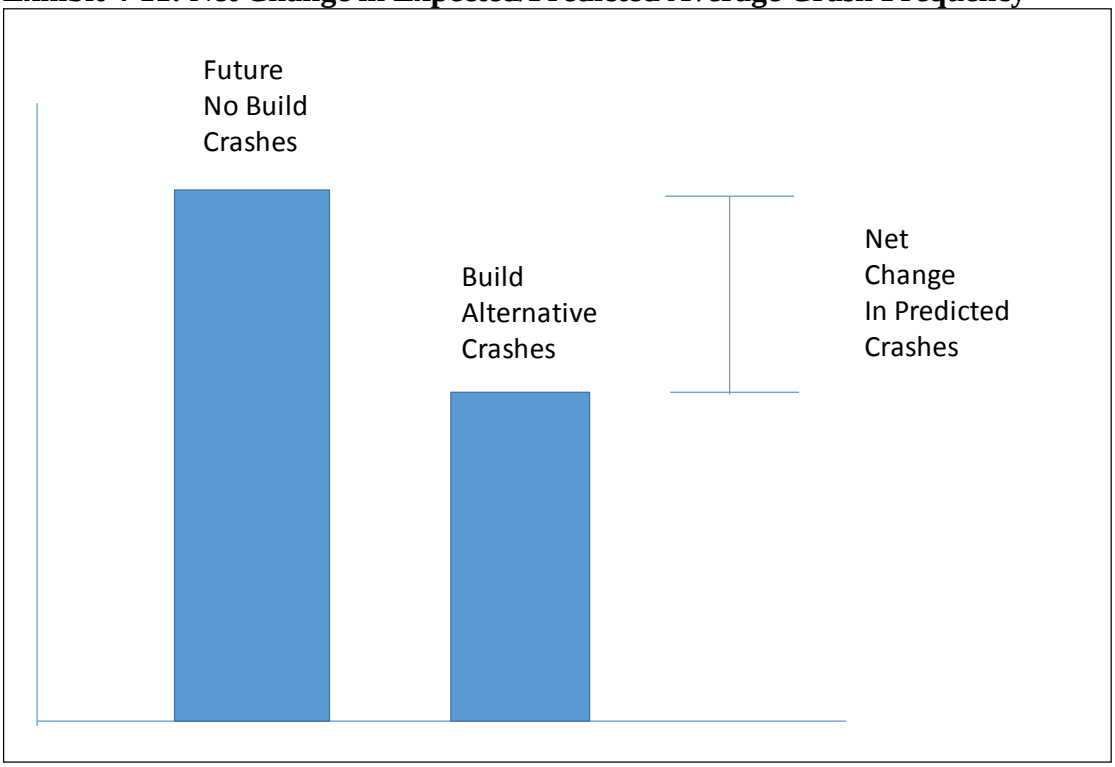
Alternatives should be compared using the net change in expected or predicted crashes, by severity, if possible. Expected crashes can be determined for alternatives if the only changes are in AADT (see APM Section 4.4.5 for more information). If expected crashes can be calculated for all alternatives under consideration, use net change in expected crashes. Otherwise, use net change in predicted crashes. Calculate expected or predicted crashes for each alternative, including the no-build alternative. Subtract the expected or predicted crash frequency of the no-build alternative from each build alternative to determine the net change in expected or predicted crashes for the build alternative. Any alternative with a negative net change in expected or predicted crashes indicates a modeled decrease in crashes. Alternatives with positive net change in expected or predicted crashes indicate a modeled increase in crashes.

> Net Change In Expected/Predicted Average Crash Frequency = Expected/Predicted No Build Crash Frequency - Expected/Predicted No Build Crash Frequency

An example of Net Change in Expected/Predicted Average Crash Frequency is illustrated in Exhibit 4-11. In this example, the Net Change in Predicted Crashes represents a reduction in

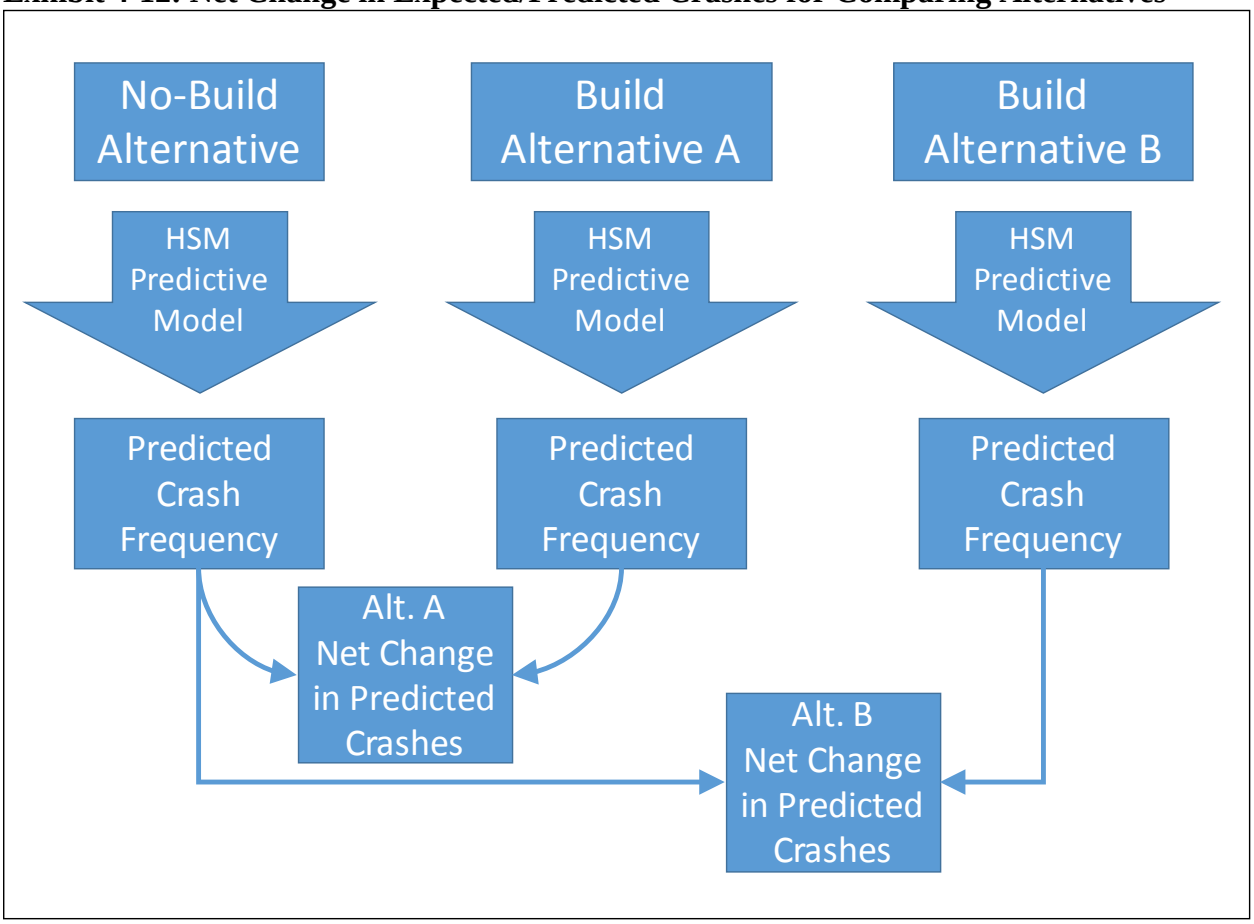
crash frequency, meaning that in comparison to the No Build, the Build Alternative will reduce the long term average crash frequency at this site by the amount of the Net Change.

Exhibit 4-11: Net Change in Expected/Predicted Average Crash Frequency



The Net Change in Crash Frequency can also be used to compare alternatives with each other, as shown in Exhibit 4-12.

Exhibit 4-12: Net Change in Expected/Predicted Crashes for Comparing Alternatives



4.4.7 Data Needs and Sources

HSM predictive methods require a substantial amount of roadway, geometric design, and traffic control data. Primary data are routinely collected during a project or are available in the ODOT TransGIS Database or the ODOT State Highway Inventory Reports. The ODOT Transportation Development Trans Data Portal provides a quick guide to many ODOT data sources. Other data will need to be collected through a desk survey using satellite imagery and street-level imagery (such as the ODOT Digital Video Log or Google StreetView) or through field visits. Some information may be infeasible to collect and can be estimated using the resources in this section.

Each HSM predictive model requires different data to estimate crashes, depending on the SPF base condition and available model CMFs. The analyst should consult the appropriate model methodology reference text before beginning an analysis to determine the data needed for each model and for the required data collection procedures.

- Rural two-lane roads (HSM Part C Chapter 10, Section 10.4)
- Rural multilane roads (HSM Part C Chapter 11, Section 11.4)
- Urban and suburban arterials (HSM Part C Chapter 12, Section 12.4)
- Freeways and interchanges (ISATe User Manual, Chapter 2, Page 19)

Based on sensitivity tests performed with the HSM models, accurate information on AADT volume data is the most important input. This includes minor street AADT for all models and pedestrian volumes for urban intersection models.

If minor street AADT is not available from the local jurisdiction, the analyst should provide a best estimate. If AADTs will be estimated, consult with TPAU to determine the appropriate methodology before beginning an analysis. In some situations, minor AADT may be inferred from nearby volumes or travel demand models may help provide an estimate. The major road AADT to minor road AADT ratio of similar intersections is another possible starting point for estimation. ITE trip generation rates may be appropriate for isolated minor roads.

If daily pedestrian volumes are not available, HSM Table 12-15 provides guidance on estimating daily pedestrian volumes based on general level of pedestrian activity.

Exhibit 4-13 is meant to give a general sense of the site characteristic data required for the HSM predictive method, but it is not intended to be exhaustive.

Exhibit 4-13: Data Needed for HSM Predictive Methods

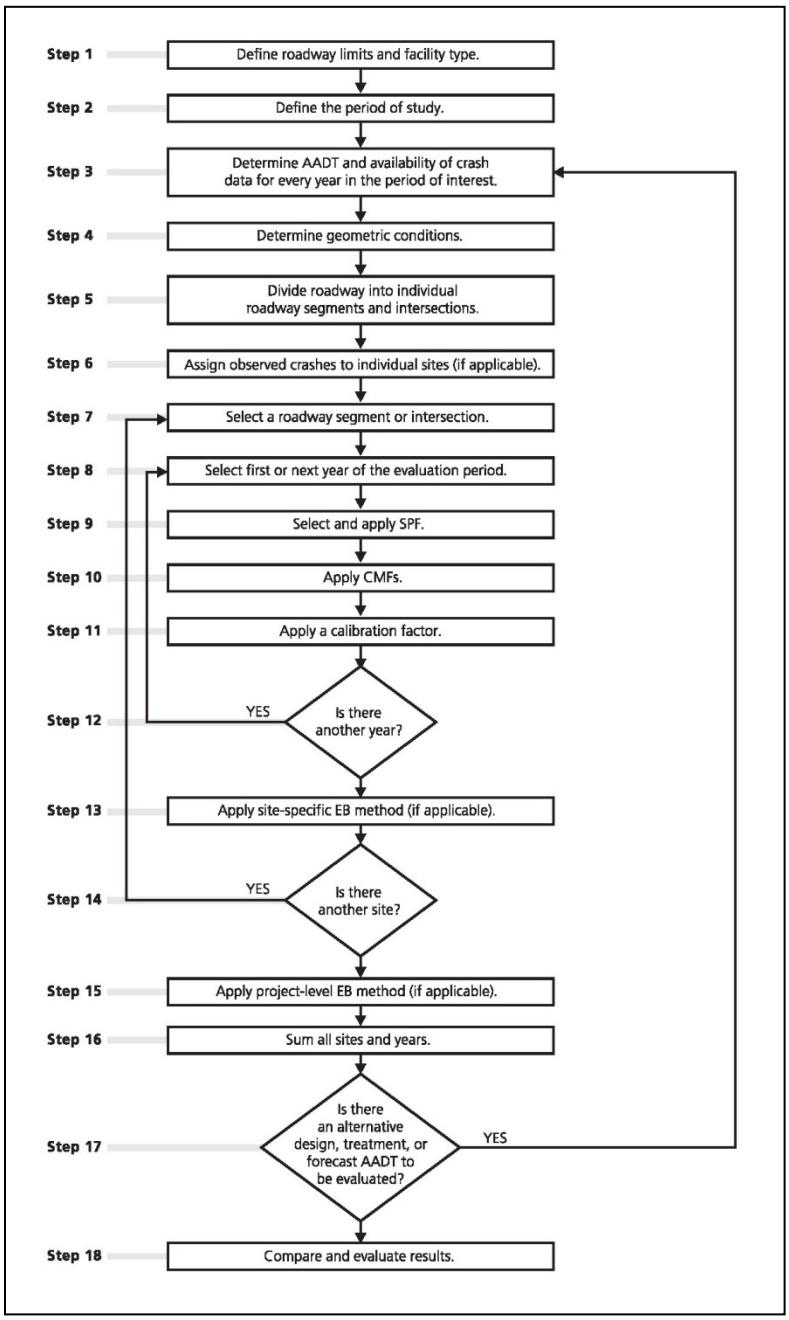
Information Needed	Data Source
Roadway Segments	
Length of Segment	TransGIS or Imagery
AADT	TransGIS or Inventory Report or Project
Lane Width	TransGIS or Inventory Report or Imagery
Shoulder Width and Type	TransGIS or Inventory Report or Imagery
Horizontal Curve Dimensions	TransGIS or Inventory Report or Imagery
Grade	Imagery or Inventory Report or Elevation Maps
Driveway Density and Type	TransGIS Imagery
Centerline and Edgeline Rumble Strips	Imagery
Passing Lanes	TransGIS or Inventory Report or Imagery
Two-Way Left-Turn Lanes	TransGIS or Inventory Report or Imagery
Roadside Hazard Rating	Imagery
Segment Lighting	Imagery
Automated Speed Enforcement	Imagery
Median Type and Median Width	Imagery or Inventory Report
Sideslope	Imagery
Type of On-street Parking	Imagery
Roadside Fixed Object Density and Offset	Imagery
Actual or Posted Speed	TransGIS or Imagery
Intersections	
Number of Intersection Legs	TransGIS or Imagery
Type of Traffic Control	Imagery
Intersection Skew Angle	TransGIS or Imagery
Approaches with Right-Turn Lanes	Imagery
Approaches with No Right-Turn on Red	Imagery
Approaches with Left-Turn Lanes	Imagery
Approaches with Left-Turn Signal Phasing	Imagery or Signal Timings
Intersection Lighting	Imagery
Most Traffic Lanes Crossed by Pedestrians	Imagery
Number of Bus Stops within 1,000 feet	TransGIS or Imagery
Presence of Schools within 1,000 feet	Imagery or Other Point-of-Interest Reference
Number of Alcohol Sales Locations within 1,000 feet	Imagery or Other Point-of-Interest Reference
Presence of Red Light Camera	Site Visit

4.4.8 Predictive Method Process

The HSM Predictive Method process consists of 18 steps that result in an estimation of crash frequency for a project area. Each analysis site is considered individually for each year of analysis. These individual results are summed to determine the study area total. This process is repeated for each alternative to be evaluated. Exhibit 4-14 illustrates this process graphically. HSM Section C.5 describes these steps:

- **Step 1:** Define the limits of the roadway and facility types in the study network, facility, or site for which the expected average crash frequency, severity, and collision types are to be estimated
- **Step 2:** Define the time period of interest
- **Step 3:** For the study period, determine availability of AADT and (if using the EB Method) observed crash data
- **Step 4:** Determine geometric design features, traffic control features, and site characteristics for all sites in the study network
- **Step 5:** Divide the roadway network or facility under consideration into individual roadway segments and intersections, which are referred to as sites
- **Step 6:** Assign observed crashes to the individual sites (if using the EB Method)
- **Step 7:** Select the first or next individual site in the study network. If there are no more sites to be evaluated, go to Step 15.
- **Step 8:** For the selected site, select the first or next year in the period of interest. If there are no more years to be evaluated for that site, proceed to Step 15.
- **Step 9:** For the selected site, determine and apply the appropriate SPFs for the site's facility type and traffic control features
- **Step 10:** Multiply the result obtained in Step 9 by the appropriate CMFs to adjust the predicted average crash frequency to site-specific geometric design and traffic control features
- **Step 11:** Multiply the result obtained in Step 10 by the appropriate calibration factor
- **Step 12:** If there is another year to be evaluated in the study period for the selected site, return to Step 8. Otherwise, proceed to Step 13.
- **Step 13:** Apply site-specific EB Method (if using the EB Method)
- **Step 14:** If there is another site to be evaluated, return to Step 7, otherwise, proceed to Step 15
- **Step 15:** Apply the project level EB Method (if the site-specific EB Method is not applicable)
- **Step 16:** Sum all sites and years in the study to estimate total crashes or average crash frequency for the network
- **Step 17:** Determine if there is an alternative design, treatment, or forecast AADT to be evaluated. Steps 3 through 16 of the predictive method are repeated for each alternative.
- **Step 18:** Evaluate and compare results

Exhibit 4-14: HSM Predictive Method Process



Source: HSM Section C.5, Figure C-2

4.4.9 Study Area Segmentation

Segmentation, step 5 in the predictive method, is the process of dividing the study area into smaller analysis sites that are each relatively uniform in character. Sites should be comprehensive, collectively covering all of the study area. When a segment ends or begins at an intersection, the segment lengths are measured from the center of the intersection.

Each intersection with a public road should be an individual site, even if it is a minor local road. Roadway segments, such as highways, streets, freeways, and ramps, should be divided into individual sites at a minimum at every intersection. Segments between intersections may need to be split into multiple sites, so that each site is uniform in character for the predictive model. Segments do not need to be split at driveways. Limiting the minimum segment length to 0.10 miles is appropriate to keep the analysis manageable.

Segments should always be split into distinct sites where any of the following change:

- Number of through lanes
- AADT
- Land use (rural/urban)
- Presence or type of median
- Posted speed limit

Continuous values such as lane width, shoulder width, or grade are generally rounded to some extent for the purposes of segmenting. The unrounded values are then averaged (weighting by length) for the predictive analysis. Some characteristics, such as the presence of curves and rumble strips, may not require the creation of a new site in some models and can instead be expressed as a percent of the site with that characteristic.

Segmenting requirements vary by predictive model, and the analyst is referred to the appropriate predictive model methodology reference text for further details before starting an analysis.

- Rural two-lane roads (HSM Part C Chapter 10, Section 10.5)
- Rural multilane roads (HSM Part C Chapter 11, Section 11.5)
- Urban and suburban arterials (HSM Part C Chapter 12, Section 12.5)
- Freeways and interchanges (ISATe User Manual, Chapter 2, Page 34)

4.4.10 Multiple-Year Analysis

The predictive method requires each year of the analysis period to be modeled individually. For future alternatives, a single year of analysis is adequate. For historical analysis, three to five years of crash data and matching site characteristics should be used. Often, most site characteristics do not change over the analysis period aside from the AADT.

When AADT is not available for every year in the analysis period, the following rules can be used for estimating AADT:

- For years between two known AADT values, use a linear interpolation
- For years after the latest known AADT value, use the latest known AADT value
- For years before the first known AADT value, use the first known AADT value

Example 4-7: HSM Predictive Analysis

Predictive Method for Urban and Suburban Arterial Intersections

The predictive method for urban and suburban arterials is described in the 1st edition HSM, Volume 2, Chapter 12, Section 12.4. The HSM lists an 18-step process for the urban/suburban arterial predictive method.

Note: The predictive method example is based on Adams St. and 128th St., which is a four-leg signalized intersection. The example is done only for the year 2010. A full analysis would analyze each year in the study period, from 2006-2010.

Step 1: Determine the limits of the roadway and facility types that will be included in the study network, facility, or site
Step 2: Define the time period of interest
Step 3: Determine AADT and availability of crash data for each year in the period of interest
Step 4: Determine geometric design features, traffic control features, and site characteristics for all sites in the study network

Data for the case study of the Adams St. and 128th St. intersection are shown in the following table for use in this example problem. The figure below shows these data in the HSM spreadsheet tool.

Data Requirement	Intersection of Adams St. and 128th St.
AADT (vehicles/day)	AADTs were found through the local agency's traffic counts information page. Major street AADT is 23,150 vpd, and minor street AADT is 12,300 vpd.
Pedestrian volumes	The pedestrian volume was estimated as 50 pedestrians per day. Table 12-15 of the 1st edition HSM, Volume 2, Chapter 12 gives estimates of pedestrian crossing volumes based on the general level of pedestrian activity.
Number of intersection legs	The intersection has four legs.
Type of traffic control	The intersection is signalized.
Number of approaches with a left-turn lane	All four of the approaches to the intersection have left-turn lanes.
Number of approaches with left-turn signal phasing and type of left-turn signal phasing for each movement	All four of the left-turn lanes have protected/permissive phasing.
Number of approaches with a right-turn lane	None of the approaches to the intersection have right-turn lanes.
Number of approaches with right-turn-on-red operation prohibited	None of the approaches have prohibited right-turn-on-red movements.
Presence/absence of intersection lighting	There is intersection lighting.
Presence/absence of Red Light Cameras	No red light cameras.
Maximum number of traffic lanes to be crossed by a pedestrian in any crossing maneuver at the intersection considering the presence of refuge islands	The maximum number of lanes to be crossed by a pedestrian is five lanes.
Number of bus stops within 1,000 feet of the intersection	There are four bus stops located within 1,000 feet of the intersection.
Presence of schools within 1,000 feet of the intersection	There are no schools located within 1,000 feet of the intersection.
Number of alcohol sales establishments that sell alcohol within 1,000 feet if the intersection	There are four different establishments that sell alcohol within 1,000 feet of the intersection.

HSM Spreadsheet Data Input

Worksheet 2A -- General Information and Input Data for Urban and Suburban Arterial Intersections			
General Information		**Location Information**	
Analyst	TPAU	Roadway	Adams Street
Agency or Company	ODOT	Intersection	128th Street
Date Performed	01/01/11	Jurisdiction	
		Analysis Year	2010
Input Data		**Base Conditions**	**Site Conditions**
Intersection type (3ST, 3SG, 4ST, 4SG)		--	4SG
AADT $_{major}$ (veh/day)	$AADT_{MAX}$ = 67,700 (veh/day)	--	23,150
AADT $_{minor}$ (veh/day)	$AADT_{MAX}$ = 33,400 (veh/day)	--	12,300
Intersection lighting (present/not present)		Not Present	Present
Calibration factor, C_i		1.00	1.05
Data for unsignalized intersections only:		--	
Number of major-road approaches with left-turn lanes (0,1,2)		0	
Number of major-road approaches with right-turn lanes (0,1,2)		0	
Data for signalized intersections only:		--	
Number of approaches with left-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	4
Number of approaches with right-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	0
Number of approaches with left-turn signal phasing [for 3SG, use maximum value of 3]		--	4
Type of left-turn signal phasing for Leg #1		Permissive	Protected / Permissive
Type of left-turn signal phasing for Leg #2		--	Protected / Permissive
Type of left-turn signal phasing for Leg #3		--	Protected / Permissive
Type of left-turn signal phasing for Leg #4 (if applicable)		--	Protected / Permissive
Number of approaches with right-turn-on-red prohibited [for 3SG, use maximum value of 3]		0	0
Intersection red light cameras (present/not present)		Not Present	Not Present
Sum of all pedestrian crossing volumes (PedVol) -- Signalized intersections only			50
Maximum number of lanes crossed by a pedestrian (n_{lanesx})		--	5
Number of bus stops within 300 m (1,000 ft) of the intersection		0	4
Schools within 300 m (1,000 ft) of the intersection (present/not present)		Not Present	Not Present
Number of alcohol sales establishments within 300 m (1,000 ft) of the intersection		0	4

Step 5: Divide roadway into individual roadway segments and intersections

- Since there is only one site to be analyzed, this step is unnecessary.

Step 6: Assign observed crashes to individual sites

- It is useful to summarize the observed crashes to match with the crash prediction categories used by the predictive model. The Urban/Suburban Intersection model predicts multiple vehicle crashes and single vehicle crashes separately using different SPFs. It also provides predicted crash breakdowns by severity, fatal and injury (FI) or property damage only (PDO). Vehicle-bicycle crashes and vehicle-pedestrian crashes are independently identified.
- A total of nine observed crashes in 2010 were assigned to this site:
  - 4 FI crashes
  - 5 PDO crashes
  - 8 multiple-vehicle crashes
  - 1 single-vehicle crash
  - 1 vehicle-bicycle crash (also considered a single-vehicle crash)

Step 7: Select a roadway segment or intersection

- The intersection of Adams St. and 128th St. has been selected for further study.

Step 8: Select first or next year of the evaluation period

- Year 2010 is being considered in this example.

Step 9: Select and apply SPF

- SPFs relevant to Urban and Suburban Arterial Intersections are found in Section 12.6.2 of the 1st edition, HSM, Volume 2.
- Multiple-vehicle collisions: 6.884 total, 2.284 FI, 4.601 PDO
- Single-vehicle collisions: 0.435 total, 0.113 FI, 0.322 PDO
- Vehicle-bicycle collisions (predicted as a fixed portion of all vehicle collisions): 0.070 total, 0.070 FI, 0 PDO
- Vehicle-pedestrian collisions: 0.029 total, 0.029 FI, 0 PDO

Step 10: Apply CMFs

- Intersection left-turn lanes: CMF_{1i} (Table 12-24 in the 1st edition, HSM, Volume 2, Chapter 12)
  - For the intersection of Adams St. and 128th St., CMF_{1i} = 0.66
- Intersection left-turn signal phasing: CMF_{2i} (Table 12-25 in the 1st edition, HSM, Volume 2, Chapter 12)
  - For the intersection of Adams St. and 128th St., CMF_{2i} = 0.96
- Intersection right-turn lanes: CMF_{3i} (Table 12-26 in the 1st edition, HSM, Volume 2, Chapter 12)
  - For the intersection of Adams St. and 128th St., CMF_{3i} = 1.00
- Right-turn-on-red: CMF_{4i}
  - $CMF_{4i} = 0.98^{n_{prohib}}$

    Where:

    CMF_{4i} = crash modification factor for the effect of prohibiting right turns on red on total crashes

    n_{prohib} = number of signalized intersection approaches for which right-turn-on-red is prohibited
  - For the intersection of Adams St. and 128th St., CMF_{4i} =1.00
- Lighting: CMF_{5i}
  - $CMF_{5i} = 1 - 0.38 \times p_{ni}$

    Where:

    CMF_{5i} = crash modification factor for the effect of intersection lighting on total crashes

p_{ni} = proportion of total crashes for unlighted intersections that occur at night Default values for p_{ni} can be found in Table 12-27 in the 1st edition HSM, Volume 2, Chapter 12. It is recommended to replace the default values with locally derived values.

- For the intersection of Adams St. and 128th St., CMF_{5i} =0.95 using a locally-derived value (p_{ni} =0.154)

- Red-light cameras: CMF_{6i}
  - CMF_{6i} is based on the presence of red-light cameras. The base condition is their absence. There are no red-light cameras at the intersection of Adams St. and 128th St., so for the example CMF_{6i} =1.00. The formula for CMF_{6i} is (12-37) found in the 1st edition HSM, Volume 2, Chapter 12.

CMF_{1i}	CMF_{2i}	CMF_{3i}	CMF_{4i}	CMF_{5i}	CMF_{6i}	CMF_i
0.66	0.96	1.00	1.00	0.95	1.00	0.60

The CMFs above apply to vehicle crashes and have a combined value of 0.60.
The CMFs below apply only to vehicle-pedestrian crashes and have a combined value of 4.65.

- Bus stops: CMF_{1p} (Table 12-28 in the 1st edition, HSM, Volume 2, Chapter 12)
  - There are more than three (two bus stops at 128th and Adams St., one a block north on 128th and one half a block west on Adams St.) bus stops within 1,000 feet of Adams St. and 128th St., so CMF_{1p} =4.15.

- Schools: CMF_{2p} (Table 12-29 in the 1st edition, HSM, Volume 2, Chapter 12)
  - There are no schools within 1,000 feet of Adams St. and 128th St., so CMF_{2p} =1.00.

- Alcohol sales establishments: CMF_{3p} (Table 12-30 in the 1st edition, HSM, Volume 2, Chapter 12)
  - There are four (two stores, one restaurant, and one gas station) alcohol sales establishments within 1,000 feet of Adams St. and 128th St., so CMF_{3p} =1.12.

CMF_{1p}	CMF_{2p}	CMF_{3p}	CMF_p
4.15	1.00	1.12	4.65

Step 11: Apply a calibration factor

- The recommended Oregon Highway Safety Manual Calibration factor for urban and suburban four-way signalized intersections is 1.05.
- The resulting predicted crash values are:
    - 4.4 predicted multiple-vehicle crashes
    - 0.3 predicted single-vehicle crashes
    - 0.14 predicted pedestrian crashes
    - 0.07 predicted bicycle crashes

Step 12: Is there another year? If yes, return to step 8. (Only one year is included in this example.)

Step 13: Apply site-specific EB Method (This step is not included in this example.)

- Observed crashes are matched with the output of each SPF, and the EB Method is performed using the overdispersion parameter of the SPF.
- The following graphic shows the results of the site-specific EB Method calculation for vehicle crashes using the HSM Spreadsheets.

HSM Spreadsheet Results with Site-Specific EB Method

Worksheet 3A -- Predicted Crashes by Severity and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes, $N_{observed}$ (crashes/year)**	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency,**
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix
INTERSECTIONS							
Multiple-vehicle							
Intersection 1	4.367	1.450	2.918	8	0.390	0.370	6.656
Single-vehicle							
Intersection 1	0.276	0.071	0.204	1	0.360	0.910	0.341
COMBINED (sum of column)	4.643	1.521	3.122	9	--	--	6.997

Worksheet 3B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1)	(2)	(3)
Site Type	N_{ped}	N_{bike}
INTERSECTIONS		
Intersection 1	0.141	0.073
COMBINED (sum of column)	0.141	0.073

Worksheet 3C -- Site-Specific EB Method Summary Results for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	$N_{predicted}$	N_{ped}	N_{bike}	$N_{expected\ (VEHICLE)}$	$N_{expected}$
Total	$(2)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(8)_{COMB}$ Worksheet 3A	(3)+(4)+(5)
	4.6	0.1	0.1	7.0	7.2
Fatal and injury (FI)	$(3)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(5)_{TOTAL} * (2)_{FI} / (2)_{TOTAL}$	(3)+(4)+(5)
	1.5	0.1	0.1	2.3	2.5
Property damage only (PDO)	$(4)_{COMB}$ from Worksheet 3A	--	--	$(5)_{TOTAL} * (2)_{PDO} / (2)_{TOTAL}$	(3)+(4)+(5)
	3.1	0.0	0.0	4.7	4.7

Step 14: Is there another site? If yes, return to step 7. (This step is not included in this example.)

Step 15: Apply project-level EB Method (This step is not included in this example.)

Step 16: Sum all sites and years

- Results from all sites and all years would be summed together for the study area total.
- For this intersection, the calibrated predictive method results for 2010 are:
    - 7.2 expected crashes
    - 2.5 expected fatal and injury crashes
    - 4.7 expected property damage only crashes
    - 0.14 predicted pedestrian crashes (assumed fatal or injury)
    - 0.07 predicted bicycle crashes (assumed fatal or injury)
- Results should ultimately be reported as excess expected, which is the expected crash value minus the predicted crash value.
    - 2.6 excess expected crashes
    - 1.0 excess expected fatal and injury crash
    - 1.6 excess expected property damage only crashes

Step 17: Repeat for alternative designs, treatments, or forecast AADT to be evaluated

- The predictive method is repeated for each alternative to be evaluated; however, no alternatives are included in this example.
- Countermeasures that are included in the predictive model can be evaluated by changing the CMFs used in the predictive method. This includes the addition of dedicated turn lanes, left-turn signal phasing, lighting, etc. This can be quickly achieved by duplicating and modifying the HSM spreadsheet used for the original analysis.
- Countermeasures that are not included in the predictive model can be evaluated by using CMFs from other sources. No more than three CMFs should be evaluated simultaneously in this fashion.
- See APM Section 4.6 for further information on countermeasures.
- See APM Section 4.4.5 to determine if the EB Method can be applied to alternative designs, treatments, or forecast AADT.

Step 18: Evaluate and compare results

- The evaluation and reporting of predictive method results is discussed below, in APM Section 0.

Note: Although the steps seem quite lengthy, the calculations can be expedited through the use of spreadsheets or other tools, discussed below in APM Section 4.4.13.

4.4.11 Reporting Predictive Method Results

When reporting predictive results, include the predictive models used along with a table of sites and characteristics. Depending on the availability of calibration factors and the use of the EB Method, the predictive method will result in one of these types of estimates for each site:

- Uncalibrated predicted crash frequency

- Calibrated predicted crash frequency
- Expected crash frequency
- Excess expected crash frequency

Depending on the predictive model used, these results may be reported by crash severity and/or collision type. Within a study area, this may result in a mix of these estimate types. When summing the predictive results for a project area total, each estimate type (uncalibrated predicted, calibrated predicted, expected, and excess expected) should be summed individually by severity and identified in the reporting. Any sites that are analyzed uncalibrated should be denoted.

Existing conditions evaluations should be reported using excess expected crash frequency, by severity, if possible. A positive excess expected crash frequency indicates that the site is performing more poorly than the HSM models suggest is normal for that site. Higher values of excess expected crash frequency indicate more potential for improvement.

Alternatives should be compared using the net change in expected or predicted crashes, by severity, if possible. Expected crashes can be determined for alternatives in limited situations (see APM Section 4.4.5 for more information).

Predicted or expected crashes should be reported over the study period as the total number of crashes in the study period, rounded to the nearest integer (for example, 15 crashes over five years). Alternatively a long-term yearly average frequency could be reported, for example 3.4 crashes per year.

4.4.12 Project-Induced Volume Changes

A project build alternative will often create new capacity and relieve congestion in the study area. As a result, the new roadway can attract previously latent demand. The project build alternative will thus have higher forecast traffic volumes than the no-build alternative. For large projects with regional impact, the difference in forecast volumes can be substantial.

It may be valuable to report and discuss the safety impacts of a project's design, independent of the effects of increased vehicle exposure. If there are significant (more than 10%) volume changes due to project build alternatives, the analyst has the option of reporting predictive results using both the actual build volumes and the future no-build volumes on the build alternative. The use of future no-build volumes must be clearly identified as such, and the report should acknowledge that the results are not the actual forecast estimates and are for discussion purposes only.

4.4.13 Tools for Implementing Predictive Methods

Computational tools are available to help in implementing the HSM Predictive Method. These tools are recommended to ensure uniform and transparent application of analysis techniques.

HSM Spreadsheets
The HSM spreadsheets were developed as part of National Cooperative Highway Research

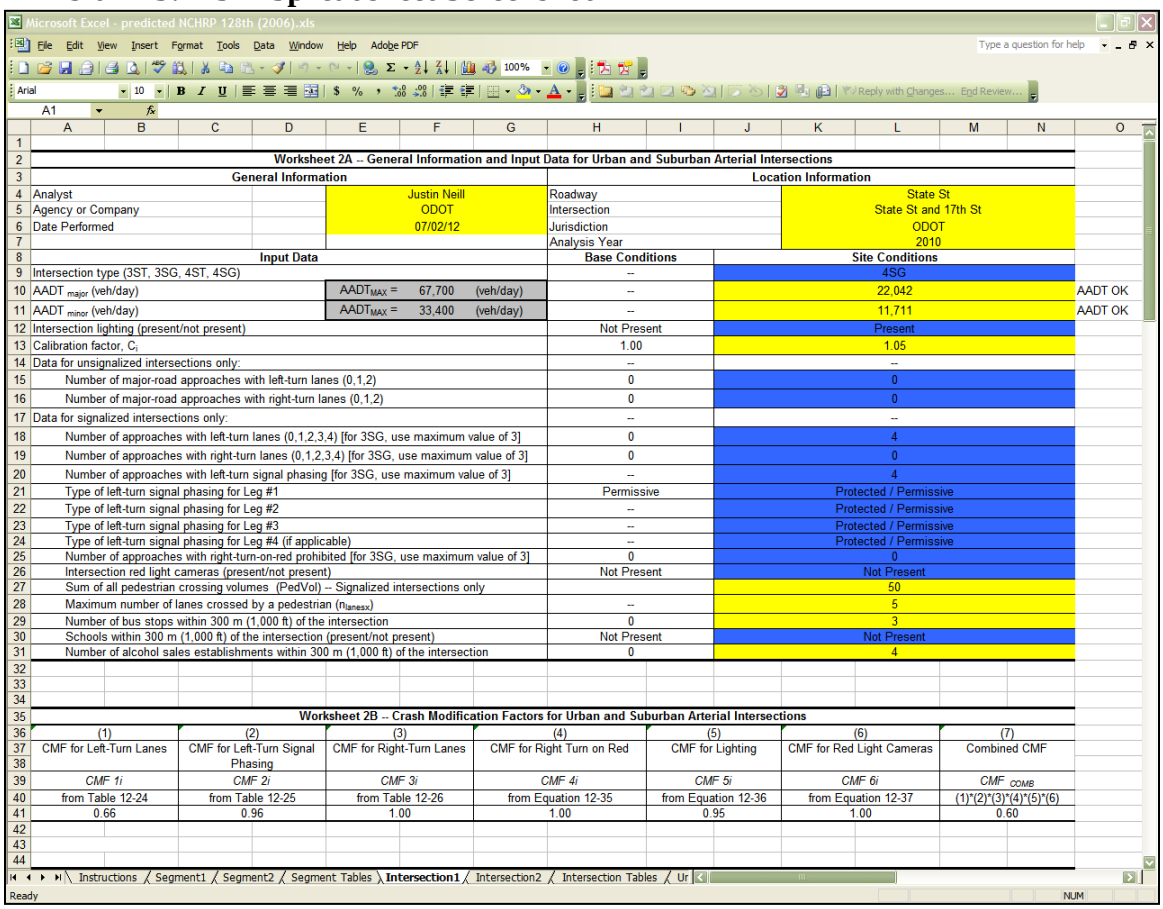
Program (NCHRP) Project 17-38, Highway Safety Manual Implementation and Training Materials, to aid in training the HSM Part C predictive method (see Exhibit 4-15). These spreadsheets are designed for only two segments and two intersections for one year, but can be modified to include additional segment and intersection capacity. However, adding worksheets to increase the number of segments and intersections in an analysis can be moderately time consuming.

The spreadsheet displays results by segments and intersections and also separates the results into crashes by single-vehicle, multiple-vehicle non-driveway, and multiple-vehicle driveway-related. The worksheets are free to download, but do not have any technical support, at this time, for any changes or updates to the HSM. Data needs are consistent with the normal HSM Part C requirements.

The basic NCHRP spreadsheets allow the user to apply the EB Method for the current analysis period, but post-processing is required to apply the EB Method to alternatives where no observed crash data are available. See the discussion in APM Section 4.4.5 for more information on applying the EB Method.

The spreadsheets containing Oregon-specific calibration factors and crash proportions can be downloaded from the ODOT HSM Webpage. The general, non-calibrated, spreadsheets can be downloaded from the HSM Website.

Exhibit 4-15: HSM Spreadsheet Screenshot



Microsoft Excel - predicted NCHRP 128th (2006).xls

Worksheet 2A -- General Information and Input Data for Urban and Suburban Arterial Intersections					
General Information			**Location Information**		
Analyst		Justin Neill	Roadway	State St	
Agency or Company		ODOT	Intersection	State St and 17th St	
Date Performed		07/02/12	Jurisdiction	ODOT	
			Analysis Year	2010	
Input Data			**Base Conditions**	**Site Conditions**	
Intersection type (3ST, 3SG, 4ST, 4SG)			--	4SG	
AADT $_{major}$ (veh/day)	$AADT_{MAX}$ =	67,700 (veh/day)	--	22,042	AADT OK
AADT $_{minor}$ (veh/day)	$AADT_{MAX}$ =	33,400 (veh/day)	--	11,711	AADT OK
Intersection lighting (present/not present)			Not Present	Present	
Calibration factor, C_i			1.00	1.05	
Data for unsignalized intersections only:			--	--	
Number of major-road approaches with left-turn lanes (0,1,2)			0	0	
Number of major-road approaches with right-turn lanes (0,1,2)			0	0	
Data for signalized intersections only:			--	--	
Number of approaches with left-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]			0	4	
Number of approaches with right-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]			0	0	
Number of approaches with left-turn signal phasing [for 3SG, use maximum value of 3]			--	4	
Type of left-turn signal phasing for Leg #1			Permissive	Protected / Permissive	
Type of left-turn signal phasing for Leg #2			--	Protected / Permissive	
Type of left-turn signal phasing for Leg #3			--	Protected / Permissive	
Type of left-turn signal phasing for Leg #4 (if applicable)			--	Protected / Permissive	
Number of approaches with right-turn-on-red prohibited [for 3SG, use maximum value of 3]			0	0	
Intersection red light cameras (present/not present)			Not Present	Not Present	
Sum of all pedestrian crossing volumes (PedVol) -- Signalized intersections only				50	
Maximum number of lanes crossed by a pedestrian (n_{lanesx})			--	5	
Number of bus stops within 300 m (1,000 ft) of the intersection			0	3	
Schools within 300 m (1,000 ft) of the intersection (present/not present)			Not Present	Not Present	
Number of alcohol sales establishments within 300 m (1,000 ft) of the intersection			0	4	

Worksheet 2B -- Crash Modification Factors for Urban and Suburban Arterial Intersections						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
CMF for Left-Turn Lanes	CMF for Left-Turn Signal Phasing	CMF for Right-Turn Lanes	CMF for Right Turn on Red	CMF for Lighting	CMF for Red Light Cameras	Combined CMF
CMF 1i	*CMF 2i*	*CMF 3i*	*CMF 4i*	*CMF 5i*	*CMF 6i*	*CMF $_{COMB}$*
from Table 12-24	from Table 12-25	from Table 12-26	from Equation 12-35	from Equation 12-36	from Equation 12-37	(1)*(2)*(3)*(4)*(5)*(6)
0.66	0.96	1.00	1.00	0.95	1.00	0.60

Instructions / Segment1 / Segment2 / Segment Tables / Intersection1 / Intersection2 / Intersection Tables / Ur

Ready

Cost-Effectiveness Index Analysis spreadsheet

The Cost-Effectiveness Index Analysis spreadsheet is an adaption of the HSM spreadsheets to analyze countermeasures for bicycle and pedestrian crashes on urban and suburban arterials. This spreadsheet allows up to 9 segments and 8 intersections to be analyzed. If countermeasure costs are known a cost effectiveness index can be calculated.

ISATe

The Enhanced Interchange Safety Analysis Tool (ISATe) is a predictive model for freeway mainline segments and common interchange elements in both urban/suburban and rural contexts, implemented as a macro-enabled spreadsheet. The methodology used is consistent with the HSM Part C Predictive Method. ISATe has been incorporated in the HSM 2014 Supplement as Chapters 18 and 19. The ISATe spreadsheets and users guide are available for download from the HSM website as one of the spreadsheet tools.

ISATe can be used to analyze a single type of site, such as an extended length of freeway mainline. It can also be used to analyze a collection of interconnected sites of different types, such as a complex interchange. If the study area includes sites that are not covered by ISATe, other HSM Part C predictive methods can be used to complete the study area analysis. For example, the urban arterial predictive model may be used to evaluate the freeway overpass or neighboring intersections as applicable.

Predicted crashes are reported by each of the KABCO severity levels and by crash type. Expected crashes can be reported using the site-specific or project-level EB Method if crash data are available. The spreadsheet automates applying the EB Method with crash data from any time period, not only the analysis time period. The EB Method should be used only when study conditions are similar to those during the crash period, as described in APM Section 4.4.5.

As with other HSM predictive methods, ISATe requires the analyst to segment the facility into homogenous sites. Segmentation requirements for ISATe are somewhat more specific than other HSM models. Additional details are available in the "Segmentation Criteria" section of the ISATe User Manual on page 34. ISATe screen captures are shown Exhibit 4-16 through Exhibit 4-18.

Exhibit 4-16: ISATe Main Screen

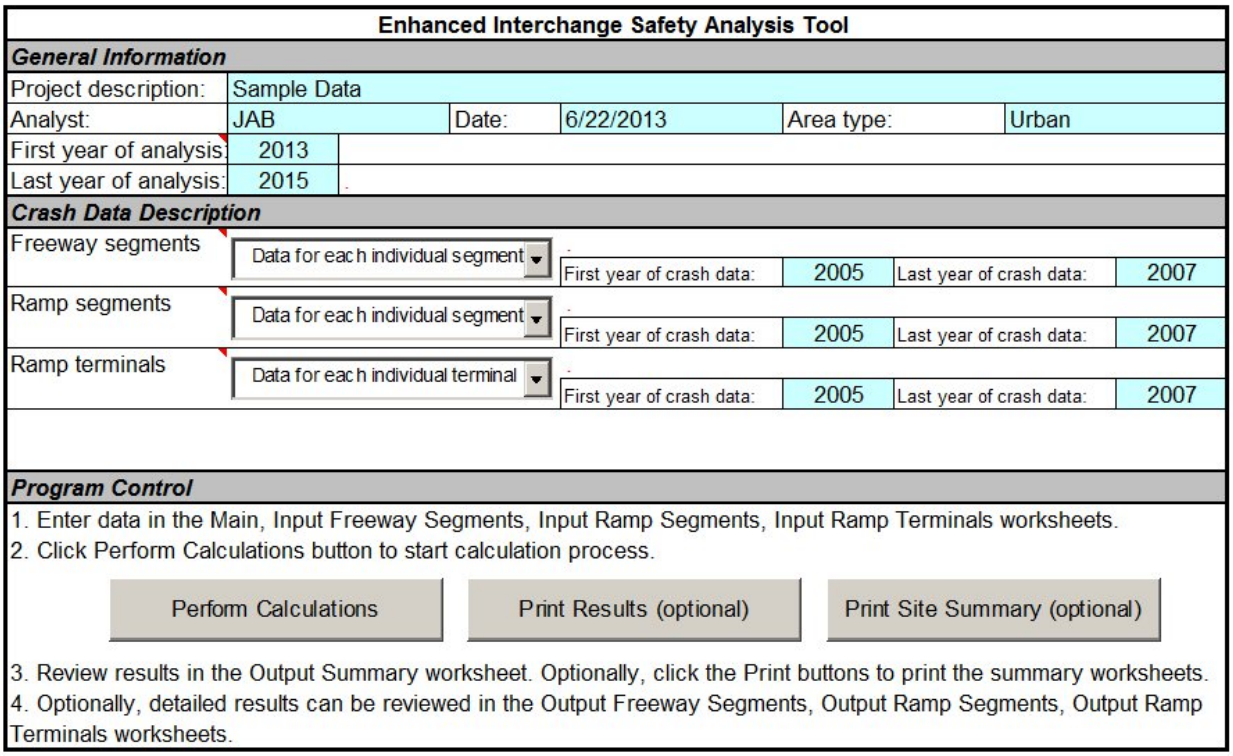


Exhibit 4-17: ISATe Input Worksheet (Partial)

Input Worksheet for Freeway Segments

Clear | Echo Input Values (View results in Column AV) | Check Input Values (View results in Advisory Messages)

		Segment 1		Segment 2		Segment 3		Segment 4	
		Crash Period	**Study Period**	**Crash Period**	**Study Period**	**Crash Period**	**Study Period**	**Crash Period**	**Study Period**
Basic Roadway Data									
Number of through lanes (n):		5	5	5	5	4	4	4	4
Freeway segment description:		Station 0+00.00		Station 4+75.20			Alt seg		
Segment length (L), mi:		0.09	0.09	0.05	0.05	0.08	0.08	0.25	0.25
Alignment Data									
Horizontal Curve Data	See note								
1	Horizontal curve in segment?:	No	No	No	No	No	No	Both Dir.	Both Dir.
	Curve radius (R_1), ft:							2800	2800
	Length of curve (L_{c1}), mi:							0.23	0.23
	Length of curve in segment ($L_{c1,seg}$), mi:							0.15	0.15
2	Horizontal curve in segment?:							No	No
	Curve radius (R_2), ft:								
	Length of curve (L_{c2}), mi:								
	Length of curve in segment ($L_{c2,seg}$), mi:								
3	Horizontal curve in segment?:								
	Curve radius (R_3), ft:								
	Length of curve (L_{c3}), mi:								
	Length of curve in segment ($L_{c3,seg}$), mi:								
Cross Section Data									
Lane width (W_l), ft:		10.8	12	10.8	10.8	12	12	12	12
Outside shoulder width (W_s), ft:		4	4	5	5	9	9	10	10
Inside shoulder width (W_{is}), ft:		2.5	2.5	2.5	2.5	9	9	9	9
Median width (W_m), ft:		7	7	7	7	21	21	22	22
Rumble strips on outside shoulders?:		No	No	No	No	Yes	Yes	Yes	Yes
	Length of rumble strips for travel in increasing milepost direction, mi:					0.08	0.08	0.25	0.25
	Length of rumble strips for travel in decreasing milepost direction, mi:					0.08	0.08	0.25	0.25
Rumble strips on inside shoulders?:		No	No	No	No	Yes	Yes	Yes	Yes
	Length of rumble strips for travel in increasing milepost direction, mi:					0.08	0.08	0.175	0.175
	Length of rumble strips for travel in decreasing milepost direction, mi:					0.08	0.08	0.175	0.175
Presence of barrier in median:		Center	Center	Center	Center	Center	Center	Center	Center

Exhibit 4-18: ISATe Output Summary (Partial)

Output Summary							
General Information							
Project description:	Sample Data						
Analyst:	JAB	Date:	12/16/2014	Area type:	Urban		
First year of analysis:	2013						
Last year of analysis:	2015						
Crash Data Description							
Freeway segments	Segment crash data available?		Yes	First year of crash data:			2005
	Project-level crash data available?		No	Last year of crash data:			2007
Ramp segments	Segment crash data available?		Yes	First year of crash data:			2005
	Project-level crash data available?		No	Last year of crash data:			2007
Ramp terminals	Segment crash data available?		Yes	First year of crash data:			2005
	Project-level crash data available?		No	Last year of crash data:			2007
Estimated Crash Statistics							
Crashes for Entire Facility		**Total**	**K**	**A**	**B**	**C**	**PDO**
Estimated number of crashes during Study Period, crashes:		120.5	0.3	1.7	10.9	40.3	67.4
Estimated average crash freq. during Study Period, crashes/yr:		40.2	0.1	0.6	3.6	13.4	22.5
Crashes by Facility Component	**Nbr. Sites**	**Total**	**K**	**A**	**B**	**C**	**PDO**
Freeway segments, crashes:	4	24.5	0.1	0.4	2.2	4.3	17.5
Ramp segments, crashes:	6	4.9	0.0	0.1	0.7	1.1	3.0
Crossroad ramp terminals, crashes:	6	91.1	0.1	1.2	8.0	34.9	46.9
Crashes for Entire Facility by Year	**Year**	**Total**	**K**	**A**	**B**	**C**	**PDO**
Estimated number of crashes during the Study Period, crashes:	2013	40.1	0.1	0.6	3.6	13.4	22.4
	2014	40.2	0.1	0.6	3.6	13.4	22.5
	2015	40.2	0.1	0.6	3.6	13.4	22.5

PLANSAFE

PLANSAFE is a free GIS-based tool that estimates the anticipated safety impact of changes in traffic flow, demographics, and safety policy at a regional scale. PLANSAFE is not an HSM-based tool, although it is based on a similar methodology that has been modified for macroscopic implementation. The PLANSAFE SPFs were designed for use with the limited data typically available for a long-range regional analysis.

The tool uses outputs from a travel demand model and historic crash data with macro-level predictive analysis to determine the predicted future safety performance at a census block group or Transportation Analysis Zone (TAZ) unit of resolution. The results can be used to evaluate relative safety across an entire study area, neighborhoods/districts, a city, or a region.

PLANSAFE is available for download on the PLANSAFE TRB webpage. An updated version is in development but is not yet publically available.

PLANSAFE is an option for use on TSPs that involve major transportation network modifications or significant demographic changes. It provides a system-wide safety assessment for future scenario analysis that is unavailable with any other tool.

Minimum data requirements for PLANSAFE are the following GIS layers (geocoded) for baseline and alternative conditions:

- Road network (arterials and higher) with traffic volumes
- Intersection locations
- Baseline safety performance measure, such as total observed crash frequency
- At least one measure of demographic information, such as number of housing units

Safety performance predictions can be reported using various target crash types including all crashes, fatal and serious injury crashes, bicyclist crashes, pedestrian crashes, and others. Results are reported for each census block group or TAZ and can be exported in tabular or map form. PLANSAFE includes a variety of SPFs for each target crash type. These SPFs are dynamically evaluated and self-calibrated using observed crash data to provide the best performance with the data available. The analyst should always choose to use the SPF with the highest "Goodness of Fit" value. Additional data can be included to improve the accuracy of predictions.

Recommended data varies based on the target crash type being predicted. Recommended data sets for each target crash type are shown in Exhibit 4-19.

Exhibit 4-19: PLANSAFE Recommended Data

Variable	TC	Int	NInt	KA	KAB	Ped	Bike	Deer
Target Crashes/Polygon	X	X	X	X	X	X	X	X
Total Number of Intersections/Polygon		X		X	X	X		
Total Roadway Length/Polygon (mile)		X						
VMT/Polygon	X	X	X	X	X	X	X	
Number of Intersections/Mile	X					X		X
Population between 16 and 64/Polygon	X	X	X					
Proportion Urban Population/Polygon	X			X	X	X	X	
Proportion Minority Population/Polygon	X			X	X	X		
Housing Units/Polygon				X	X	X	X	X
Density of Children in K12/Polygon				X	X	X		
Number of Schools/Polygon							X	
Average Household Income/Polygon				X				
Proportion Population in Urban Areas/Polygon								X
Rural Minor Arterial/Polygon (mile)								X
Rural Major Collector/Polygon (mile)								X
Sum of Combined Freeways, Principal Arterial, Rural Minor Arterial/Polygon (mile)	X							

TC = Total Crashes, Int = Intersection Crashes, NInt = Non-Intersection Crashes, KA = Injury Level K and A, KAB = Injury Levels K, A, and B. Ped = Pedestrian Crashes, Bike = Bike Crashes, Deer = Large Animal Crashes

Recommended data varies based on the target crash type being predicted.

Using all recommended data, PLANSAFE SPF predictions are of a similar accuracy to HSM models, though the results are not as geographically specific as the HSM Predictive Method. Baseline and future roadway and traffic data are typically derived from a travel demand model. Baseline demographic data are available from the U.S. Census or American Community Survey. The analyst will need to provide future demographic conditions forecast through a travel demand model or by other methods. Data GIS layers are summarized by TAZ or census block group polygons using the PLANSAFE GIS tools or manually following the methodology in the PLANSAFE documentation.

PLANSAFE prediction sensitivity to demographic conditions vary based on the underlying SPF. Variables in the SPFs used in PLANSAFE generally have elasticities between 0 and 2, which describe how responsive the SPF prediction is to change in that variable. At an elasticity of 1, an X% increase in the variable will result in an X% increase in the predicted crashes. For example, consider an SPF predicting fatal and serious injury crashes that includes a variable for the percentage of population in urban areas at an elasticity of 1. An increase in urban population from 25% to 35% would increase the prediction from 100 to 110 fatal and serious injury crashes per year.

CMFs for countermeasures can be manually added to the future predictions to specific geographic regions or as systemic actions to the study area as a whole. Although a table of CMFs is provided in the PLANSAFE software, it is the responsibility of the analyst to ensure that any CMF is used appropriately and of sufficient quality (see APM Section 4.6). For example, a CMF that is intended for use with intersection crashes should not be applied to all crashes throughout the region.

At the time of this writing, some of the GIS toolbox components for PLANSAFE do not function with recent versions of ArcGIS. Without these tools, PLANSAFE can be very time-intensive and is best performed by analysts familiar with the software model. Consult the PLANSAFE manual for required GIS methodology.

Exhibit 4-20 gives an overview of the data flow within PLANSAFE and Exhibit 4-21 summarizes the analysis steps.

Exhibit 4-20: PLANSAFE Data Flow

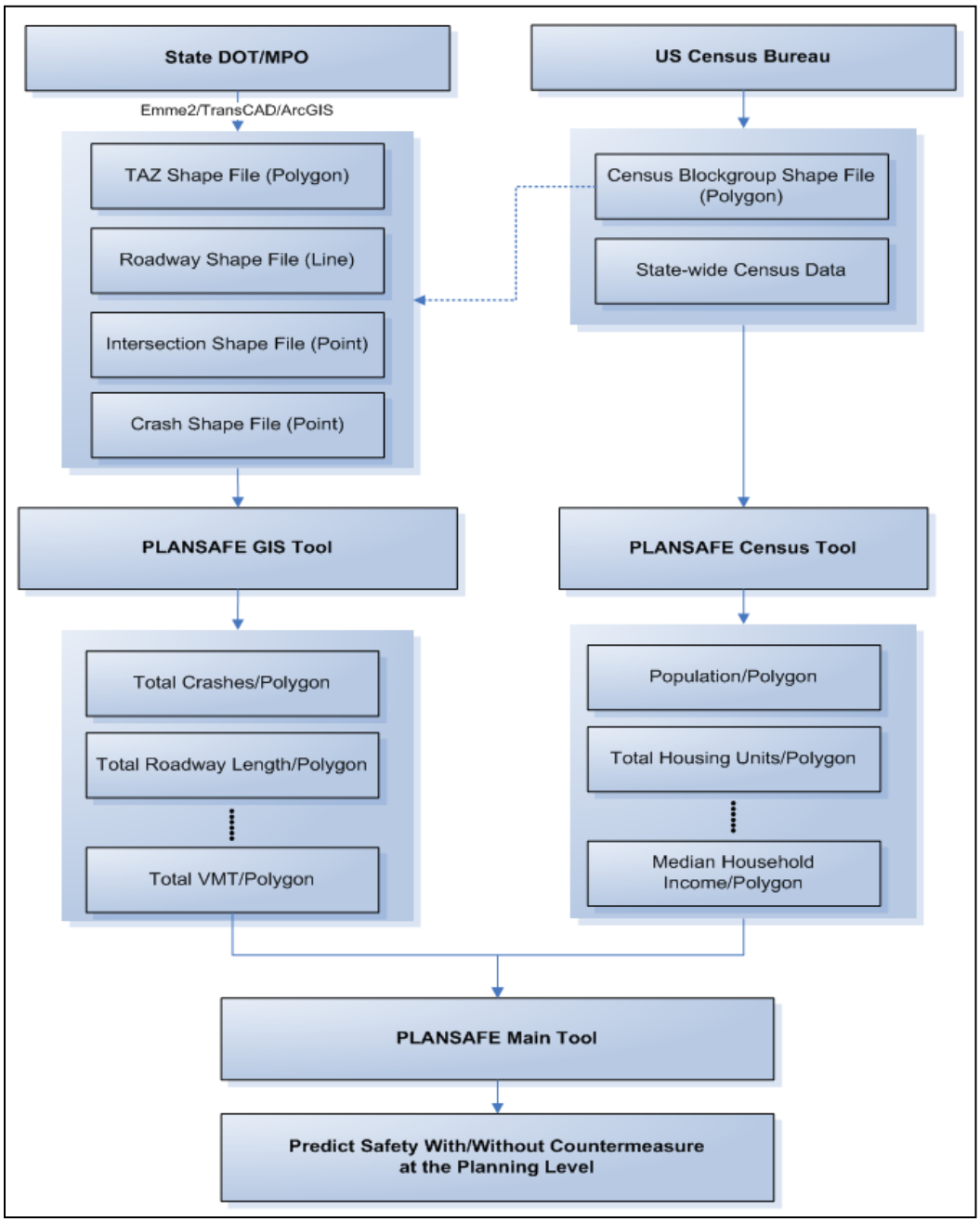
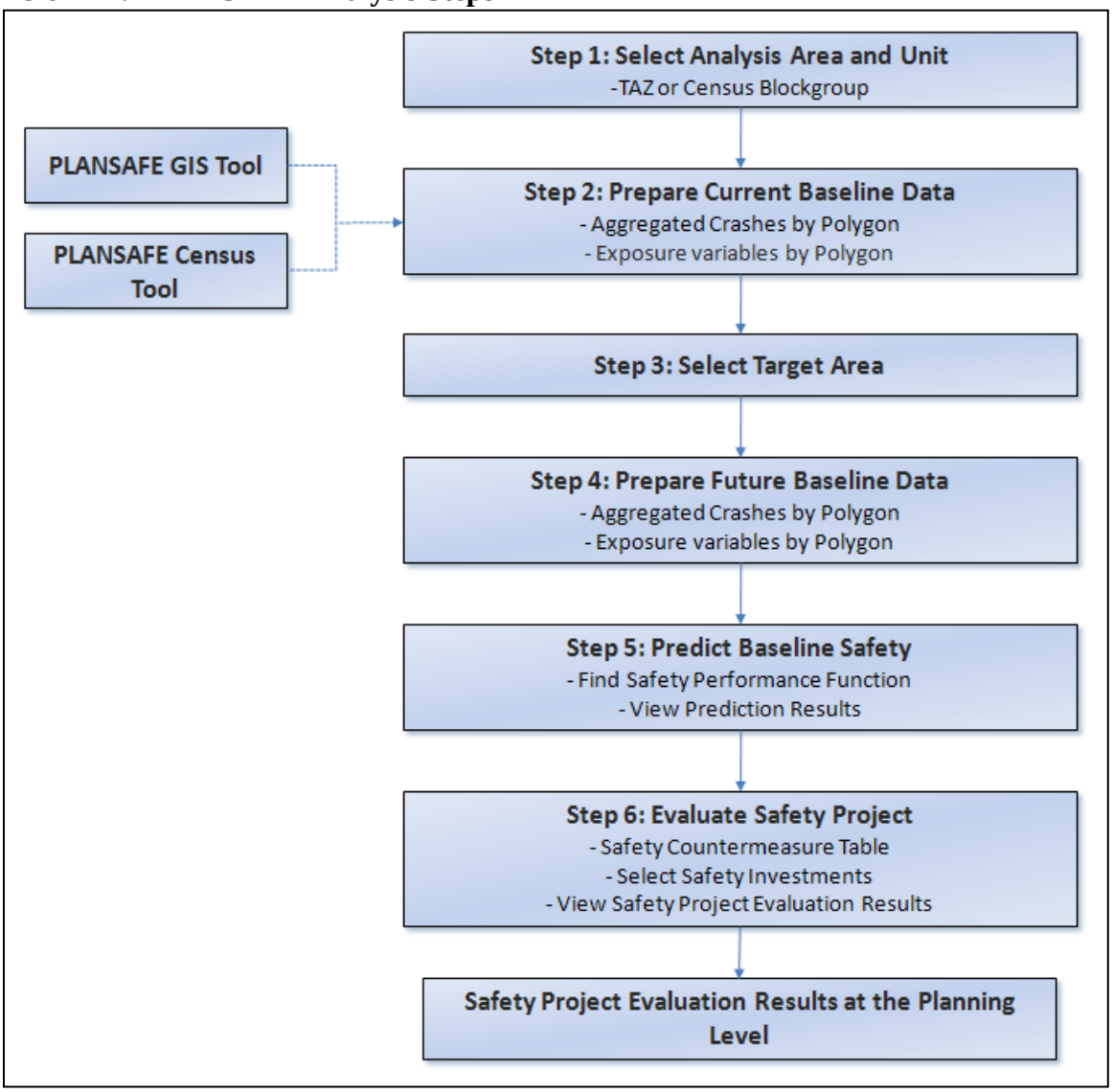


Exhibit 4-21: PLANSAFE Analysis Steps



Example 4-8: PLANSAFE Regional Safety Analysis

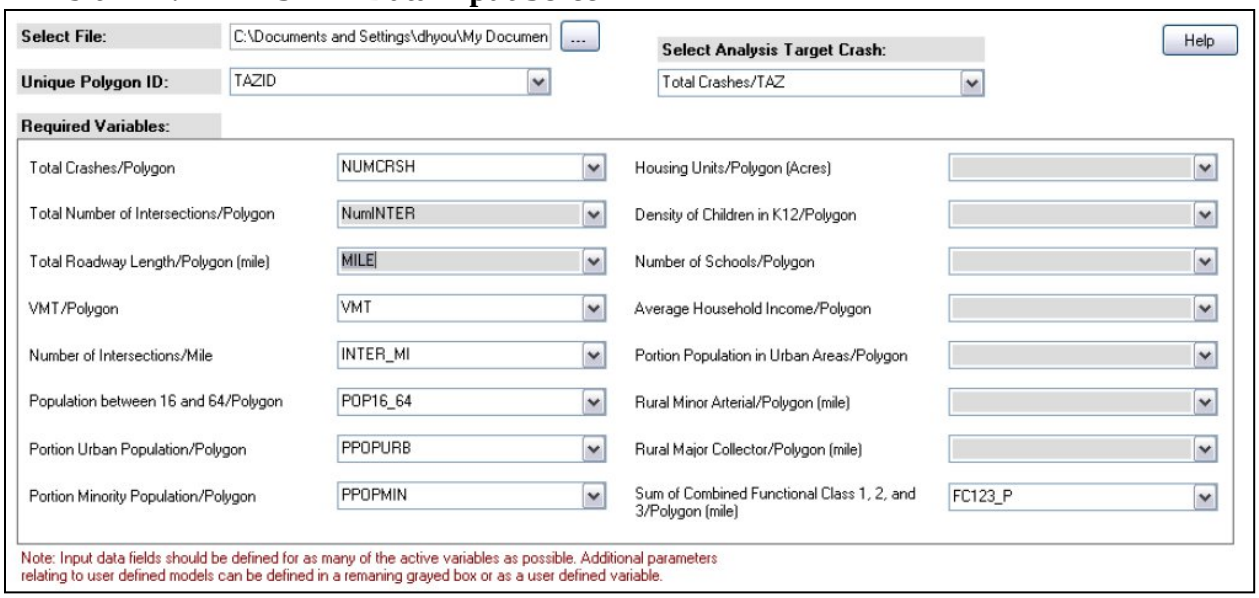
The City of Klamath Falls is preparing an update to its TSP that includes plans for considerable new residential development. In addition to an intersection-based safety analysis, it would like to perform a PLANSAFE predictive analysis to assess the overall impact of residential growth, set citywide safety performance goals, and help direct its systematic safety countermeasures.

The results of a travel demand model were exported by TAZ for the current year and for the horizon analysis year. A desktop GIS client was used with the PLANSAFE GIS tool and the PLANSAFE Census tool to post-process crash data, census data, and roadway data into the format needed for analysis in PLANSAFE.

The City's TSP safety policy is focused on reducing the total number of crashes, so this was chosen as the target crash type for the PLANSAFE analysis. Exhibit 4-22 shows the data input

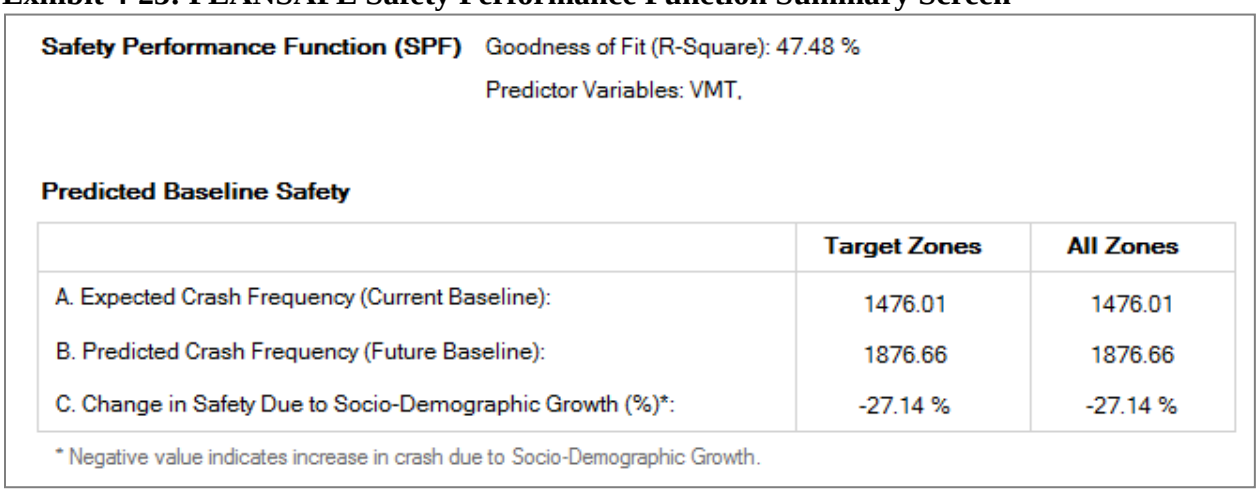
screen where field names from the GIS shapefile are matched with the required variables, shown with white input boxes. Grey boxes are optional, but including them increases model performance.

Exhibit 4-22: PLANSAFE Data Input Screen



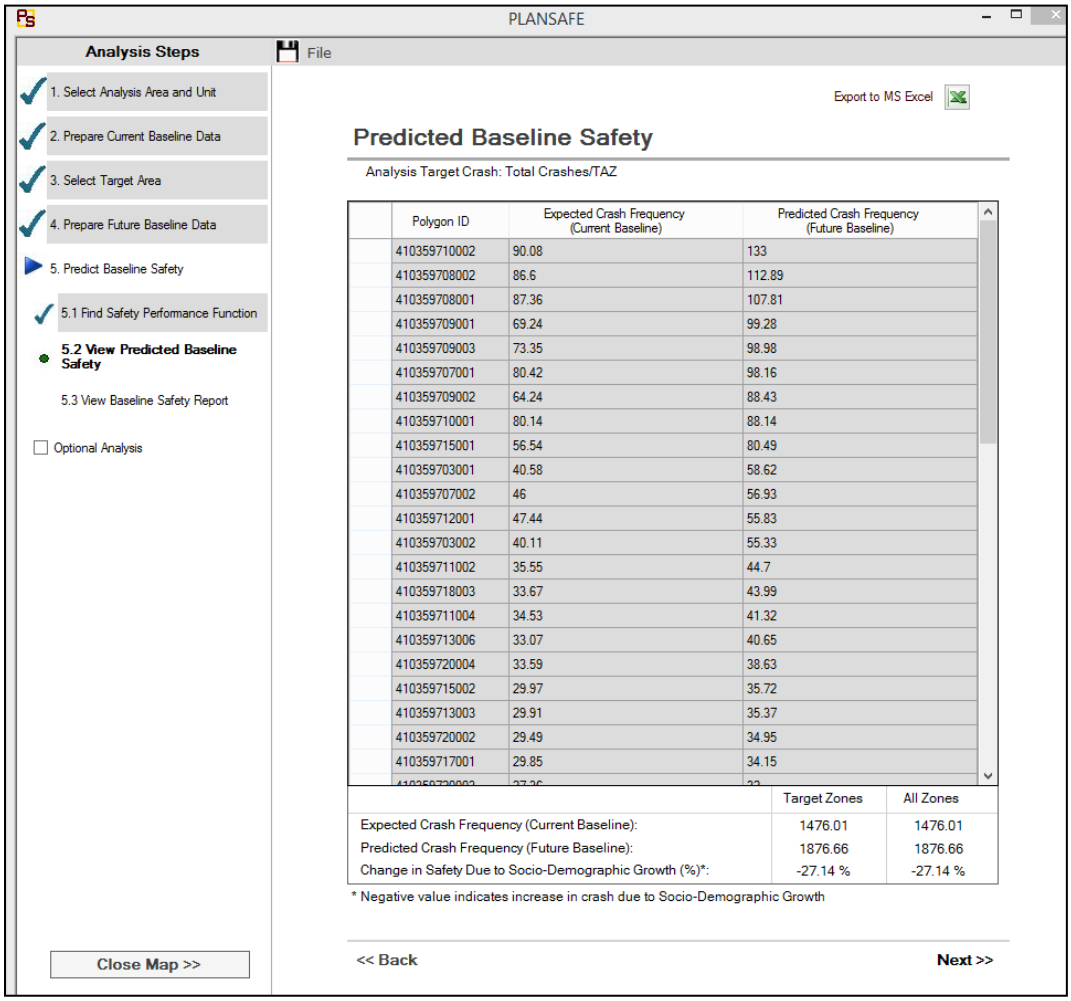
After the variables in the GIS file have been identified for the current baseline data, the analysis zone is selected and the process is repeated for the future baseline data. PLANSAFE recommends the best available SPF based on the data available, which is chosen by the City analysts. Exhibit 4-23 shows the SPF performance summary screen.

Exhibit 4-23: PLANSAFE Safety Performance Function Summary Screen



Using the selected SPF, PLANSAFE predicts the current expected crash frequency (current baseline) and future predicted crash frequency (future baseline). The results can be viewed in tabular form and with a map. Exhibit 4-24 displays the results by TAZ in table form, while Exhibit 4-25 shows the results on a map, with red indicating high predicted crash growth.

Exhibit 4-24: PLANSAFE Tabular Results

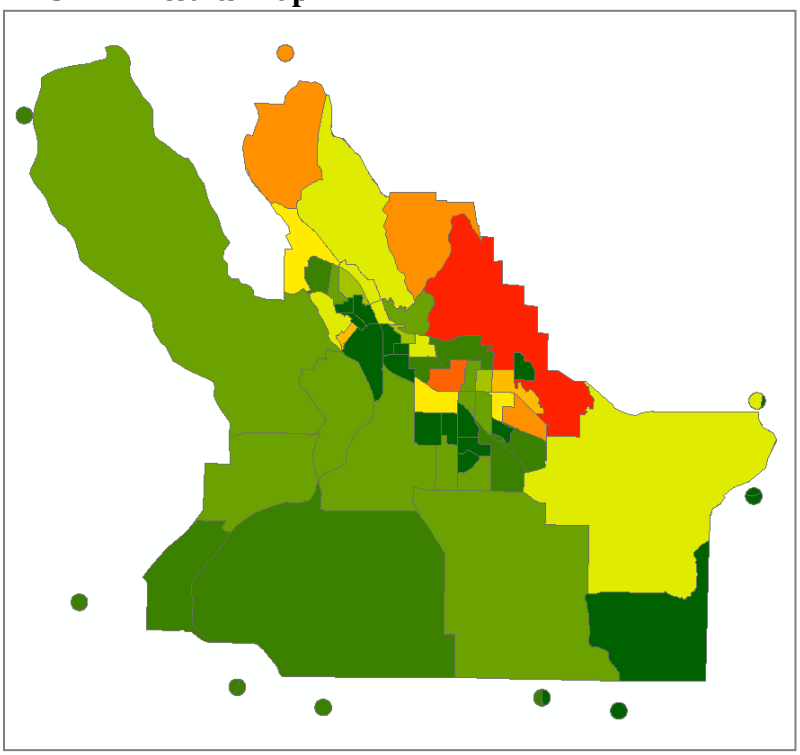


Polygon ID	Expected Crash Frequency (Current Baseline)	Predicted Crash Frequency (Future Baseline)
410359710002	90.08	133
410359708002	86.6	112.89
410359708001	87.36	107.81
410359709001	69.24	99.28
410359709003	73.35	98.98
410359707001	80.42	98.16
410359709002	64.24	88.43
410359710001	80.14	88.14
410359715001	56.54	80.49
410359703001	40.58	58.62
410359707002	46	56.93
410359712001	47.44	55.83
410359703002	40.11	55.33
410359711002	35.55	44.7
410359718003	33.67	43.99
410359711004	34.53	41.32
410359713006	33.07	40.65
410359720004	33.59	38.63
410359715002	29.97	35.72
410359713003	29.91	35.37
410359720002	29.49	34.95
410359717001	29.85	34.15

	Target Zones	All Zones
Expected Crash Frequency (Current Baseline):	1476.01	1476.01
Predicted Crash Frequency (Future Baseline):	1876.66	1876.66
Change in Safety Due to Socio-Demographic Growth (%)*:	-27.14 %	-27.14 %

* Negative value indicates increase in crash due to Socio-Demographic Growth

Exhibit 4-25: PLANSAFE Results Map



Based on the analysis, it is anticipated that the 24% growth in vehicle miles traveled (VMT), 15% growth in population and 18% growth in housing units in the region will, on average, result in a predicted increase in crashes by 27%, to 626 per year by the year 2025.

The analysis results estimate that without additional systemic countermeasures, there will be a 27% growth in the total number of crashes in the city due to demographic growth. Based on this, the City implements a safety program in its TSP with the goal of keeping the city's total crash growth below 15% through the forecast horizion.

Later in the TSP process, the City will evaluate systemic countermeasure options using PLANSAFE to quantify the expected results.

4.5 Multimodal Safety Analysis

Pedestrians and bicyclists are considered to be vulnerable road users, and identifying and improving conditions for these road users is an important part of many transportation plans and projects. Safety analysis for these modes is more difficult than for typical motor vehicle crashes because of practical limitations such as:

- Compared to motor vehicle crashes, fewer pedestrian and bicycle crashes occur and only a portion are reported. With fewer reported crashes to study, identifying statistically significant crash patterns is more difficult than for other types of vehicular crashes.

- Exposure data, such as pedestrian and bicycle volumes, is not widely available and travel patterns vary by user.
- Few systematic countermeasures for reducing pedestrian and bicycle crashes have been studied.

Although most frequently discussed in the context of pedestrian and bicycle safety, these limitations apply to other modes with limited data—such as motorcycles, freight, and transit—that may also be of interest in a safety analysis.

These practical limitations may limit the multimodal utility of the screening and predictive analysis methods included in this chapter. Additionally, subjective safety (the perceived safety by the traveling public) is an important component of multimodal planning and design. A person's choice of mode and route is strongly affected by how safe and comfortable the person feels about them.

4.5.1 Using Screening and Predictive Methods with Multimodal Crashes

When an analysis has few records of crashes involving pedestrians and bicyclists, reporting the details of those crashes with a narrative may be the only option available. In instances where sufficient crash data and/or exposure data exists, the screening and predictive analysis methods described in this chapter may be used.

4.5.2 Screening

SPIS does not include explicit consideration of multimodal crashes, but OASIS can be used to quickly identify hot-spots of crashes involving pedestrians or bicyclists across a large geographic region. This is done by adjusting the OASIS crash conditions criteria to include only pedestrian- or bike-involved crashes. The same can also be done for truck-involved crashes.

The critical crash rate method can be applied with a multimodal focus in two ways. One way is to use the traditional critical crash rate methodology with multimodal crashes as the target crash type. This would evaluate the pedestrian and bicycle crash frequency while controlling for vehicular exposure. Since vehicles are involved in all recorded multimodal crashes and vehicular exposure is usually at least an order of magnitude higher than multimodal exposure, this is generally sufficient.

Another potential way is to use pedestrian or bicycle volumes in the analysis. This should be limited to situations where multimodal traffic is generally high and varies in the project area, with available good historic data. An example is a popular mixed-use path with many street crossings. This analysis uses the same critical crash rate methodology described in APM Section 4.3.4, but with a crash rate calculated for a specific target mode, such as vehicle-bicycle crashes per million entering bicycles. Considerations would need to be given for historically and seasonally adjusting the pedestrian and bicycle volumes. This alternative analysis should be in addition to a traditional critical crash rate.

The excess proportions of specific crash types method is well suited for multimodal crash analysis, as this method does not require exposure data. As long as the target mode is included as

a crash type to be considered, the analysis will flag locations where crashes of that mode are overrepresented. However, the analyst should be aware that this method may overlook crash types that are not well represented in the overall sample, which may hinder multimodal analysis particularly for small study areas.

4.5.3 Predictive

Most HSM Part C predictive analysis methods report pedestrian and bicycle crashes separately from other crash types and thus can be used for multimodal analysis. In general, the pedestrian and bicycle HSM predictive methods are less well developed than the motor vehicle predictive methods. Pedestrian crashes at urban and suburban signalized intersections are characterized by a unique SPF, considering vehicle and pedestrian volumes and pedestrian crossing distance. However, all other pedestrian and bicycle crashes are predicted using a locally derived crash adjustment factor. This factor is developed for each basic road configuration, considering vehicle speed, and predicts pedestrian or bicycle crashes as a simple fixed percentage of motor vehicle crashes.

ISATe does not predict pedestrian or bicycle crashes. Although freeways are generally not designed for pedestrians or bicyclists, interchange terminals may have high amounts of multimodal activity. Safety for these users is not evaluated through ISATe.

PLANSAFE does allow for pedestrian or bicycle crash prediction, though results are reported aggregated by census block group or TAZ.

4.5.4 Risk-based Multimodal Safety Analysis

The recent ODOT Pedestrian and Bicycle Safety Implementation Plan includes an effort to address the limitations inherent in multimodal safety analysis through a risk-based screening methodology. The risk-based process identifies roadway characteristics that have contributed to pedestrian and bicycle crashes in the historical crash data then evaluates the road network based on the presence of high-risk characteristics. This allows for a prioritization of safety projects that is proactive, addresses perceived safety by users, and is applicable where no or few pedestrian or bicycle crashes have been recorded.

Identified high-risk screening characteristics include:

- Posted speed
- Number of lanes
- Presence of bicycle facilities
- Number of driveways
- Presence of transit stops
- Occurrence of pedestrian or bicycle crashes
- Annual average daily traffic
- The presence of signalized intersections or pedestrian activated systems

The risk-based method of the plan is limited by the availability of data for the roadway network.

Although the risk of serious pedestrian crashes is probably related to factors such as pedestrian volume, pedestrian age, and volume of turning vehicles, these factors were not included in the method because the data were not available across the roadway network.

This risk-based screening method is distinct from the HSM screening and predictive methods. Unlike the HSM screening methods, it is not based on crashes and does not require any crashes to have been recorded in the study area. Unlike the HSM predictive methods, the aim is not to quantify the effects of any particular treatment or roadway design. Risk-based screening is a complement to HSM analysis methods.

Although risk-based safety analysis methods can be useful in many planning contexts, the results cannot be used to apply for funding from the FHWA's Highway Safety Improvement Program (HSIP). Risk-based analysis results can be used to support an application to the "Enhance" portion of ODOT's State Transportation Improvement Program (STIP) but not to the "Fix-It" portion of the STIP.

The analyst is encouraged to contact TPAU if a risk-based multimodal safety analysis is being considered for a project or system plan.

4.6 Countermeasure Selection and Evaluation

Most crash analysis projects will specify general or potential ranges of countermeasures. The results of the analysis methods in this chapter can be used as a starting point for identifying countermeasures. Sites that demonstrate an excess of a specific crash type are more likely to benefit from countermeasures targeted at that crash type.

There are many resources that provide potential countermeasures for a given crash pattern.

- The initial source for countermeasures should be the ODOT approved set of proven countermeasures and associated CRFs that are used for the All Roads Transportation Safety (ARTS) Program. Use of these CRFs allow for all countermeasures to be evaluated consistently and fairly. If the desired countermeasure is not in the ARTS CRF list, a CMF from Part D or from the CMF Clearinghouse (studies with 3 star rating or better) may be used.
- Information on countermeasure selection is included in the ODOT Safety Investigations Manual and Chapter 6 of the HSM.
- Part D of the HSM is also an extensive resource of countermeasure treatments and includes quantitative CMFs that estimate the expected change in crash frequency resulting from implementation.
- The CMF Clearinghouse (http://www.cmfclearinghouse.org) is an active online database maintained by the FHWA providing CMFs and supporting research. The FHWA has developed a list of proven systemic countermeasures that are widely applicable to common situations. The ODOT CMF Instructions page provides guidance for using the CMF Clearinghouse and selecting appropriate CMFs.

- PedBikeSafe.org is an interactive FHWA guide to pedestrian and bicycle safety countermeasures. The website guides users to targeted countermeasures based on crash trends, patterns, and the road context.

Some CMFs are applicable only for specific facility types, AADT ranges, or base conditions. Engineering judgment is critical in selecting the appropriate CMF for a project. CMFs are an active area of research, and the best available CMF for a situation may change frequently.

If CMFs are being used that are not derived from the ARTS CRF list, the ODOT CMF standard is to use CMFs with quality ratings of three stars or better (star rating is a rating of the type of research and more stars indicate better, more reliable results). For many countermeasures, there may be multiple CMFs available with different levels of crash reduction.

Care should be taken not to just pick the CMF with the highest reduction because a particular CMF may apply to all crashes, or just severe crashes, or for a particular crash type. The CMF study parameters may limit applicability to a particular roadway configuration or to a specific volume range. The CMF AADT range should be no more than +/- 10% away from the countermeasure location AADT. Values greater than this indicate that the subject roadway likely does not have the same characteristics as the one in the CMF study.

Certain countermeasures may require coordination, review, or approval by the Region or State Traffic Engineer (see list of ODOT Traffic Engineering Authorities). Region Traffic will likely perform a detailed safety investigation of the crash patterns later during project delivery/design phase. When selecting countermeasures, the analyst should coordinate with Region Traffic and/or ODOT TRS.

Countermeasures can generally be grouped into four categories: education, enforcement, emergency medical services and engineering.

- **Education** is a variety of public information campaigns using a broad range of media to reach a target audience. These campaigns can be effective in reducing driver error or problematic behaviors by making motorists aware of the risks and consequences of certain driving behaviors and environments encountered. These can be handled by the Region Public Information office (for a specific area) or by the Traffic Safety Division (for programmatic issues).
- **Enforcement** involves increased policing activity to encourage compliance with existing traffic controls and regulations. Increased enforcement is often implemented due to frequent driver violations. The application of enforcement countermeasures is typically coordinated by Region Traffic Sections.
- **Emergency Medical Services (EMS)** involves working with EMS providers to improve response time to incidents, which plays a role in the severity of the crash.
- **Engineering** is a broad range of improvements to the transportation system to improve roadway safety. These may include geometric improvements, ITS applications, changes

to traffic controls (signing, striping, signals, etc.), changes to roadway surfacing, or operational enhancements.

Specific investigation into countermeasures should be at the appropriate level for the analysis being conducted.

Countermeasure options in a system plan or alternative design concepts should be screened based on the relative safety improvement expected, which may be reported as a range of feasible values. This reduction can be determined using CMFs applied to historic crash values. Reporting should indicate the source and quality of CMFs used. Reporting should also identify what types of crashes the CMFs are expected to reduce. When possible, report crash reductions by severity level with an emphasis on fatal and serious injury crashes.

4.7 Multimodal Mixed-Use Areas (MMAs)

A recent amendment to Oregon Administrative Rule (OAR) 660-012-0060 (Plan and Land Use Regulation Amendments) introduced the Multimodal Mixed-Use Area (MMA) designation that local governments can use to gain new flexibility in applying transportation performance standards in specific locations. An MMA allows a local government to amend a functional plan, comprehensive plan, or land use regulation without consideration of motor vehicle congestion, delay, or travel time.

Amendments within an MMA must still comply with transportation standards and policies promoting safety for all modes.

In evaluating a local request for ODOT concurrence with a proposed MMA designation near an interchange, ODOT must consider the following safety factors per OAR 660-012-0060(10)(a):

- Whether the interchange area has a crash rate that is higher than the statewide crash rate for similar facilities. The statewide crash rate tables are available on the ODOT Crash Analysis and Reporting Unit Publications webpage.
- Whether the interchange area is in the top 10% of locations identified by the SPIS. SPIS locations can be found on the SPIS webpage or through TransGIS.
- Whether existing or potential future traffic queues on the interchange exit ramps extend onto the mainline highway or the portion of the ramp needed to safely accommodate deceleration. Procedures for estimating queue lengths are found in Section 7.5 of the APM Version 1. Intersection functional areas are discussed in APM Section 4.8.1.

It is strongly encouraged that these considerations be taken into account during ODOT review of all proposed MMA designations, including those that are not near an interchange. In addition, a predictive analysis is encouraged for roadways within the proposed MMA to determine the excess expected average crash frequency. This crash frequency can be used in addition to crash rates to characterize the prevailing safety conditions of the MMA area.

Additionally, for local governments, it is suggested that safety performance standards using one of the predictive methods described in this chapter be established for considering land use amendments within designated MMAs. Standards could be based on reducing or maintaining

within a predetermined range the predicted or expected crash frequency. Increases in estimated crashes caused by exposure would be offset by proposed safety countermeasures or payment into a safety fund.

4.8 Other Safety-related Techniques

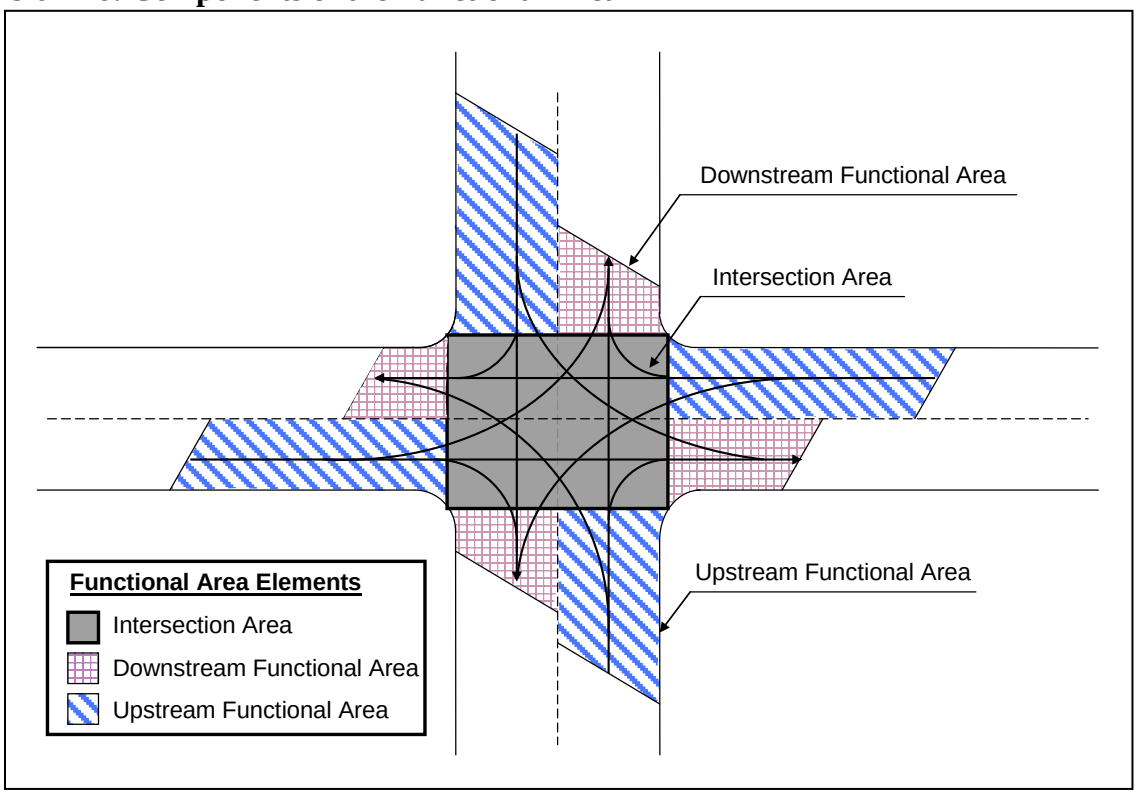
The techniques listed in this section provide a detailed review of the safety impact associated with intersection functional areas, sight distance, intersection conflict points, and segment access management. These techniques can be used in addition to the screening and predictive tools identified in this APM chapter to assist in evaluating a proposed build alternative or safety mitigation. The application of these techniques incorporates necessary human factors into the analysis. Functional area, sight distance, conflict points and other techniques focus on the need to spread apart the necessary driver information processing points. Drivers can be confused or miss obstacles if information about driveways, intersections, and other elements are too closely spaced. In addition, as the driving population ages, the importance of analyzing the human factor cannot be overstated. The analyst is strongly encouraged to be familiar with Chapter 2 of the HSM.

4.8.1 Functional Area of an Intersection

A functional area analysis should be done to evaluate the impact of closely-spaced intersections, access points, or any combination of both. This can be for either existing or proposed (alternative) conditions. Areas with long queues should also be reviewed for functional area impacts. The analysis should also be done when adding new connections to a roadway to verify that functional area overlap does not occur and vehicle maneuvers can be performed lawfully. The functional area of an intersection is the area in which an intersection affects vehicle paths. The intersection functional area—defined as the physical area where two roads overlap—influences driver decisions, vehicle movements, and vehicle queues. The sections beyond the intersection area are composed of upstream and downstream functional areas. The upstream functional area for vehicles moving toward the intersection has four maneuvering elements. The downstream functional area for vehicles traveling away from the intersection has one. These maneuvering elements are listed in the next section. Each element is unique in its contribution to the functional area. Exhibit 4-26 shows the functional area of an intersection.

The upstream functional area described in this section is defined similarly to the "influence area" used in the Highway Safety Manual (HSM). The HSM does not use the downstream functional area definition. In addition, the functional area in this section is not the same as the weaving distance calculation used in the approach permitting (development review) process

Exhibit 4-26: Components of the Functional Area[2]



Both upstream and downstream functional areas may need to be studied for an intersection improvement or any project with access in the immediate intersection area. However, only the upstream functional area needs to be studied if an access is opened upstream of an intersection and only the downstream functional area needs to be studied if an access is opened downstream of an intersection. Functional area analysis may determine the placement of an access, the provision of turn movements, or the number of travel lanes.

Upstream Functional Area

Four elements make up the distance a vehicle travels as it approaches an intersection:

- **Distance traveled during the perception-reaction time (d_1):** The perception-reaction time has four phases—perception, intellection, emotion, and volition (PIEV). This distance involves the driver seeing the intersection, thinking about their options, making a decision, and initiating their response. The perception-reaction time is 2.0 seconds for desirable conditions and 1.0 seconds for limiting conditions as set by the Transportation Research Institute (TRI) of Oregon State University in Discussion Paper No. 7, Functional Intersection Area (January 1996), which was prepared for ODOT to support its policies, practices, and procedures. A table of perception-reaction distances for varying time intervals is shown in Exhibit 4-28.

[2] Data referenced through exhibits in this section were obtained from the Discussion Papers presented to the Oregon Department of Transportation by the Transportation Research Institute (TRI) of Oregon State University.

- **Distance traveled while the driver decelerates or brakes and moves laterally into a turn bay (d_2):** The limiting condition for a vehicle traveling laterally over a 12-foot lane is three seconds in urban areas with an assumed lateral movement at four feet per second (fps). For each 12-foot lane, three seconds of travel time should be added. Four seconds of travel time per 12-foot lane should be assumed for rural conditions, with an assumed lateral movement at three fps.
- **Distance traveled during full deceleration (d_3):** These maneuver distances are based on a 6.7 fps^2 deceleration rate accommodating 85% of drivers. The limiting condition accommodates 50% of drivers with a deceleration rate of 9.2 fps^2 or higher. The distances of d_1, d_2, and d_3 are dependent on vehicle speed. Maneuver distances ($d_2 + d_3$) and PIEV plus maneuver distance ($d_1 + d_2 + d_3$) are based on the intersection functional area approaches from the ODOT's Access Management Manual. Values for just the maneuver distance and PIEV plus maneuver distance are developed from the uniform acceleration formulas and are listed in the table in Exhibit 4-29. Note that storage length, d_4, is not included in the values of Exhibit 4-29. Perception-reaction time may not always be included in an upstream functional area analysis if decisions are made prior to the driver's approach to the intersection.
- **Storage length (d_4):** Calculated by the 95th percentile queue for turning or through traffic, whichever is greater.

Exhibit 4-27 depicts the succession of these movements.

Exhibit 4-27: Upstream Functional Area; d_1, d_2, d_3, and d_4

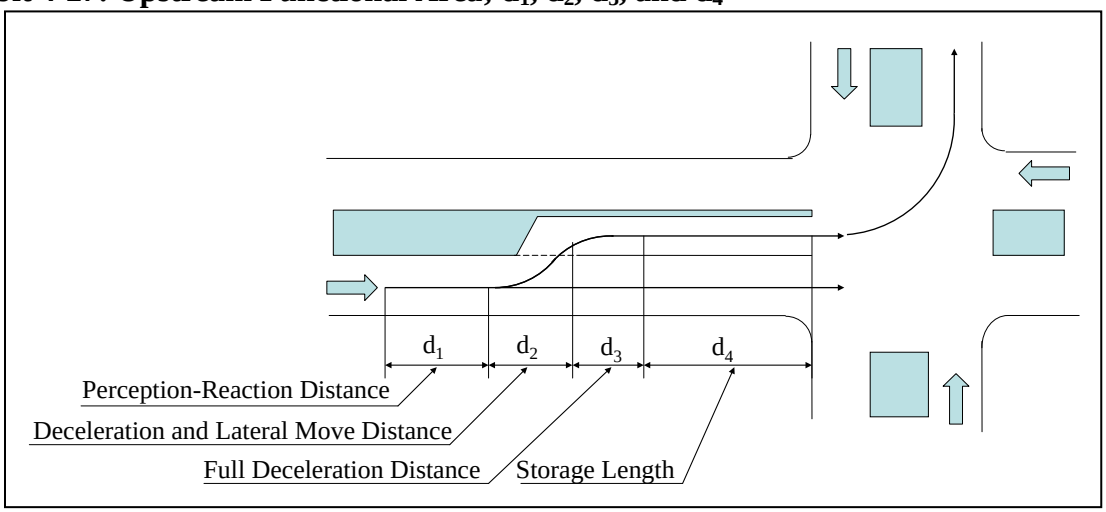


Exhibit 4-28: Perception-Reaction Time, d_1

Distance Traveled During Perception-Reaction					
US Customary Units (Feet)[(1)(2)]					
Speed (mph)	Perception-Reaction Time (Seconds)[(3)]				
	1.0	2.0	3.0	4.0	5.0
30	45	90	130	175	220
40	60	115	175	235	295
45	65	130	200	265	330
50	75	145	220	295	370
60	90	175	265	355	440
70	105	310	310	410	515

(1) Rounded to 5 feet

(2) US Customary: distance (feet) = 1.47*(speed in mph)*t

(3) Distance traveled in t-seconds

A functional area analysis has four possible values:

- The unfamiliar path under desirable conditions
- The unfamiliar path under limiting conditions
- The familiar path under desirable conditions
- The familiar path under limiting conditions

Limiting conditions are used for projects that have design constraints. A project using limiting conditions must justify this reasoning and provide appropriate documentation. From one to all of these scenarios may need to be checked depending on driver types and roadway conditions.

The familiar vehicle path would be used by drivers who would anticipate the intersection and know the lane to be in to complete the turn. This is more likely near grocery stores or residential areas. The unfamiliar vehicle path would be used by drivers who may not know anything about the intersection before approaching. This is more likely near developments such as tourist areas and regional stores.

Exhibit 4-29 demonstrates the difference between desirable conditions and limiting conditions. Desirable conditions allow for a longer perception-reaction time and a lesser rate of deceleration. Area demographics may affect these values because older, younger, and unfamiliar drivers may have longer perception-reaction times.

Exhibit 4-29: Upstream Functional Intersection Area, $d_1 + d_2 + d_3$

Upstream Functional Intersection Area Excluding Storage, in Feet[1]				
Speed (mph)	Desirable Conditions		Limiting Conditions	
	Maneuver Distance[2] [6] (ft)	PIEV[3] Plus Maneuver Distance (ft)	Maneuver Distance[4] [6] (ft)	PIEV[5] Plus Maneuver Distance (ft)
	$d_2 + d_3$	$d_1 + d_2 + d_3$	$d_2 + d_3$	$d_1 + d_2 + d_3$
20	70	130	70	100
25	110	185	105	140
30	160	250	145	190
35	215	320	190	240
40	275	395	245	305
45	345	475	300	365
50	425	570	365	440
55	510	670	435	515
60	605	780	510	600
65	710	900	590	685

(1) Rounded to 5 feet

(2) 10 mph speed differentials, 5.8 fps^2 deceleration while moving from the through lane into the turn lane; 6.7 fps^2 average deceleration after completing lateral shift into the turn lane

(3) 2.0 second perception-reaction-time

(4) 10 mph speed differential; 5.8 fps^2 deceleration while moving from through lane into the turn lane; 9.2 fps^2 average deceleration after completing lateral shift into the turn lane

(5) 1.0 second perception-reaction time

(6) Assumes turning vehicle has "cleared the through lane" (a following through vehicle can pass without physically encroaching on the adjacent through lane when the turning vehicle has moved laterally 10 ft. Also assumes a 12 ft. lateral movement will be completed in 3.0 seconds

Turn lanes may be installed at unsignalized intersections to improve safety and at signalized intersections to expand the roadway capacity. The minimum length for a turn bay (including the taper) is the deceleration and lateral move distance and the full deceleration distance, plus the

storage length ($d_2 + d_3 + d_4$). The upstream functional area increases/decreases with the number of lanes (related to d_2), the rate of deceleration (related to d_3), and the queue (d_4). Vehicles that change lanes at an intersection expand the influence area of the intersection and the intersection functional area.

Turn lanes remove turning vehicles from the general flow of traffic allowing through vehicles to proceed without significant slowing or stopping. Research indicates that the crash potential between turning vehicles and through traffic increases exponentially as the speed differential increases. It is desirable to have no more than a 10 mph speed differential between vehicles in the through lanes and vehicles entering turn bays. Providing a turn lane with adequate deceleration distance significantly lowers the speed differential between turning vehicles and through traffic.

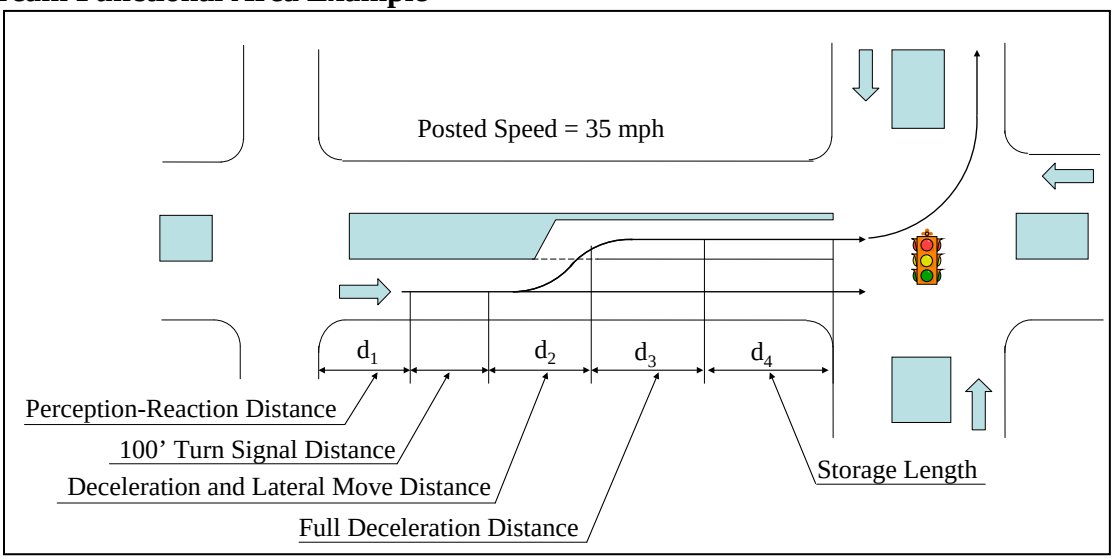
Turn lanes at a signalized intersection serve as capacity expanders and are constructed where demand approaches or exceeds capacity. The typical urban turn bay is 100 feet unless capacity or speeds require it to be longer, while the typical rural turn bay is 150 feet. The 95th percentile queue is generally calculated by traffic analysis software for signalized intersections. Chapter 13 contains the procedures to consider turn bays for intersections and estimating the length for right-turn and left-turn vehicle queues.

Example 4-9: Upstream Functional Area Distance Calculation

A development proposes to access the roadway upstream of a signalized intersection. The intersection shown has a volume of 100 vph using the left-turn lane.
The road has a posted speed of 35 mph. How close to the intersection can a proposed driveway be placed?

Assume the signal has a 120-second cycle length.

Upstream Functional Area Example



Solution

PIEV Plus Maneuver Distance ($d_1 + d_2 + d_3$)

Check values from Exhibit 4-29:

Limiting Condition

$d_{L1} = d_1 + d_2 + d_3 = 240$ feet

Desirable Condition

$d_{D1} = d_1 + d_2 + d_3 = 320$ feet

Storage Length (d_4)

For this signalized intersection, the Left-Turn Movement Queue Estimate Technique from Chapter 14 was used.

Assume each cycle is 120 seconds (30 per hour)

Assume the constant, t, is 1.85 to find the 95th percentile queue. (See Chapter 7 for background information)

$$\text{Length} = \frac{\text{volume}}{\#\text{ of cycles/hour}} * t * 25\text{feet}$$

$$\frac{100\text{ vph}}{30\text{ cycles/hr}} * 1.85 * 25\text{ feet} = 154.17\text{ feet} = 154\text{ feet (rounded)}$$

Turn Signal Length

Another 100 feet must be added to provide distance for the turn signal to be used.

Total Functional Area Length

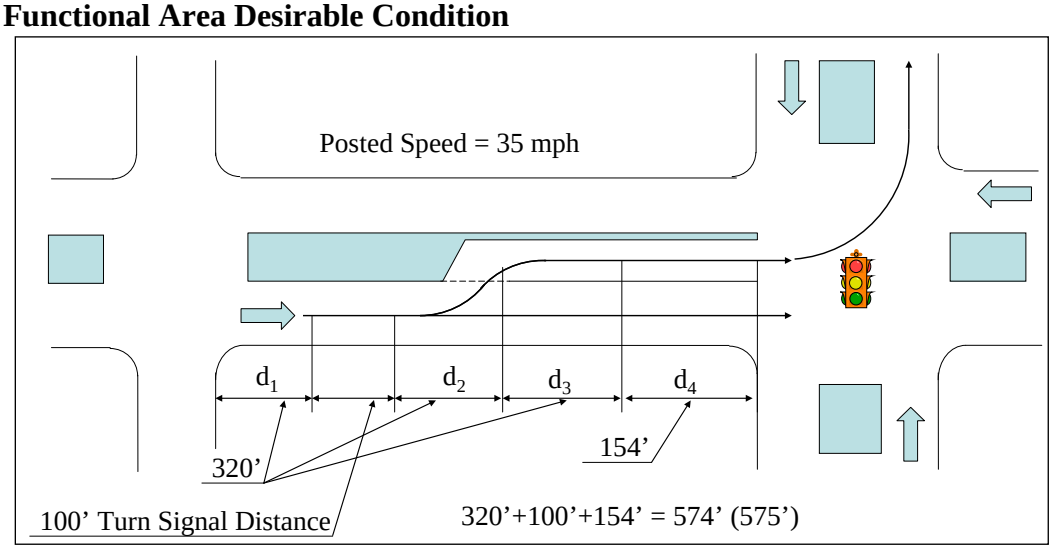
Limiting Condition

$d_{LTotal} = d_1 + d_2 + d_3 + d_4 +$ Signal Distance = 240’ + 154’ + 100’ = 494 feet

Desirable Condition

$d_{DTotal} = d_1 + d_2 + d_3 + d_4 +$ Signal Distance = 320’ + 154’ + 100’ = 574 feet

Upstream Functional Area Desirable Condition



Using the values for a 35-mph speed in Exhibit 4-29, the desirable conditions path is 575 feet long and the limiting conditions path is 495 feet long. The desirable condition calculated using

the value from Exhibit 4-29 is the greatest distance and is the closest location to access the highway with respect to the intersection. The driveway should be no less than 575 feet from the intersection.

Downstream Functional Area

As a vehicle travels away from an intersection the driver needs a minimum stopping sight distance (d_5) before approaching another intersection or driveway. The stopping sight distance is the distance traveled while braking to avoid an unexpected obstacle. Stopping sight distance is determined by AASHTO by the speed, brake reaction time, and the deceleration rate. A table developed from the following AASHTO equation is shown in Exhibit 4-30:

$$d = 1.47 * V * t + 1.075 * \left(\frac{V^2}{a} \right)$$

Where: V – speed, mph
t – brake reaction time, 2.5s
a – deceleration, ft/s^2

If an acceleration lane is present, the stopping sight distance is measured from the end of the taper. The downstream intersection functional area includes the distance traveled during acceleration before merging into the general traffic flow. Acceleration lanes are rarely provided for at-grade arterials. Lane drops that have an auxiliary lane longer than the distance traveled during acceleration before merging will not be included in the functional area analysis.

Exhibit 4-30: Downstream Functional Area

Downstream Intersection Functional Area	
Speed (mph)	**AASHTO Stopping Sight Distance (Feet)**
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570

Note that the downstream functional area analysis is a check for adequacy in safety and legality. Further analysis will be necessary to ensure the adequacy of the design.

Functional Intersection area is detailed in the ODOT Access Management Manual and further

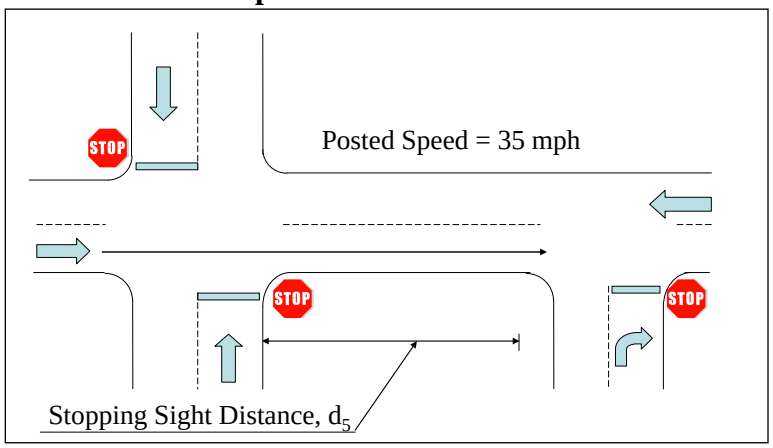
information is contained in Discussion Paper No. 7, Functional Intersection Area, Transportation Research Institute (TRI) of Oregon State University (January 1996).

Example 4-10: Downstream Functional Area Distance Calculation

A driveway is located 350 feet downstream of the intersection shown. The main street has no traffic control and a speed of 35 mph.

Is there adequate spacing between the intersection and the driveway? What is the stopping sight distance (d_5) for this intersection? The following figure shows a general diagram of the intersection area.

Downstream Functional Area Example



Solution

Stopping Sight Distance, d_5

Check values from Exhibit 4-30: AASHTO Stopping Sight Distance at 35 mph

d_5 = 250 feet

The driveway must be at least 250 feet from the next downstream intersection to avoid a stopping sight distance conflict. Keep in mind that the downstream functional area analysis is a check for adequacy in safety and legality. Further analysis will be necessary to ensure the adequacy of the design.

Functional Area Application

The principles of functional area can be used to test geometric and operational adequacy before detailed analysis starts. The primary objective is to check vehicle paths for adequate length to perform safe and legal maneuvers. For example, a path that connects a right turn onto a roadway to a turn left at the next intersection, or two paths come from two roadways merging together and terminating at a signal, may require lane changes that have safety and legal constraints. Although

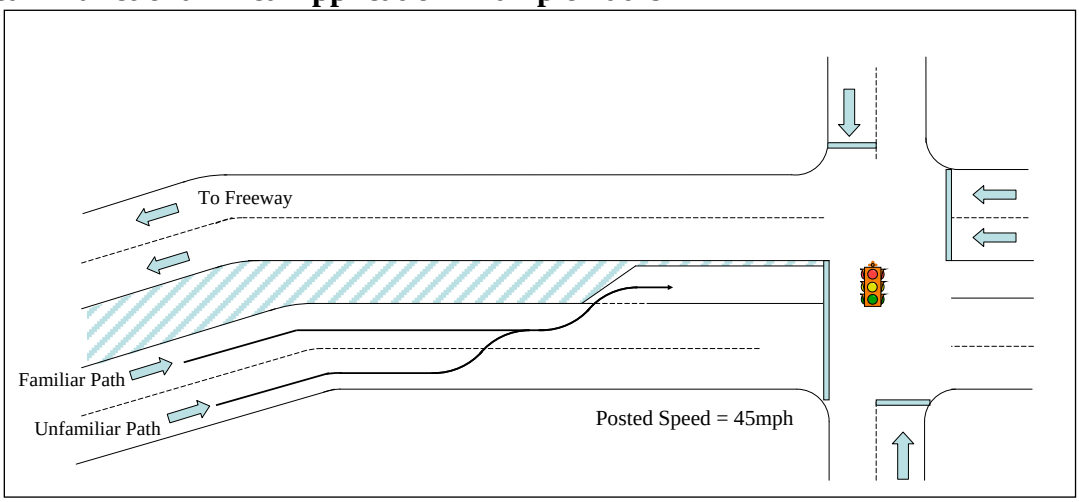
a functional area analysis may reveal potential conflicts, simulation is used to ensure the adequacy of design in the detailed analysis. Generally, functional area overlaps will appear in simulation results as slowdowns or bottlenecks.

Example 4-4: Functional Area Application – Geometric Adequacy

There is a two-lane ramp transitioning from a freeway to an arterial and has geometry similar to an interchange. An intersection is proposed on the arterial near this ramp as shown in the following figure. The queue at a speed limit of 45 mph is estimated at 400 feet.

Test the adequacy of the design for a driver in either lane of the exit ramp to turn left into the driveway. Can movements from the off-ramp to northbound intersection leg occur safely in this design? Check both the familiar path and the unfamiliar path.

Upstream Functional Area Application Example Paths



Solution

Familiar drivers will generally use the familiar path, the lane closest to the turn bay, in anticipation of the left turn. Unfamiliar drivers may take the unfamiliar path, which starts from the furthest lane or the "wrong lane" and must change lanes into the turn bay. The maneuver distance over one lane is 198 feet when a three-second maneuver time is assumed.

<u>At Speed Maneuver Distance</u>

$$\left(\frac{45\text{miles}}{\text{hr}}\right)*\left(\frac{1\,\text{hr}}{3600\,\text{s}}\right)*\left(\frac{5280\text{ft}}{1\,\text{mile}}\right)*3\text{s}=198\text{ft}\ \ (200\text{ feet})$$

Perception-reaction (PIEV) distances are found in Exhibit 4-28. Assume a two-second PIEV (130 feet) for desirable conditions and a one-second PIEV (65 feet) for limiting conditions as set by the TRI.

The maneuver distances for the turn bay include the deceleration and lateral move distance along with the full deceleration distance. The maneuver distances are found in Exhibit 4-29. For a speed of 45 mph, there should be 300 feet of distance to meet the limiting conditions and 345

feet is desirable.

Lane changes and turn movements should be signaled for 100 feet prior to the action. If an unfamiliar driver follows the unfamiliar path, a lane change must be signaled to move laterally into the near lane and the turn bay separately. The following figures show the components of the unfamiliar path and familiar path for desirable and limiting conditions.

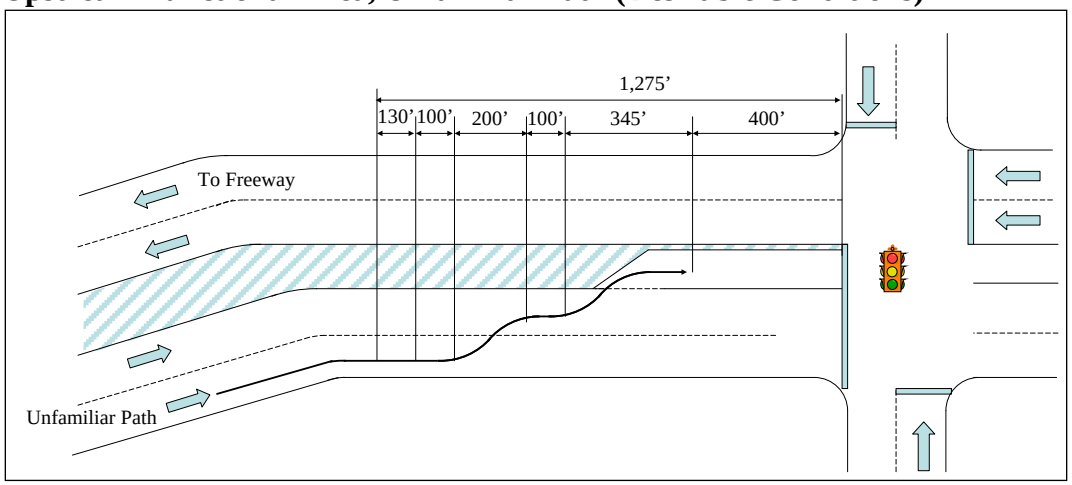
<u>Unfamiliar path (desirable conditions)</u>

d_{UD} = 130’ (PIEV) + 100’ (turn signal) + 200’ (at speed maneuver) + 100’ (turn signal) + 345’ (desirable distance into the turn bay) + 400’ (queue)
d_{UD} = 1,275’

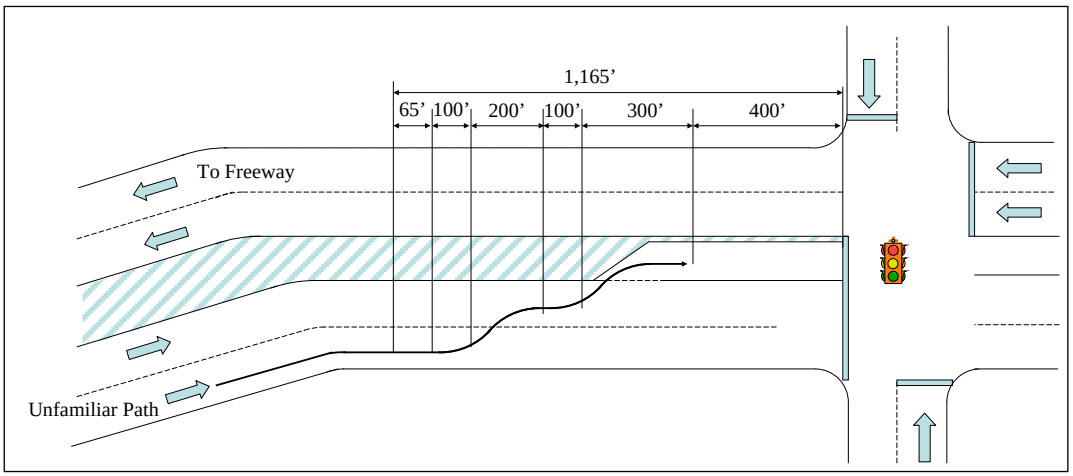
<u>Unfamiliar path (limiting conditions)</u>

d_{UL} = 65’ (PIEV) + 100’ (turn signal) + 200’ (at speed maneuver) + 100’ (turn signal) + 300’ (limiting distance into the turn bay) + 400’ (queue)
d_{UL} = 1,165’

Upstream Functional Area, Unfamiliar Path (Desirable Conditions)



Upstream Functional Area, Unfamiliar Path (Limiting Conditions)



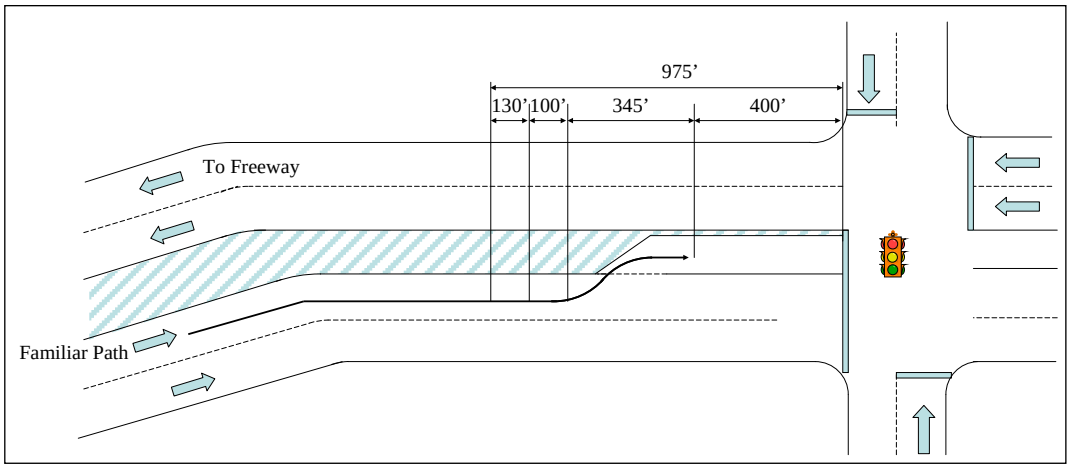
<u>Familiar path (desirable conditions)</u>

d_{FD} = 130’ (PIEV) + 100’ (turn signal) + 345’ (desirable distance into the turn bay) + 400’ (queue)
d_{FD} = 975’

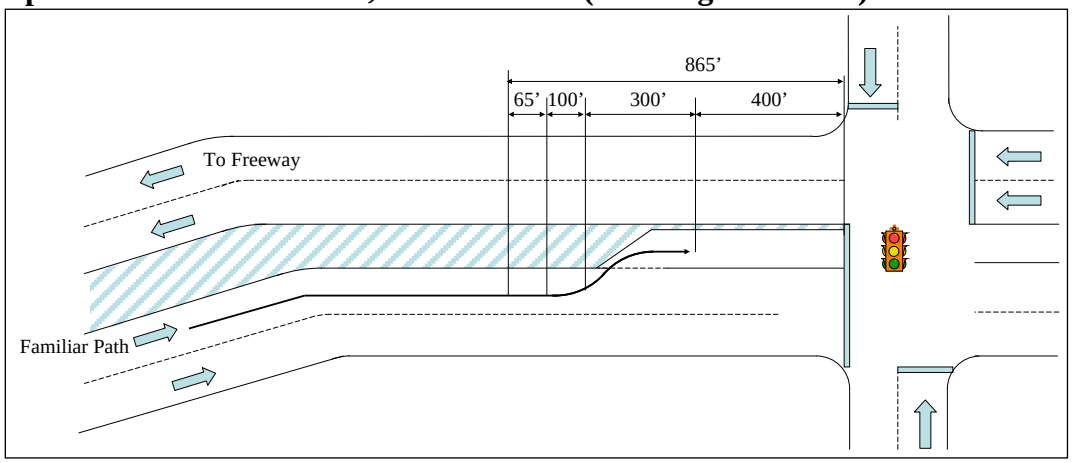
Familiar path (limiting conditions)

d_{FL} = 65’ (PIEV) + 100’ (turn signal) + 300’ (limiting distance into the turn bay) + 400’ (queue)
d_{FL} = 865’

Upstream Functional Area, Familiar Path (Desirable Condition)



Upstream Functional Area, Familiar Path (Limiting Condition)



Unfamiliar path (desirable conditions): d_{UD} = 1,275’
Unfamiliar path (limiting conditions): d_{UL} = 1,165’
Familiar path (desirable condition): d_{FD} = 975’
Familiar path (limiting condition): d_{FL} = 865’

Ideally, the design would need to allow 1,275 feet between the stop bar at the intersection back to the gore point. If the distance available was between 865 feet and 1,165 feet, then drivers using the unfamiliar path would be subject to high speed differentials.

4.8.2 Sight Distance

The length of roadway visible to a driver is referred to as "sight distance." The amount of visible roadway needed by a driver at any given time depends on the maneuvers or decisions that must be made at that moment. The four basic categories of sight distance are:

- Intersection sight distance
- Stopping sight distance
- Decision sight distance
- Passing sight distance

Note: Some portions of the access management process use different sight distance methods than what would be normally used for operations and project development. See OAR 734-051 for more information.

Although each of these is briefly described below, intersection and stopping sight distance are most frequently examined in traffic analysis. For additional information on sight distance refer to ODOT's Highway Design Manual or Section 3.2 of the AASHTO Green Book.[3]

- **Intersection sight distance** is considered adequate when drivers at or approaching an intersection have an unobstructed view of the entire intersection and of sufficient approach lengths of the intersecting roadways to see oncoming vehicles and select appropriate turning gaps. Sight distance must be unobstructed along both approaches at an intersection and across the corners to allow the vehicles simultaneously approaching to see each other and react in time to prevent a collision. Intersection sight distance should be obtained at every road approach, whether it is a signalized intersection or private driveway. In no case should the sight distance be less than safe stopping sight distance (minimum).
- **Stopping sight distance** is the minimum distance required for a vehicle traveling at a particular design speed to come to a complete stop after an obstacle on the road becomes visible. This distance is used frequently for fatal-flaw screening in project analysis.
- **Decision sight distance** should be provided at locations where multiple information processing, decision making, and corrective actions are needed. Sample locations where decision sight distance is needed include unusual intersection or interchange configuration and lane drops.
- **Passing sight distance** is the minimum distance required for a vehicle to safely and comfortably pass another vehicle. If adequate passing sight distance opportunities cannot be accommodated in the project design, passing lanes or climbing lanes should be considered.

4.8.3 Conflict Points

[3] AASHTO A Policy on Geometric Design of Highways and Streets, 6th Edition, 2011.

Introduction

It is good practice to determine the conflict points at intersections and major accesses in the study area for most analysis work other than TSPs. Bicycle and pedestrian conflicts especially should be determined in areas of high multimodal demand such as transit-oriented developments (TODs) and MMAs. Areas with functional area overlaps or overrepresentation of crashes should have the conflict points quantified. The number of conflict points can also be a good alternative screening evaluation criteria.

Every roadway access creates conflict points for drivers, pedestrians, and bicyclists. Conflict points are locations where one vehicle path impacts another. Each conflict point is a possible crash location. Crashes occur at conflict points when one roadway user fails to yield to another. The crash potential associated with each conflict point varies depending on the complexity, volume of the movements, and speed. Multilane highways have more conflict points and a higher crash potential because of the increased exposure area, exposure time, and potential for obstructed sight distance by vehicles in adjacent lanes. Reducing the number of conflict points decreases crash potential.

Conflict points are classified as diverging, merging, weaving, turning, and crossing. Crossing paths are major conflicts. Diverging, merging, and weaving paths are minor conflict points. Diverging conflicts occur where one path separates into two. Merging conflicts occur where two paths come together. Weaving conflicts involve vehicles changing paths. Both major and minor conflict points may occur at high speeds, but minor conflicts typically involve vehicles traveling in the same direction. Vehicles crossing paths at high speeds may not have the sight distance or ability to minimize the severity of the crash.

Turning and crossing conflicts can also involve pedestrians and bicyclists. A crossing conflict point, which involves pedestrians and bicyclists, occurs where a vehicle path passes through a crosswalk or bike path; a turning conflict point occurs where the turning vehicle path passes through a crosswalk or bike path. Pedestrian crashes are not limited by locations. The pedestrian-vehicle conflicts are counted separately from vehicle-vehicle conflict points.

This section is a reference only. Every intersection is unique and must be analyzed appropriately. The analysis should consider geometry, permitted turn movements, the level of control of non-permitted movements, and the number of lanes for each movement. Reducing conflict points allows drivers to move through an area with less distraction so that traffic flows smoothly at constant speeds. With fewer conflict points, drivers can better maintain their attention on roadway conditions.

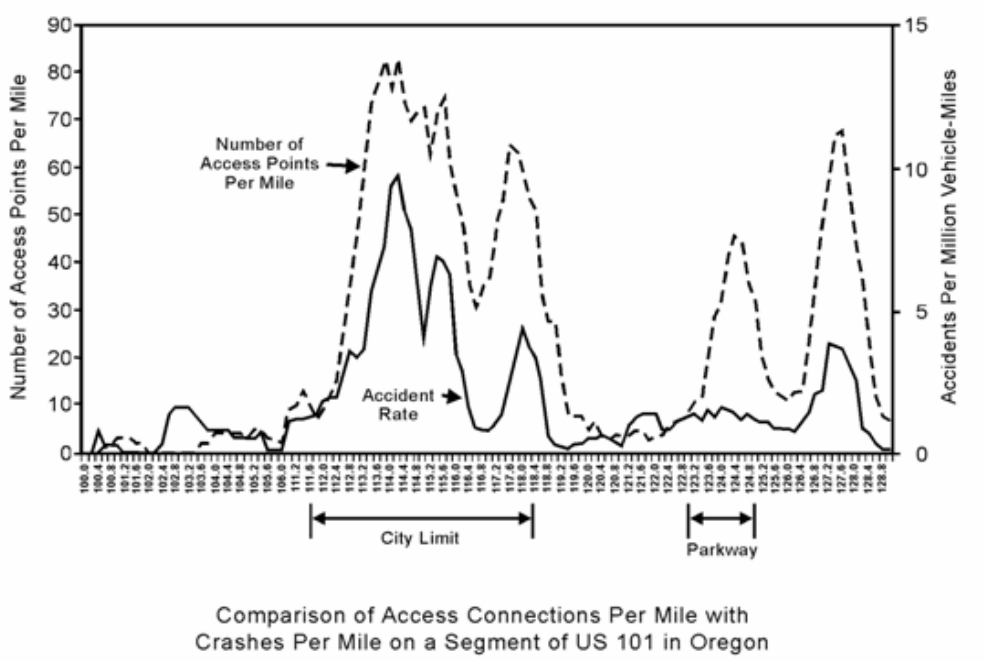
Conflict points can be reduced through three measures:

- Limit the number and/or type of access points
- Install medians, channelization, and other control devices (e.g., roundabouts) to restrict or control turning movements
- Grade separate traffic flows

Limit the Number and/or Type of Access Points
Limiting driveways or access points should be considered at locations with limited sight distance, high crash frequency, high volume-to-capacity ratios, or poor access to facilities. Combining driveways reduces access and conflict points. Accommodating entering traffic at one location simplifies driver tasks. Combining multiple driveways into one joint-use driveway directs traffic more safely, clearly, and efficiently.

Exhibit 4-31 shows the relationship between access density and crash rates in Lincoln City and Lincoln Beach. The crash rates increase as the density of access points increases. The area labeled City Limit in Exhibit 4-31 is Lincoln City on US101, which has a high density of access points. The area labeled Parkway is in Lincoln Beach where a non-traversable landscaped median limits access to driveways and side streets. Crash rates in the Parkway section are greatly reduced.

Exhibit 4-31: Access Points Per Mile vs. Crashes Per Mile



From Analysis of Traffic Accidents Within the Functional Area of Intersections and Driveways Technical Report Trans 1-95 1995

Locating driveways on lower classification roadways or backage/frontage roads also reduces the number of conflict points along the main roadway. Removing driveways from an arterial or a collector decreases delay caused by turning vehicles. Diverting traffic to local roads directs traffic to one access point and simplifies conditions.

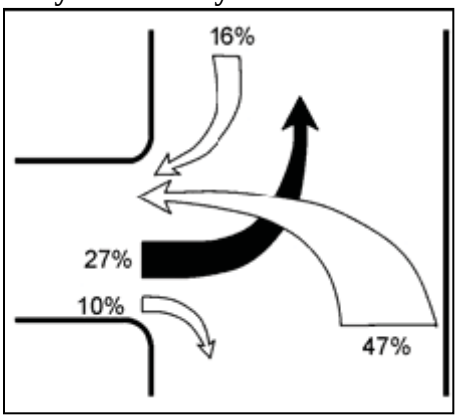
Refer to OAR 734, Division 51 for information concerning signal spacing, backage/frontage roads, or access rights. Sometimes access rights to individual parcels are obtained. Rules

regarding obtaining property access rights to state highways, signal spacing, and backage/frontage roads are found in OAR 734, Division 51 and on the ODOT Access Management website.

Non-Traversable Median or Traffic Control Devices to Restrict Turning Movements
Medians are a roadway element intended to separate traffic traveling in opposite directions. A median can be traversable or non-traversable. A traversable median may be a painted or concrete mountable median that allows emergency traffic to cross over it. A non-traversable median is a physical barrier (examples include the Jersey barrier, landscaped, or grassy median) that separates opposing traffic and prohibits movement across the median. Installing a non-traversable median restricts turning and crossing movements at roadway accesses. Non-traversable medians reduce conflict points by eliminating turn movements that impact the general traffic flow. More information about median types can be found in Chapter 5.5 of the Oregon Highway Design Manual (HDM).

A median that impacts the State Highway Freight System must comply with the ORS 366.215 which states that the Oregon Transportation Commission (OTC) may not permanently reduce the vehicle-carrying capacity of an identified freight route when altering, relocating, changing, or realigning a state highway unless safety or access considerations require the reduction. According to the Transportation Research Board, Access Management Manual 2003, 47% of crashes involve left-turn ingress movements and 27% of crashes involve left-turn egress movements, shown in Exhibit 4-32. Controlling turn movements can allow one turn direction and divert others elsewhere.

Exhibit 4-32: Percent of Driveway Crashes by Movement



Non-traversable medians reduce overall crash frequency, improve pedestrian safety, and enhance visuals. They restrict traffic from making complex left turns and provide median openings at designated locations. They may also provide a pedestrian refuge between directions of traffic and decrease pedestrian clearance intervals. Including a raised median can significantly reduce pedestrian collisions at uncontrolled locations, with CMFs of 0.61 when used with an unmarked crosswalk and 0.54 when used with marked crosswalks.[4] Replacing a two-way left-turn lane with

[4] Zegeer, C. V., Stewart, R., Huang, H., and Lagerwey, P., "Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines." FHWA-RD-01-075, McLean, Va., Federal Highway Administration, (2002)

a raised median in urban environments has demonstrated a CMF of 0.77 for all crashes.[5] Landscaping large medians improves the aesthetics of the roadway. Although medians improve the roadway, they are costly and may require the acquisition of right-of-way.

Grade-Separated Roadways

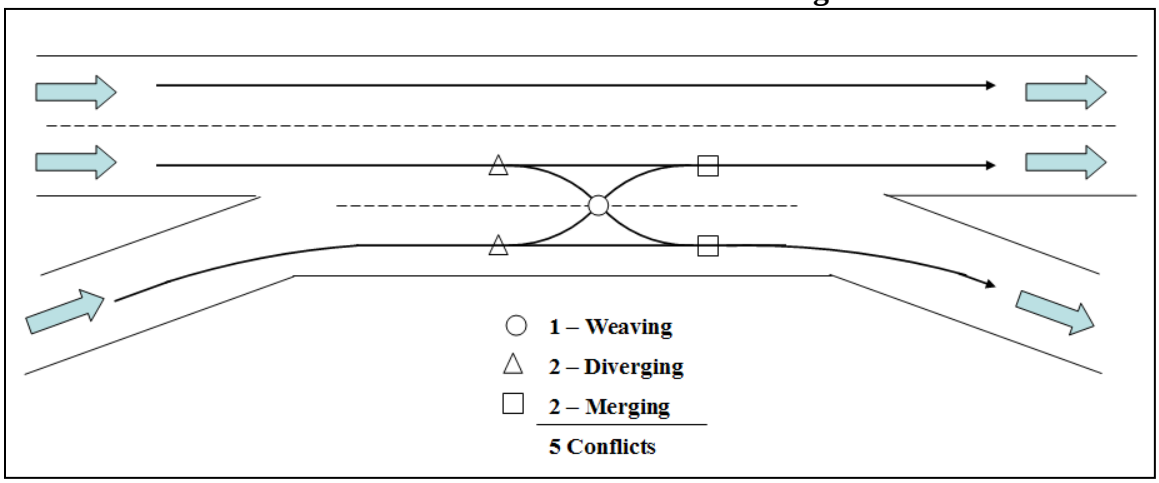
Grade-separated roadways are locations where one roadway crosses over the other. Grade separation should be considered where an at-grade signal cannot accommodate traffic capacity or where crash history indicates a need for grade separation. Conflict points are decreased by removing major flow grade crossings and by rerouting turning traffic. Interchanges are grade-separated connections of two or more roads. Interchanges reduce conflict points and the severity of crashes. Although interchanges occupy a large amount of space and require costly structural work, they reduce delay, reduce crashes, and improve efficiency of a corridor.

It can be difficult to accommodate pedestrians at interchanges because of the separation of paths. For more information about accommodating pedestrians or bicyclists, refer to the Oregon Bicycle and Pedestrian Plan and the related Bicycle & Pedestrian Design Guide.

Weaving Segments

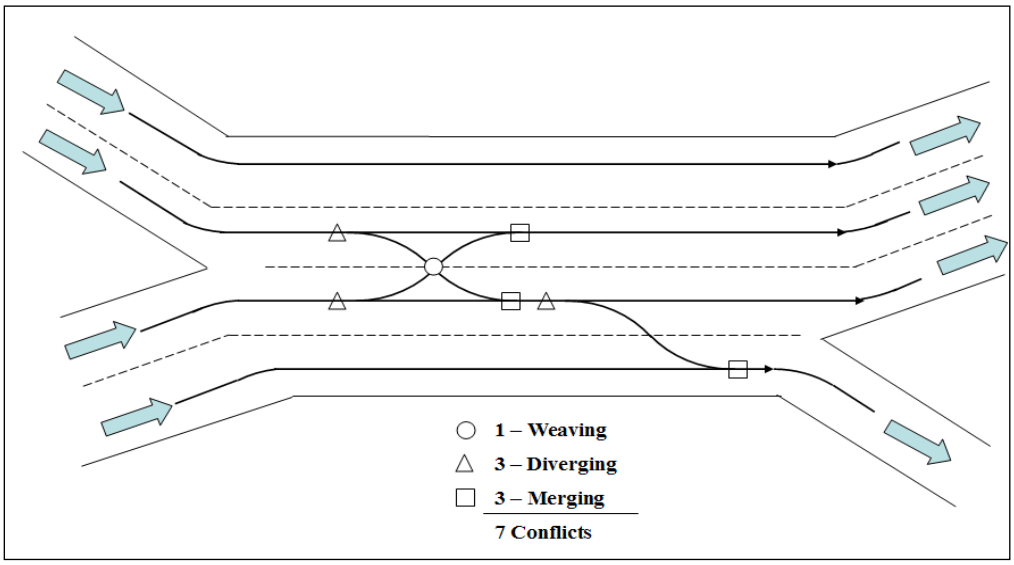
Weaving segments, where vehicles traveling in the same direction cross paths, create several conflict points. Exhibit 4-33 and Exhibit 4-34 show two examples of weaving vehicle paths entering and exiting the roadway. A single-lane change weaving segment has five minor conflict points. A lane-balanced two-lane change weaving segment has seven minor conflict points. More information about weaving segments can be found in Chapter 12.

Exhibit 4-33: Conflict Points for a Weave with One Lane Change



[5] Mauga, T. and Kaseko, M., "Modeling and Evaluating the Safety Impacts of Access Management (AM) Features in the Las Vegas Valley." Transportation Research Record: Journal of the Transportation Research Board 2171, pp. 57-65, 2010

Exhibit 4-34: Conflict Points for a Weave with Two Lane Changes



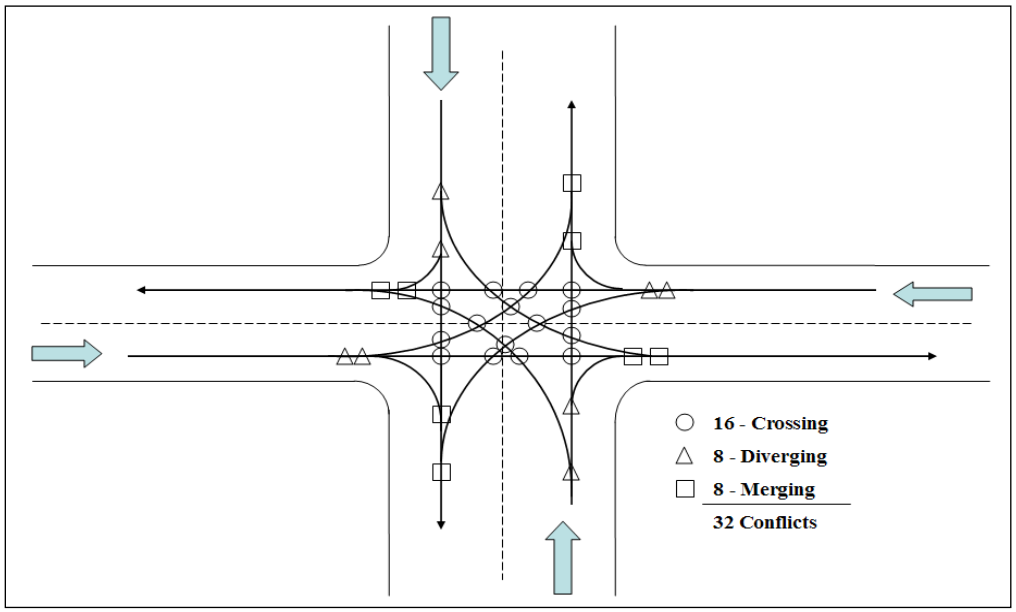
Unchannelized Intersections

Unchannelized intersections are where two roadways without medians and/or turn restrictions intersect and that allow full access to traffic. Every such intersection should be analyzed as a unique situation. Unchannelized intersections may have other forms of traffic control such as a traffic signal. Although a traffic signal does not reduce the number of conflict points, it increases driver communication and awareness. For movements that operate with separate signal phases, the exposure to conflicts is significantly reduced compared to movements that operate with unsignalized control or permissive signal phasing.

Note: The intersections analyzed and illustrated in the figures are typical configurations; however, for clarity, turn lanes are not included. The addition of single turn lanes should not increase the number of conflict points. Any additional through or dual turn lanes must be included in the analysis.

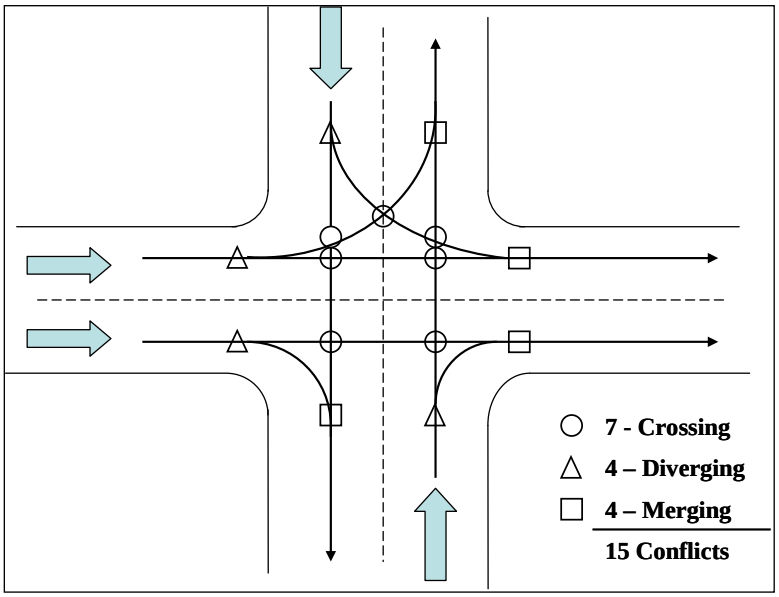
Four-Leg Intersection
The four-leg intersection with no medians, shown in Exhibit 4-35, has the most conflict points of all intersections. The four-leg intersection allows movement in all directions and is the most familiar to drivers.

Exhibit 4-35: Conflict Points for a Four-Leg (Both Two-Way Roads) Intersection



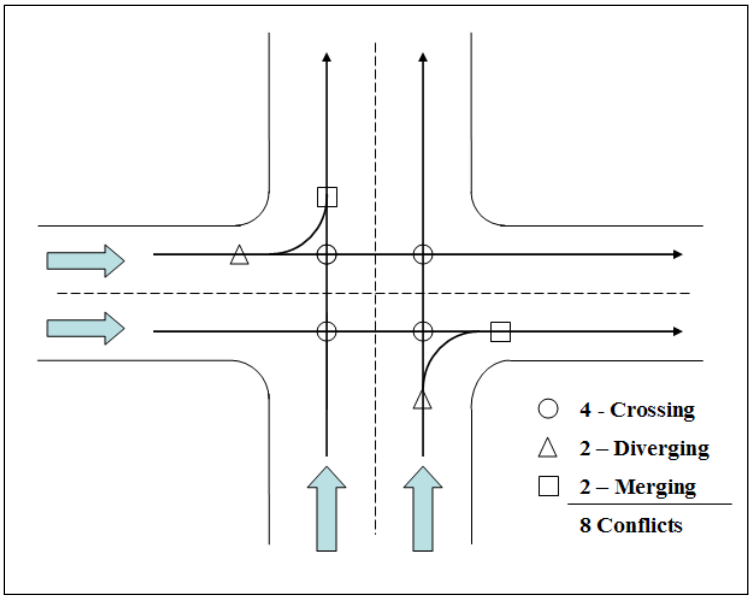
Four-Leg Intersection of a Two-Way Road and a One-Way Road
A four-leg intersection of a two-way road and a one-way road is shown in Exhibit 4-36. The one-way road may be part of a couplet. The one-way road limits turns and reduces conflict points.

Exhibit 4-36: Conflict Points for a Four-Leg Intersection of a Two-Way Road and a One-Way Road



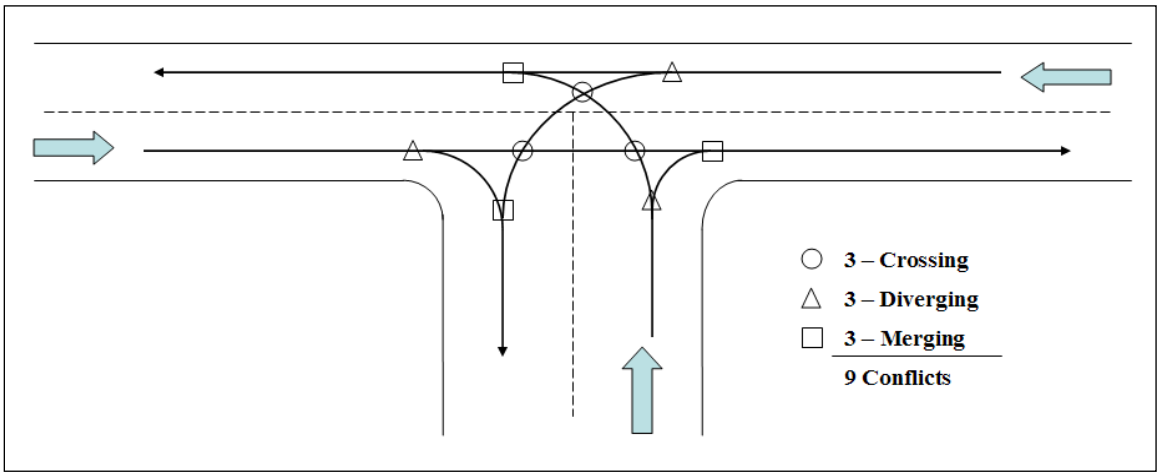
Four-Leg Intersection of Two One-Way Roads
A four-leg intersection of two one-way roads is shown in Exhibit 4-37. The one-way roads may be part of a couplet. The one-way roads limits turns and reduce conflict points.

Exhibit 4-37: Conflict Points by Lane for a Four-Leg Intersection of Two One-Way Roads



T-Intersection
A T-intersection is a location where one roadway ends at its intersection with another roadway. The T-intersection shown in Exhibit 4-38 permits turns in all directions. The intersection in the figure has nine conflict points, three of which are major.

Exhibit 4-38: Conflict Points for the T-Intersection

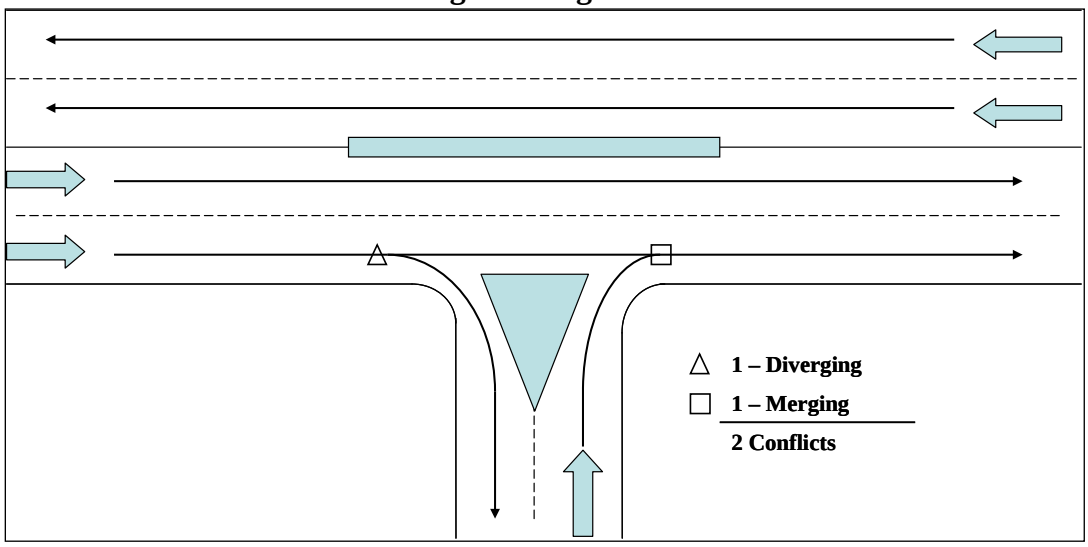


Channelized Intersections
A channelized intersection restricts turn movements by signs, pavement markings, medians, or some other type of traffic control. Channelized intersections include, but are not exclusive to, right-in/right-out intersection, non-traversable median separated four leg intersection, left-turn ingress intersection, left-turn egress intersection, and roundabout. Both ends of the non-traversable median should be analyzed for the required traffic control in order to meet traffic needs safely.

Intersections and driveways that are restricted to right-in/right-out have two conflict points, but complex channelized intersections may have up to eleven conflict points.

Right-In/Right-Out (RIRO) Intersection
The right-in/right-out (RIRO) geometry shown in Exhibit 4-39 restricts traffic to right-turn movements only and forces roadway users to complete a left turn at another location either in a permitted U-turn or at a completely different intersection or roadway. Additional lane changing/weaving may also be necessary. This reduces crashes at the location of the right-in/right-out intersection, but requires left-turning vehicles to travel farther to get to their destination. The analyst needs to address where the left-turning vehicles will end up so potential safety issues are not created elsewhere.

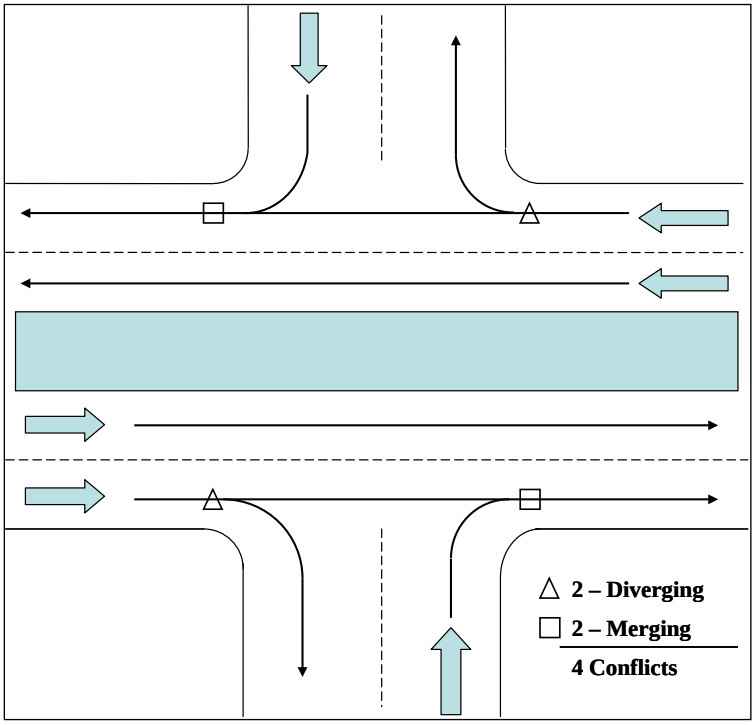
Exhibit 4-39: Conflict Points for the Right-In/Right-Out Intersection



Non-Traversable Median Separated Four-Leg Intersection

Installing a non-traversable median changes the traffic flows of the typical four-leg intersection by effectively creating two right-in/right-out intersections as shown in Exhibit 4-40. Left-turning or crossing vehicles must complete those maneuvers at another location, eliminating the major conflict points. This reduces the conflict points from the typical 32 to just four. The intersection is restricted to right turns, which improves safety and operations but also adds out-of-direction travel.

Exhibit 4-40: Conflict Points for a Median Separated Four-Leg Intersection



Roundabout

Roundabouts are considered at locations where speeds and volumes may not require a traffic signal for smooth operations. The roundabout, shown in Exhibit 4-41, directs all traffic to move in a counter-clockwise direction that allows movements in all directions. This limits conflict points to merging and diverging movements. It also reduces vehicular travel speed, which reduces the severity of any associated crashes. Bypass lanes would produce additional conflict points at their respective merge and diverge locations. A multilane roundabout, shown in Exhibit 4-42, has more conflict points and increased capacity. Chapter 13 contains capacity analysis procedures for roundabouts and bypass lanes.

Exhibit 4-41: Conflict Points for a Single Lane Roundabout

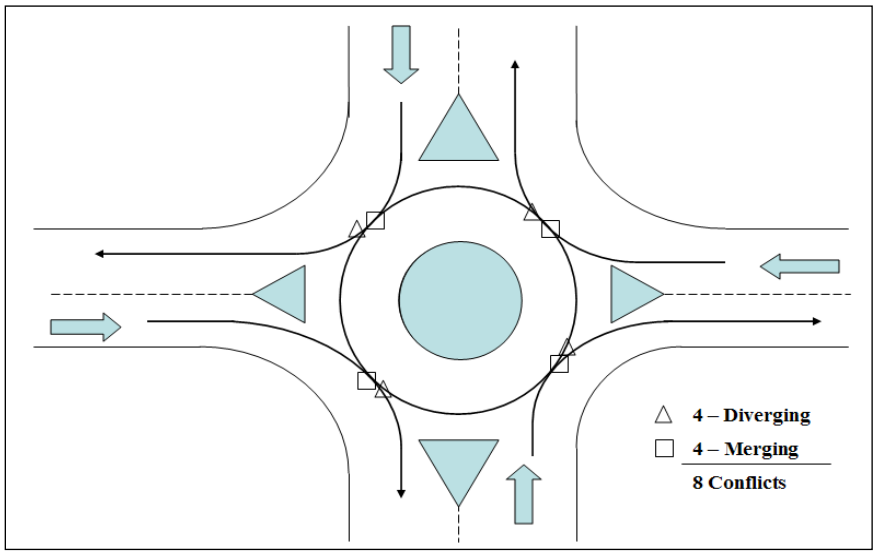
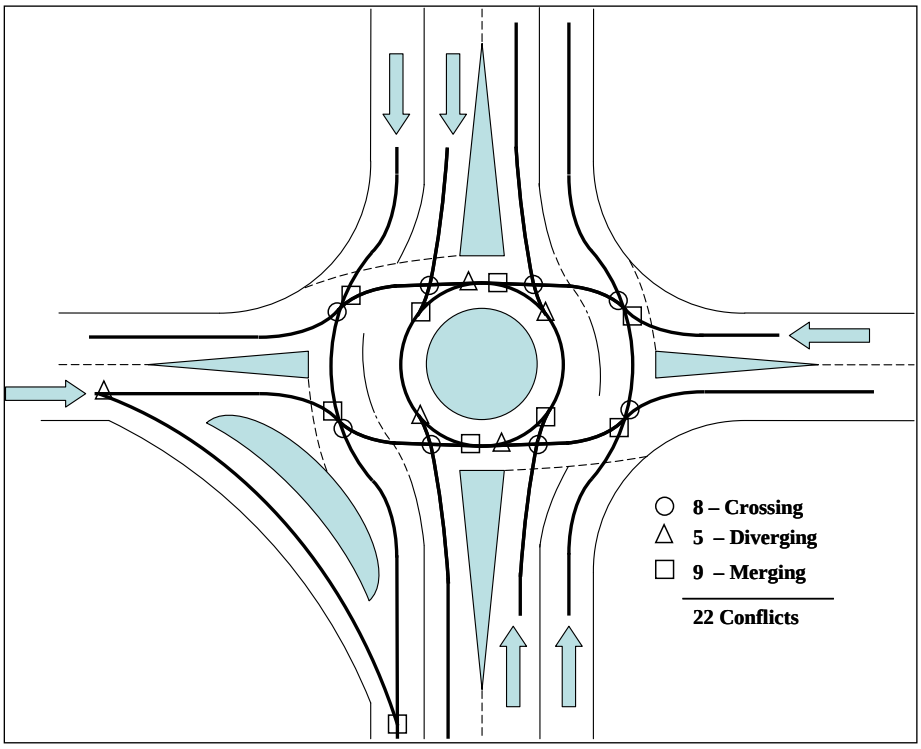


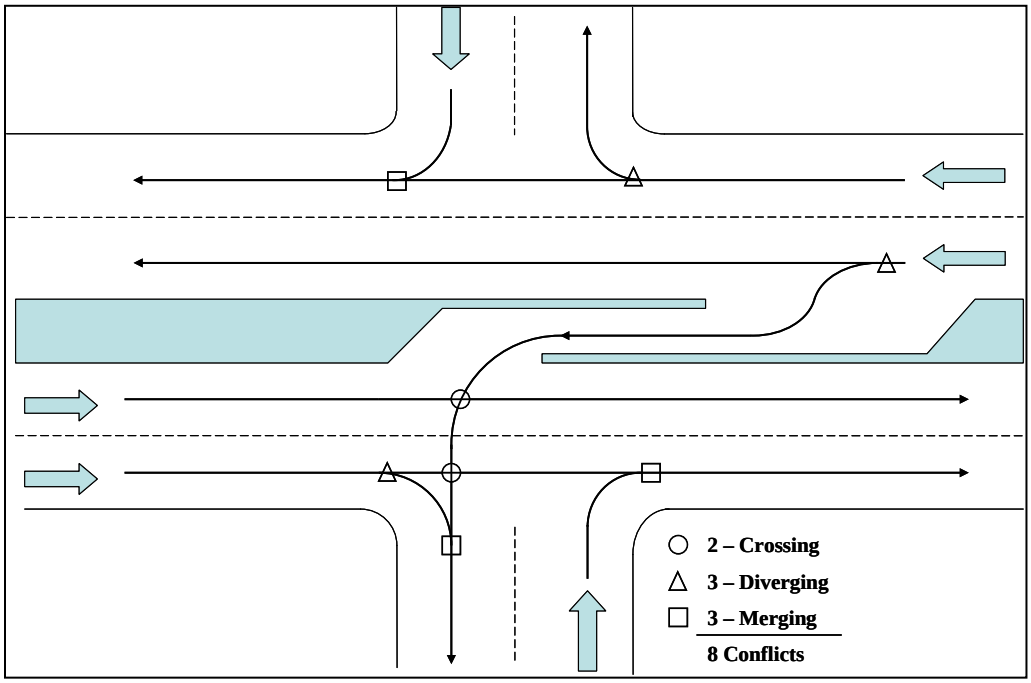
Exhibit 4-42: Conflict Points for a Multilane Roundabout



Left-Turn Ingress Intersection

The left-turn ingress intersection shown in Exhibit 4-43 permits one direction of traffic to turn left, from a turn bay, while the opposing left and crossing movements are prohibited. The permitted left turn may have significantly higher volumes or may service a critical access.

Exhibit 4-43: Conflict Points for a Median with One Left-Turn Ingress Intersection



Two Left-Turn Ingresses Intersection

Exhibit 4-44 shows the geometry for two left-turn ingresses. Only the traffic turning left into the access street is permitted through the median. Vehicles can remain in the median until there is a sufficient gap to complete the turn. More left-turn egress and left-turn ingress examples are shown in Exhibit 4-45 through Exhibit 4-47. Locations that provide a median restricting egress or ingress turns require median openings for vehicles to make U-turns. The median openings add a merge and a diverge point to the segment or intersection. Any intersection along a median that permits U-turns must be analyzed for conflict points, with the inclusion of the merge and diverge conflict points caused by the U-turn.

Exhibit 4-44: Conflict Points for a Median with Two Left Turn Ingresses Intersection

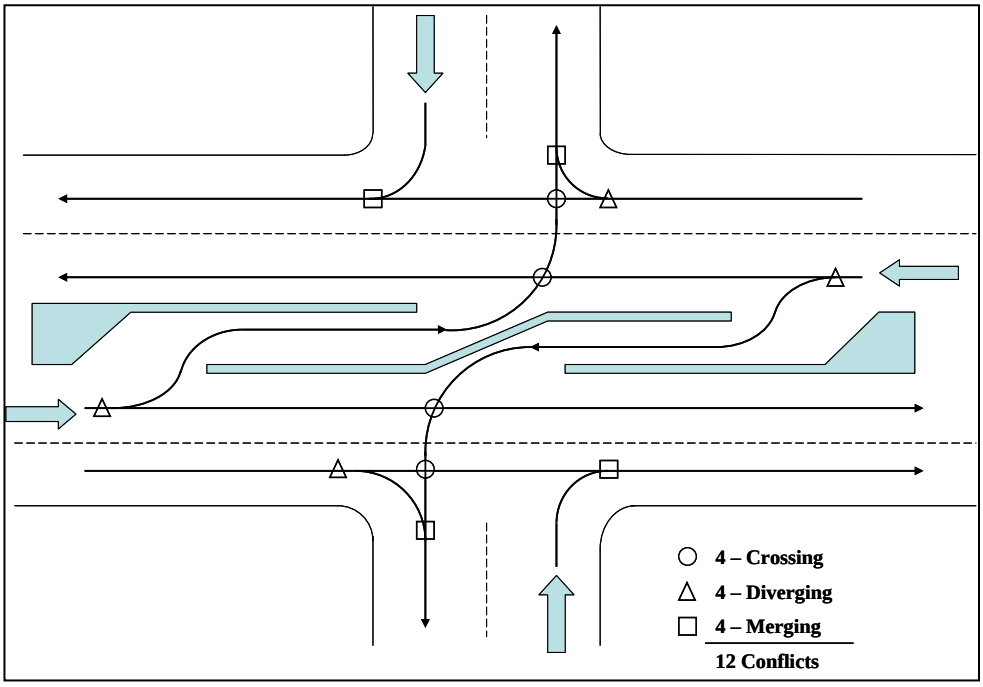


Exhibit 4-45: Conflict Points for a Median with a Left-Turn Ingress and Egress Intersection

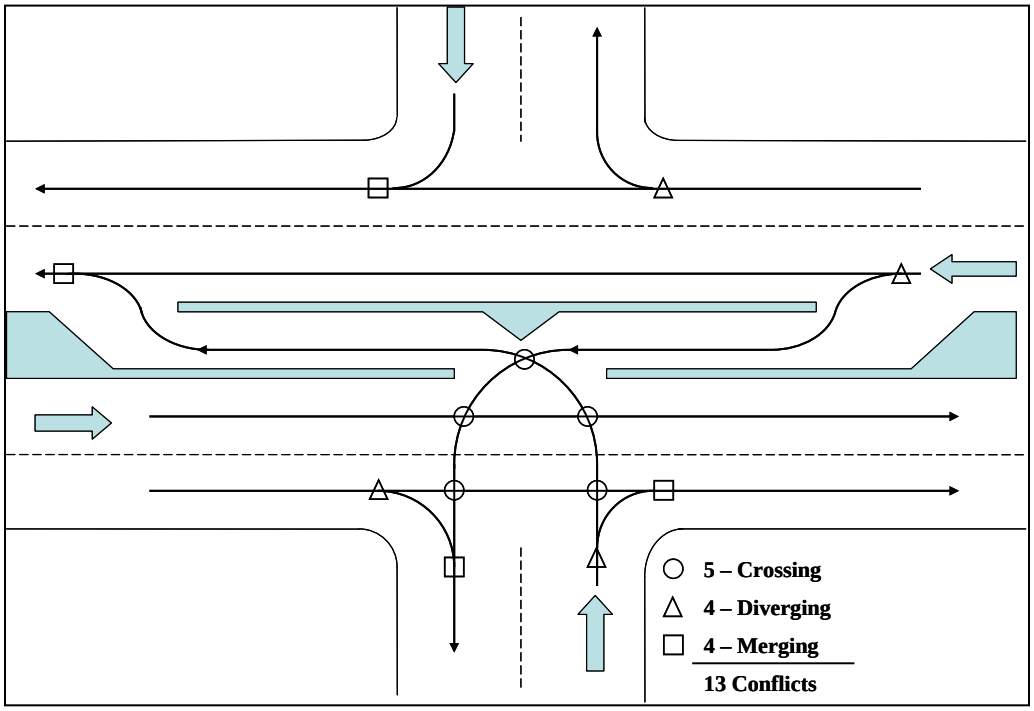


Exhibit 4-46: Conflict Points for a Median with One Left-Turn Egress Intersection

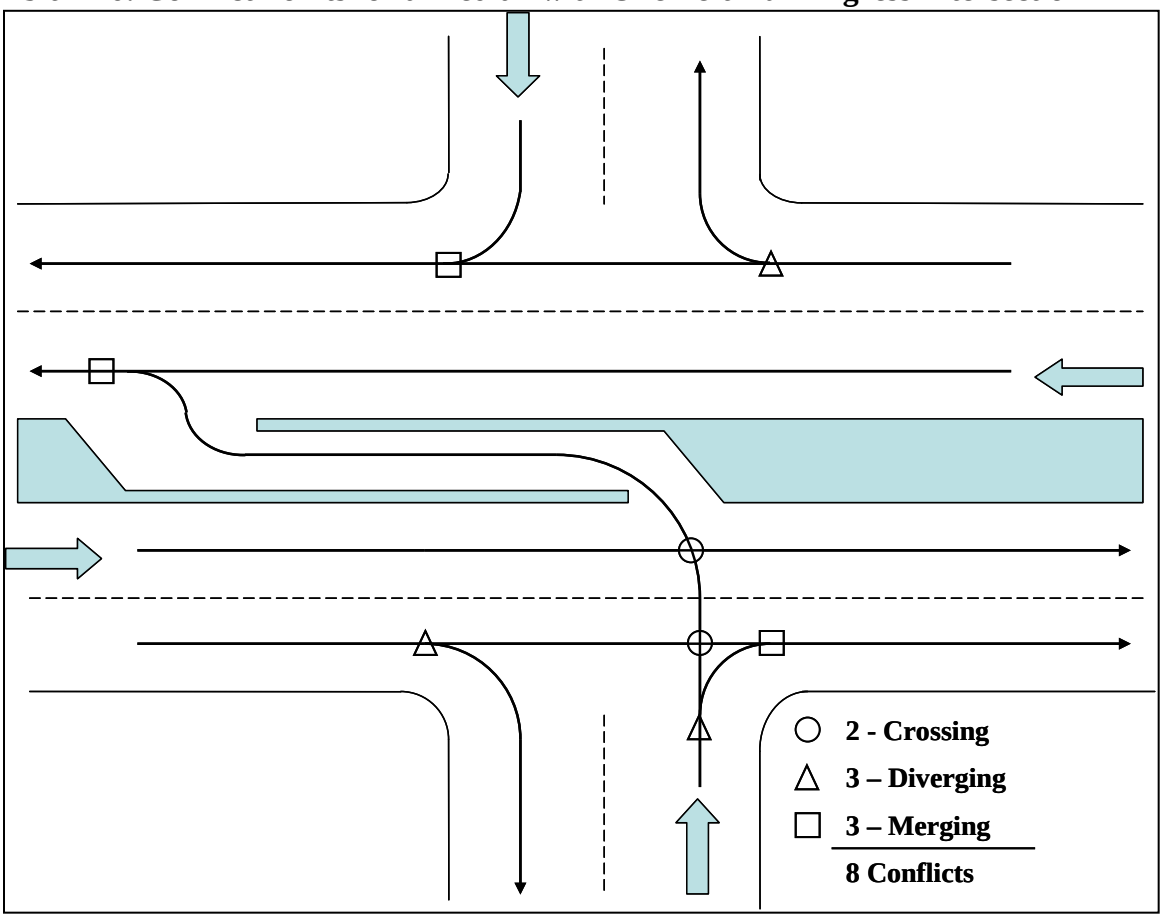
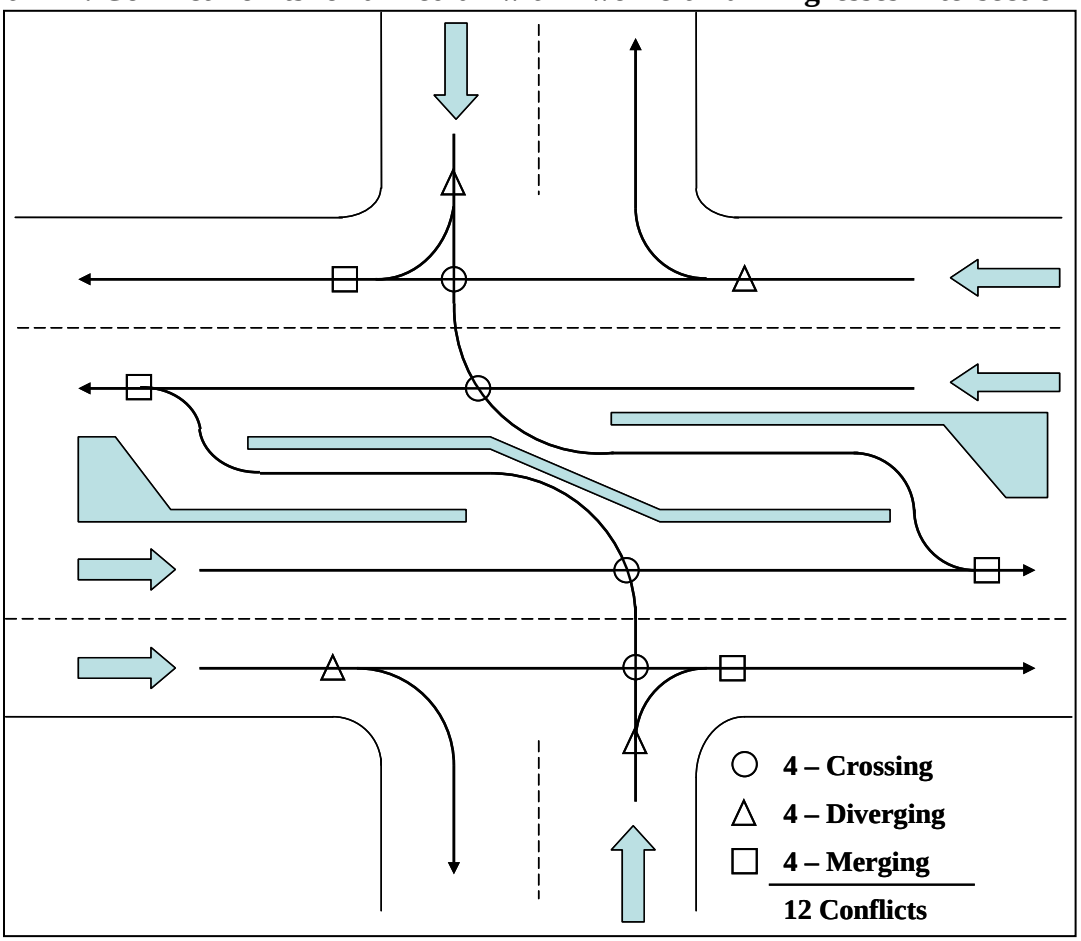


Exhibit 4-47: Conflict Points for a Median with Two Left-Turn Egresses Intersection



Indirect Left Turns

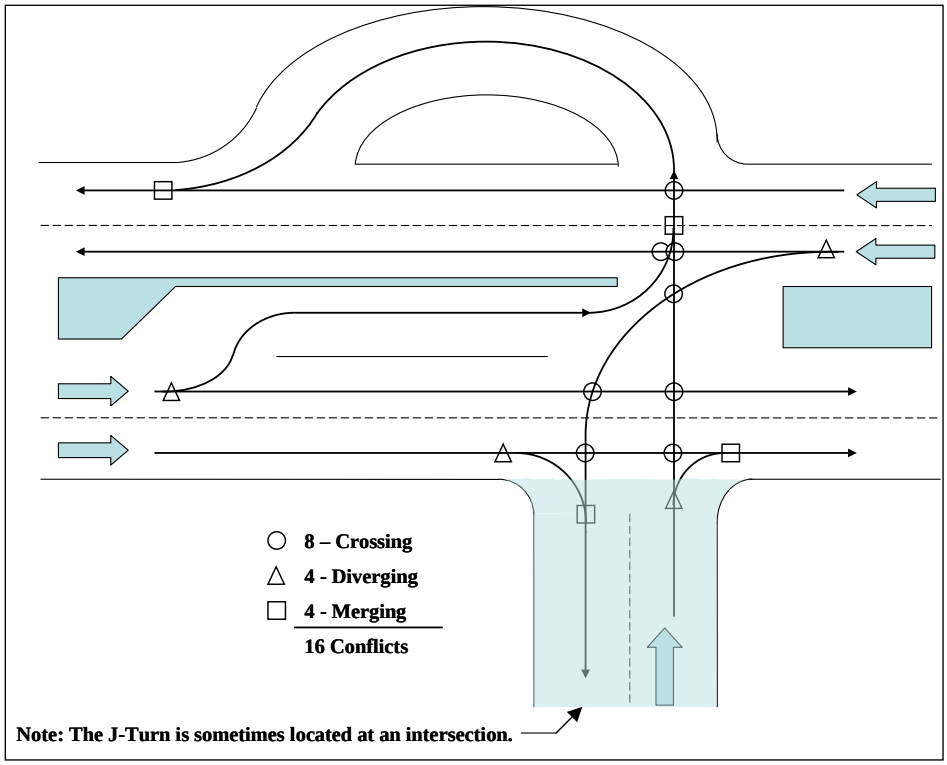
Some intersections require creative accommodations for left turning vehicles. The treatment of left turns must be considered at intersections with restricted turns, high volumes or high speeds to achieve the greatest capacity and safety for traffic.

J-Turn

The J-turn is an opportunity for larger vehicles to turn left on either side of a non-traversable median. The median restricts intersections and driveways to right-in/right-out, which reduces the conflict points. Vehicles can turn left at median openings which may be accompanied by a stand-alone J-turn, a J-turn intersection, or a signalized J-turn intersection. The J-turn intersection shown in Exhibit 4-48 has sixteen conflict points. Locations where the J-turn does not meet a crossing roadway or driveway have three conflict points: one diverge, one crossing, and one merge conflict point.

The J-turn intersection also allow turning vehicles to join traffic moving in its desired direction. An add-lane at the J-turn will eliminate the merge conflict point, shown in Exhibit 4-48, and increase the capacity of the segment. The J-turn reduces the congestion and improves the safety of median openings. A J-turn intersection may or may not have pedestrian crossings.

Exhibit 4-48: Conflict Points for a J-Turn Intersection

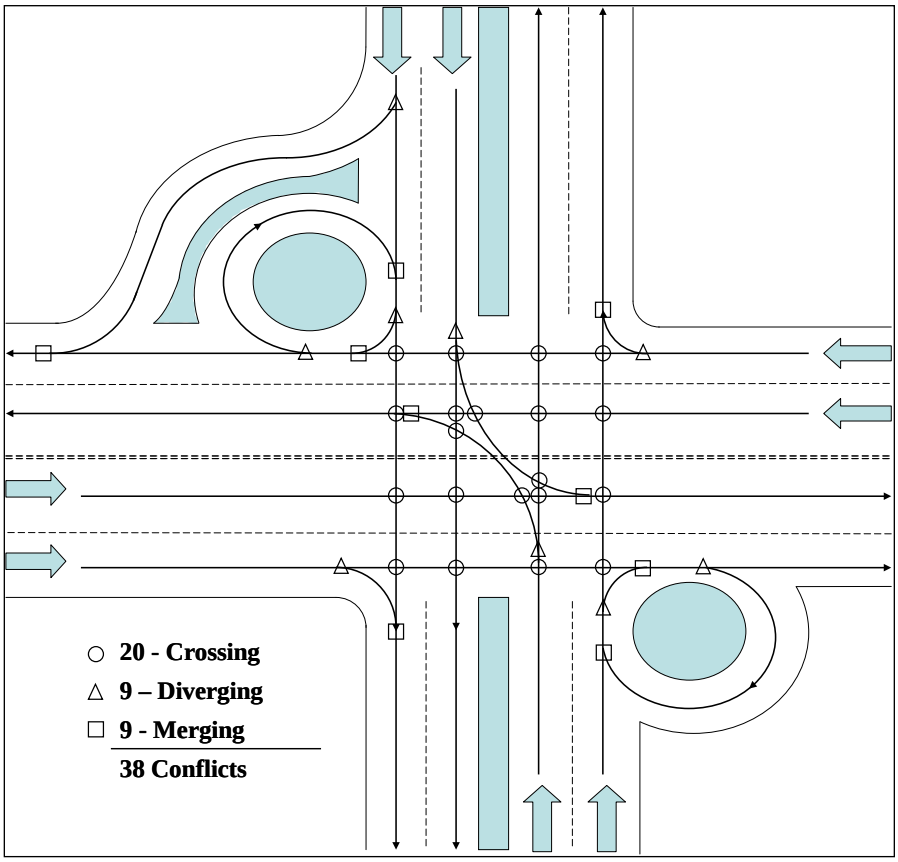


Jug Handle Intersection

The jug handle intersection, shown in Exhibit 4-49, is commonly used when there are high left-turn volumes which cannot be accommodated by a signalized intersection. The left-turning traffic passes through the intersection as a through movement both before and after diverging onto a loop ramp to complete the left turn. This reduces the congestion by removing phases from the traffic signal and improves the safety of the intersection by reducing the number of conflict points. The jug handle can be located in various quadrants of the intersection depending on the restricted turn movements.

Note: Jug handle configurations are not always installed as pairs and are not always accompanied with right turn bypass lanes.

Exhibit 4-49: Conflict Points for a Jug Handle Intersection



Pedestrian Conflict Points

Pedestrian conflict points are counted separately from vehicle-vehicle conflict points. Pedestrian conflict points are located at the intersection crosswalks or midblock crossings. Turning vehicles and crossing vehicles are counted separately. Intersections with wide cross-sections, such as a median separated four-way intersection, are more attractive to pedestrians when a curb-protected pedestrian refuge is provided between directions of travel. Exhibit 4-50 through Exhibit 4-52 show examples of pedestrian conflict points for intersections of two-way roads with and without a median and a four-way intersection with restricted left-turn ingresses.

Exhibit 4-50: Pedestrian Conflict Points for a Four-Leg Intersection

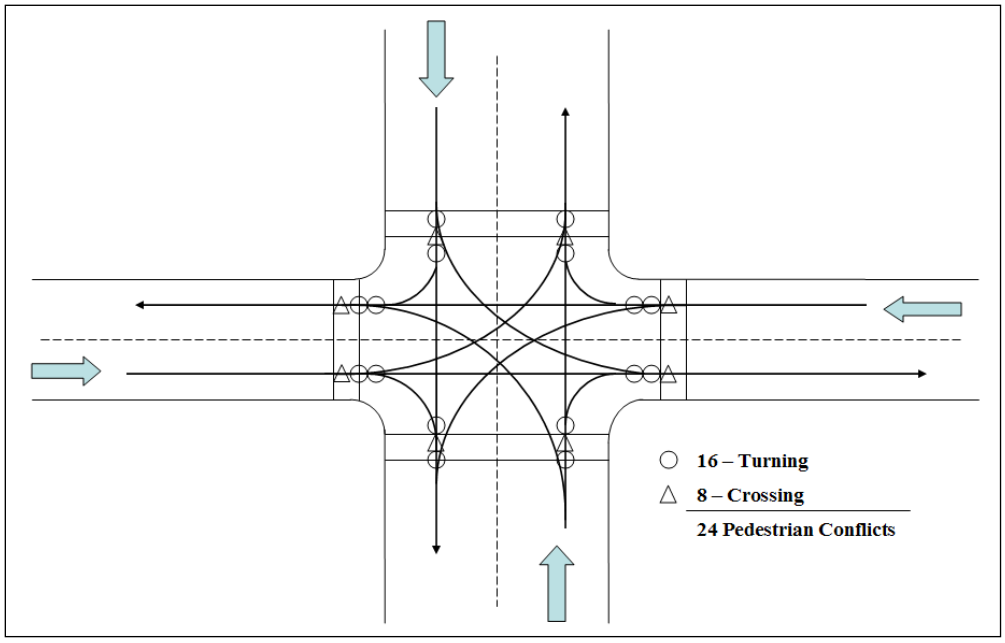


Exhibit 4-51: Pedestrian Conflict Points for a Median Separated Four-Leg Intersection

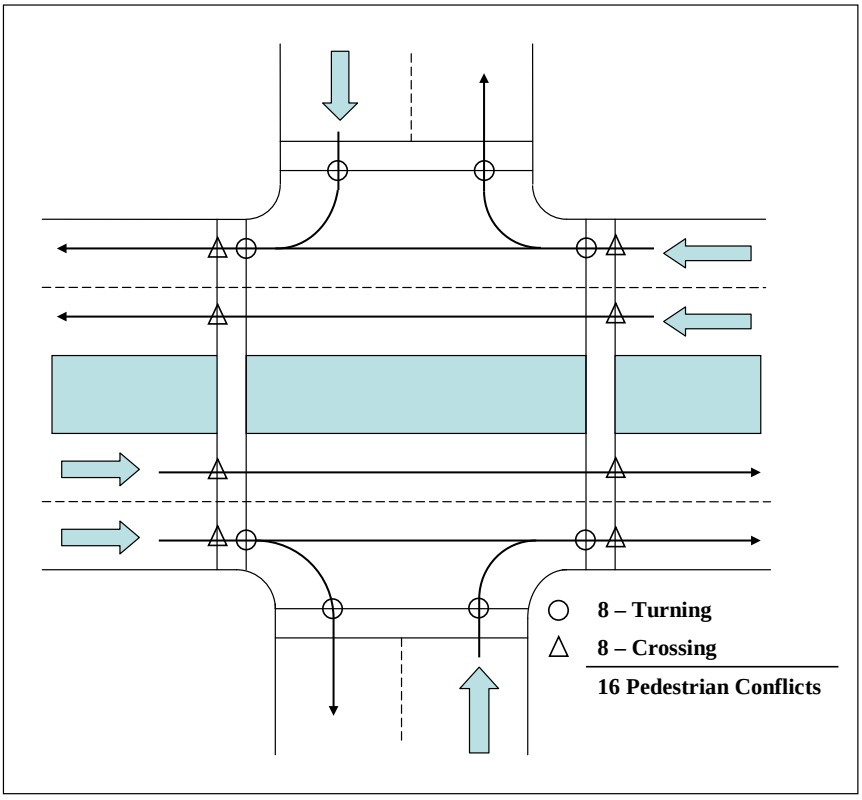
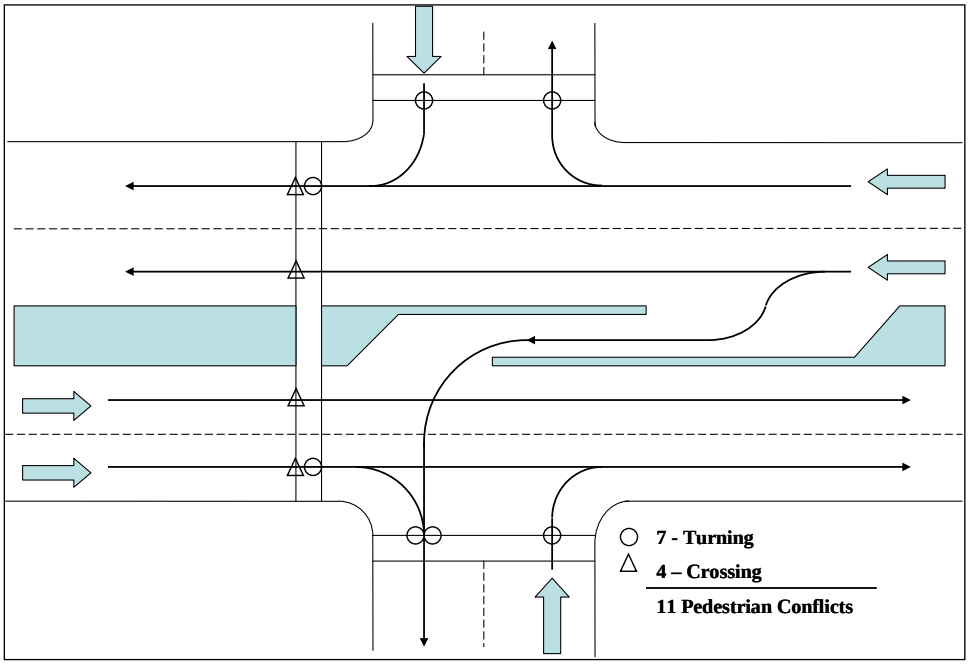


Exhibit 4-52: Pedestrian Conflict Points for a Median with One Left-Turn Ingress Intersection

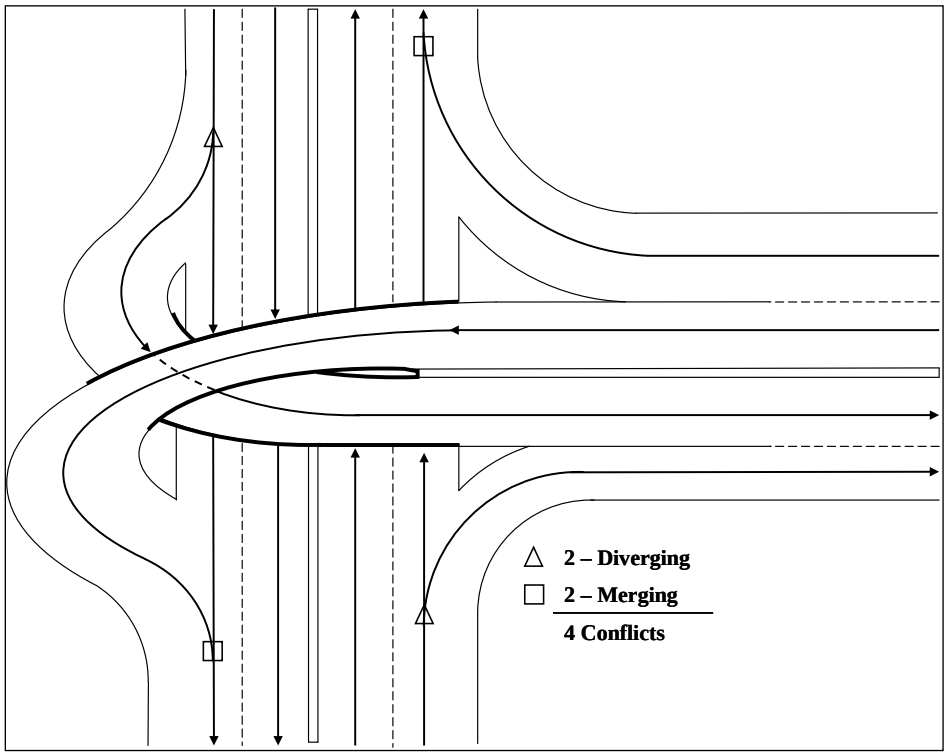


Grade-Separated Access
High-speed and high-volume junctions may need grade-separated access to meet traffic capacity while reducing crashes. Interchanges remove major flow grade crossings increasing capacity and reducing conflict points. Interchanges may have as few as six conflict points (directional interchange) or as many as 28 conflict points (left-turn flyover).

Directional Interchange
The directional interchange has all free flow ramps with only four (three diverging and three merging) minor conflict points in the system as seen in Exhibit 4-53. It is similar to a T-intersection with large volumes and high speeds. Traffic does not cross paths due to the grade separation. Each free-flow connection has a merge and diverge conflict point. Due to the high volumes and speed, pedestrian crossing does not occur at the street level.

The full-directional interchange, shown in Exhibit 4-53, has three levels of grade separation. A partial directional interchange is a junction where one leg has lower speeds and is accommodated by a loop ramp. A partial directional interchange has only two levels of grade separation. Since each free-flow ramp has one merge and one diverge conflict point, the partial directional interchange has the same conflict points as the full-directional interchange. Likewise, a four-way directional interchange would have eight conflict points, four merge and four diverge. Add itional conflict points could be introduced if ramps are closely spaced.

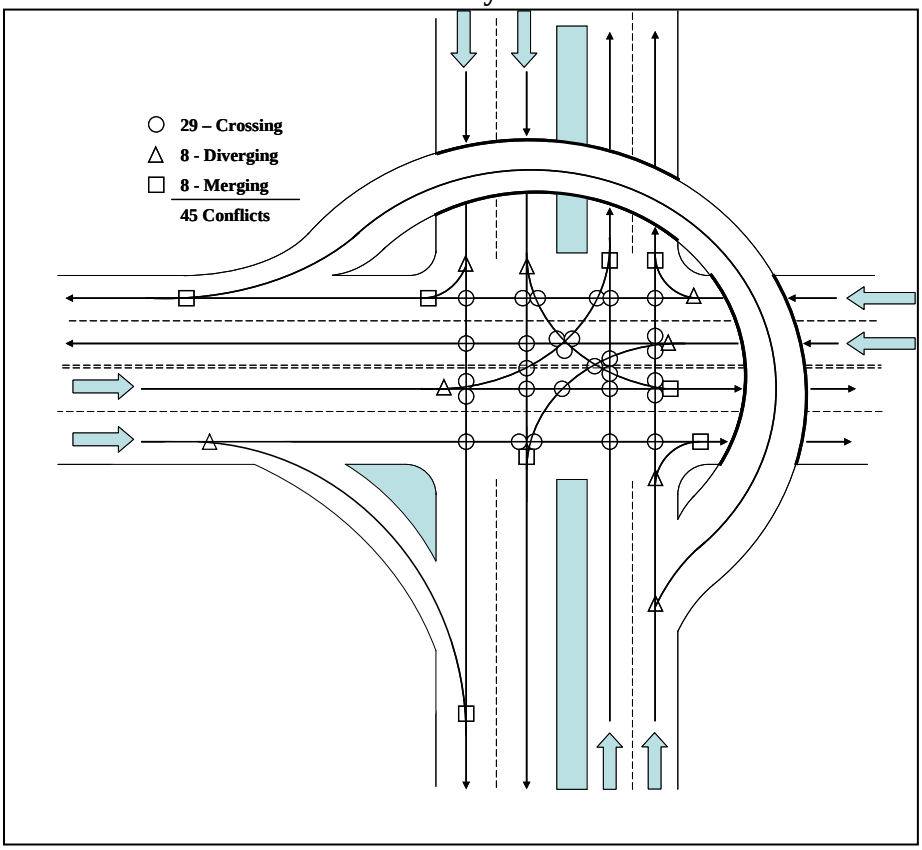
Exhibit 4-53: Conflict Points for a Directional Interchange



Left-Turn Flyover Intersection

The left-turn flyover intersection, shown in Exhibit 4-54, is commonly used when one direction has high left-turn volumes that cannot be accommodated by a signalized intersection. The left-turning traffic is grade-separated as it crosses over the opposing traffic, reducing conflict points and congestion. Pedestrian crossings may or may not be modified from the standard intersection.

Exhibit 4-54: Conflict Points for a Left-Turn Flyover Intersection

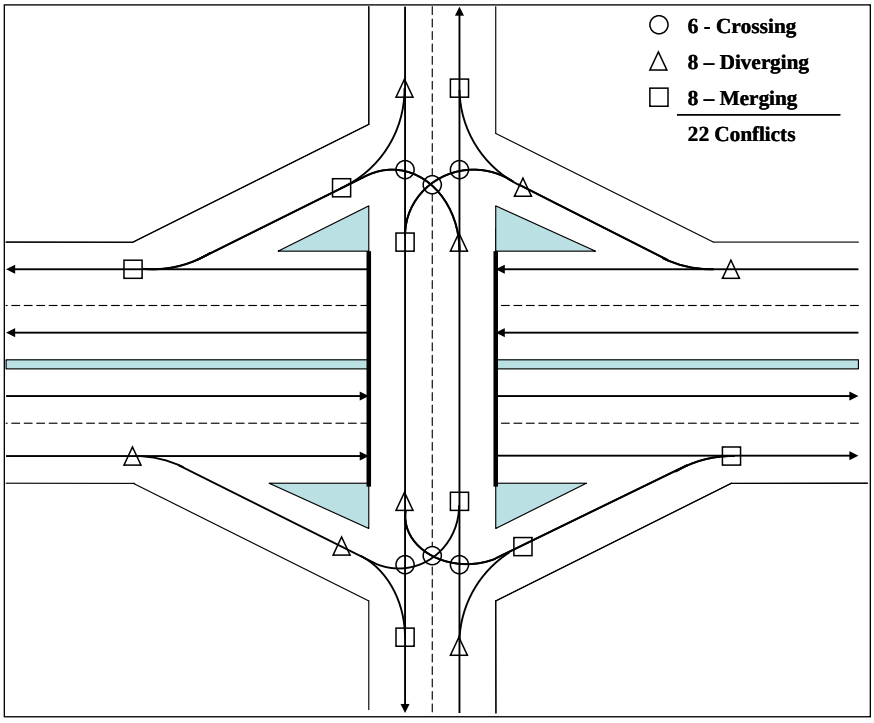


Diamond Interchange

The diamond interchange has four ramps and may have traffic control at the minor road. Traffic is directed to turn on or off each ramp, which creates conflict points. There is potential for weaving conflicts if this interchange has two or more lanes in each direction. Conventional, compressed, and tight diamond interchanges all travel the same paths and the conflict points are the same. Exhibit 4-55 shows the conflict point configuration for a conventional diamond interchange.

Pedestrian crossings are generally not provided at locations along the major, free-flowing movement.

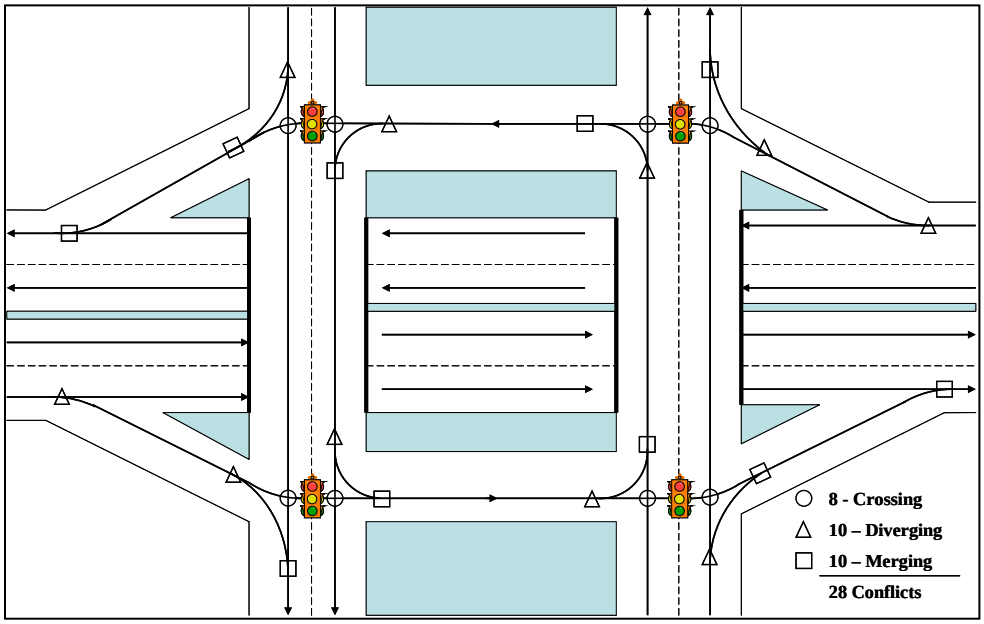
Exhibit 4-55: Conflict Points for a Diamond Interchange



Split Diamond Interchange

A split diamond interchange, shown in Exhibit 4-56, has only four ramps that connect to each other with segments that travel parallel to the major roadway. This type of interchange is appropriate where minor roads are one-way streets and will most likely be accompanied with traffic signals at the ramp terminals. It may be furnished on a regular grid system where the minor streets are two-way as well.

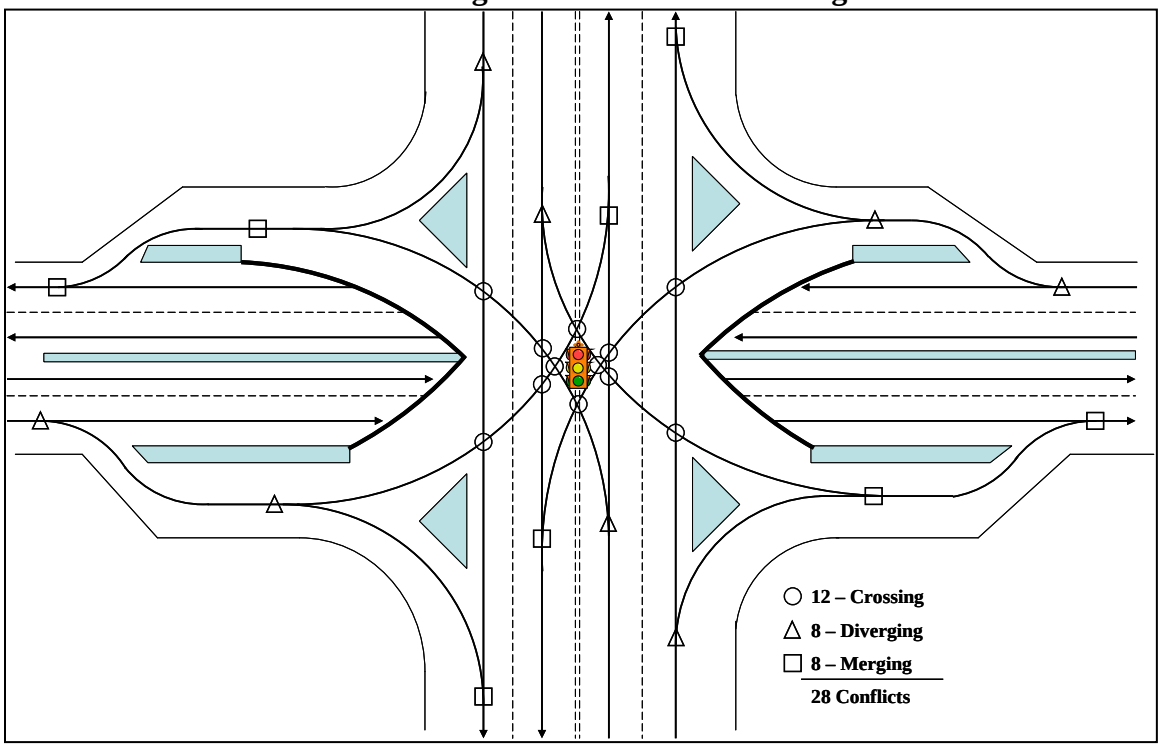
Exhibit 4-56: Conflict Points for a Split Diamond Interchange



Single Point Urban Interchange (SPUI)

The single point urban interchange has four ramps that converge to one point that is controlled by a traffic signal. All minor movement vehicles must travel through the same grade-separated intersection. This type of interchange conserves space and provides large capacity, since the signal operates with fewer phases. These conflict points are shown in Exhibit 4-57.

Exhibit 4-57: Conflict Points for a Single Point Urban Interchange

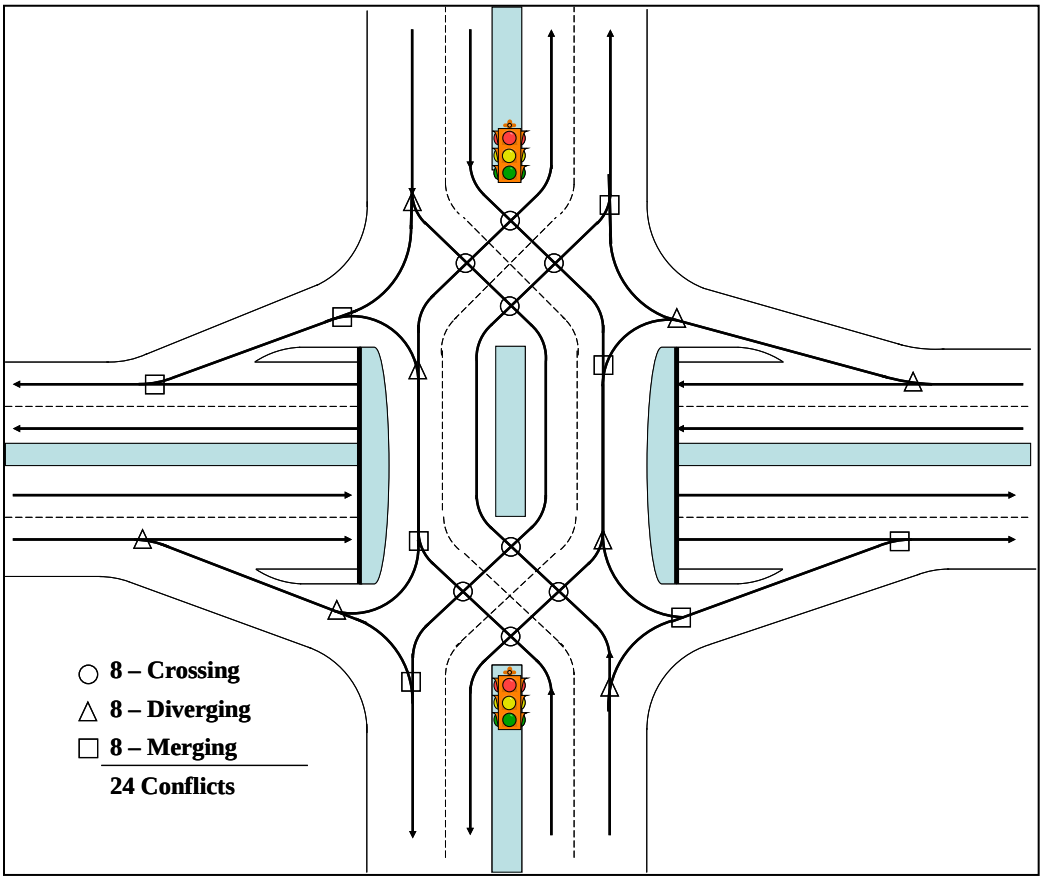


Divergent Diamond Interchange

The divergent diamond interchange has four ramps where vehicles that want to turn right may get on or off the roadway, as shown in Exhibit 4-58. The divergent diamond is designed so that as traffic on the minor roadway approaches the interchange intersections, the opposing lanes change the side of the road that is being used. This allows turn conflicts to be merge/diverge rather than crossing. Vehicles that want to turn left follow the appropriate traffic flow and merge into the receiving lane without interference of opposing traffic. The divergent diamond overlap allows vehicles to turn left at the designated signalized intersections reducing crossing paths and conflict points. This configuration also allows the use of fewer phases in the traffic signal operation.

Due to high speeds and high volumes, the divergent diamond must consider appropriate pedestrian crossings. There have been designs that show pedestrian crossings over the ramps and down the middle of the minor leg.

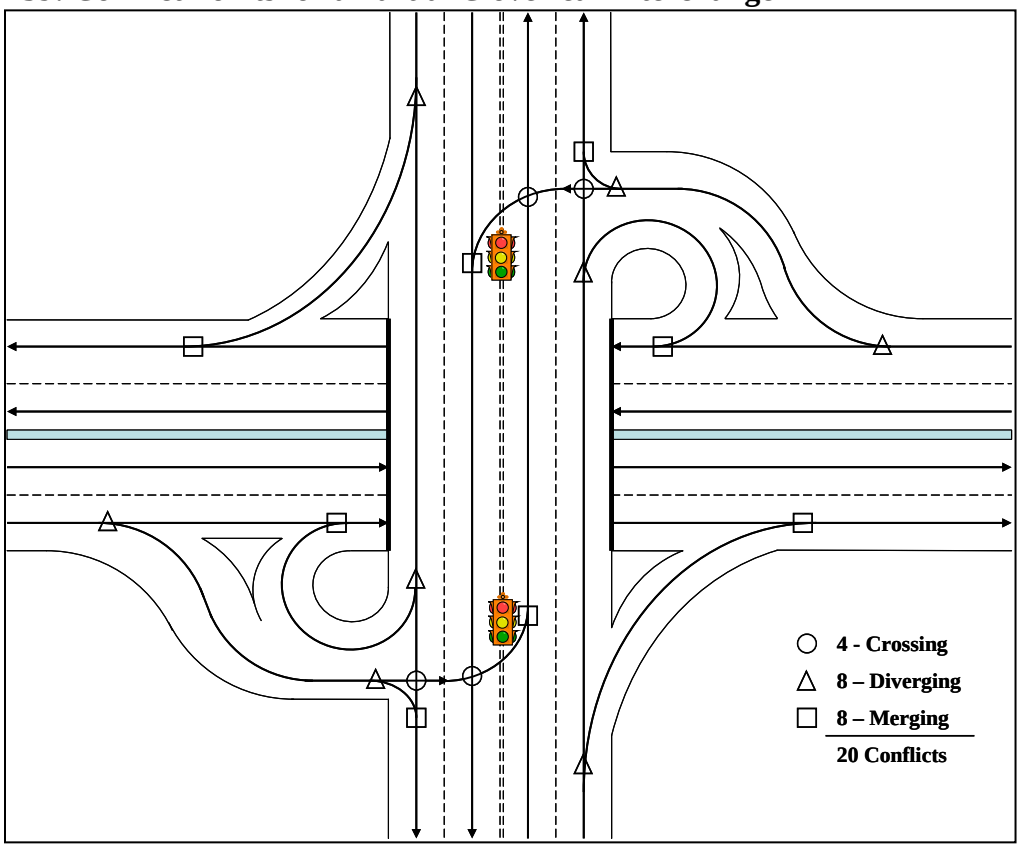
Exhibit 4-58: Conflict Points for a Divergent Diamond Interchange



Partial Cloverleaf Interchange
The partial cloverleaf, shown in Exhibit 4-59, reduces conflict points by providing elevated ramps to maneuver on and off the roadway. The on ramps are free flow but the off-ramps are controlled by traffic signs or signals. Vehicle paths cross only for left-turning traffic from the ramps. There is potential for weaving conflicts if this interchange has two or more lanes in each direction.

Although a full cloverleaf configuration is a possible design, Oregon and many other states no longer use them because of the short distance between the merging/diverging paths of the ramps. If present, pedestrian crossings would direct people over the ramps where the speeds are lowest and drivers have adequate sight distance.

Exhibit 4-59: Conflict Points for a Partial Cloverleaf Interchange



4.8.4 Access Management

Access management is the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway. Appropriate access management promotes the safe and efficient use of the transportation network while providing access to adjacent land uses. Access management can often be a low-cost solution to congestion and reduce crashes.

In 1948, the Oregon State Highway Department was tasked with policing access to Oregon's state highways. The state highway approach permitting process was created to regulate the

number of private driveways or public approaches onto a state highway. The Highway Division was also required to regulate the design of driveways, in order to ensure they complied with current design standards. When ODOT was established in 1973, access management remained a department duty with processes specified in the Oregon Administrative Rules (OARs). The goal of this policy was and is to protect viability of the state's highway infrastructure and to provide the motoring public with safe and reasonable access.

Note: Conflict points are discussed in detail in Section 4.8.3

4.8.5 Effects of Access Management Implementation

Good access management techniques improve both the roadway and adjacent land use. Details and research citations on the safety, operational, economic and other effects of access management as noted below are documented in the TRB's Access Management Manual[6].

Safety Effects

- Reduction of crashes involving vehicles as well as pedestrians and bicyclists[7]
- Limit number of traffic conflict points
- Separate conflict areas
- Preserve functional area of intersections
- Fewer conflicts for bicyclists
- Medians reduce crashes as well as provide pedestrian dwelling areas for two-stage crossings
- Reduced speed differentials resulting from through traffic meeting with turning traffic.
- Improved sight distance

Operational Effects

- Proper spacing of access points and intersections improves the flow of traffic. Poor spacing, design and location of driveways may reduce average travel speeds by up to 5 mph to 10 mph from desired speeds.[8]
- Reduced access density improves free-flow speed and reduces delay and congestion
- Up to 40% fewer vehicle hours of delay on access controlled roadways as compared to uncontrolled roadways
- Preserve integrity of the roadway system
- Extend functional life of the roadway

Economic Effects

- Access improvements on corridors have been shown to result in increased property values by decreasing travel time.
- Predictable travel times benefit service industries and manufacturing facilities operating under "just in time" delivery contracts

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[6] Access Management Manual, Transportation Research Board, 2003.
[7] HSM Part D, Chapter 13, Section 13.14 includes CMFs for access management on rural two-lane roads and urban/suburban arterials. See also ODOT Driveway Safety Models.
[8] Access Management and the Relationship to Highway Capacity and Level of Service, Florida DOT, 1996

- Combining driveways creates more room for parking and landscaping and may result in lower maintenance. Providing cross-access between retail parking lots often encourages multistop business trips by customers who otherwise may not have stopped.
- Non traversable median projects generally have little or no overall adverse impact on business activity.

Other Effects

- Improved traffic flow resulting from access management reduces vehicle emissions and fuel consumption.

Driveway Safety Assessment Predictive Models

ODOT has produced a predictive model to assist with assessing driveway safety on rural and urban arterial roadways in Oregon. The Revised ODOT Driveway Safety Models are available as a spreadsheet tool with instructions, with background information available in the Validation Report and Original SPR 720 Report.

The Revised ODOT Driveway Safety Models spreadsheet can be used to quantify and predict the effect of access management changes on non-intersection crashes. It includes a model for urban arterials and for rural arterials. The model has the following data requirements:

- Segment length
- Annual average daily traffic
- Speed limit
- Total number of through travel lanes
- Presence of a two-way left-turn lane (urban only)
- Number of commercial plus industrial driveways (urban only)
- Total driveways in segment (rural only)
- Number of industrial driveways (rural only)
- Total number of driveway clusters (rural only, methodology included in spreadsheet)

The spreadsheet provide the number of predicted crashes in five years, split into a baseline exposure value and an additional roadside and driveway effect value.

Rules, Policies, and Guidance

Laws pertaining to the control of access to public highways in Oregon are found in Oregon Revised Statutes (ORS) Chapter 374.

Administrative rules for highway approaches, access control, spacing standards and medians are found in OAR Chapter 734, Division 51 (OAR 734-051). Division 51 establishes procedures, standards, and approval criteria used by ODOT to govern highway approaches, access control, spacing standards, medians and restriction of turning movements.

The Oregon Highway Plan (OHP) serves as the policy basis for implementing OAR 734-051 through three goals:

- **Goal 1: System Definition.** To maintain and improve the safe and efficient movement of people and goods and contribute to the health of Oregon's local, regional, and statewide economies and livability of its communities.
- **Goal 2: System Management.** To work with local jurisdictions and federal agencies to create an increasingly seamless transportation system with respect to the development, operation, and maintenance of the highway and road system that:
    - Safeguards the state highway system by maintaining functionality and integrity;
    - Ensures that local mobility and accessibility needs are met; and
    - Enhances system efficiency and safety.
- **Goal 3: Access Management.** To employ access management strategies to ensure safe and efficient highways consistent with their determined function, ensure the statewide movement of goods and services, enhance community livability and support planned development patterns, while recognizing the needs of motor vehicles, transit, pedestrians and bicyclists.

The ODOT Access Management program website provides guidance on access management.

Types of Access Management Efforts
Access management encompasses a variety of different activities. The following is a brief description of each area. Detailed guidance on these efforts can be found on the ODOT access management website. It is important to coordinate with the Region Access Management Engineer (RAME) and other access management staff early in planning and project development processes.

Standards
Section 4020 of Division 51 contains standards for approval of private approaches, including the access spacing tables for roadways and interchanges. The spacing standards are also contained in OHP Appendix C. In addition, Table 12 of OHP Appendix C contains standards for spacing between interchanges.

Planning
Access management is one of the principal goals of the OHP (Goals 1, 2 & 3). Plans involving public road connections to the highway should be coordinated with the RAME as they are not subject to the approach permitting process. A resource for more information on access management in planning is NCHRP Report 548, *A Guidebook for Including Access Management in Transportation Planning*.

ODOT encourages the development of access management plans and interchange area management plans to maintain and improve highway performance and safety by improving system efficiency and management before adding capacity. Division 51 includes requirements and criteria for Access Management Plans and Interchange Area Management Plans in section 734-051-7010.

An **Access Management Plan (AMP)** is a plan adopted by the OTC for managing access on a designated section of highway or the influence area of an interchange to maintain and improve highway performance and safety. Detailed guidance on AMPs can be found on the ODOT access

management website.

An **Interchange Area Management Plan (IAMP)** is a plan to determine transportation solutions or land use/policy actions needed in an interchange area and how best to balance and manage transportation and land use issues over time. It is an important tool in protecting the function and operations of state highway interchanges and the supporting local street network. Assistance in the preparation of IAMPs is available in the ODOT Interchange Area Management (IAMP) Guidelines.

Project Development

Access management in project delivery in addressed in Division 51 Section 734-051-5120. ODOT encourages the development of access management strategies and access management plans during project delivery to maintain and improve highway performance and safety by improving system efficiency and management before adding capacity.

An **Access Management Strategy (AMStrat)** is a product developed by the project team that identifies the location and type of approaches and other necessary improvements that will occur as part of the project. The strategy may range from general statements on a preservation project to maps showing specific access closures in a modernization project. Division 51 requires access management strategies for modernization projects, projects within an influence area of an interchange where the project includes work along the crossroad, or projects on an expressway. Access management strategies may be developed for other highway projects.

The goal of an AMStrat is to improve safety and operations through measures taken during project delivery. These may include physical improvements to reduce conflicts such as medians and deceleration lanes, with treatments of existing approaches to mitigate, modify, relocate, consolidate, or close them as needed and as resources allow.

Operational notices provide requirements and guidance on access management in project development and delivery. PDLT Notice 03 addresses access management in project development. PDLT Notice 03(A) addresses access management specifically for pavement preservation projects.

A tabular evaluation of spacing standards should be conducted as part of existing conditions, future no-build, and alternative analyses and documented in the appropriate technical memorandums and narratives. This should cover all applicable roadway segments in the study area. Local jurisdiction's spacing standards shall be used for non-state roadways.

Example 4-5 Access Spacing Standards Reporting

This is an example of a typical access spacing standards reporting at the project development level included in a technical report.

The spacing and location of intersections and driveways affect traffic safety and operations. These access points introduce conflicts and are frequently the cause of slowing or stopping vehicles that can significantly degrade the flow of traffic and reduce the efficiency of the

transportation system. Appendix C in the OHP has spacing standards for public road approaches and private access to be used in the planning process.

The following spacing standards apply to this project:[9]

- **Interchange to interchange:** Two miles for freeway interchanges with two-lane crossroads in a rural area, measured between interchange lane tapers.
- **Next intersection adjacent to ramp terminal:** 1,320 feet for a two-lane crossroad in a rural area next to a full or right-in/right-out intersection.
- **Street spacing:** 1,320 feet for a rural statewide highway at 55 mph and 500 feet for a rural district highway at 45 mph. There is no standard for private accesses as they are discouraged on state highways.

The table below shows the comparison between roadway segments and their appropriate spacing standard. Existing street and ramp spacing is well below standards for all segments in the project area. In the example, on I84 the distance between the Biggs-Junction and Rufus interchange is approximately five miles, which is compliant with standards. Bargeway Lane directly accesses the I84 westbound on-ramp acceleration lane. The access point is less than 300 feet downstream of the I84 westbound ramp terminal intersection and approximately 600 feet upstream of the freeway entrance. Extending the length of the on-ramp, so that the acceleration lane begins west of the Bargeway Lane, will reduce the potential for accelerating vehicles to crash with slow moving and/or turning vehicles entering/exiting Bargeway Lane.

On US97, the distance between the I84 EB ramp terminal and the Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection is less than half the spacing standard. Queuing and blocking on this segment will become an issue as volumes grow; however, because of the topography and waterway constraints, meeting the spacing standards for this segment will not be possible even under the best conditions. On the segment south of the Celilo-Wasco/Biggs Rufus Frontage Rd. and US97 intersection, there are two driveways for the Shell Gas and Travel Stop; the first (for cars) is approximately 550 feet south of the intersection and the second (for trucks) is approximately 900 feet south of the intersection.

On the Celilo-Wasco Spur, there are multiple driveways on both sides of the highway. The first, for McDonalds and the Grand Central Travel stop on the opposite side of the road, is approximately 150 feet west of the Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection. The second, for both locations, is approximately 300 feet west of the intersection.

[9] OAR 734-051, Highway Approach Permitting, Access Control, and Access Management Standards. Effective June 30, 2014.

Spacing Standard Summary

Access Management Classification	Roadway	Segment	Spacing Standard*	Existing Conditions**
Interchange to Interchange	I84	Between Biggs Junction and Rufus Interchange	2 miles	5 miles
Next intersection adjacent to ramp terminal	US97	Between I84 EB ramp terminal and Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection	1320 feet	600 feet
Street Spacing: Statewide Highways	US97	Between Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection and entrance to Shell Gas and Travel Stop	1320 feet	550 feet
Street Spacing: District Highways	Celilo-Wasco Spur	Between Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection and the entrance to McDonalds / Travel Stop	500 feet	150 feet

** OHP Spacing Standards*
***Approximate approach spacing*
Black-shaded cells indicate that the spacing standard is not met.

Permits
An Application for State Highway Approach is required for new approaches and in other circumstances. The outcome of the permitting process is issuance of a permit to construct the approach. Once construction is approved, a final Permit to Operate, Maintain and Use a State Highway Approach is issued. Details on the permitting process are found in Division 51 as well as Chapter 4 of ODOT's Access Management Manual.

Access Management Techniques

A variety of administrative and design techniques can be applied to preserve and enhance the safety and operational character of a roadway segment and to mitigate the traffic problems at many types of locations. The appropriate technique depends on the context of the roadway, traffic, land use, and environmental characteristics. There is no one-size-fits-all solution. The following is not an exhaustive list. HDM Section 8.2 contains additional information on the design of road approaches.

- **Minimize:** Relocate driveways to farthest edge of property, consolidate driveways to increase separation, close, acquire access rights, joint and cross access, provide secondary access
- **Administrative:** Access policies and codes, subdivision and partition review, vehicle use limitations, purchase of access control, Division 51, spacing tables
- **Alternate Access:** Backage or frontage roads
- **Restrictions:** Painted/Non Traversable medians, porkchops to preclude direct left turns. Raised medians remove major conflict points from direct left turns. Studies indicate

significant crash reductions from installation of raised medians.[10] Raised medians also significantly benefit pedestrian safety.[11]

- **Location:** Sight distance, spacing, corner clearance, signal spacing
- **Design:** Width reduction, definition, throats vs. aprons, curb radius, directional median openings, shoulder bypass, jug handles, frontage roads, service roads, illumination, visual cues at driveways. Indirect turns such as U-turns and J-turns or roundabouts are safer than direct left turns.[12] Frontage and backage roads facilitate traffic circulation by separating local from through traffic.
- **Channelization:** Left- and right-turn lanes on adjacent roadway and on access. Providing space for left turns away from through traffic can significantly reduce crashes.[13]

4.8.6 Turn Lane Criteria and Traffic Control

Certain crash types and the overall crash frequency at a location may be addressed by mainline turn lanes or improved traffic control. Analysis of the existing or no-build conditions should identify these safety deficiencies that are addressed in the build alternative analysis. Left- and right-turn lanes at unsignalized locations can be installed to reduce high-speed rear-end collisions by removing slower turning vehicles from through traffic. The criteria for turn lanes are outlined in detail in Chapter 7.

High frequency of turning or angle crashes may indicate a need to investigate traffic control improvements. Traffic control improvements may remove simultaneous conflict points such as an all-way stop, roundabout, or a traffic signal. Conflict points could also be removed or minimized by using medians, channelization, or grade separation. Traffic control may also include bike or pedestrian islands and devices. Traffic control is discussed in detail in subsequent chapters.

4.9 Online Safety Resources

4.9.1 ODOT Safety Resources

Oregon Highway Safety Website
Overview webpage describing ODOT safety programs and resources. Includes links to many analysis tools and data resources, as well as information on funding sources and ODOT research.

Oregon Highway Safety Manual Website

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[10] Mauga, T. and Kaseko, M., "Modeling and Evaluating the Safety Impacts of Access Management (AM) Features in the Las Vegas Valley." Transportation Research Record: Journal of the Transportation Research Board 2171, pp. 57-65, 2010

[11] Zegeer, C. V., Stewart, R., Huang, H., and Lagerwey, P., "Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines." FHWA-RD-01-075, McLean, Va., Federal Highway Administration, (2002)

[12] Xu, L., "Right Turns Followed by U-Turns Versus Direct Left Turns: A Comparison of Safety Issues." ITE Journal, Vol. 71, No. 11, Washington, D.C., Institute of Transportation Engineers, (2001) pp. 36-43.

[13] Lyon, C., B. Persaud, N. Lefler, D. Carter, and K. Eccles. "Safety Evaluation of Installing Center Two-Way Left-Turn Lanes on Two-Lane Roads." TRB 87th Annual Meeting Compendium of Papers CD-ROM. Washington, D.C., 2008.

Oregon-specific HSM tools, research, and implementation information. Includes links to pre-calibrated HSM Predictive Method spreadsheets.

Highway Safety Investigations Manual
The Highway Safety Investigations Manual is a resource to assist ODOT traffic investigators and analysts with detailed highway safety project screening and evaluations. The manual includes checklists and analysis procedures suitable for a variety of field and office safety investigations and assessments. A set of worksheets is available containing tools and forms to facilitate the analysis.

Low-Cost Systemic Safety Countermeasures
Guidance and fact sheets on the use of research-proven low-cost safety countermeasures that can be deployed on a systematic basic. Through the collective efforts of ODOT's Traffic Operations Leadership Team (TOLT) and Highway Safety Engineering Committee (HSEC), many of these safety countermeasures are thoroughly integrated into the options the ODOT Regions must consider when addressing highway safety issues to reduce fatal and serious injury crashes throughout Oregon.

Transportation Development Trans Data Portal
Index page that lists many transportation data sources available through ODOT.

4.9.2 ODOT Safety Plans

Transportation Safety Action Plan (TSAP)
The TSAP is the guiding safety policy document for ODOT and includes the specific actions that are being taken to provide a safer travel environment. The document also serves as the federally mandated Strategic Highway Safety Plan (SHSP).

Roadway Departure Safety Implementation Plan
Roadway Departure crashes account for approximately 66% of all fatalities in Oregon. Data analysis of Oregon crashes was combined with cost-effective strategies to identify locations for the most effective use of funds to achieve an approximate 20% reduction in roadway departure fatalities. This systematic approach involves deploying large numbers of relatively low-cost, cost-effective countermeasures on targeted segments of road with a history of roadway departure crashes.

Intersection Safety Implementation Plan
This plan developed by Oregon and FHWA focuses on reducing fatal and major injury crashes at intersections. In Oregon, an average of 72 fatalities at intersections occurs each year. Although this number is declining, this plan is geared towards reducing this number even more. Using cost-effective strategies to apply both systemic improvements as well as hot spot improvements can be used to reach approximately a 13% reduction in intersection fatalities.

Bicycle and Pedestrian Safety Implementation Plan
Provides a systemic approach to reducing pedestrian and bicycle risks and crashes in Oregon. Includes two network screening methods, a traditional crash-based process and a risk-based systemic safety planning process using roadway characteristics that have contributed to

pedestrian and bicycle crashes over the study period. The plan provides a list of candidate priority locations and a toolbox of relevant countermeasures.

4.9.3 National Safety Analysis Resources

Official AASHTO Highway Safety Manual Website
Includes purchasing information, case studies, implementation tools, and online training guides for the HSM. Also includes user forums for practitioners and published corrections to the HSM.

Crash Modification Factors Clearinghouse
Companion tool to HSM Part D Crash Modification Factors. Provides a searchable database of up-to-date CMFs with details on applicability and links to the original research. This is a free web site funded by FHWA and maintained by the University of North Carolina Highway Safety Research Center.

PEDBIKESAFE.org
FHWA website for the Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE) and Bicycle Safety Guide and Countermeasure Selection System (BIKESAFE). The site includes practitioner guidebooks, proven countermeasure information, and various case studies covering treatment implementation.

5 DEVELOPING EXISTING YEAR VOLUMES

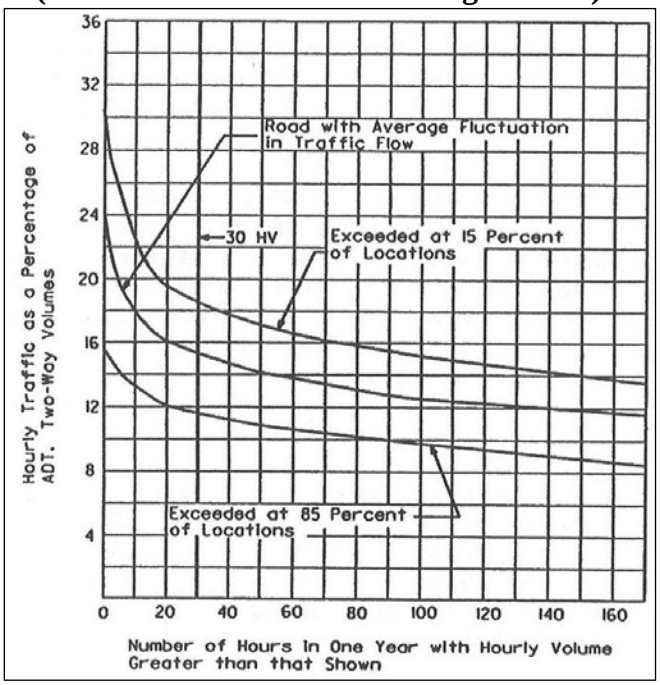
5.1 Purpose

Traffic counts alone should not be used for design or operational analysis of projects. This chapter will outline procedures for developing 30th highest hour volumes (30HV) and average daily traffic volumes (ADT) for planning and project level analysis. Existing and count-level data is also needed to support other volume –related analysis inputs such as peak hour factors and truck percentages. This chapter also provides the basis for developing the future volumes shown in Chapter 6.

5.2 30th Highest Hour Volumes

For most traffic studies, the 30th highest hour volumes (30HV) should be used to represent existing and future volumes. Future volumes are often referred to as Design Hour Volumes (DHV). The 30HV is the target hour based on the concept that designs are not done to the absolute highest hour of the entire year, but to design to meet most of the needs. Plotting an entire year's hourly volume data ranked from highest to lowest at a specific point will yield a flow curve. The break point between the steep and shallow regions of the curve is typically located at the 30th highest hourly volume as illustrated in the Exhibit 5-1below. Alternatives are generally analyzed at the 30HV to be consistent with accepted analysis methods and comparisons.

Exhibit 5-1 Relation between Peak-Hour and Average Daily Traffic Volumes on Rural Arterials (2011 AASHTO Green Book Figure 2-28)



The overall process for developing the 30HV is as follows:

1. Document raw count volumes, types and durations (see Section 5.5.3).
2. Identify a system peak hour (see Section 5.3).
3. Calculate seasonal adjustments; bring counts to a common month (see Section 5.4).
4. Calculate historical adjustments; bring counts to a common year (see Section 5.5).
5. Balance the 30HV across the network (see Section 5.5.1)
6. Round the 30HV (see Section 5.5.2)
7. Document on figures the 30HV process (see Section 5.5.3)

The peak hour from a manual count is converted to the 30HV by applying a seasonal factor. The 30HV is then used for design and analysis purposes. Experience has shown that the 30HV in large urban areas usually occurs on an afternoon on a weekday during the peak month of the year. The Metropolitan Planning Organization's (MPO) of Metro, Salem and Eugene are large enough that the average weekday peak hour approximates the 30HV. Smaller MPO's such as Corvallis and Medford do not have the steady flow throughout the year and the 30HV is concentrated into peak periods of the year. For the Bend MPO, the average weekday peak hour 30HV approximation is limited to commuter-flow dominated high volume arterials such as US97; other areas are subject to normal seasonal fluctuations. The 30HV for an urban area typically ranges from 9- to 12-percent of the Average Annual Daily Traffic (AADT). For a recreational route, the 30HV usually occurs on a summer weekend and ranges from 11- to 25-percent of the AADT.

It is recommended a top 200- to 500-hour count listing of the Automatic Traffic Recorders (ATR) is obtained from the Transportation Systems Monitoring Unit. The 30HV at the ATR(s) will be included in the list so that it will be possible to determine approximately when the 30HV occurs during the day and in the week. Since the actual 30HV determination is based off of at least the previous year's (ideally at least three years) data, the actual time and day when it occurs for the base year cannot be determined. Manual counts can then be timed for the period when the 30HV will likely occur, minimizing seasonal adjustments.

5.3 System Peak Hour Selection

Daily traffic volumes, while useful for planning purposes, cannot alone be used for design or operational analysis purposes. Once all of the traffic counts have been obtained, the intersection counts should be adjusted to a single system peak hour. The peak hour is the single hour of the day that has the highest hourly volume. Use of the 15-minute breakdowns in the traffic counts is necessary in order to determine the true peak hour, resulting in a time period such as 4:00 PM to 5:00 PM or, just as easily, 4:45 PM to 5:45 PM. The final selection of a peak hour may be based on a simple majority of counts that have the same peak hour, using a controlling intersection, or the count(s) that the analyst believes are the most accurate. Counts that have longer durations or that are taken close to the 30HV are generally more accurate. A procedure using TruckSum to determine the system peak hour volumes and other factors when the count peak hour is different from the system peak hour is provided in Chapter 11 of APM Version 1.

Generally PM peak hour volumes are higher than AM peak hour volumes. In areas where there are large industries with shift changes, the hour during the shift change may be as high as or higher than the PM peak hour for the remainder of the transportation network. If this is true,

another set of volumes should be developed. Volumes for the non-standard peak hour should be developed along with the PM peak hour volumes so that all of the volumes may be analyzed at a later date. Multiple sets of volumes may be necessary in these circumstances, which may include areas of heavy industrial, retail or recreational uses; coastal routes; or on routes with highly directional commuter flows.

5.4 Seasonal Factors

Since manual counts are taken throughout the year, data derived from a count taken in a particular month may need to be converted to the peak month by applying a seasonal factor. The Highway Capacity Manual 2010 Chapter 3 has background information on variations in traffic flow. Seasonal factors can be created using data collected from the ODOT ATR stations.

As of November 2013, there are 177 active ATR stations and 6 proposed ATR sites throughout the State Highway System. Most of these locations have loops in the roadway that count traffic flows for 24 hours a day, 365 days a year, and many have been in operation for many years. In addition, some ATR sites have been replaced with Automatic Vehicle Classifiers (AVC) which classifies vehicles continually in addition to counting. As of the date mentioned, there are 18 AVC sites throughout the system. In the future, it may be possible to create seasonal factors for freight movements using data from the AVCs. ATR information is available from the ODOT Transportation (Traffic) Volume Tables (TVT) located on the TDD Transportation Data Traffic Counting Program web site, as well as the ATR Characteristic Table and the Seasonal Trend Table located on the Transportation Analysis webpage of the TDD Planning Section website.

Localized seasonal factors could be derived from other sources of data such as the PORTAL system on the Portland area-freeways and from the 170/2070 traffic signal controller downloads for local non-state streets.

ATRs provide the percentage of AADT that occurs in the count month and in the peak month. AADT is the annual average value for all days of the year including holidays. This information can then be used to develop a seasonal adjustment that may be applied to the manual count using one of the following three methods.

- On-Site ATR Method
- ATR Characteristic Table Method
- ATR Seasonal Trend Table Method

The On-Site ATR Method is the best and most accurate method to use, followed by the ATR Characteristic Table Method and then the ATR Trend Table Method. All of the seasonal adjustment tables and ATR information are updated annually.

Seasonal factors greater than 30% should be avoided. Factors such as these indicate that a count was NOT taken at or close to the time that the 30HV occurs. Using a winter count with a high seasonal factor to represent the peak summer period will likely not represent traffic turning movements accurately, as driving patterns change in the winter compared to the summer. If alternate periods are used other than the typical summer like what would be used for an alternate

mobility standard, then counts need to be taken in those alternate periods so resulting seasonal factors do not exceed 30%. As an example, suppose a count was taken at a rural intersection in the winter months with one of the minor legs of the intersection serving a campground beyond the intersection. The turning volume in the direction of the campground may be small or non-existent; say 5 vph. Even with a seasonal factor of 50%, this would result in an adjusted volume of only 8 vph, compared to an actual summer 30HV that may be 20 vph. Simply factoring for the season would still leave the turning movements too low.

5.4.1 On-Site ATR Method

The On-Site ATR Method is used when an ATR is within or near the project area. If located outside of the project area, there should be no major intersections between the ATR and the project area, and it should be within a minimal distance so that the traffic characteristics such as road class, number of lanes, rural/urban area, etc., are comparable. It is also important to check that the project area's AADT in the Transportation Volume Table is within +/- 10% of the ATRs AADT.

When using the ATR Summaries from the TVT's, the analyst should note both the average weekday and average daily percentages. Average weekday traffic (AWD) percentages include values for Monday through Thursday while average daily traffic (ADT) includes all days of the week. When there is little variation between the AWD and ADT percentages, using AWD supports the notion that the peak is likely on an average weekday. If the ADT is much larger than the AWD, then the peak is likely on a weekend day, so use the ADT Percentage. Check the Weekly Traffic Trend column from the ATR Characteristic table to aid in this calculation.

Example 5-1 Seasonal Factor – On-Site ATR

On-Site ATR in Project Area

A traffic count was taken June 15th–18th along Kings Valley Highway No. 191 (OR 223) at MP 28.00.

- **Step 1: Transportation Volume Table -** ATR 02-005, located on Kings Valley Highway at MP 26.40, can be used.
- **Step 2: Check ATR Characteristic Table** weekly traffic trend column to identify whether to use the ADT or AWDT for seasonal factor. In this case, the Characteristic Table identifies this as a Weekend ATR; therefore the ADT column is used.
- **Step 3: ATR Trend Summary -** The ATR number corresponds to a table in the last half of the TVT that contains yearly summaries for each ATR. Since the Average Daily percentages are much higher than the average weekday, select a value from the column titled "Average Daily Traffic/Percent of ADT." Both the count month and the peak month percentage of ADT should be recorded. This information should be obtained from the ATR Summaries in the TVT's for the past five years. The peak month is the month with the highest percentage. The highest and lowest percentages should be eliminated to account for construction activity that may have occurred in the vicinity of the ATRs during the five year period. An average percent of ADT is then calculated for the

remaining three years. The percentages shown in the TVT represent the 15th day of the month, so interpolation is needed if the count was taken near the beginning or end of a month.

Seasonal Adjustment Using ATR #02-005

	2012	2011	2010†	2009	2008
Peak Month (September)	115%	119%	124%	121%	126%
Count Month (June)	104%	104%	103%	106%	106%

† – Sometimes the Peak Month may vary between months, depending on the year. As in this case, 4 of the 5 Peak Months were in September. Therefore, you assume September is the Peak Month for every year of ATR data used.

As shown above, the percentage of ADT values listed during June and September for the past five years are reviewed to calculate the average. The highest and lowest values, shown as shaded, are dropped from this calculation. The average monthly factors are determined as follows:

- The average peak month (September) is: (121%+124%+119%) / 3 = 121%.
- The average count month (June) is: (106%+104%+104%) / 3 = 105%.
- The seasonal adjustment is September/June = 121% / 105% = 1.15.

Therefore, traffic volumes in the month of September are 1.15 times greater than in June. To convert the June traffic data to the 30HV:

30HV = (June PHV) x (Peak Month Percent of ADT/Count Month Percent of ADT).

If one of the peak hour turning movement volumes was 75 vph in June, then the 30HV for September would be 1.15 x 75 vph = 91 vph.

When there are two or more ATR's within the project area use the following guidance to determine the appropriate seasonal adjustment:

Scenario # 1: The project area has two ATR's one at each end. The project area ADT, roadway characteristics and roadway functional class are the same as at both ATR's. In order to seasonally factor the peak hour volumes within the project area, an average of the two ATR seasonal factors recommended.

Scenario # 2: The project area has two ATR's on the same highway within the project area but have a major roadway between them. The roadway has different characteristics on each side of the major intersecting roadway. With this scenario, each side should be seasonally factored using the ATR on that side.

Scenario # 3: The project area has two (or more) ATR's located on different roadways. If the roadway has the same characteristics as the ATR then use that one, if not average the ATR's. NOTE: If the ATR's report dramatically different roadways (i.e. freeways and local

streets), then they should not be averaged together.

5.4.2 ATR Characteristic Table Method

The ATR Characteristic Table provides general characteristics for each ATR in Oregon, and should be used when there is not an ATR on-site. The Characteristic Table is a filterable Excel table that will often provide more than one ATR with similar characteristics. To use the table, filter through the column characteristics from left to right to create a list of ATRs with similar characteristics. See example in Exhibit 5-2 which is an excerpt of the Summer<2500 trend.

Averaging multiple ATRs with similar characteristics will yield a more appropriate factor than if only one ATR is used. Follow the steps described in the on-site ATR Method for averaging count and peak months over 5 years for each ATR with similar characteristics. The factor used to convert the traffic data to 30HV will be an average of these similar characteristic ATR factors. Seasonal Traffic Trend groupings for the table were constructed by plotting the monthly percent of AADT for each ATR. The plots were then grouped into trends with the greatest influence in traffic patterns.

Exhibit 5-2 ATR Characteristic Table Example

2013 ATR Characteristic Table										
Seasonal Traffic Trend	**Area Type**	**# of Lanes**	**Weekly Traffic Trend**	**2012AADT**	**OHP Classification**	**ATR**	**County**	**Highway Route, Name, Location**	**MP**	**State Highway Number**
Summer < 2500	Rural	2	Weekday	790	District Highway	01-001	Baker	US 30, La Grand	37.70	66
Summer < 2500	Rural	2	Weekday	210	District Highway	01-007	Baker	OR 203, Medical	36.86	340
Summer < 2500	Rural	2	Weekend	390	District Highway	13-005	Harney	OR 205, Frenchglen	0.01	440

It is important to note that the trends provided in the table are not the only trends attributed to each ATR, but are the dominant trends. Over time, some ATRs may shift trend categories which are mainly the Summer/Summer<2500 and Recreational Summer/Summer<2500 which are typically small changes. Typically, ATR characteristics stay constant from year to year. After the seasonal traffic trend characteristic is selected, other trend groupings, including area type (e.g., urban, rural), number of lanes and weekly traffic trends are broken down to provide more comparable sub-groupings.

ATRs are characterized by only one of eleven seasonal trends, described below and illustrated in Exhibit 5-3. Project areas should be characterized by these trends in the order listed below.

1. **Interstate Urbanized**: ATRs located on any section of urbanized (areas of population > 50,000).interstate. (Example: I-5, Iowa Street - ATR #26-016.)
2. **Interstate Non-Urbanized**: ATRs located on any non-urbanized interstate section. (Example: I-84, west of Troutdale - ATR #26-001.)
3. **Commuter**: ATRs characterized by small seasonal changes in traffic patterns and commuting between city pairs. (Example: OR 22, West Salem Bridges - ATR #24-014.)
4. **Coastal Destination**: ATRs characterized by summer peaks to/or within larger coastal city destinations as well as favorable routes from the valley. Favorable routes for Coastal Destinations include: Salmon River Highway (OR 18), Corvallis-Newport Highway (US 20/OR 34), Alsea Highway (OR 34), and Florence-Eugene Highway (OR 126). (Example: OR 18, east of Valley Junction - ATR #27-001.) Note: This grouping does not include the Sunset Highway.
5. **Coastal Destination Route**: ATRs characterized by high summer peaks on predominantly rural routes to/or between large coastal cities and coastal destinations. Rural routes include the Sunset Highway (US 26) from the Wilson River Hwy. junction, Umpqua Highway (OR 38), and Redwood Highway (OR 199). (Example: US 101, south of Rockaway - ATR #29-001.)
6. **Agriculture**: ATRs characterized by peaking in the late summer and fall harvest months. (Example: Kings Valley Highway - ATR #02-005.)
7. **Recreational Summer**: ATRs characterized by high summer peaks in recreational areas. (Example: Crater Lake Highway, south of Fort Klamath - ATR #18-021.)
8. **Recreational Summer/Winter**: ATRs characterized by both summer and winter peaks in recreational areas. (Example: Timberline Highway - ATR #03-008.)
9. **Recreational Winter**: ATRs characterized by high winter peaks in recreational areas. (Example:OR35, Mt Hood Highway – ATR #03-007)

If the project area trend does not fall into Trends 1 through 9, either Trend 10 or 11 should be used.

10. **Summer**: ATRs characterized by a smaller summer increase in traffic patterns when compared to Recreational Summer. (Example: US 26, south of Warm Springs - ATR #16-006.)
11. **Summer < 2,500 ADT**: ATRs with less than 2,500 ADT characterized by a smaller summer increase in traffic patterns when compared to Recreational Summer. (Example: OR36, Mapleton-Junction City Highway - ATR #20-004)

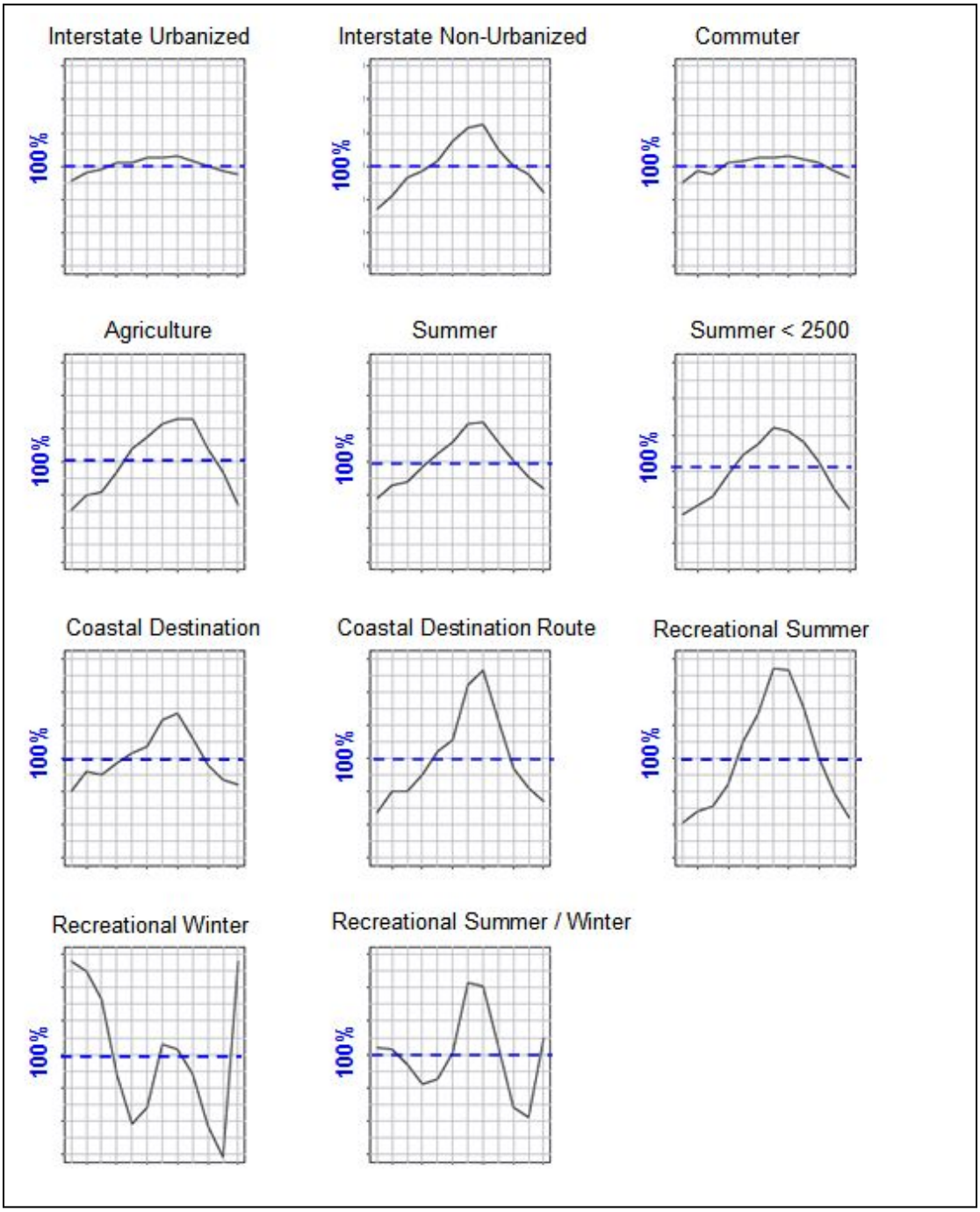
5.4.3 Non-State and other Roadway Trends

Many of the state highways mimic characteristics on rural county roads and urban streets. Some of the ATR Characteristic trends can be used to approximate seasonal factors on non-state highway approaches.

- Commuter: Non-state streets in urbanized cities (Example: US20/OR99E, Albany Junction City Highway - ATR # 22-022)
- Summer: Non-state streets in small cities (Example: OR42, Coos Bay Roseburg Highway - ATR #10-006)
- Summer<2,500 ADT: Rural off-system county roads. (Example: OR36, Mapleton-Junction City Highway - ATR #20-004)

Interchange ramps mix characteristics of the mainline freeway and the intersecting cross-roads, so seasonal factors for ramps should be created by averaging mainline and cross-road factors. State frontage roadways should use the applicable seasonal trend other than Interstate, or the bulleted list above.

Exhibit 5-3 Seasonal Trends



ATRs are also characterized by weekly traffic trends and ADT/AWD.

- **Weekday:** Day of the week when the 30HV occurs; typical occurs on weekdays (Monday through Thursday) for commuter trend and urban areas.
- **Weekend:** Day of the week when the 30HV occurs; typical occurs on weekends (Friday through Sunday) for recreational trend and coastal destination trend.

ATRs are also characterized by area type and number of lanes.

- **Urbanized:** ATRs within areas of population > 50,000. (Examples: Portland and Salem) Urban Fringe: ATRs influenced by an urban area, such as an MPO area. (Example: Wilsonville)
- **Small Urban:** ATRs within areas of population between 5,000 and 49,999. (Examples: Albany and Pendleton)
- **Small Urban Fringe:** ATRs influenced by a small urban area. (Examples: US 101 south of Coos Bay and I-5 north of Albany)
- **Rural:** ATRs on routes outside of areas with population <5,000.
- **Rural Populated:** ATRs in cities with a population of less than 5,000. This also includes unincorporated communities. (Examples: Sisters and Tillamook)

To use the table, filter through the column characteristics from left to right to create a list of ATRs with similar characteristics. The table **must** be filtered starting on the far left otherwise, the groupings at the end will not be correct. Starting with the "Seasonal Traffic Trend" column, filter out the traffic trend that best describes the project area. Next, filter the area type, number of lanes, and weekly traffic trend. Make sure that the section of highway where the ATR(s) is located and the project area for which the seasonal adjustments are being made have similar traffic characteristics. To be considered comparable, the AADT of the characteristic ATR should be within +/- 10% of the Transportation Volume Table AADT for the project area.

Example 5-2 Seasonal Factor – ATR Characteristics Table

ATR Characteristic Table Method for a Project Area

A count was taken June 15th–18th along Corvallis-Lebanon Highway No. 210 (OR 34), west of I-5 at MP 9.75. The 2012 Transportation Volume Table AADT is 24,900.

- **Step 1: Transportation Volume Table**: There are no ATRs on this section of the highway.
- **Step 2: ATR Characteristic Table**: This section of highway can be categorized as Commuter/Small Urban Fringe/Five-Lanes/Weekday. Filtering through the ATR Characteristic Table from left to right, two ATRs have similar characteristics to the project area. However, ATR 31-003 has an AADT of 11,300; as previously noted, characteristic AADT counts should be within +/- 10% of the Transportation Volume Table AADT in order to be considered comparable to the project area. Alternatively, ATR 09-020 has identical field

conditions to the project site and has an AADT of 26,300, which is within 10% of the TVT AADT. The characteristics of these two representative locations are summarized below.

Example ATR Characteristic Table (Year 2013)

Characteristics	ATR Location 1	ATR Location 2
Seasonal Traffic Trend	Commuter	Commuter
Area Type	Small Urban Fringe	Small Urban Fringe
Number of Lanes	5	5
Weekly Traffic Trend	Weekday	Weekday
2010 ADT	11,300	26,300
OHP Classification	Statewide Hwy	Statewide Hwy
ATR	31-003	09-020
County	Union	Deschutes
Highway Route, Name and Location	OR82, Wallowa Lake Hwy	US97, The Dalles-CA Hwy
ATR Milepoint	1.74	124.40
State Hwy Number	10	4

Step 3: ATR Trend Summary: Data from ATR #09-020 is located in the ATR summary in the back of the TVT and under the "ATR Trend Summaries" on ODOT's Traffic Counter Program website TDD Transportation Data Traffic Counting Program. The count was taken on June 15th, which is in the middle of the month, so the ATR percentages from the TVT can be used directly without interpolation. The peak month was found to be August for two of the three years.

Seasonal Adjustment Using ATR #09-020

	2012	2011	2010	2009	2008
Peak Month (August)	113%	111%	110%	108%	107%
Count Month (June)	109%	107%	108%	108%	107%

- The average peak month (August) is: (111%+110%+108%) / 3 = 109%.
- The average count month (June) is: (107%+108%+108%) /3 = 108%.
- The seasonal adjustment is August/June = 109% / 108% = 1.01.

Therefore, traffic volumes in the month of August are 1.01 times greater than in June. To convert the June traffic data to the 30 HV: 30 HV = (June PHV) x (Peak Month Percent of ADT / Count Month Percent of ADT).

If one of the peak hour turning movement volumes were 100 vph in June, then the 30 HV

for August would be 1.02 x 100 vph = 101 vph.

5.4.4 Seasonal Trend Method

The seasonal trend table is used when there is not an ATR nearby or in a representative area. The Seasonal Trend Table was constructed by averaging seasonal trend groupings from the ATR Characteristic Table and is based on ADT. Essentially, by using a factor from the table, the average for the entire trend grouping is applied to the project area as shown in Exhibit 5-4.

Exhibit 5-4 Example ATR Seasonal Trend Table (Year 2013)

	Jan 1	Jan 15	Feb 1	Feb 15	Dec 15	Peak Period Seasonal Factor
Recreation Summer/Winter	1.0783	0.9668	0.9719	0.9771	0.9091	0.7038
Recreation Winter	0.7454	0.6408	0.6536	0.6663	0.6398	0.6398

To determine the appropriate seasonal trend, select from the list the trend that best describes the project area. The seasonal trends have been placed graphically on an ATR Characteristic Trend Map for ease of reference. Trends should be characterized in the same order as previously described in the ATR Characteristic Table Method. The Seasonal Factor Table is updated yearly. It is not necessary to average five years' worth of seasonal factors for this method, or compare AADTs because, as previously stated, this method uses an average of all ATRs in the characteristic trend. In certain areas, averaging seasonal trends may yield a more appropriate factor than just a single trend. These areas include:

- **Coastal Destination and Coastal Destination Route Trends:** It may be necessary to average trends in areas such as Warrenton, Depoe Bay and Yachats. While these cities are destinations along the Oregon Coast, they do not have the summer influx of traffic associated with larger coastal destinations such as Lincoln City and Seaside. A Coastal Destination Trend Factor for these areas may be too high, while a Coastal Destination Route Trend Factor may be too low. When analyzing coastal cities such as these, it is appropriate to average the trends to yield a more reasonable factor.
- **Summer and Commuter Trends**: It may be necessary to average trends when analyzing mid-sized cities such as Philomath, Dallas and Sutherlin. For urbanized areas the commuter trend is appropriate, while for smaller areas the summer trend is appropriate. However, for mid-sized areas such as these, the summer or commuter trends may alone be too high or too low. A more reasonable factor

would be obtained by averaging the summer and commuter trends.

- **Interstate and Interstate Urbanized Trends**: It may be necessary to average trends when analyzing interstates in small urban and fringe areas (urban and small urban) such as Albany, Wilsonville and north of Roseburg. For rural areas the interstate trend is appropriate, while for urbanized areas the interstate urbanized trend is appropriate. For small urban and fringe areas such as these, however, these trends may alone be too high or too low. A more reasonable factor would be obtained by averaging the interstate and interstate urbanized trends.

It is important to note that these are the only trend grouping pairs that would be appropriate to average, Interstate should only be averaged with interstate urbanized, and should never be averaged with Coastal or Recreational. The same is true for the other trends not listed in the above examples. The Seasonal Trend Table is located on the Transportation Analysis webpage of the TDD Planning website.

Factoring count data to the peak month requires dividing the seasonal factor for the count period by the seasonal factor for the peak period. The peak period seasonal factor for a traffic trend is the lowest value in the row, and is highlighted in the last column in the table.

Seasonal factors are given for the 1st and the 15th of each month so if the count date is not at the beginning/end or in the middle of a month interpolation is needed.

Example 5-3 Seasonal Factor – Seasonal Trend Table

This example demonstrates the Seasonal Trend Method for a Project Area.

A count of 11,000 was taken July 1st – 5th along Oregon Coast Highway No. 9 (US 101) at MP 63.19 which is just north of Tillamook city limits.

- **Step 1: Transportation Volume Table**: There are no ATRs on this section of the highway.
- **Step 2: ATR Characteristic Table**: This section of highway can be categorized as Coastal Destination/Rural/Two-Lanes. Filtering through the ATR Characteristic Table, from left to right, four ATRs have similar characteristics to the project area. However, none of the characteristic ADT values are within +/- 10% of the Transportation Volume Table ADT for the project area. Refer to the table below for details regarding these four candidate locations.

Example ATR Characteristic Table (Year 2013)

Characteristics	ATR Location 1	ATR Location 2	ATR Location 3	ATR Location 4
Seasonal Traffic Trend	Coastal Destination	Coastal Destination	Coastal Destination	Coastal Destination
Area Type	Rural	Rural	Rural	Rural
Number of Lanes	2	2	2	2
Weekly Traffic	Weekday	Weekend	Weekend	Weekend
2012 ADT	2000	5700	4700	17200
OHP Classification	District Hwy	Statewide Hwy	Statewide Hwy	Statewide Hwy
ATR	02-003	20-005	21-006	27-001
County	Benton	Lane	Lincoln	Polk
Highway Route, Name and Location	OR34, Alsea Hwy No. 27, southwest of Corvallis-Newport Hwy No. 33 (US20/OR34)	OR126, Florence-Eugene Hwy No. 62, west of Territorial Hwy No. 200 (OR200)	US20, Corvallis-Newport Hwy No. 33, west of Lincoln-Benton County Line	OR18, Salmon River Hwy No. 39, east of Three Rivers Hwy No. 32 (OR22)
ATR MP	53.89	43.86	34.24	23.23
State Hwy Number	27	62	33	39

- **Step 3: Seasonal Trend Table**: Since there are no ATRs with similar characteristics, the Seasonal Trend Table must be used. The correct values are obtained by following the "Coastal Destination" row to the "Jul_1" count month column, and to the "Peak Period Seasonal Factor" column at the end of the table, as summarized below.

Seasonal Trend Table (Year 2013)

	Jun 15	Jul 1	Jul 15	Aug 1	Peak Period Seasonal
Coastal Destination	0.9345	0.8749	0.8153	0.8005	0.7857

- The peak period seasonal factor is 0.7857.
- The count date seasonal factor (July 1st) is 0.8749.
- The seasonal adjustment is: Count Date Seasonal Factor/Peak Period Seasonal Factor = 0.8749/0.7857 = 1.11.

Therefore, the peak period volumes for a Coastal Destination are 1.11 times greater than volumes for the 1st – 5th of July.

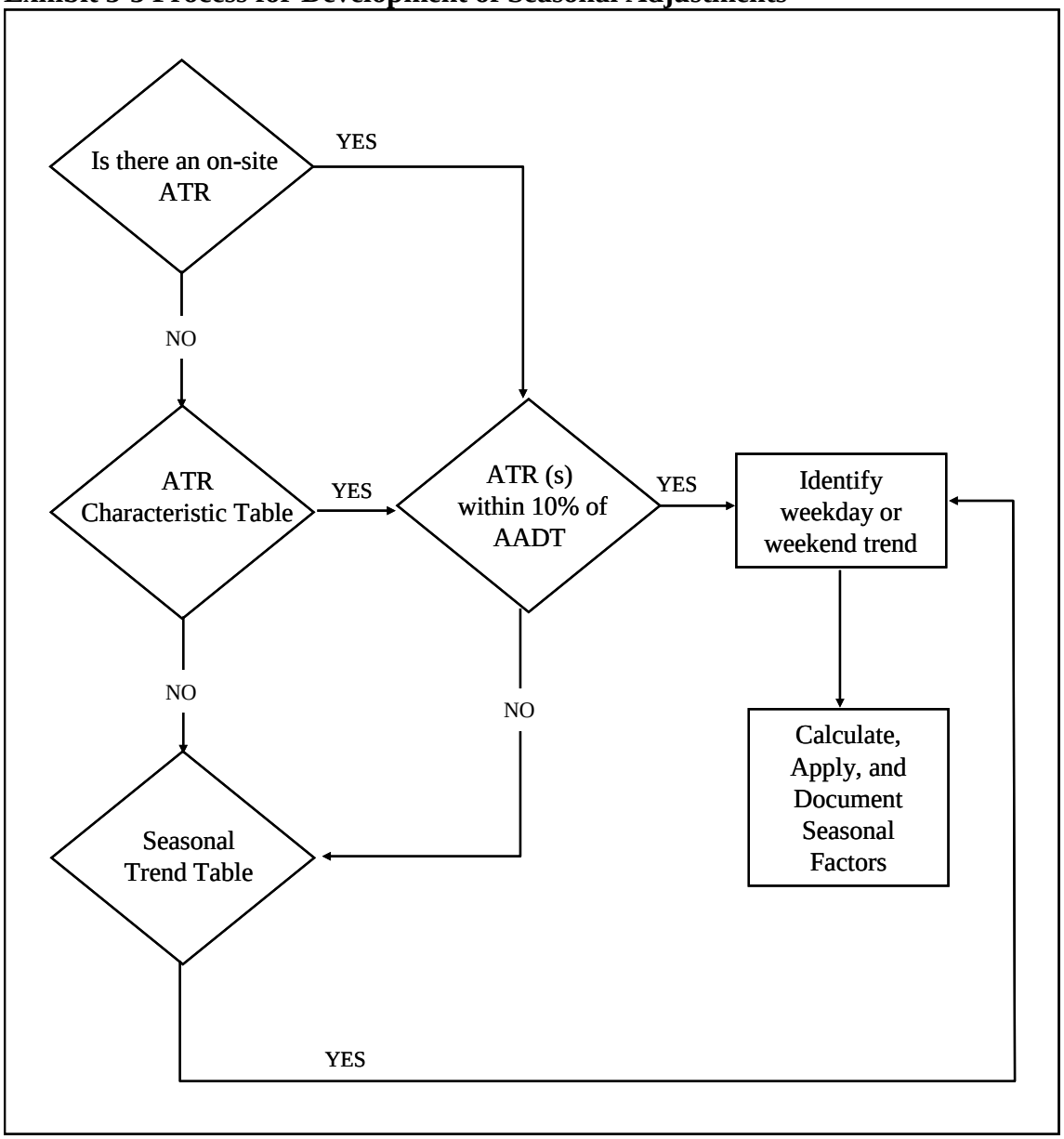
To convert the July traffic data to the 30HV:

30HV = (July PHV) x (Count Date Seasonal Factor / Peak Period Seasonal Factor).

If one of the peak hour turning movement volumes were 100 vph in July, then the 30HV would be 1.11 x 100 vph = 111 vph.

Exhibit 5-5 below is a simplified flow chart of the process for seasonal adjustments.

Exhibit 5-5 Process for Development of Seasonal Adjustments



Seasonal Adjustment for Alternate Periods

If it is desired to factor count data to an annual average time of year (Oct or May typically) for determination of an alternate mobility standard, the values in the Seasonal Trend table can still be used. This is same process that the Transportation Data Section uses to create average annual daily traffic (AADT) to create the Transportation Volume Tables.

Example 5-4 Seasonal Characteristic Table Adjustment for Alternate Period

This is a continuation of Example 5-2 Seasonal Factor – ATR Characteristics Table (count taken June 15th–18th along OR 34 west of I-5). It is desired to obtain average annual peak hour volumes for this location. It was previously determined using the ATR Characteristic Table method that ATR #09-020 should be used for seasonal adjustments for this site.

Seasonal Adjustment Using ATR #09-020

	2012	2011	2010	2009	2008
Count Month (June)	109%	107%	108%%	108%%	107%

For this site location, the ratio of (Count Month ADT)/(AADT) from ATR #09-020 is used. For the five years of this example, dropping the high and low, the average count month % of AADT was found to be 109%.

$$\frac{\text{Count Month ADT}}{\text{AADT}} = 1.09$$

To convert to average annual volumes, count month volumes are divided by this ratio (1.09), i.e., the average annual peak hour volume = (Site June PHV) / (ATR June ADT/ATR AADT)

If one of the site peak hour turning movement volumes were 100 vph in June, then the site average annual peak hour turning movement volume would be 100 vph / 1.09 = 92 vph.

Example 5-5 Seasonal Trend Table Adjustment for Alternate Period

This is a continuation of Example 5-3 Seasonal Factor – Seasonal Trend Table (count of 11,000 taken July 1st – 5th along US 101 north of Tillamook). It is desired to obtain the average annual peak hour volumes for this location. The seasonal trend table was used for this location. The applicable seasonal trend was determined to be Coastal Destination.

The factors in the seasonal trend table are ratios of AADT to the month ADT (AADT/Month ADT). The ratio of the AADT/Month ADT is assumed to be the same for the site peak hour volumes. To convert to average annual peak hour, the site month peak hour volume is multiplied by that ratio for that month.

Site Average Annual Peak Hour Volume = Site Month peak hour volume x Trend Table Factor for that month

In this example, the count was taken the week of July 1st. The seasonal factor for July 1st was found to be 0.8749. If one of the site peak hour turning movement volumes were 100 vph in July, then the site average annual peak hour turning movement volume would be 100 vph x 0.8749 = 87 vph.

5.5 Historical Factors (Factoring to Current Year)

In addition, to adjusting count volumes seasonally, they need to be adjusted to the current or base year of the project. This might mean increasing or decreasing the count peak hour volume. The historical factor process uses the Future Volume Table (FVT) to adjust the volume regardless of what process is used to create the future volumes (see Chapter 6).

The Future Volumes Table is updated annually. The table is based on long-term 20-year trends of traffic counting sites (for the TVT) on Oregon highways. Each individual record trend has been analyzed to eliminate any unexplained spikes or dips in the data to improve its overall correlation with the 20-year regression curve. The trends are based on linear regression best-fit trends and are extrapolated out 20 years. Over the 20-year period, the linear trends show a steady growth and should not grossly under or over-estimate the future 20-year value outside of travel demand model areas. Use of other curve extrapolation models (i.e. compound growth) shall not be used.

Within the table, the milepoint location for the project highway that most closely resembles the traffic flows for the section being analyzed is selected. Sometimes, another milepoint may be closer to the section being analyzed, but there may be a cross street that affects traffic volumes on the highway so that the growth rate is different.

There are three columns in the table for the most recent three years of traffic count data. Only one of the columns is filled; corresponding to the last year that the location was counted. The far right column contains the R-squared value for the regression equation that was used to estimate the historical trend. The R-squared value measures the degree of correlation between the dependent variable (historical traffic volumes) and the independent variable (time). A value of 1.0 indicates an exact linear relationship between the historical counts and time. Ideally, the R-squared value should exceed 0.75. However, values higher than 0.50 are still acceptable, if there is nothing else available. Conversely, a low R-squared value indicates a weak relationship. In this case, the table should be investigated for a nearby location having similar traffic characteristics and a more acceptable R-squared value.

In areas that have travel demand models, the R-squared value is replaced by the "MODEL" code. This code indicates that the historical trend has been replaced by the model growth rate (future year divided by the base year). In larger areas, use of the historical growth rate can overestimate volumes, so the use of the model growth rate allows for consideration of capacity constraints. These model growth rates are updated as the models are updated (typically every five years or so).

For non-state roadways, or ramps/frontage roads, historical factors can be averaged from similar roadways with the same characteristics. The seasonal factor sections in this chapter can apply to help locating highway sections with similar characteristics. For example, an interchange ramp is affected by growth on the mainline freeway as well as the intersecting crossroad, so the ramp historical adjustment would be the average of the two.

Local land use changes should also be reviewed if they have occurred between the time that the count was taken and the desired base year of the project. In this case, the Future Volume Table should not be used because it is likely that double-counting would occur. The additional trips from the background and development sections in the traffic impact analysis document need to be added to the count volumes to approximate the existing traffic levels.

Example 5-6 Adjusting Counts to Current Year

The project base year is 2013 but the counts available were counted in 2010. The Future Volume Table is used to adjust the counts to the base year.

For the Madras ATR (#16-002) located on US 97 at MP 96.92, The following table shows the 2011 traffic volumes, projected Year 2032 traffic volumes and the R-squared value.

Example Future Volumes Table

Hwy#	DIR	MP	Description	2011	2032	RSQ
4	1	96.46	0.02 mile N of Fairgrounds Road	17700	23200	0.9150
4	1	96.92	ATR 16-002 - Madras	12200	12500	0.7037
4	1	97.31	0.02 mile S of US 26	9300	13800	0.3994
4	1	103.61	0.02 mile N of SW Iris Lane	8200	10600	0.5093
4	1	105.63	0.10 mile N of Culver Hwy	8700	13000	0.7844

RSQ = Root Mean Square

Based on the data above, the 21-year growth factor would be 12500 / 12200 = 1.024. Assuming linear growth in the future, the annual growth factor would be (1.024 –1.0) / 21 = 0.00114, or 0.114%%. The R-squared value of 0.7037 is acceptable. To convert the 2010 30HV, for example a minor approach left volume of 115 vph, to a 2013 DHV, the 2010 30HV is multiplied by the 3-year growth factor.

2013 DHV = 2010 30HV x [(3 x Annual Growth Rate) + 1] = 115 vph x [(3 x 0.00114) + 1]
= 115 vph x 1.0034
= 115 vph

5.5.1 Network Balancing

The 30HV network needs to be balanced. Balancing is somewhat of an "art" that techniques vary from project to project and within areas on a project, so it is hard to list out a specific process. The exhibits and examples below illustrate some different balancing techniques. Balancing is simply, "what goes into an intersection or segment needs to come out." Without balancing, it is possible to have two intersections with nothing between them with the volume that leaves one intersection and enters the next one be 200 vph or more different.

Interstates and expressways with interchanges or roadway segments with no accesses need to balance perfectly from one intersection or interchange to another. Roadways with accesses probably will not balance perfectly, but should be consistent from intersection to intersection. Roadways with many non-counted accesses (especially major ones) should not be forced to balance as this will artificially increases or decreases the adjacent intersection volume beyond the realistic point. If a segment fails to balance because of accesses, it may be best to perform a peak hour count at the point or points to help reduce the balancing needed.

The timing of the traffic counts can help determine how easy a network is to balance. Counts that are spread throughout the allowable three-year span taken at different times of the year will be harder to balance than counts all taken on the same day or within a week of each other. Counts that have similar peak hours will be easier to balance than counts of varying peaks.

Network balancing should be done initially on paper as it is easier to track differences and proportional changes as the process proceeds. An intersection may have to be adjusted more than once in a single balancing process, so a record of the "chronological" adjustments/steps is needed for the analyst to retrace or a reviewer to follow. Trying to follow a spreadsheet-based balancing process is difficult and it becomes more of an effort to identify whether the right formula was used versus the right thought process was used. If a spreadsheet is used, then the thought-process needs to be shown via comments/notes. Once the network is balanced, then the results should be rounded and placed into spreadsheets or figures. The important point is that the balancing thought process be reasonable, logical and be well documented. The balanced network must be reviewed before the values are used in any further analysis or construction of future year volumes.

When balancing, it is important to keep the general proportions of turn splits and leg directional factors relatively constant unless the analyst knows that the counts did not capture the true conditions.

Identifying High/Low Imbalances

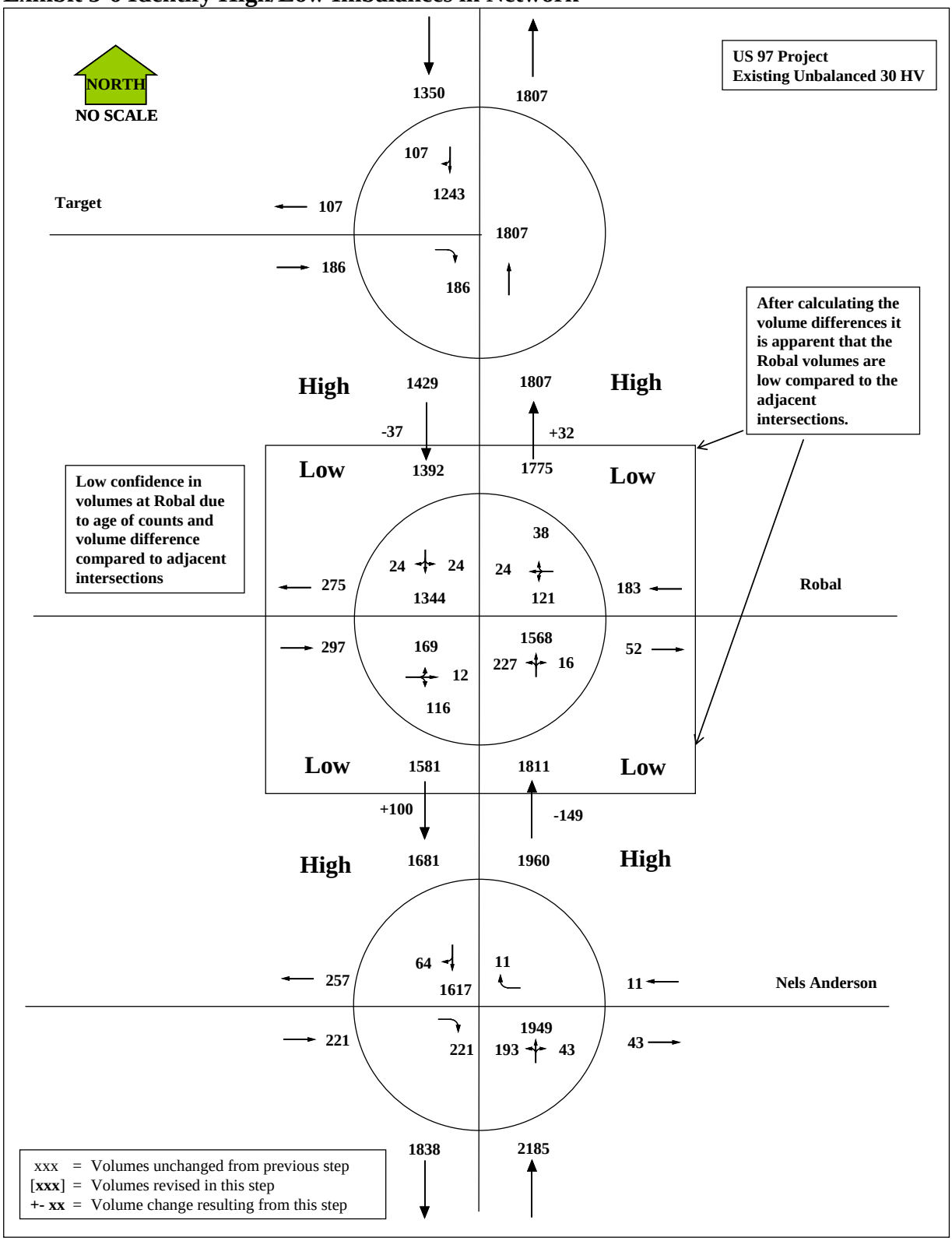
A good way to start the balancing process is to first identify which intersections/segments are high or low and likely techniques that could be used. Sum up the inflows and outflows on each approach and exit leg and note the differences between them across each intersection. Doing this graphically via sketches on paper with different colors for high and low segments can expedite the process. Note whether the differences seem to be on through movements or turn movements. The count dates, durations, and the analyst's overall confidence in the intersection counts should also be documented.

Small differences overall likely mean that a single point could be held and the differences proportionally distributed. Large differences likely mean that differences will need to be split between intersections first. Intersections with whole approaches that are low or high, especially on minor approaches, may mean that the whole approach will need to be adjusted. The average project study area will have many of these conditions so a combination of methods is necessary.

Intersections that are identified to have a high-low-high-low pattern generally have a better success rate in balancing cleanly versus a high-high-high or low-low-low pattern which might create too much of a difference at the network edge.

The following series of exhibits illustrates a small network consisting of three intersections on US 97 and will be used to demonstrate many of these network balancing techniques. Volumes shown in Exhibit 5-6 have been previously developed by factoring counts up to a common year and applying seasonal adjustment factors. The exhibit identifies the high and low imbalances between intersections. There are no driveways between intersections so volumes should balance.

Exhibit 5-6 Identify High/Low Imbalances in Network



Holding an Intersection Constant

If differences are relatively small between intersections, holding an intersection constant and pushing the differences away proportionally may be used. Another use of this method is if the analyst has good confidence in a major intersection count based on count year or duration. For example, long duration counts generally are better to hold than short duration counts. Larger intersections (number of legs and/or volumes) are generally better to hold than smaller intersections. Depending on the situation, it may be best to start with the intersection with the greatest differences.

The selected intersection is held constant and the differences are pushed to the next intersection. The difference is resolved by identifying the splits between the approach turn movements from the next intersection's subject approach and applying those splits to the difference. The difference in the opposing direction is obtained from the proportional splits that make up the movements going onto the exit leg. This is repeated for each segment of the held intersection. Then, the difference is moved away from the held intersection and the difference is proportionally reduced the further away it gets as portions are removed by each turn movement.

It is possible that as the difference is worked downstream, the increases/decreases at an intersection become too great or seem to be going away from convergence (getting worse). In this case, either another intersection could be selected to be held, an entire approach may needed to be adjusted, or better, the differences need to be split instead of held.

This method can also be used to just hold particular approaches constant if desired. This is useful if the analyst believes that the minor street leg growth factors seem to be off and has more confidence in the major approaches.

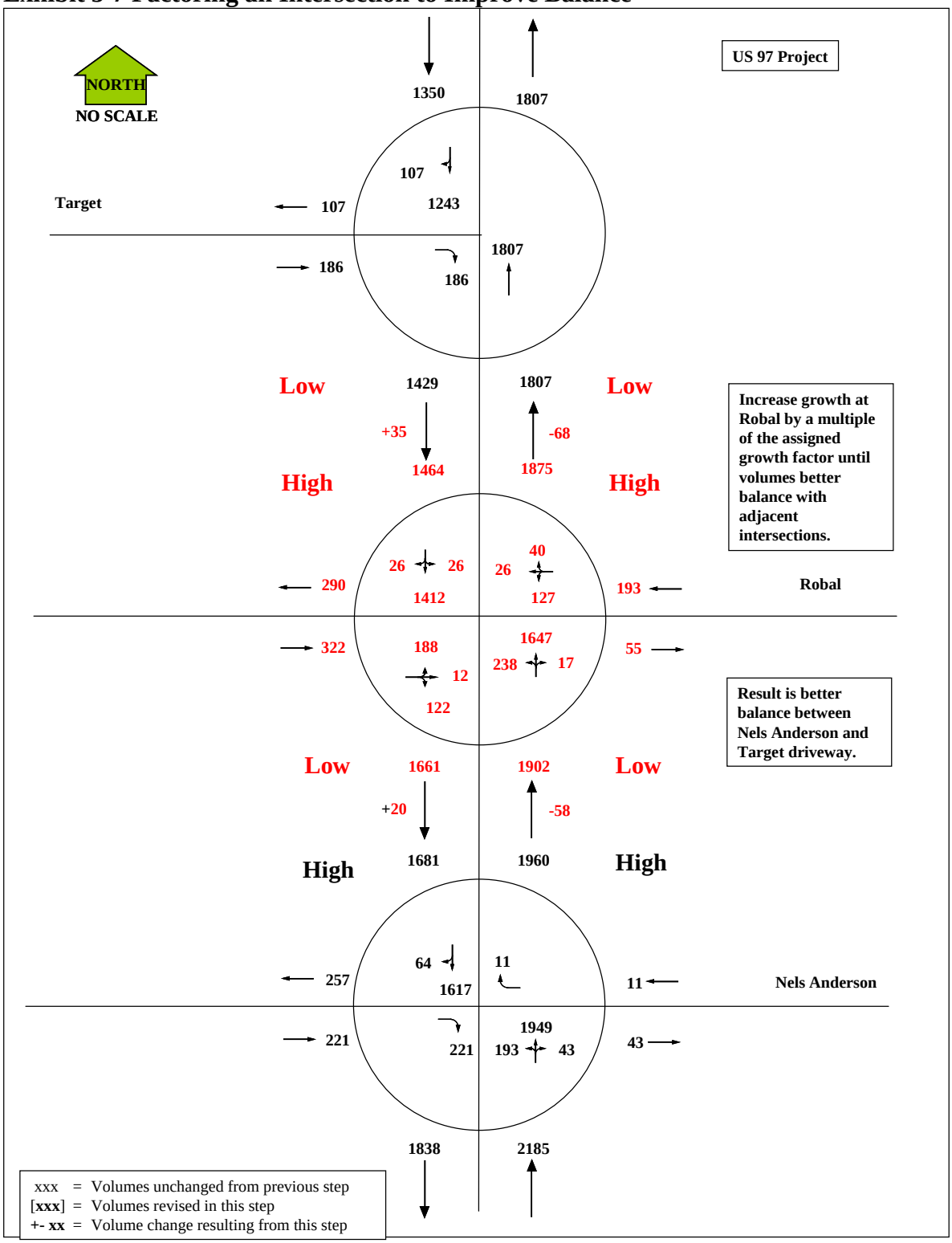
Factoring Approaches/Legs/Intersections

Sometimes, after identifying the high and low imbalances, an approach, or a leg, or an entire intersection appears to be significantly low or high for some reason. These areas may be have been influenced by driveway closures, nearby road construction/diversion, incidents, or special events. Sometimes the count might have an error so this should be checked thoroughly even up to replacing the count with a new one if necessary. If no obvious errors /issues exist then these can be factored up or down to more closely agree with adjacent intersections which the analyst has more confidence in. If these are on state highways, these is most easily done by using the Future Volume Tables to adjust the appropriate leg or intersection further with a growth factor as similarly done in Section 5.5. If a travel demand model exists, then this can be used to create annual growth factors for local roadways.

Exhibit 5-7 illustrates a situation where the volumes on US 97 at Robal are low in comparison to adjacent intersections. In this case there is less confidence in the volumes at Robal because they are based on an older count even though they have been adjusted to

a common base year. There is greater confidence in the volumes at Nels Anderson and the Target driveway. In this case volumes at the entire intersection of Robal volumes are increased by a factor of 1.057 based on the Future Volume Table growth along this segment. This factor represents three multiples of the annual growth factor to bring the intersection to as close as possible without making it too high. The volume imbalance is then recalculated. After this adjustment, Robal is now high compared to the Target driveway to the north, and low compared to Nels Anderson intersection to the south. But the imbalance is now smaller and more realistic.

Exhibit 5-7 Factoring an Intersection to Improve Balance



Splitting the Difference

Large differences between intersection exit leg and the next intersection approach leg need to have the difference split. In this way the difference is moved proportionally in both directions rather than in just one. The proportional adjustments are the same as described above. This is repeated for every intersection until the edge of the network is reached. It may be necessary to re-adjust previously balanced sections of a particular leg does not balance cleanly (does not converge), or if the network circulates the difference back around to the starting spot. Some small differences may be possible to assign to minor streets or non-counted locations.

Exhibit 5-8 illustrates splitting the difference between Robal and Nels Anderson in both the northbound and southbound directions. In order to avoid increasing the imbalance to the north, only turn movement volumes at Robal to and from the south are adjusted. As balanced volumes are created they are rounded to the nearest five vehicles.

Next, the difference between Robal and the Target driveway to the north is addressed by splitting the difference as shown in Exhibit 5-9. Again, the through movement volumes at Robal are held to avoid re-introducing an imbalance to the south. The difference is proportionately assigned at Robal to the turn movements to from the north only.

In the next step as shown in Exhibit 5-10, the volume adjustments previously made are pushed off the network.

In reviewing the resulting volumes, the drop in turning movement volumes at Robal is determined to be excessive. An iteration is performed by holding the southbound turning movement volumes at Robal and instead applying the difference to the southbound through movement as shown in Exhibit 5-11. That volume adjustment is then pushed off the network. This results in more realistic volumes and illustrates how the balancing process is often iterative, i.e., initial assumptions may need to be changed during the process in order to improve the balance.

Once satisfied that no further improvements in network balance can be made, final balanced volumes are shown as in Exhibit 5-12. Any remaining volumes that were not adjusted and rounded in previous steps were rounded.

Exhibit 5-8 Splitting the Difference

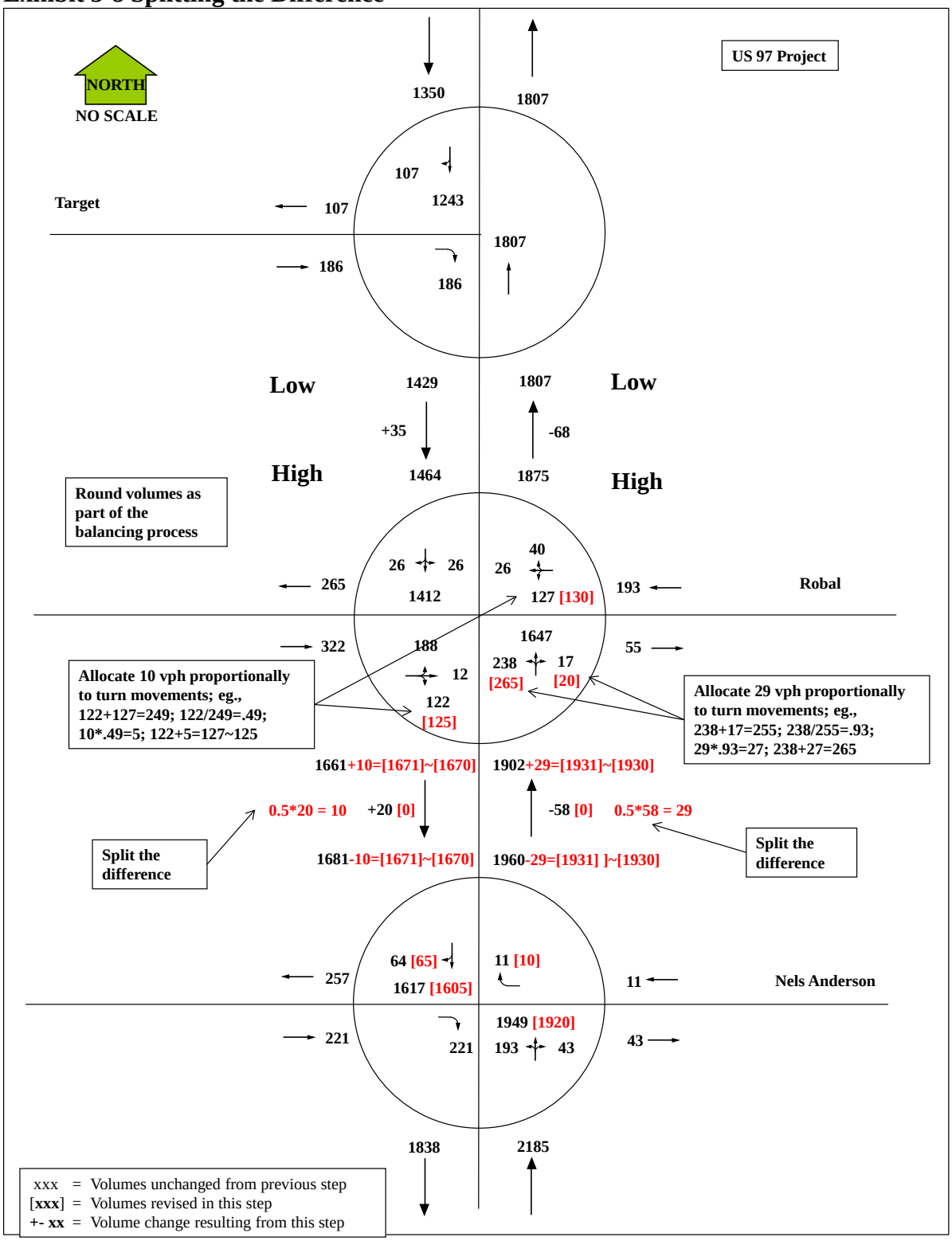


Exhibit 5-9 Adjustment Between Robal and Target Driveway

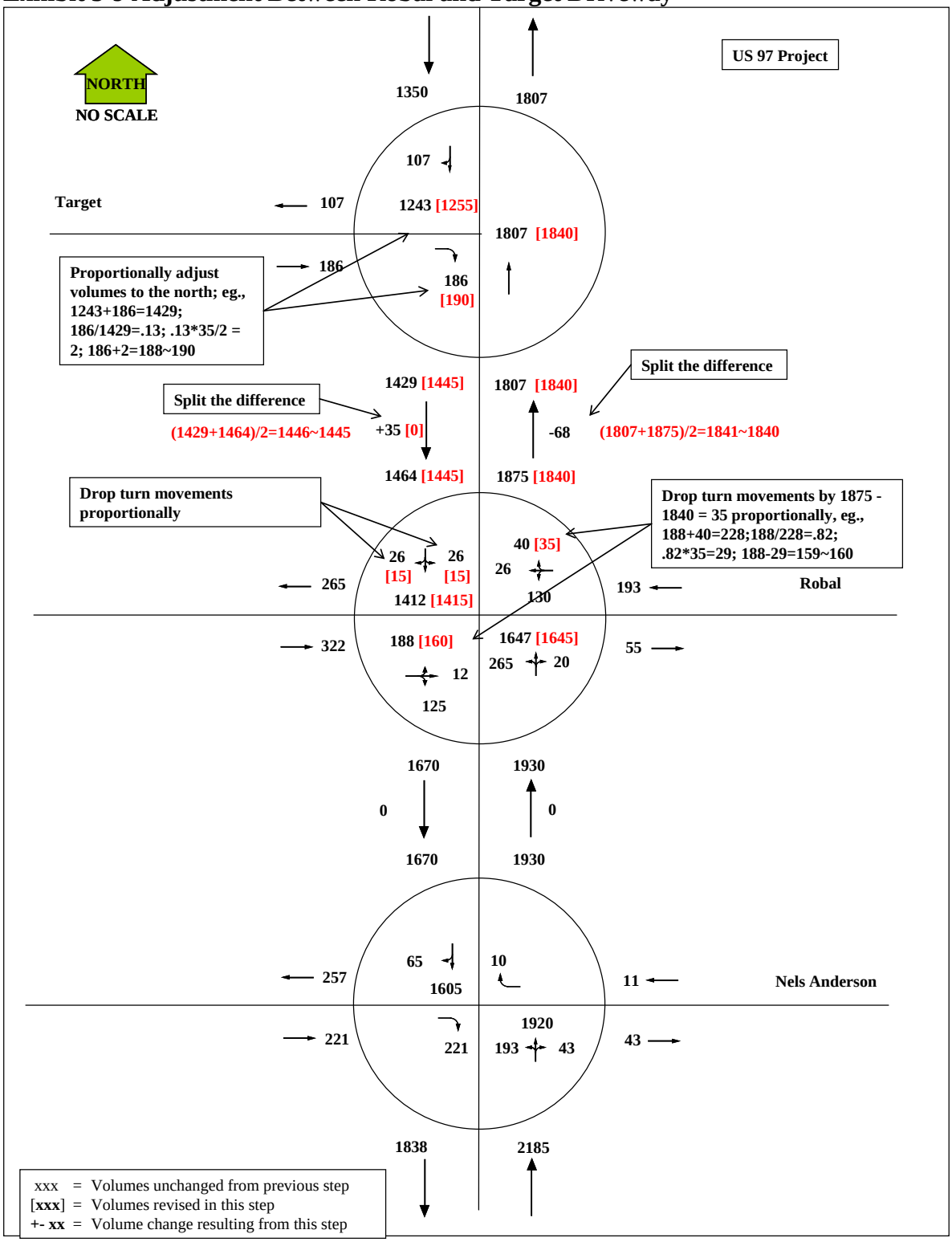


Exhibit 5-10 Adjusting volumes on Side Streets and Off the Network

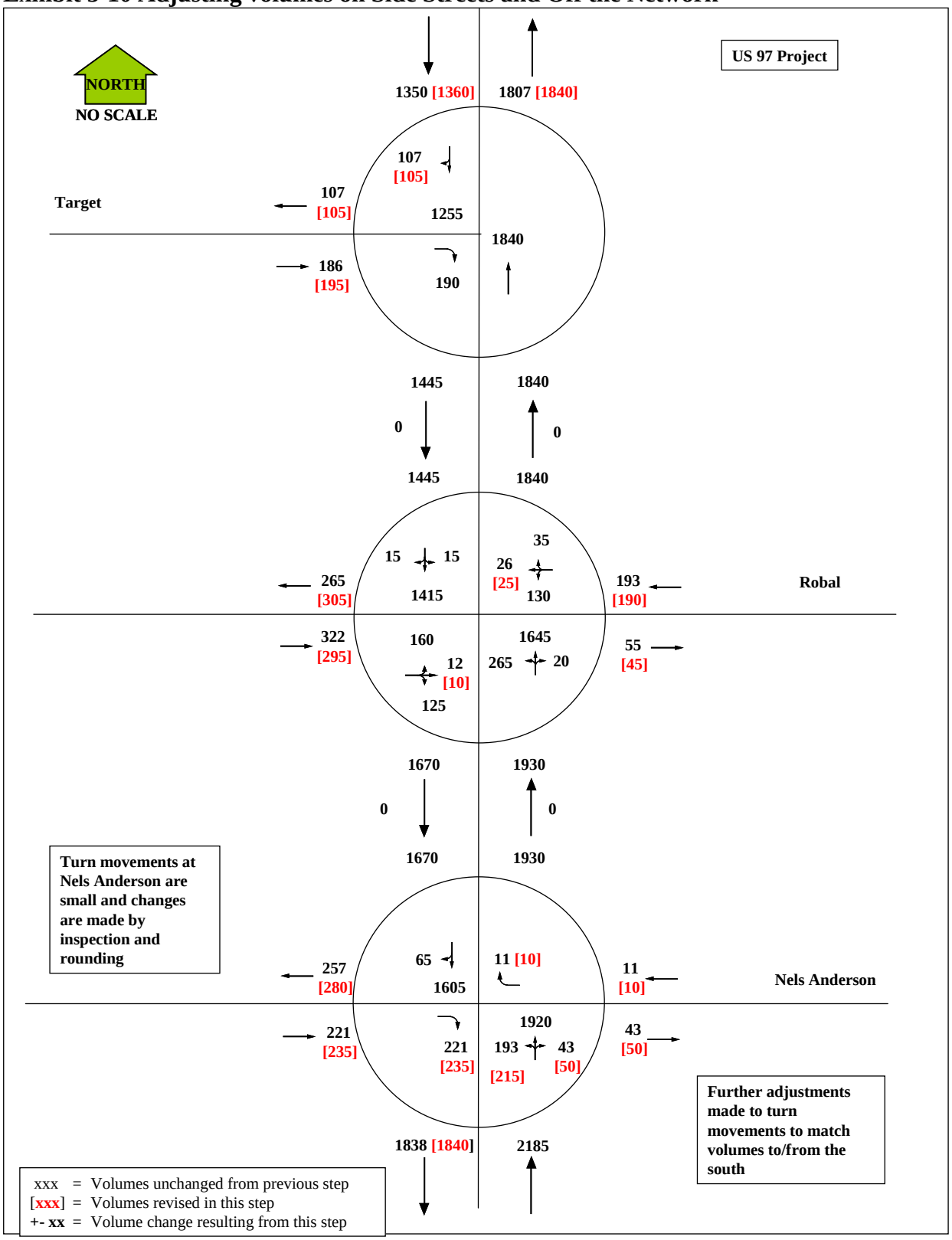


Exhibit 5-11 Revising Initial Assumption to Improve Balance

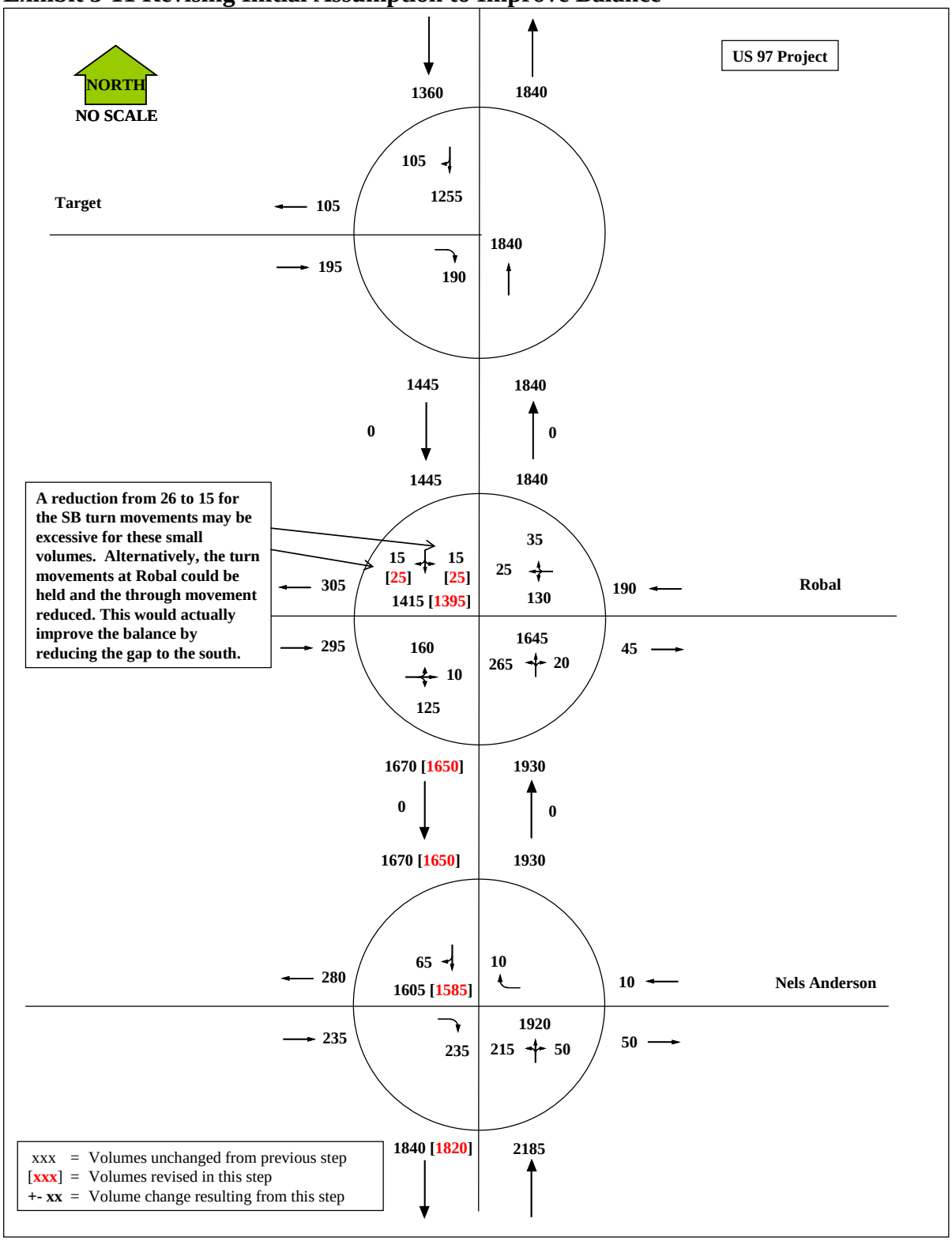
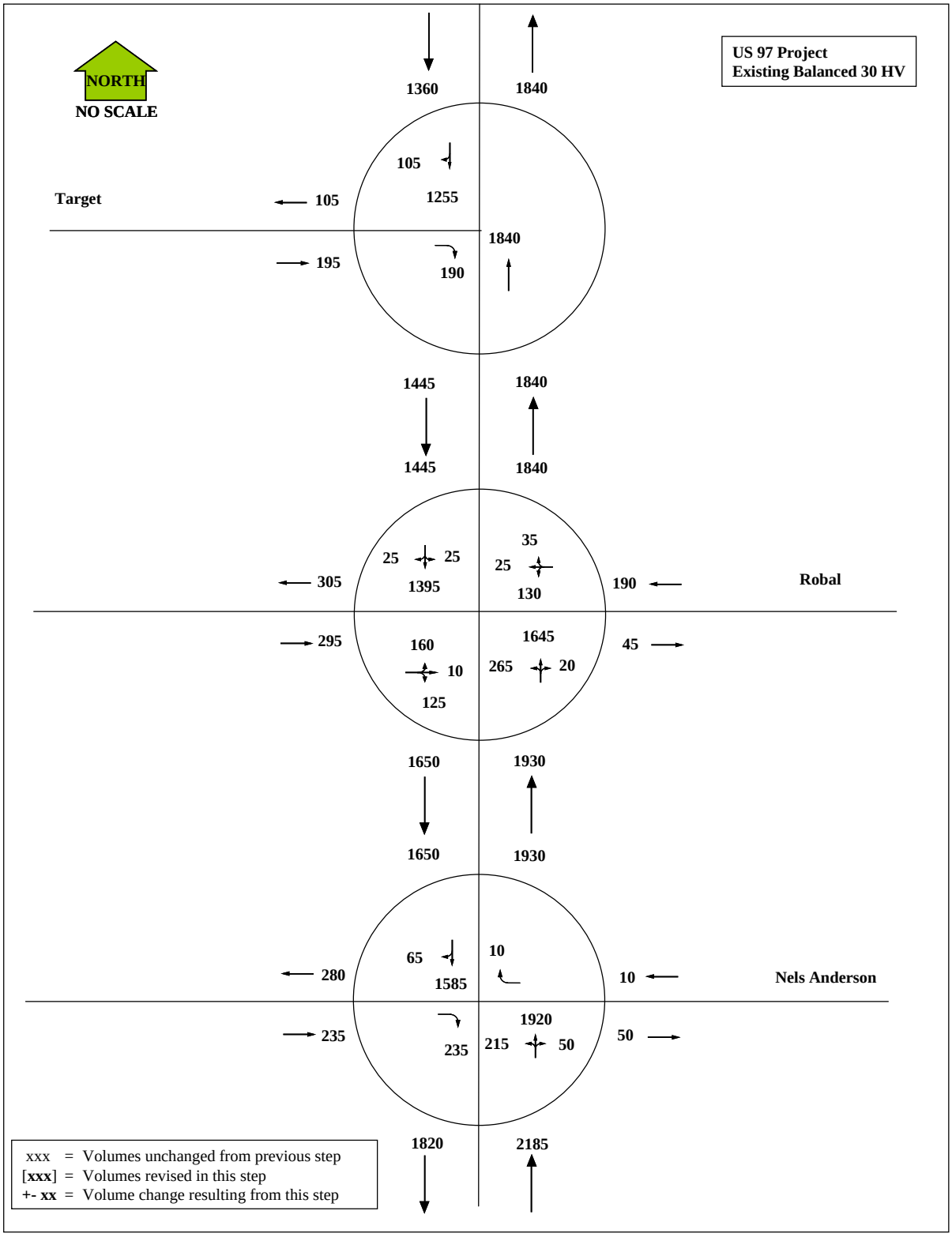


Exhibit 5-12 Final Balanced 30HV



5.5.2 Rounding

The final 30HV need to be rounded. The traffic volumes are not that precise to go down to one vehicle with the normal errors that occur within the counting and adjusting processes. For reduction of systematic error, balancing should occur before rounding of values. However, balancing the network can be easier if the network is not down to the individual vehicle. The analyst can choose a methodology, but the important thing is to stick with one method consistently through the entire project. Volumes should be rounded to the nearest five for the existing or base year. Volumes less than five vehicles should use the "<5" symbol instead of using zero.

5.5.3 Documentation

It is critical that after every step in the 30HV volume development process that all of the assumptions and factors are carefully documented, preferably on the graphical figures themselves. Count specifics, raw and system peak hours used, ATR's used, seasonal adjustments, ATR 30HV adjustments, and yearly growth factors are some of the items that need to be documented. If all is clearly documented then anyone can easily review the work or pick up on it quickly without questioning the assumptions made. The documentation figures will eventually end up in the final report or in the technical appendix. The volume documentation should include:

- Map-based figure showing (See Exhibit 5-13):
    - Roadway network and intersection lane configurations and control type
    - Raw traffic volumes showing raw peak hour
    - For each intersection, count date, duration, type, and raw peak hour time
- Map-based figure showing (See Exhibit 5-14):
    - Selected system peak hour time
    - Raw count data by movement for the selected system peak hour
- Map-based figure showing (See Exhibit 5-15):
    - Yearly growth and seasonal factors used for each intersection
    - Unbalanced factored 30HV
- Map-based figure showing (See Exhibit 5-16) balanced 30HV (this figure is used in an existing year analysis technical memorandum).

Exhibit 5-13 Raw Traffic Counts

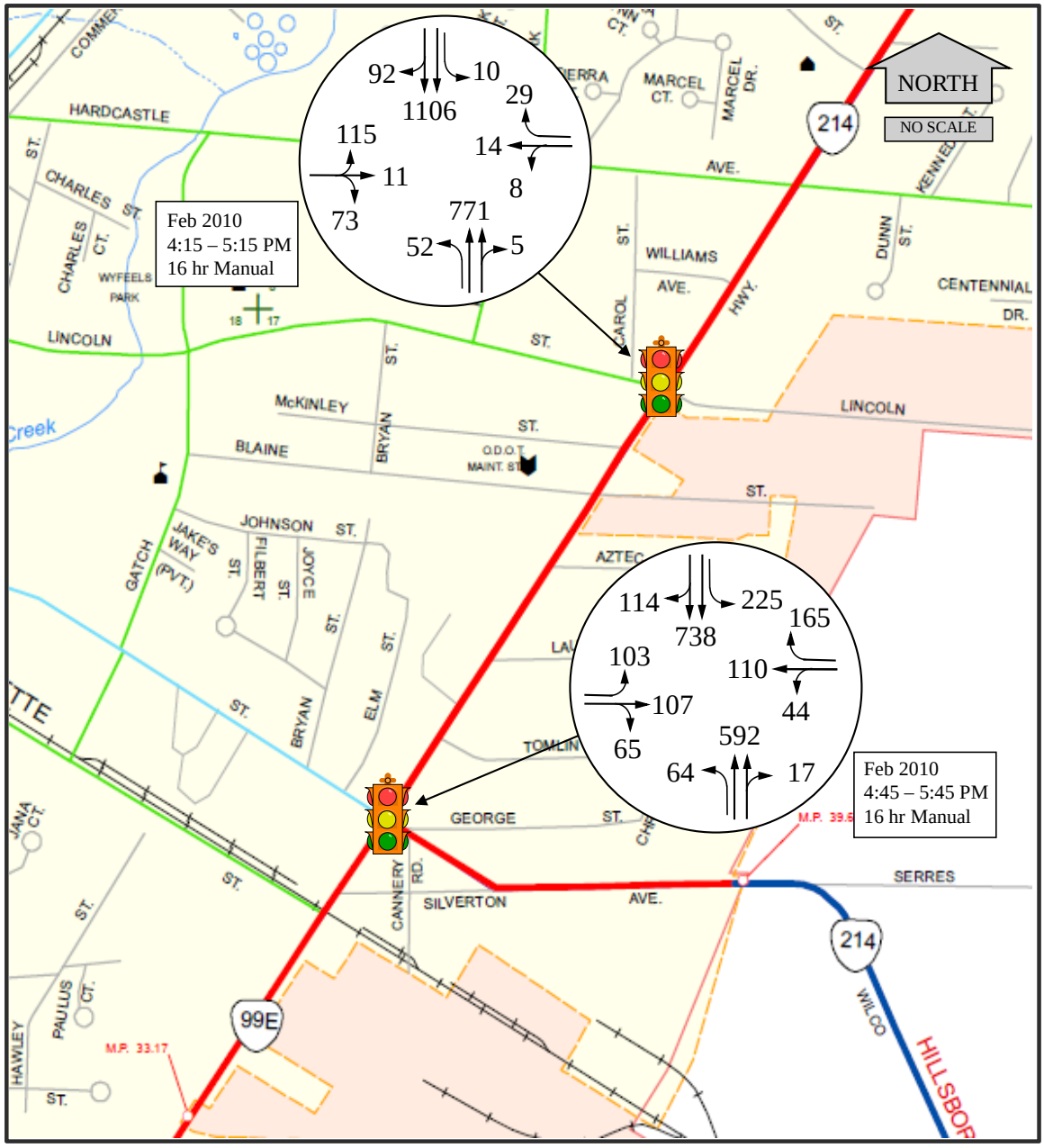


Exhibit 5-14 System Peak Hour

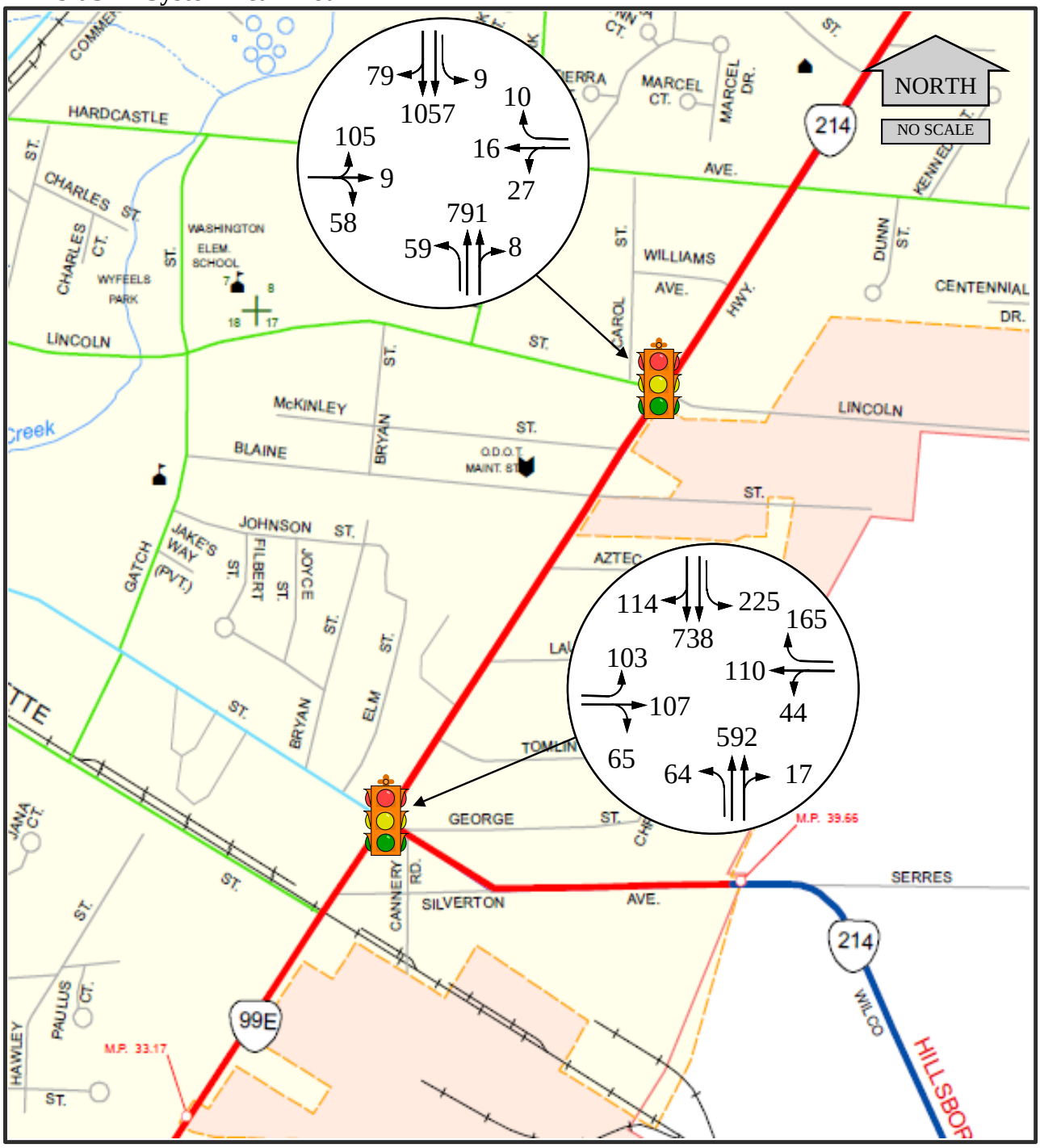


Exhibit 5-15 Seasonal and Historical Growth

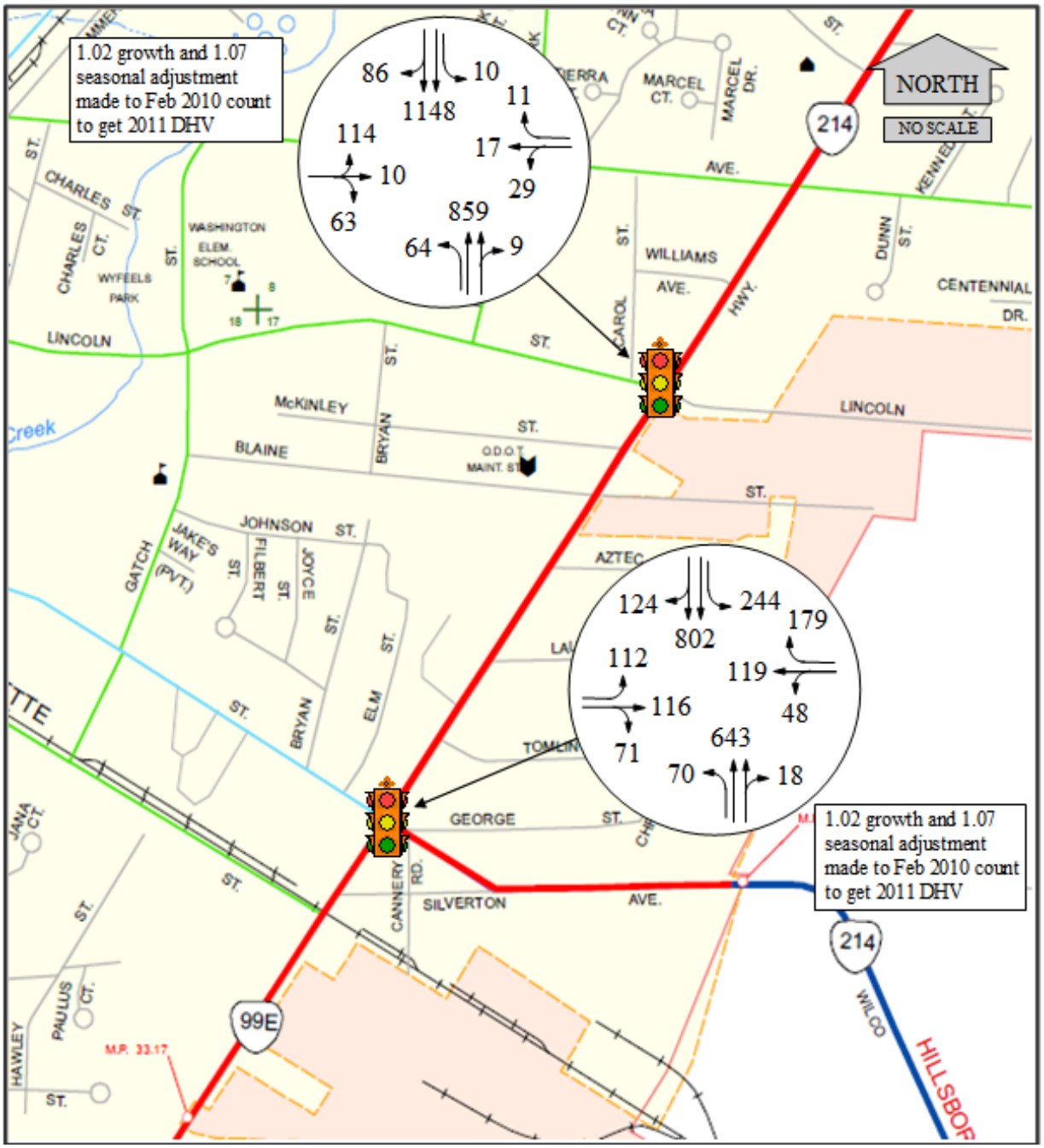
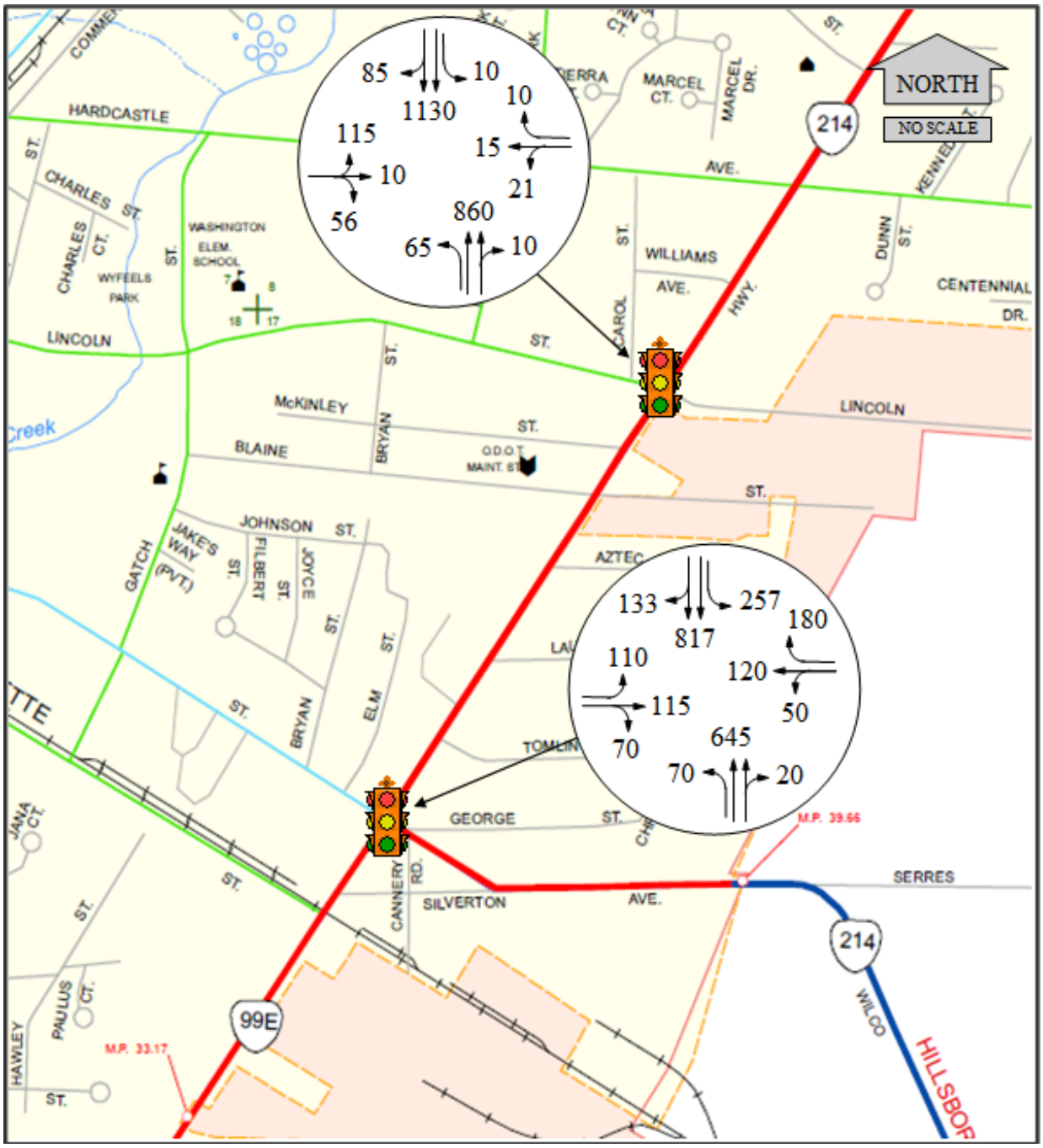


Exhibit 5-16 Balanced Network



5.6 K-30 Factor Development

For certain planning studies, such as a county Transportation System Plan (TSP) analysis, sketch planning level analysis of highway segments may be appropriate, for all or portions of the study. To develop planning-level design hour volumes, TVT AADT volumes can be used. The TVT AADT volumes are used to derive the 30HV by multiplying by the K-30 factor. A K factor is the ratio between a peak hour and the ADT. The K-30 factor is the ratio of the 30th highest hour to the AADT and should be used for this purpose. Short term count K factors should not be used for this purpose. A background report on this topic is available on the TPAU website[14].

K-30 factors are derived from ATRs and can be found in the TVT section on "Summary of Trends at ATR Stations". They are listed under Historical Traffic Data, Percent of ADT for the 30th Hour. A representative ATR needs to be identified following the procedures described in Section 5.4.

Example 5-7 Converting AADT to DHV using the (K_{30}) factor

This example illustrates how to calculate and apply the K-30 Factor.

Find the 30HV for sketch planning analysis for a segment of Kings Valley Highway No. 191 (OR 223) at MP 28.00.

- **Step 1: Transportation Volume Table** – The TVT is used to find the AADT for this segment.

The 2012 AADT from the Transportation Volume Table is found to be 1000.

- **Step 2: ATR Trend Summary** – ATR 02-005, located on Kings Valley Highway at MP 26.40, can be used for this location. The ATR number corresponds to a table in the last half of the TVT that contains yearly summaries for each ATR. From the column titled "Percent of AADT" the 30th Hour percent of AADT should be recorded for the past five years. The highest and lowest percentages should be eliminated to account for construction activity that may have occurred in the vicinity of the ATR during the five- year period. An average percent of AADT is then calculated for the remaining three years.

K-30 Factors Using ATR #02-005

	2012	2011	2010	2009	2008
K-30	12.6%	12.6%	12.6%	13.4%	12.6%

Note: Shaded values dropped from average calculation.

As shown in When using the ATR Summaries from the TVT's, the analyst should note

[14] Use of Short-Term Interval Counts to Determine K Factors, Don R. Crownover, P.E., ODOT Transportation Systems Monitoring (TSM) Unit, August, 2006.

both the average weekday and average daily percentages. Average weekday traffic (AWD) percentages include values for Monday through Thursday while average daily traffic (ADT) includes all days of the week. When there is little variation between the AWD and ADT percentages, using AWD supports the notion that the peak is likely on an average weekday. If the ADT is much larger than the AWD, then the peak is likely on a weekend day, so use the ADT Percentage. Check the Weekly Traffic Trend column from the ATR Characteristic table to aid in this calculation.

Example 5-1 Seasonal Factor – On-Site ATR, the percentage of AADT values listed during June and September for the past five years are reviewed to calculate the average. The highest and lowest values, shown as shaded, are dropped from this calculation. The average K-30 factor is determined as follows:

- The average K-30 factor is: (12.6% + 12.6% + 12.6%) / 3 = 12.6%.

Calculate the two-way 30HV:

30HV = (AADT) x (Average K-30 Factor) = 1000 x 0.126 = 126 vph.

Obtain the directional split for the 30th highest hour as defined by the D-30 factor from the TCM Ranked Hour report (see Traffic Count Management (TCM) Program Count Report Guide).

From the 2012 Ranked Hour report for ATR 02-005
D-30 NB = 0.30 and D-30 SB = 0.70

Calculate the directional 30HV:

30HV NB = (30HV) x (D-30 factor) = 126 x 0.30 = 38 vph.
30HV = (30HV) x (1-D-30 factor) = 126 x 0.70 = 88 vph

5.7 Average Daily Traffic (ADT) Development

A number of operational analysis processes need to use ADT instead of 30HV. Some of these are the preliminary signal warrants (link) and air/noise data (link). Many sketch planning and the HCM Planning analysis methods use ADT. ADT is also more perceivable by the public and is frequently used in meetings, environmental documents, and other traffic-related efforts. ADT should be thought of as a “peak month” ADT as it is developed using 30HV. This is not the same as annual average daily traffic (AADT) as AADT is developed using ATR sites which count all days of the year so seasonal trends can be accounted for.

ADT can be created directly on a link basis from 24-hr counts but these counts are unlikely to be done comprehensively over a study area or may be just limited to tube counts which do not catch turning movements. More typically, ADT is created from the

30HV or peak hour volumes.

The ADT conversion process requires the use of counts that can support ADT calculations (12 hours or more). In most cases, ADT cannot be created from peak hour or peak period counts. Use of shorter counts may be acceptable for use in preliminary signal warrants and safety-based analyses. K30 factors are not to be used in ADT development regardless of count duration as those are too general for a project analysis. K-factors and D (directional) factors need to come straight from an ADT-capable count or be derived from counts on other study area intersections/roadways with similar characteristics.

The TruckSum spreadsheet is a good source for obtaining initial K's & D's for all intersection legs of a count at once. Use the TCM TruckSum report to get the input data in the correct format for the spreadsheet (see TCM Program Count Report Guide and APM Version 1 Chapter 11). If non-cardinal directions (NW, SE, etc.) are included, the analyst will need to convert these to the cardinal directions (N, S, E, W) first before copying and pasting (Use Paste Special…Values Only) into the TruckSum Spreadsheet. As shown in Exhibit 5-17 below, the K-factors are shown explicitly and data is available to readily create the D-factor.

Exhibit 5-17 TruckSum K and D-Factors

Divide the directional volumes by the total volume to obtain the D-Factor. For the North leg, the directional split would be 23/51 = 45% NB and 28/51 = 55% SB.

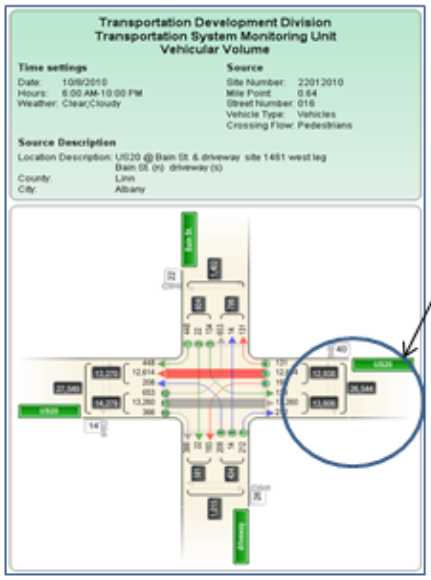
All Vehicle ADT		NORTH LEG		EAST LEG		SOUTH LEG		WEST LEG	
Factor	1.1	volume		volume		volume		volume	
	NB	23	EB	3626	SB	880	WB	1657	
	SB	28	WB	1958	NB	2464	EB	1736	
	TOTAL	51	TOTAL	5584	TOTAL	3344	TOTAL	3392	

All Vehicle PHV		NORTH LEG		EAST LEG		SOUTH LEG		WEST LEG	
		volume	factor	volume	factor	volume	factor	volume	factor
	NB	4	0.173	EB 355	0.098	SB 64	0.073	WB 139	0.084
	SB	2	0.073	WB 155	0.079	NB 250	0.101	EB 155	0.089
	TOTAL	6	0.119	TOTAL 510	0.091	TOTAL 314	0.094	TOTAL 294	0.087

K-Factor shown in decimal form for each direction on an intersection leg.
For the north leg of the intersection, the K-factors would be 17.3% NB and 7.3% SB.

If a TruckSum spreadsheet is not available, develop Ks and Ds from the count. Exhibit 5-18 shows a typical intersection count output and where to pull the data needed for the calculations. Note that the system peak hour should be used to develop the K and D - factors, rather than the individual intersection peak hour. For each directional link, calculate the K factor by dividing the system peak hour volume by the 24-hour volume ADT.

Exhibit 5-18 K & D – Factors from Counts



K and D- Factors from Counts

K-Factor

Westbound

$\frac{941}{12938} = 0.073$ or 7.3%

Eastbound

$\frac{1199}{13606} = 0.088$ or 8.8%

D-Factor

Westbound

$\frac{12938}{26544} = 0.49$ or 49%

Eastbound

$\frac{13606}{26544} = 0.51$ or 51%

Summary of Traffic Count
Transportation Development Division

Site:	22012010	Date:	10/8/2010
County:	Linn	Hours:	6:00 AM-10:00 PM
City:	Albany	Highway #:	016
		Location:	US20 @ Bain St. & driveway site 1461 west leg
Milepoint:	0.64		
Count Number:	1.00	Weather:	Clear;Cloudy

	Summary By Movements														Entering Volumes			
Time of Day	N-E	N-S	N-W	E-N	E-S	E-W	S-N	S-E	S-W	W-N	W-E	W-S		TOTAL	North	East	South	West
14:15	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
14:30	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
14:45	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
15:00	1	1	6	2	2	223	0	4	4	9	266	3		521	8	227	8	278
15:15	1	0	6	0	0	233	0	3	2	8	277	8		538	7	233	5	293
					0	236	1	2	6	12	267	6		544	11	239	9	285
					2	216	0	1	3	13	251	7		504	10	219	4	271
16:00	3	2	11	2	1	230	1	4	4	8	276	5		550	16	236	9	289
16:15	4	0	11	2	2	216	0	3	5	9	248	13		513	15	220	8	270
16:30	3	1	7	2	3	218	1	6	4	9	271	5		530	11	223	11	285
16:45	2	1	8	1	3	253	0	3	1	13	228	7		520	11	257	4	248
17:00	3	0	10	0	3	243	0	3	2	6	307	13		590	13	246	5	326
17:15	0	0	7	3	2	232	1	4	2	18	308	4		581	7	237	7	330
17:30	3	0	4	1	3	225	0	3	2	11	267	6		525	7	229	5	284
17:45	0	0	11	2	1	226	0	3	3	10	298	5		559	11	229	6	313
18:00	3	1	10	11	7	862	0	20	4	40	933	15		1906	14	880	24	988
18:15	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
					0	0	0	0	0	0	0	0		0	0	0	0	0
Total Count	121	20	407	119	175	11467	12	192	189	593	12054	332		25681	548	11761	393	12367
24hr Factor	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1		1.1	1.1	1.1	1.1	1.1
24hr Volume	134	22	448	131	193	12614	14	212	208	653	13260	366		26544	603	12938	433	13606

System Peak Hour

24-hour volume ADT

When the full 24-hour volume is not available, use the count expansion factors in Exhibit 5-19 to estimate from shorter duration counts.

Exhibit 5-19 Count Expansion Factors

Count Length (hours)	Expansion Factor
12	1.25
14	1.18
16	1.10
24	1.00

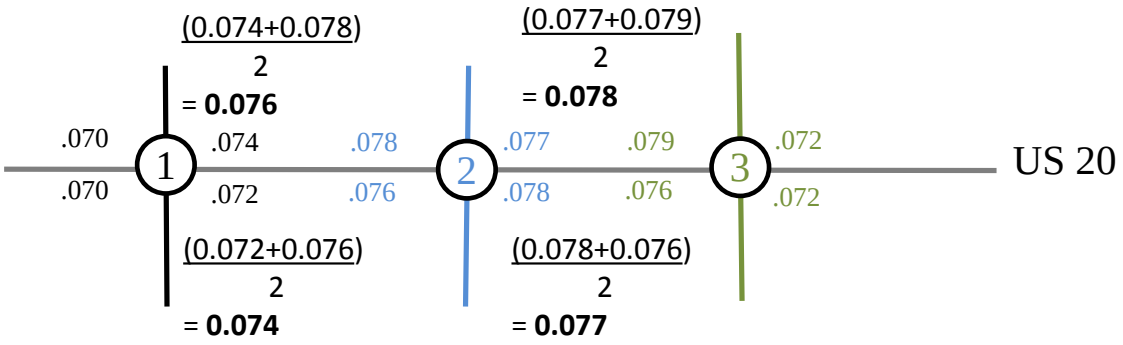
The D factor is calculated by dividing the highest 24-hour one-way volume by the two-way 24-hour volume.

Draw a link diagram of the study area. Label the K factors on one diagram and D factors on another diagram. Calculate average K factors between intersections. Links missing K or D factors (such as those using peak period counts) can be obtained (estimated) by averaging links with similar characteristics together in the study area. Divide the 30 HVs by the K factors to obtain the ADT on each directional link. Now sum the directional link ADTs to obtain two-way link ADTs. Now multiply the two-way ADTs by the D factor to obtain directional ADTs. The resulting splits may differ between the 30HV and ADT volumes.

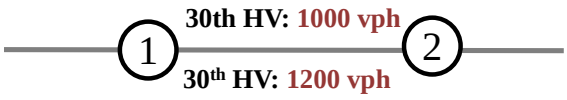
ADT's should be documented on a map-based figure on a link approach basis rather than showing individual turn movements.

Example 5-8 ADT Calculations

1. Label link diagram with K-Factors, average K-values between nodes:



2. Divide 30 HV by average link K-value (Step 1) to calculate ADT, sum ADT:

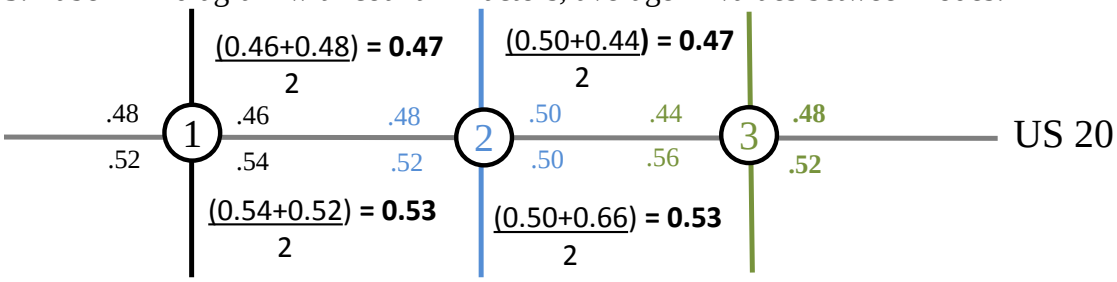


1000/.076 = 13,158 ADT

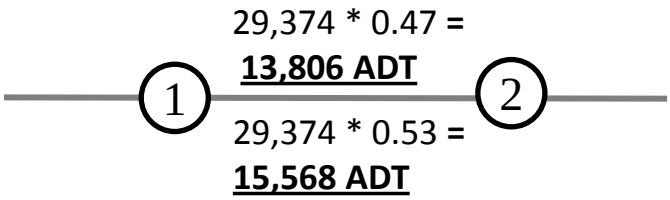
1200/.074 = 16,216 ADT

∑ 29,374

3. Label link diagram with count D-Factors, average D-values between nodes:



4. Multiply ADT link sum (Step 2) by average D-value to calculate directional ADT:

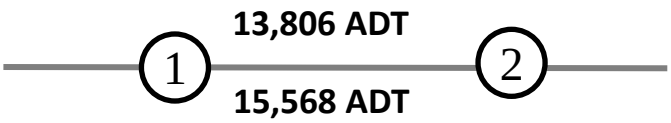


5.7.1 Converting ADT to AADT

ADT can be converted to AADT by applying the seasonal factor (See Section 5.4) straight instead of using the inverse in the 30HV process. This will convert the ADT to an average value (May/October). Example 5-9 ADT to AADT Conversions shows the typical calculations.

Example 5-9 ADT to AADT Conversions

Counts used to create the ADT values from the previous Example 5-8 ADT Calculations, were taken October 8th in a location characterized by a summer trend. After review of the ATR Characteristic Table it is determined that there are no characteristic ATR's that can be applied therefore, the Seasonal Trend Table must be used to convert the ADT to AADT.



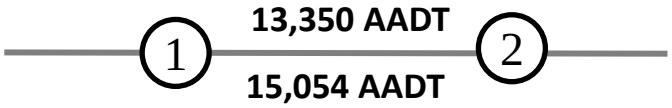
1. Using the Seasonal Trend Table under Summer Trend, averaging the October 1st and

15th column, the factor is 0.9670.

TREND	15-Feb	1-Mar	15-Mar	1-Apr	15-Apr	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec
INTERSTATE URBANIZED	1.0390	1.0322	1.0254	1.0050	0.9845	0.9849	0.9968	1.0130	1.0292	1.0414	1.0536
INTERSTATE NONURBANIZED	1.2265	1.1538	1.0811	1.0579	1.0347	0.9551	0.9989	1.0247	1.0506	1.1208	1.1910
COMMUTER	1.0352	1.0428	1.0503	1.0158	0.9813	0.9720	0.9803	1.0074	1.0346	1.0547	1.0749
COASTAL DESTINATION	1.0873	1.0993	1.1114	1.0737	1.0359	0.9635	1.0370	1.0906	1.1441	1.1672	1.1903
COASTAL DESTINATION ROUTE	1.2552	1.2561	1.2571	1.1881	1.1191	0.9389	1.0669	1.1473	1.2276	1.3028	1.3779
AGRICULTURE	1.2653	1.2511	1.2369	1.1493	1.0617	0.8622	0.9263	0.9984	1.0705	1.2224	1.3742
RECREATIONAL SUMMER	1.5130	1.4824	1.4519	1.3336	1.2152	0.9005	1.0231	1.1707	1.3183	1.4751	1.6319
RECREATIONAL SUMMER WINTER	0.9771	1.0169	1.0567	1.1357	1.2146	1.2207	1.4874	1.5592	1.6311	1.2701	0.9091
RECREATIONAL WINTER	0.6663	0.7094	0.7526	0.9446	1.1365	1.4499	1.7607	2.2112	2.6618	1.6508	0.6398
SUMMER	1.1778	1.1604	1.1430	1.0881	1.0332	0.9436	0.9904	1.0445	1.0985	1.1455	1.1925
SUMMER < 2500	1.2418	1.2093	1.1768	1.1022	1.0276	0.9126	0.9590	1.0366	1.1142	1.1979	1.2816

*Seasonal Trend Table factors are based on previous year ATR data. The table is updated yearly.
*Grey shading indicates months were seasonal factor is greater than 30%

2. Multiply the factor times by ADT to convert to AADT



5.8 Development of Volume-based Analysis Inputs

5.8.1 Existing Peak Hour Factors

Peak hour factors (PHF) are used to account for the non-uniformity of traffic flow within the peak hour by converting hourly volumes to peak flow rates associated with a selected interval of time within the peak hour. The most common interval of time selected for traffic analysis is the peak 15 minutes. In areas near capacity the peak 15-minute flow can cause up to several hours of congestion. This typically happens when the demand exceeds the available capacity of the transportation system resulting in “peak hour spreading”, which is the extension of the peak period caused by a system breakdown. Therefore, it is often essential that the transportation system be designed to accommodate the peak 15 minutes of the peak hour.

Peak hour factors should be applied in most capacity analyses in accordance with the HCM, which selected 15-minute flow rates as the basis for most of its procedures. It is especially critical to examine the peak 15-minute period when potential queue lengths may become an issue, and at locations with sharp peaking characteristics such as employment sites and locations with low peak hour factors (less than 0.90). Some alternate mobility standards do not use PHFs where the volume-to-capacity ratio is equal to or greater than 1. Alternate mobility standards procedures are discussed further in Chapter 10.

5.8.2 Calculation

The PHF is typically calculated using data from traffic counts. It is the traffic volume

during the peak 60-minute period divided by four times the volume during the peak 15-minute period.

$$PHF = \frac{\text{Volume During Peak 60-Minute Period}}{4 \times (\text{Volume During Peak 15-Minute Period})}$$

Typical PHF values range between 0.80 and 0.98. Factors greater than 0.95 are indicative of high traffic volumes, while factors less than 0.80 occur in locations with high peak demand (i.e. schools, factories with shift changes, or venues with scheduled events). PHFs calculated from actual traffic count data should always be used for analysis of existing conditions. For all applications other than sketch planning-level analysis, traffic count data should be obtained in 15-minute intervals. In calculating PHF, the system peak hour is first selected, and PHFs are calculated within that hour.

For segment analysis at a sketch planning-level, where traffic counts are not provided in 15-minute intervals, the HCM 2010 suggests the following PHF defaults:

- 0.95 for urban freeways;
- 0.92 for interrupted flow facilities;
- 0.88 for rural freeways, multilane highways and two-lane highways

Intersection PHF

The analysis method for intersections uses an intersection PHF to estimate peak 15-minute period equivalent hourly flow rates from the peak 60-minute period volumes. The peak 15-minute period with the highest intersection total entering volume (TEV) should be used to determine the PHF for each intersection. The application of global PHFs is generally not appropriate when count data is available. The intersection PHF is calculated as follows.

- **Step 1**: Determine the peak 15-minute period that has the highest intersection total entering volume (TEV).
- **Step 2**: Calculate the intersection PHF based on the time period determined in Step 1, by dividing the peak 60-minute TEV by four times the TEV occurring during the peak 15 minutes.
- **Step 3**: In the analysis software, apply the intersection PHF from Step 2 for all movements at the intersection (flow rates are then usually calculated by the analysis software).

Movement PHF should not be used because using the individual peak 15-minute periods by movement creates a situation that overestimates the volumes and does not exist in reality akin to the reasoning behind using a system peak hour. Conversely, using a single 15-minute period in essence creates a need to force this on all intersections which would create a “false precision” level of detail in the analysis (a system 15-min is too detailed), not to mention the difficulties in choosing the proper interval which may result in analyzing multiple intervals. In circumstances of unusually pronounced peaking on an intersection approach where an alternative method is desired, a written explanation

detailing the analysis area context and proposed alternative methodology must be submitted and approved by TPAU and Region Traffic prior to use.

For intersection analysis at a sketch planning-level, where traffic counts are not provided in 15-minute intervals, the following intersection PHF defaults should be used:

- 0.95 for major arterial-major arterial;
- 0.92 for major arterial-minor arterial;
- 0.90 for minor arterial-minor arterial;
- 0.88 for minor arterial-collector;
- 0.85 for collector-collector or lower classification

5.8.3 Future Conditions PHF

Because traffic flow patterns may change over time and future conditions cannot be directly measured, analysis of future years should incorporate the sketch planning default values for PHF listed previously.

Engineering judgment must be used in the selection of PHFs for future years. In cases where the existing PHF is higher than the default value for the future PHF, it may be appropriate to retain the existing value for the future year, as PHFs do not typically decrease as traffic volumes and congestion increase. Likewise for areas that have low existing peak hour factors, using the future PHF default values could produce results that would underestimate the future traffic conditions. For areas with aggressive traffic demand management strategies contained in an adopted plan, a different PHF (to reflect spreading of the demand) may be used for future year analysis if agreed to by ODOT during the scoping process. For areas with pronounced peaking characteristics, such as industrial sites and schools, PHFs lower than the default values listed above should be considered.

Revising PHF for Future Year

In areas where alternative mobility targets are in place and the volume to capacity ratios are at or exceed 1.0 (capacity), PHFs may be assumed to be equivalent to 1.0.

5.8.4 Truck Factor Development and Documentation

Most deterministic analyses will require truck percentages. These can be developed directly from the counts or from the TruckSum spreadsheets. Truck percentages are made up of the bus, single unit, single trailer, and multiple trailer vehicle classifications. Exhibit 5-20 shows a typical intersection count with the necessary fields highlighted.

Exhibit 5-20 Truck Classifications to use in an intersection count

Traffic Count Summary Sheet
Transportation Development Division (S-W)

Site: 19796 | Date: 10/1/2012
County: Douglas | Hours: 6:00 AM-10:00 PM
City: Roseburg | Highway #: 001
Milepoint: 123.80 | Location: I-5 s/b ramps @ Harvard Ave. & Bellows St.
Count Number: 1.00 | Weather: Clear

Time of Day	Passenger		Other 2 axle		Sgl. Unit Truck			Sgl. Trailer Truck			Dbl. Trailer Truck			Trp. Trailer Trucks			Bus	Motor-cycle	Vehicles	Bicycle
	Car	Wtrlr	Other	Wtrlr	2 Axl	3 Axl	4+ Axl	4- Axl	5 Axl	6+ Axl	5- Axl	6 Axl	7+ Axl	7- Axl	8 Axl	9+ Axl				
12:00	111	0	89	0	4	0	0	0	0	0	0	0	0	0	0	0	1	0	205	0
12:15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12:30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12:45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13:00	129	0	92	0	1	0	0	0	1	0	0	0	0	0	0	0	1	3	227	0
13:15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13:30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13:45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14:00	169	0	136	0	1	0	0	1	0	0	0	0	0	0	0	0	5	1	313	0
14:15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14:30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14:45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15:00	40	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	0
15:15	36	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51	0
15:30	32	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0
15:45	34	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	0
16:00	33	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0
16:15	34	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0
16:30	36	0	9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	47	0
16:45	26	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0

This is the peak hour. This line will need to be "pulled" from each sheet for each direction and movement.

In the count shown above, truck volumes need to be added up for this movement (S-W) for the system peak hour. To calculate the truck percentage for the northbound approach from the south leg, sum the trucks from the S-W, S-N and S-E movements and divide by the total entering volume from the south leg. To calculate the percent trucks for each movement, divide the truck volume by the total volume for that movement.

Example calculation for Northbound Truck % on west leg (Note: Don't forget to include buses)

$$NB\ Truck\% = \sum \frac{S{\rightarrow}N_{truck} + S{\rightarrow}E_{trucks} + S{\rightarrow}W_{trucks}}{All\ NB_{veh}}$$

$$NB\ Truck\% = \sum \frac{(0) + (3+2+7+3) + (1+1+5)}{28 + 530 + 626}$$

$$NB\ Truck\% = \frac{22}{1184} \qquad NB\ Truck\% = 0.01858 = 1.86\%$$

Example calculation for S-W Truck %

$$S{\rightarrow}W\ Truck\% = \sum \frac{S{\rightarrow}W_{truck}}{All\ S{\rightarrow}W_{veh}}$$

$$S{\rightarrow}W\ Truck\% = \sum \frac{(1+1+5)}{626}$$

$$S \rightarrow W\ Truck\% = \frac{7}{626} = 0.0118 = 1.12\%$$

Some analysis tools have different splits than just a “percent trucks.” Highway Capacity Software (HCS) has bus and recreational vehicle splits. Buses can be obtained from the count directly but the recreational vehicle split has to be ignored as ODOT does not specifically call out this vehicle type. Once the appropriate classifications to use are identified, the values are summed up by intersection approach (or movement if desired).

Truck percentages can also be determined from the TruckSum Spreadsheets (if individual bus splits were not needed). The TruckSum spreadsheets split out trucks into medium and heavy categories. Medium trucks are two-axle single unit and buses while heavy trucks are the three-axle and greater single unit and all combination vehicles. See Exhibit 5-21for identification of the peak hour medium and heavy percentages. The medium and heavy percentages in TruckSum can be summed to determine the final truck percentage to be used in the analysis.

Exhibit 5-21 TruckSum vehicle classifications

Sum the medium and heavy trucks (expressed as decimals) together to obtain the truck percentage on an intersection leg. For the east leg, the total truck percentage is 3.7% medium trucks and 0.8% heavy trucks for a total of 4.5%.

PHV Trucks Only		NORTH LEG			EAST LEG			SOUTH LEG			WEST LEG	
		volume	factor*		volume	factor*		volume	factor*		volume	factor*
All factors apply	Medium	0	0.000	Medium	19	0.037	Medium	15	0.048	Medium	8	0.027
to PHV for Trucks	Heavy	0	0.000	Heavy	4	0.008	Heavy	0	0.000	Heavy	4	0.014

Generally, the truck percentages are entered into analysis software and used as is. However, in some projects and plans where truck movement is a large concern (or part of the project need) the truck percentages will need to be split out by movement and multiplied by the movement volume to determine the actual volume of trucks. This truck volume will need to be balanced as any other volume set and the actual truck percentages re-figured so the analysis is accurate. See

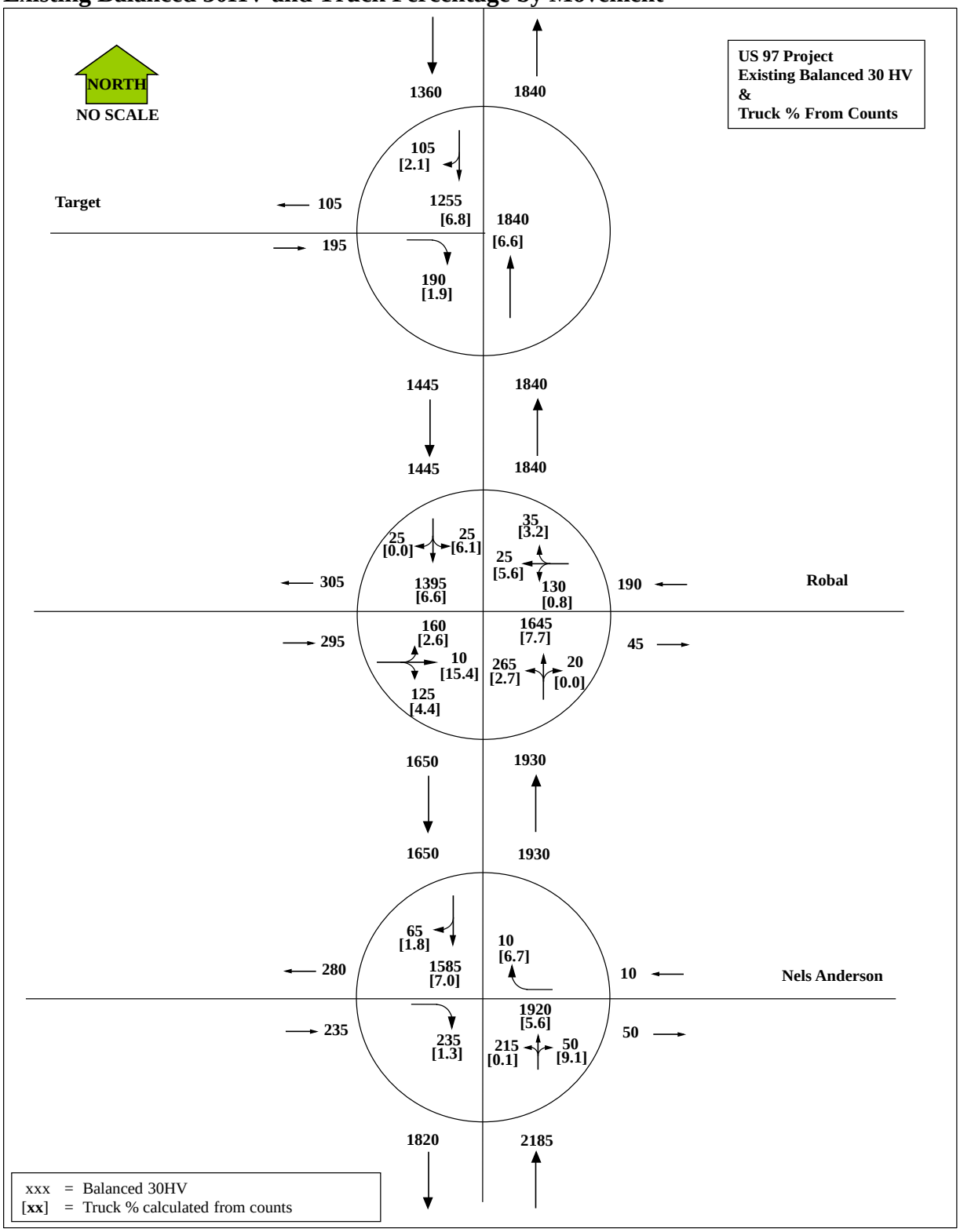
Just using approach volumes would create areas where truck volumes would be inconsistent either by having trucks “disappear” or “appear” in the middle of a link or between links that would not make sense.

Example 5-10 Actual Link Truck Factors.

Example 5-10 Actual Link Truck Factors

When truck movements are of concern on a project, it may be necessary to balance the truck volumes. This requires the truck percentages from the counts as calculated above, as well as balanced 30 HV volumes (see Exhibit 5-12). Truck volumes are not rounded as the final outputs desired are percentages. The Figure below shows the truck percentages that were calculated from the intersection counts and the balanced base year volumes.

Existing Balanced 30HV and Truck Percentage by Movement



Step 1: Calculate the 30HV Truck volumes by multiplying the calculated truck percentage and the 30HV balanced total volume. Sample calculations for the Target

intersection are shown below.

Sample Truck Volume Calculations for the Target intersection

$$Truck\ Vol = Truck\ \% \times Movement_{Total\ Vol}$$
$$N \rightarrow S_{truck\ vol} = 0.068 \times 1255 = 85.3 = 85\ Trucks$$
$$N \rightarrow W_{truck\ vol} = 0.021 \times 105 = 2.2 = 2\ Trucks$$
$$S \rightarrow N_{truck\ vol} = 0.066 \times 1840 = 121.4 = 121\ Trucks$$
$$W \rightarrow S_{truck\ vol} = 0.019 \times 190 = 3.61 = 4\ Trucks$$

Step 2: After calculating all raw truck volumes, they must now be balanced. Balance the truck volumes using the same procedure used to balance a network. In this example, the difference was split between Nels Anderson and Robal Rd. Then holding Robal Rd constant the volumes at Target were proportionally adjusted to balance the remainder of the network.

Step 3: Once the truck volumes have been balanced, a new balanced truck percentage must be calculated by dividing the balanced truck volume by the total balanced volume for each movement. Sample calculations for the balanced truck percentages for the Target intersection are shown below.

Sample Calculated Truck Percentages

$$Truck\ \% = \frac{Balanced\ Truck\ Vol}{Movement_{BalancedTotal\ Vol}}$$

$$N \rightarrow S_{Truck\ \%} = \frac{95}{1255} = 0.0756 = 7.6\%$$

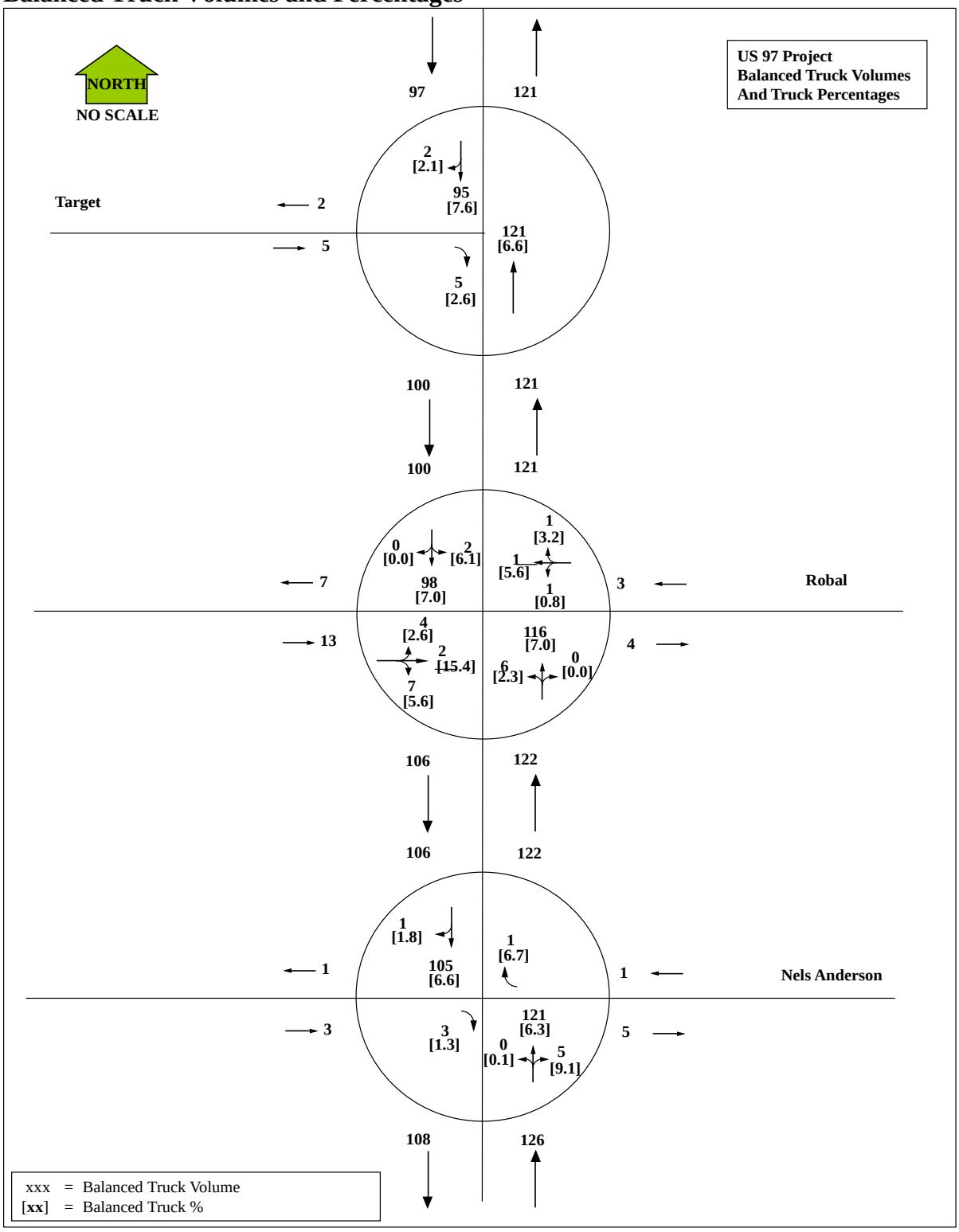
$$N \rightarrow W_{Truck\ \%} = \frac{2}{105} = 0.190 = 2.0\%$$

$$W \rightarrow S_{Truck\ \%} = \frac{5}{190} = 0.0263 = 2.6\%$$

$$S \rightarrow N_{Truck\ \%} = \frac{121}{1840} = 0.0657 = 6.6\%$$

The figure below shows the balanced truck volumes and the new calculated truck percentages. NOTE: The overall volumes do not change. The overall network is still balanced, no balanced volumes were changed. Only the truck volumes were changed and percentages adjusted to reflect the balancing of the truck volumes.

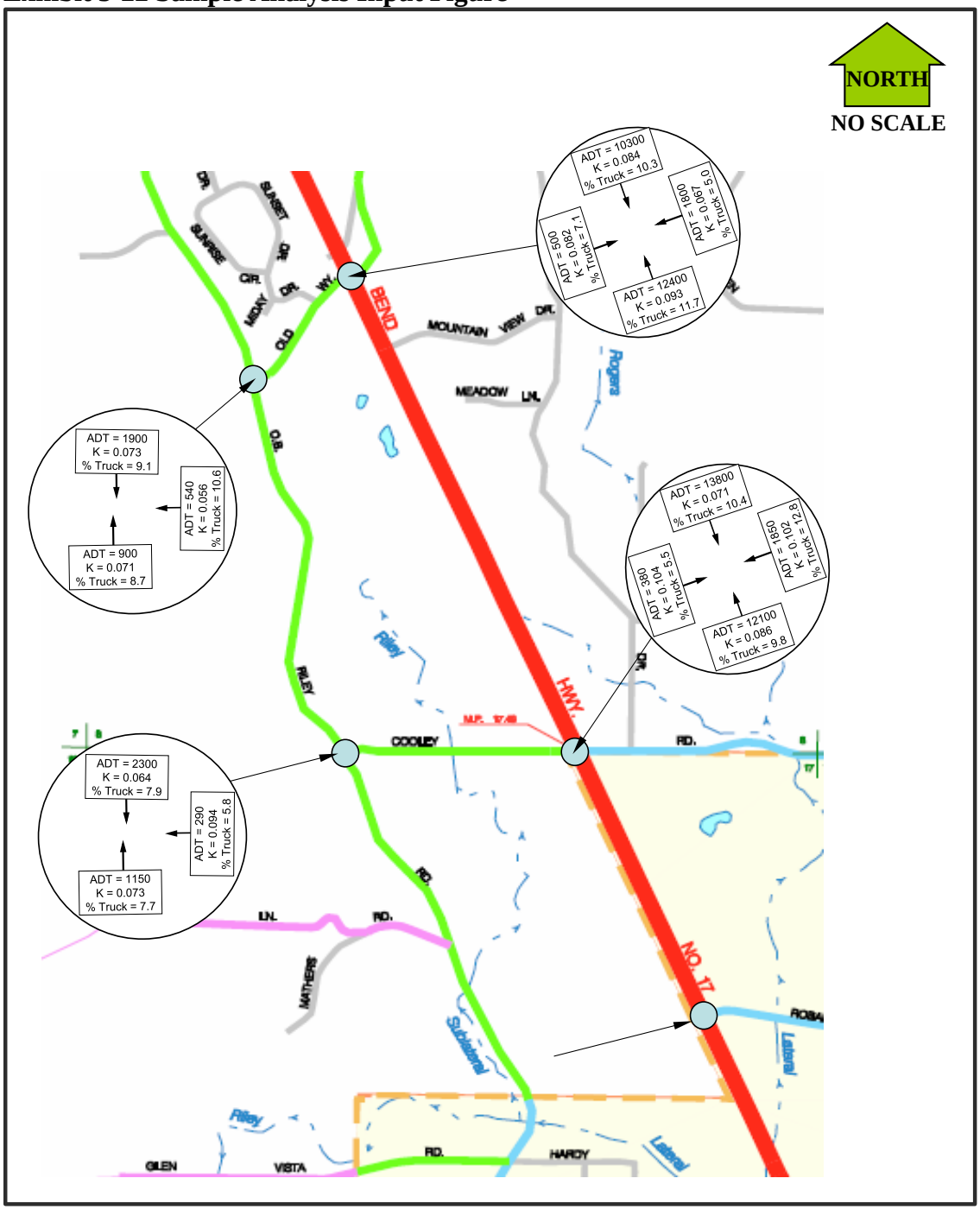
Balanced Truck Volumes and Percentages



5.8.5 Analysis Input Documentation

It is recommended that the truck percentages for each approach be put on a figure for future reference and for ease of entering into software packages. On the same figure, approach PHF's, and K-factors should also be added. This will streamline the entering of data plus make it an easy reference for the preliminary signal warrant process (which uses K-factors). See Exhibit 5-22 for a sample figure.

Exhibit 5-22 Sample Analysis Input Figure



6 FUTURE YEAR FORECASTING

6.1 Purpose

Design Hour Volumes (DHV) are used for ODOT planning and project level analyses. These are based on the existing year volumes developed in Chapter 5. The DHV is generally defined as the future year 30th highest hour (30 HV). Depending on scope and complexity of the analysis, different future methodologies are needed from simple historical trends to complex travel demand models. This chapter will outline the procedures for developing DHV and future Average Daily Traffic (ADT) used for ODOT planning and project level analysis. In addition, the processes for developing pavement design traffic volumes are also discussed. Future design hour volumes are a key input in following analysis steps and methodologies explored in later chapters. For more details on many of the methods in this chapter also refer to NCHRP Report 765.

6.2 General Considerations

The DHV typically controls the design of the project or represents a planning horizon year such as in a Transportation System Plan (TSP). These volumes can either be for no-build or build conditions.

6.2.1 Rounding

The DHV's need to be rounded before the network is balanced. The traffic volumes are not that precise to go down to one vehicle, especially considering projections that may be out 20 plus years. Balancing the network is easier if the network is not down to the individual vehicle. Future years five or ten years out should be rounded to the nearest five vehicles. Twenty-year future volumes can either be rounded to the nearest five or ten vehicles. Volumes less than five vehicles should use the "<5" symbol instead of using zero.

6.2.2 Need for Balancing

The DHV networks need to be balanced, even more so than with the existing conditions. Small differences in the existing year can become large differences in future years. Future planned changes in the network or land use remove the ability to use relationships between the obtained traffic counts as multiple growth rates are likely in effect. For areas that have travel demand models, balancing is critical to the success of post-processing. Refer to Section 5.3.2 for additional details on the balancing techniques.

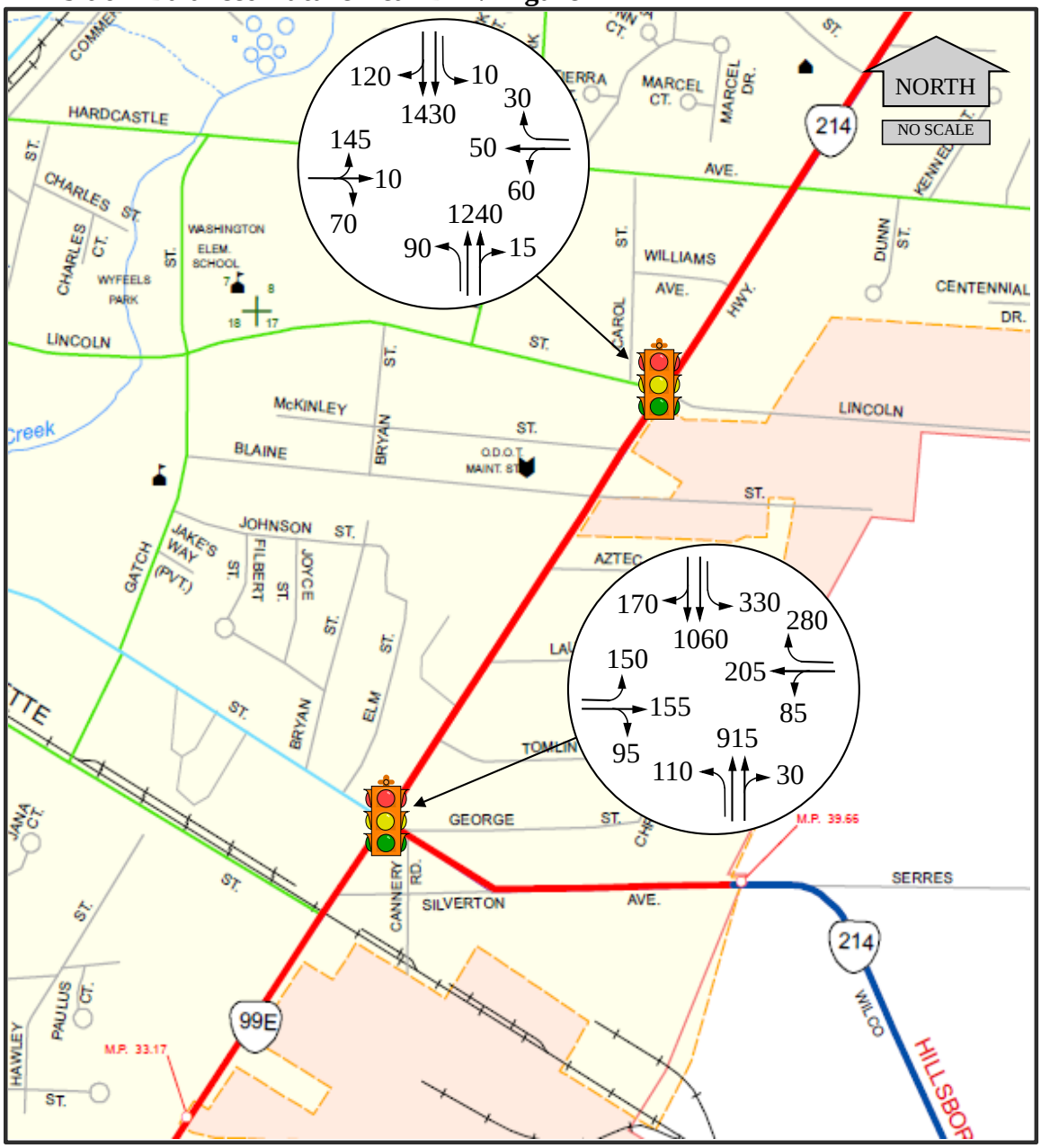
6.2.3 Documentation

It is critical that after every step in the DHV process that all of the assumptions and factors are carefully documented, preferably on the graphical figures themselves. While the existing year volume development is relatively similar across types of studies, the future year volume development can go in a number of different directions with varying amounts of documentation needed. Growth factors, trip generation, land use changes are some of the items that need to be documented. If all is documented then anyone can

easily review the work or pick up on it quickly without questioning what the assumptions were. The documentation figures will eventually end up in the final report or in the technical appendix. The volume documentation should include:

- Figures/spreadsheets showing starting volumes (30 HV)
- Figures/spreadsheets showing growth factors, cumulative analysis factors, or travel demand model post-processing.
- Figures/spreadsheets showing unbalanced DHV
- Figure(s) showing balanced future year DHV. See Exhibit 6-1
- Notes on how future volumes were developed:
    - If historic trends were used, cite the source.
    - If the cumulative method was used, include a land use map, information that documents trip generation, distribution, assignment, in-process trips, and through movement (or background) growth.
    - If a travel demand model was used, post-processing methods should be specified, model scenario assumptions described, and the base and future year model runs should be attached.

Exhibit 6-1 Balanced Future Year DHV Figure



6.3 Determining the Future Year(s)

The analyst should work with the region project leader/planner ideally during the scoping phase to determine the future year before beginning any future year forecasting. The future year determination is typically documented in a methodology and assumptions memorandum in addition to the overall scope of work/work plan.

The design hour that is used for many projects is 20 years after the year of project opening. It can be a considerable period of time between when the traffic analysis is completed and when the project is completed. Environmental documents (EA/EIS), Final

design and approvals, permits, environmental clearances, right-of-way purchases, and funding availability/Statewide Transportation Improvement Program (STIP) programming, may add anywhere from two to five years before a project starts the construction phase. Depending on the project complexity, construction may take from one to many years with phases.

In planning, a 20-year horizon is typically used when evaluating transportation needs and solutions. Future horizon years should be, at a minimum, 20 years after the estimated plan completion/adoption year. This is typically two years after the plan starts. For refinement and other similar plans, the horizon year should be 25 to 30 years out, which would increase the life of the plan, especially if the project development process does not directly follow. Existing policies may determine the planning horizon such as the Transportation Planning Rule (TPR). Transportation Impact Analysis (or Study) (TIA/TIS) horizon year procedures are provided in the Development Review Guidelines.

Many times, additional future years are necessary beyond just the typical 20-year future. In projects, the year of opening (build year) plus interim future years may be needed to support project phases or environmental air/noise/energy analyses. For example, if a project base year is 2011, its build year could be 2014, a 10-year future year would be 2024, and the project future (design) year would be 2034. This would mean three separate future years to be developed by the analyst.

For TSP's, build years are not typically done, but there may be interim years to support Urban Growth Boundary (UGB) expansions or to maintain consistency with adopted plans. For example, a TSP refinement plan with an existing conditions year of 2011 may have a 2025 year to stay consistent with the earlier TSP, but would still have a 2033 planning horizon year for a 20 year life beyond adoption.

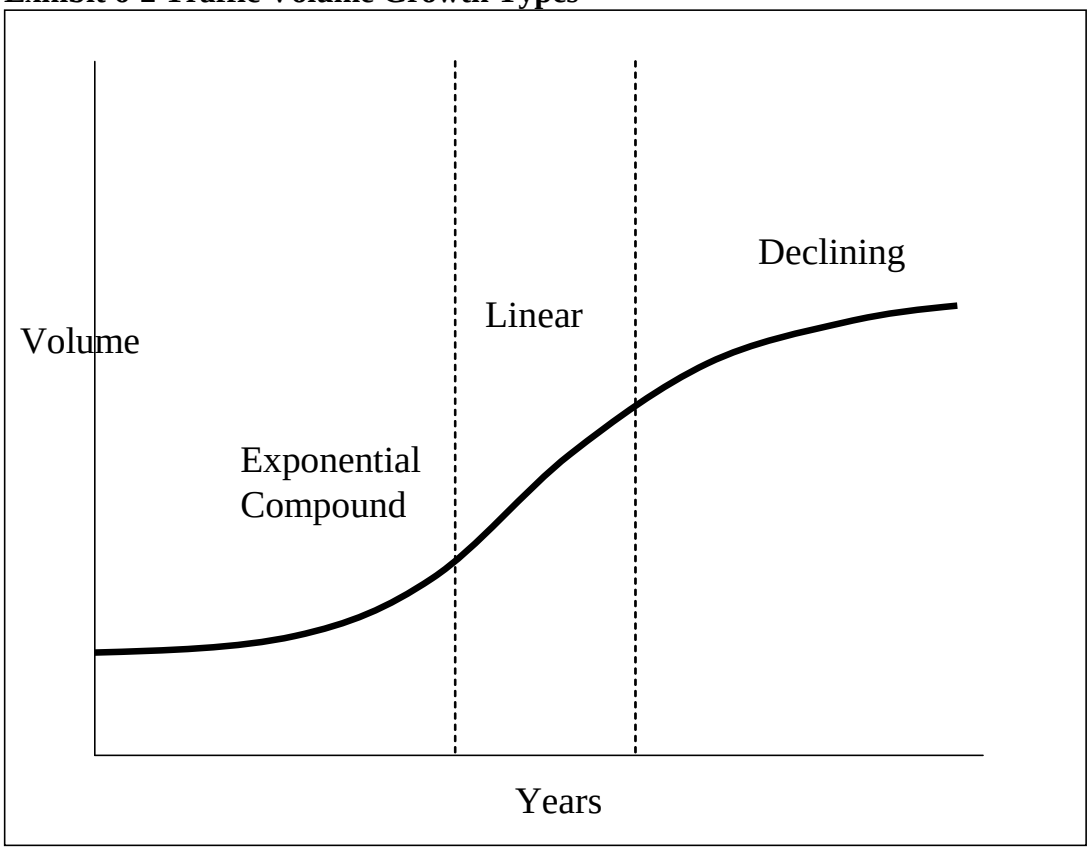
Refinement plans that will be directly supporting later project development efforts will typically have year of opening (build year) future years. Planning efforts with three or more years between the plan and a start of a following project generally do not need build year analyses as the traffic analysis will likely need to be redone anyway.

Care should be taken to not extend the horizon year beyond the normal accuracy level. The limits of detailed analysis go out to about 30 years; anything beyond this is an estimation/approximation. If a travel demand model is used, five years is the limit of extrapolation beyond the model future year. If a project/plan requires more than five years, then the model needs to be updated, which typically involves creating a new future year (reference year) for the model. Contact the Transportation Planning Analysis Unit (TPAU) or modeling staff in Metro for the Portland metropolitan area, Mid- Willamette Valley Council of Governments (MWVCOG) for the Salem-Keizer metropolitan area, and the Lane Council of Governments (LCOG) for the Eugene-Springfield metropolitan area immediately if a model update seems necessary. In some cases, if the travel demand model area is slow-growing, the extrapolation limit can be longer.

6.4 Growth Patterns

Different growth pattern types can all be present in a study area. There can be areas of fast growth (i.e. next to an urban fringe interchange), steady growth, or slowing growth (infill). Growth can be negative over the short or long term (i.e. recessions, declining industries, migration, or competition with nearby areas). The analyst must have knowledge of the study area in order to make the proper future year assumptions. The typical long-term growth curve can be a combination of three conditions on the overall timeline (see Exhibit 6-2). For instance, for the first 5 years the growth is exponential (compound), the next 10 years is linear, but the last 5 years the growth is declining (logistic). Growth curves can also be estimated by using a combination of differently sloped lines (piecewise, such as linear with different growth rates).

Exhibit 6-2 Traffic Volume Growth Types



- **Exponential Growth (Compound)** – An exponential increase in traffic volumes, typically associated with brand new growth in an area that has plenty of land and road capacity. Exponential growth predicts the future volume for a given year based on a percentage of growth from the previous year. This is typically limited to five years or less. Use of an exponential curve over a prolonged period can seriously overestimate future growth.

$$\text{Future Volume} = \text{Base Year Volume } (1 + \text{Growth Rate})^{\text{Number of Years}}$$
$$\text{Volume}_{FY} = \text{Volume}_{BY} \times (1 + Gr)^{(FY-BY)}$$

Where:
Gr = Geometric growth rate
FY = Future year
BY = Base Year

This method is not generally recommended unless it can be supported by data.

- **Linear Growth** - Linear increase in traffic volumes over time. This method assumes a constant amount of growth in each year and does not consider a capacity restraint. Areas that have or will likely have capacity constraints should use the declining growth curve shown below as long as there is sufficient evidence of a potential change. In many cases a linear growth rate is used since often there is insufficient data to support use of a more specific type of curve.

  Future Volume = (Linear Growth Rate x Number of Years) x Base Year Volume
  $Volume_{FY} = G_{Linear} \times N \times Volume_{BY}$

  Where:
  G = Linear growth rate (volume)
  N = Years beyond the base year
  FY = Future year
  BY = Base Year

- $V = \frac{V_0 C}{V_0 + (C - V_0)e^{-rt}}$ **Declining Growth (Logistic)** - Growth tapers off as land approaches built-out status and capacity of roadways. Future growth is mainly contributed by growth in background (through) traffic.

$$V = \frac{V_0 C}{V_0 + (C - V_0)e^{-rt}}$$

Where:
t= time (years)
V= the volume at time t
V_0 = the initial volume at time 0
C= capacity (maximum sustainable volume)
r= rate of volume growth when volume is very small compared to the capacity.

C (capacity) is defined as service flow or saturation flow per lane. For interstates, multilane highways, and two-lane highways, it would be the maximum service flow at level of service (LOS) E. Signalized arterials would start with the ideal saturation flow which is reduced to the actual saturation flow with a few basic parameters as shown in Equation 18-5 in the 2010 Highway Capacity Manual (HCM) . Alternatively, the capacity estimator in the Highway Design Manual (HDM) Section 10.12 can be used and then use a characteristic K-factor to convert to an hourly value

or can leave everything as ADTs (so C is an ADT-based value instead of hourly).

Once a "C" is found, then use the Future Volume Tables/model to project linearly as a test to see if C is exceeded within the design/planning horizon or close (no more than 30-40 yrs.). If volumes exceed or get close to C then this curve would be used instead of linear. This would be the curve to use for future no-build. For the build, a determination would have to be made of the potential change in C. A significant increase in capacity may result in a linear relationship while a small change may affect it only a little in which the same curve could be used but with a higher C value. Use of this curve may indicate that there is peak spreading effects in play (see Chapter 8).

Estimates for rate (r) are done for the linear portion of the curve, so they can be based from the FVT (see Section 6.5) or from a travel demand model. Growth rates have to be large enough over time (t) to be affected by the capacity value so the curve will flatten out. Small growth rates may never reach the capacity level so the curve will remain linear.

Exhibit 6-2 shows the three types of curves, starting off as exponential (compound), transitioning to linear, and then to declining growth.

6.5 Historical Trends

The historical trends method uses traffic volumes from previous years to project future volumes. This method assumes that the future growth trend will be similar to the historical trend. It is used mainly in rural or small urban areas where significant growth is not anticipated. Current and future year traffic volumes are available in the Future Volumes Table webpage. More detail on the Future Volume table structure is in Section 5.5. If desired, different growth curves can be used on historical trend data if the overall trend does not seem to be linear. Most of the time, the differences between alternate growth curves and the linear growth curve are small and not worth the effort to create the trend.

Certain areas may be in long-term decline with negative growth rates. It is not generally appropriate to forecast a negative linear growth rate as many areas could result in a zero or an unrealistically low volume before the horizon year is reached. A conservative method is to assume no growth (base year = future year). It may be warranted to do a detailed investigation of the past trends to see if a different growth curve should be used. The Transportation Planning Analysis Unit (TPAU) has data on past trends (20+ years) on the state highway system and can help with these types of issues.

Recessions/economic downturns can cause short-term dips in growth trends. It is possible to have a short-term low, none, or negative growth while still maintaining a long-term positive growth. Short- term recessions have little effect on a long-term analysis. Longer term recessions or slow growth periods need to be reviewed to make sure that the analysis is not starting from the low point (could underestimate volumes) or is projecting off the high point (could overestimate future volumes). These kinds of situations typically

require a sensitivity or “bookend” type of analysis where both conditions are analyzed. While the terms, “growth rates” and “growth factors” appear to be interchangeable, they are not. Growth rates are decimal percentages versions of the yearly percentage growth. For example, if the growth rate is 2.5% per year, this would be 0.025. Growth factors are used in calculations and may represent one or more years (i.e. 1.025). Adding a “1” will convert a growth rate into a factor. It is important to remember when to convert or not. When converting multiple year growth factors into a single growth rate, make sure to remove the “1” before dividing (See Example 6-1). The basic growth rate and factor equations are shown below:

Growth Rate = (Growth Factor -1) / Number of Years

Growth Factor = 1 + (Growth Rate x Number of Years)

Example 6-1 Future Volumes Using Historic Trend

In this example, the forecast 20-year traffic volumes are developed based on historical counts.

For the Lava Butte Automatic Traffic Recorders (ATR) (#09-003) located on US 97 at MP 142.41, The following table shows the 1999 traffic volume, Year 2019 traffic volume and the R-squared value.

Example Future Volumes Table

Hwy#	DIR	MP	Description	1999	2019	RSQ
4	1	141.01	.01 miles S of Badger Rd	28400	47200	0.9212
4	1	141.52	.22 miles S of Murphy Rd	24000	41400	0.656
4	1	142.21	ATR 09-003 - Lava Butte	19600	32000	0.9338
4	1	143.47	.01 miles S of Galen Baker Rd	14200	23600	0.7328
4	1	153.09	.01 miles S South Century Dr	9600	11100	0.5788

RSQ = R-squared is an indication of data fitting to a line.

Based on the data above, the 20-year growth factor would be 1.63 (32,000/19,600). Assuming linear growth in the future, the annual growth rate would be (1.63 –1.0) /20 = 0.032, or 3.2%. The R-squared value of 0.9338 is acceptable, indicating a strong relationship. To convert the 1997 30 HV from this example to a 2019 DHV, the 1997 30 HV is multiplied by the 20-year growth factor, with an additional two years of growth added to this.

2019 DHV = 1997 DHV x (20-Year Growth Factor + 2 x Annual Growth Rate) =
112 vph x (1.63 + (2 x 0.032))
= 112 vph x 1.694
= 190 vph

When dividing the estimated future year volume by the most recent count volume it is

important to note the numeric difference between the two years. In the example above, a 20-year growth rate was used between 1999 and 2019. Other highways may have been last counted in 1997 or 1998. This would mean that a 21- or 22-year growth rate should be applied. Dividing the total growth by 20 years would, in these cases, overestimate the growth rate.

For areas with calculated multiple growth factors, discard any with an R-squared value less than 0.75. Remaining growth factors that are within 1 or 2 percent can be averaged.

6.6 Trip Generation

Vehicle trips generated by future development are estimated using the Institute of Transportation Engineers (ITE) Trip Generation Manual (if manual trip calculations are used) or a travel demand model for larger studies (see Section 6.10 as well as the Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012). ITE trip generation rates are based on a database of trip generation studies conducted in the U.S. These studies collected data at existing land use generators including driveway vehicle counts and land use characteristics such as floor area size, number of parking spaces, etc. For each land use type, models were developed from the counts and the characteristics of the land uses, resulting in trip rates or equations for various time periods. ITE trip generation should not be confused with travel demand model trip generation, which is based on household surveys of person trips rather than vehicle counts. The following is a summary of ITE trip generation manual procedures. The manual itself should be consulted as part of any trip generation estimation process.

Trip generation rates are typically average values. There can be a large difference between the local trip generation potential and the national average values in the ITE manual. For common uses, such as single-family homes, gas stations, and shopping centers there have been plenty of studies done over the years that make up the research that is the basis for the trip generation rate or equation. Many land uses such as some commercial types have only a few studies, so the data should be used with caution. It is not uncommon for the standard deviation to exceed the averages if only a few studies exist. The ITE Trip Generation manual has guidance and cautions on the data limitations, what the assumptions/definitions for each land use are, procedures for use and conducting local trip generation studies if necessary.

Note that trip generation software such as Trip Generation by Trafficware is not standalone as it does not have the necessary background information on each land use like the manual does. The software is just a calculator tool that needs to be used in conjunction with the ITE Trip Generation Manual.

Trip generation may be composed of three basic types of trips: new/primary trips, pass-by trips, and diverted linked trips. New or primary trips are those trips that are new to the study area specifically attracted to or produced by a land use. Pass-by trips already exist along the roadway fronting the site, but now access the site before continuing on. Diverted linked trips exist in the study area but must divert onto local roads in order to access the site. Each of these types of trips is illustrated in the following Examples.

External versus Internal Trips

ITE Trip Generation rates are based primarily on single-use, free-standing sites. There are some exceptions such as shopping centers. Multi-use or mixed use developments may have interactions such as where some trips may occur internal to the site, whether by motor vehicle or by walking. The total external trip generation of these sites may be less than the sum of the individual stand-alone trip rates calculated using the ITE trip generation rates. ITE Trip generation Manual provides a methodology to estimate this effect, called internal capture (Volume 1, Trip Generation Handbook, Chapter 7 Multi-Use Development). This is a percentage reduction applied to the sum of the individual land use trip generation.

Other Considerations

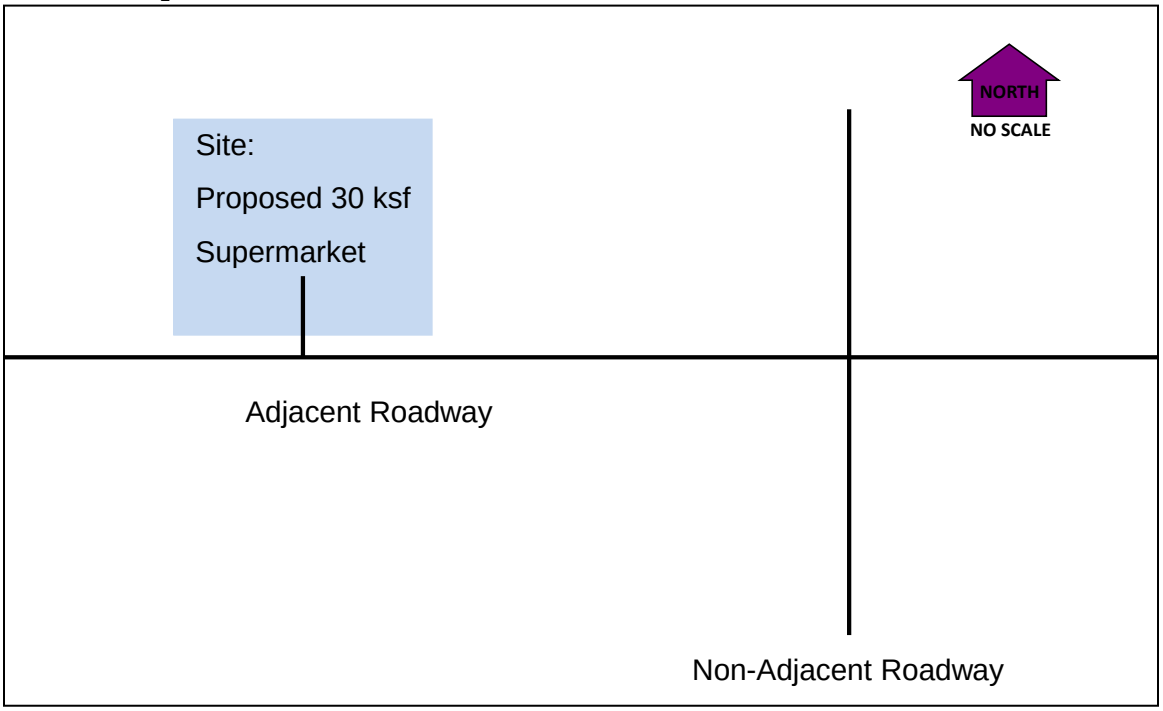
The ITE trip rates are based on data collected primarily at suburban locations with little or no transit service, nearby pedestrian amenities, or travel demand programs. The ITE Trip Generation Manual suggests the user may modify trip generation rates to reflect the presence of public transportation, Transportation Demand Management (TDM) measures, enhanced pedestrian and bicycle trip making opportunities, or other special characteristics of the site or study area. The Transportation Planning Rule (TPR) contains such a provision. OAR 660-012-0060 (6)(a) states that a ten percent reduction in ITE trip generation rates (that do not specifically account for mixed use effects) shall apply for proposed land use plan amendments which consist of mixed-use, pedestrian-friendly development and **prohibit** uses which rely solely on auto trips, such as gas stations, car washes, storage facilities, and motels.

ITE encourages users to supplement trip generation analysis with local data where practical. If local studies are conducted they should follow the ITE Trip Generation Manual guidelines for conducting a trip generation study.

Example 6-2 Trip Generation

A supermarket with floor area of 30,000 square feet is proposed as a new development within a suburban area as shown below. The proposed use is adjacent to an east-west arterial and located to the west of a north-south arterial. It is desired to estimate the trip generation for the site.

Site Development Location



From the ITE Trip Generation Manual, 9th Edition, Volume 3, a supermarket is assigned Land Use Category 850. This is only a single land use so neither the internal trip capture reductions apply nor does the TPR mixed use reduction. The trip rates or equations, as appropriate, for this land use type are obtained from the manual and shown below. The manual provides trip generation data for certain days of the week such as the average weekday, Saturday and Sunday, as well as for specific hours of the day, such as the peak hour of the adjacent street traffic, or the peak hour of the generator. In this example the peak hour of adjacent street traffic is used. Average percentages of trip entering and exiting the site are also provided. Calculations are performed either in a spreadsheet or using commercial software. The resulting trips are typically summarized in a table as shown below. These represent all motor vehicle trips with origin or destination external to the site.

Site Trip Generation Summary

	ITE Land Use[1]	**Trip Rate or Equation[2]**	**Enter**	**Exit**	**Total**
AM[3]	850	3.40X	63 (62%)	39 (38%)	102
PM[3]	850	Ln(T)=0.74Ln(X) +3.25	163 (51%)	157 (49%)	320
Average Weekday	850	102.24X	1,534 (50%)	1,534 (50%)	3,067

[1] ITE Trip Generation 9th edition
[2]X = independent variable (thousand square feet of floor area) = 30.0 ksf
[3] Peak hour of adjacent street traffic

For commercial/retail types of land uses, peak hour site trips need to be further subdivided into new (primary), pass-by, and diverted linked trips. The ITE Trip Generation Handbook may have estimates of those percentages. These ITE estimates vary by land use size and other characteristics, so the chosen estimates should be close to the size of the proposed land use. Ideally, there will be more than one applicable estimate which can be averaged together. If not, other studies may be used or conducted, along with engineering judgment.

In this example, the ITE Trip Generation Handbook lists studies of average PM peak hour pass-by and diverted linked trip generation rates for supermarkets. Average rates are taken from data points where both pass-by and diverted linked rates are provided. Select those locations with size near that of the subject site. There are five study locations near 30,000 square feet in size. Of those, four locations provide both pass-by and diverted linked trip percentages. The average of these four sites is used. The average pass-by percentage is (32 + 44 + 19 + 28)/4 = 31%. The average diverted linked trip percentage is (20 + 27 + 45 + 32)/4 = 31%. The average primary trip percentage is (48 + 29 + 36 + 40)/4 = 38%. The number of PM peak hour trips by type are then calculated and displayed in a table as follows.

Site PM Peak Hour New, Pass-By, and Diverted Linked Trips[1]

	Percentage	Enter	Exit	Total
New	38%	62	60	122
Pass-by	31%	51	49	100
Diverted Linked	31%	51	49	100
TOTAL	100%	164	158	322

[1]ITE Trip Generation Handbook and Manual, 9th Edition

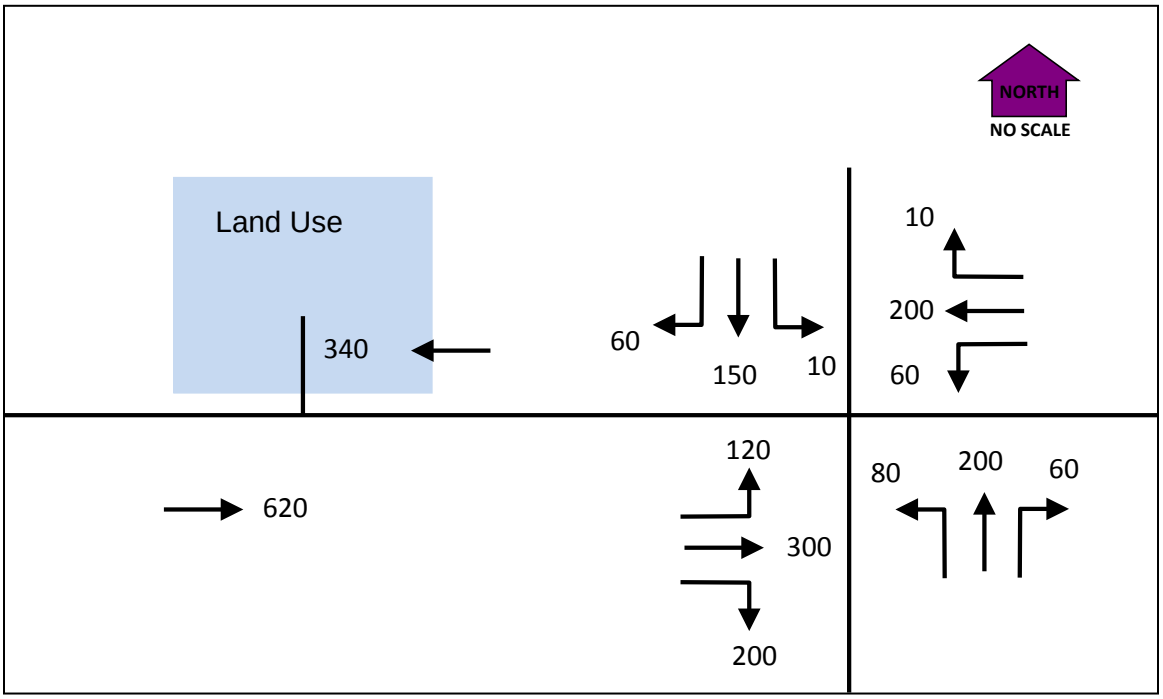
6.7 Trip Distribution

Traffic generated by a future development is distributed from the site based on existing origin-destination (O-D) study data if available, traffic count patterns for nearby similar land uses, local knowledge, or use of a travel demand model for larger studies (see Section 6.10 as well as the Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012), together with engineering judgment. Use of a travel demand model typically involves creation of the land use in a model scenario then having a select-zone analysis performed to determine in/out percentages from the site.

Example 6-3 Trip Distribution

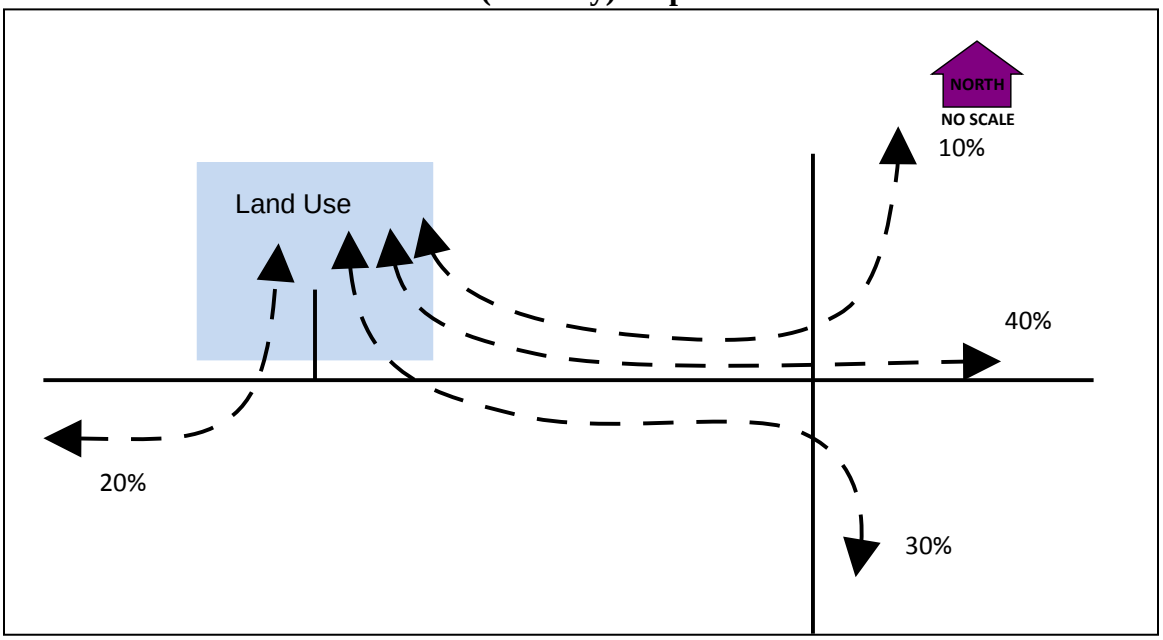
The existing PM peak hour volumes in the study area are shown below. All of the site trip adjustments will be added or subtracted from these values.

Background PM Peak Hour Traffic Volumes



Continuing from the previous example, the distribution of new trips to/from the proposed supermarket has been determined based on existing count patterns and engineering judgment and is shown in the diagram below.

PM Peak Site Distribution of New (Primary) Trips

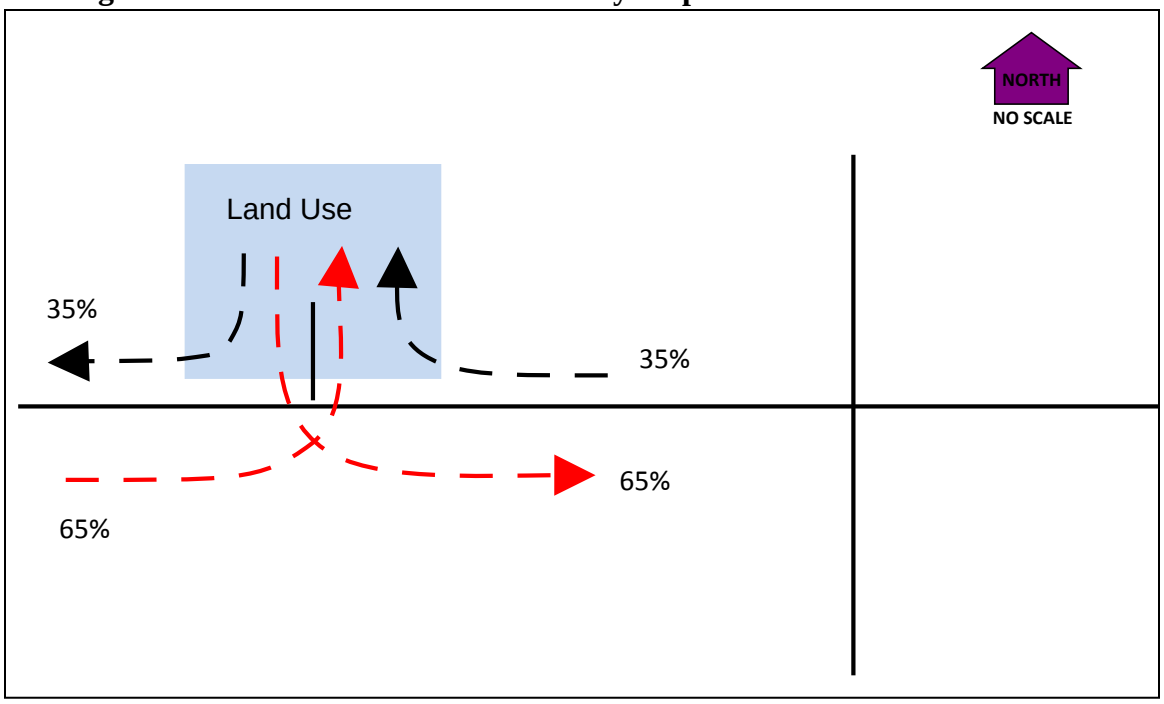


The distribution of pass-by and diverted linked trips should also be determined if present. Typically pass-by and diverted linked trips are based on traffic counts or travel demand

models. In this example, the pass-by trip percentages are assumed to be proportional to the existing east-west PM peak hour directional volume of traffic on the adjacent roadway, as shown below.

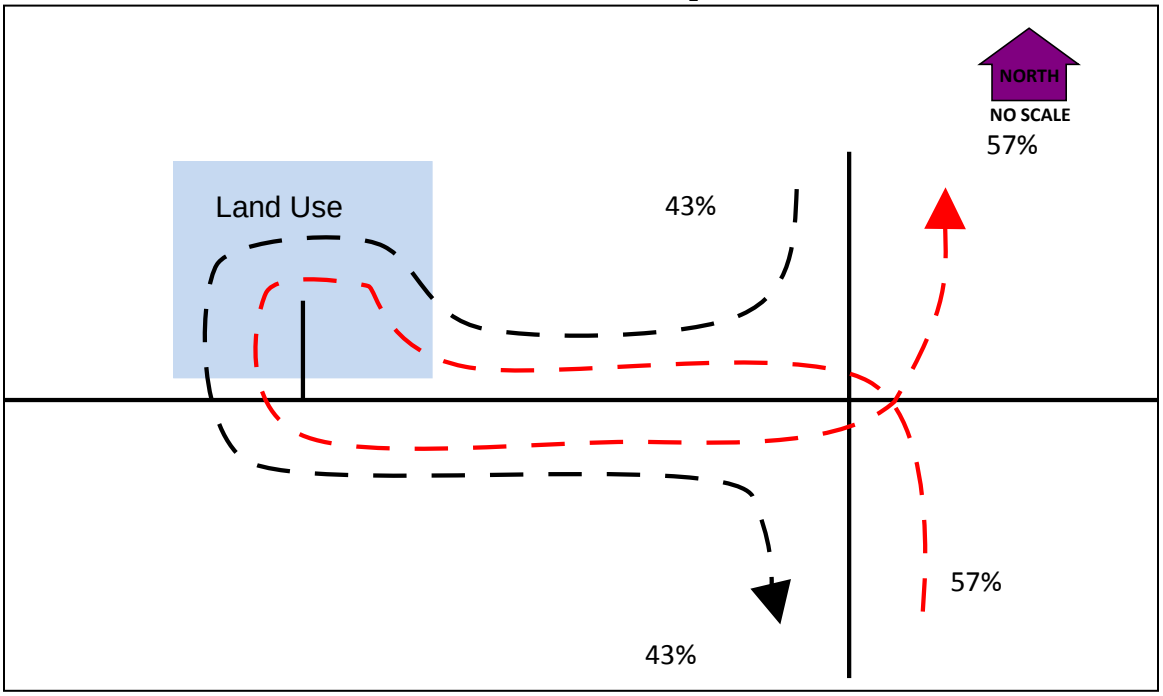
Adjacent roadway volume both directions = 340 + 620 = 960 vph.
Westbound proportion = 340 / 960 = 0.35
Eastbound proportion = 620 / 960 = 0.65

Existing PM Peak Distribution of Site Pass-by Trips



The diverted linked percentages in this example are assumed to be proportional to the north-south PM peak hour directional volume on the non-adjacent roadway, as shown in the next diagram.

Distribution of PM Peak Site Diverted Linked Trips



6.8 Trip Assignment

Traffic distribution to and from a future development is assigned to specific roadways either manually or using a travel demand model for larger studies (see Section 6.10 as well as the Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012). To create the trip assignment, apply the percentage distribution to the trip generation for the assignment of new, pass-by and diverted linked site trips. Summing up the background, new, pass-by and diverted linked trips results in the final total trip assignment.

The assignment of each of the components of site trips (primary, pass-by, and diverted linked) should be calculated and displayed on separate flow diagrams. Calculations are typically performed in a spreadsheet or with a specific software application such as Vistro.

Example 6-4 Trip Assignment

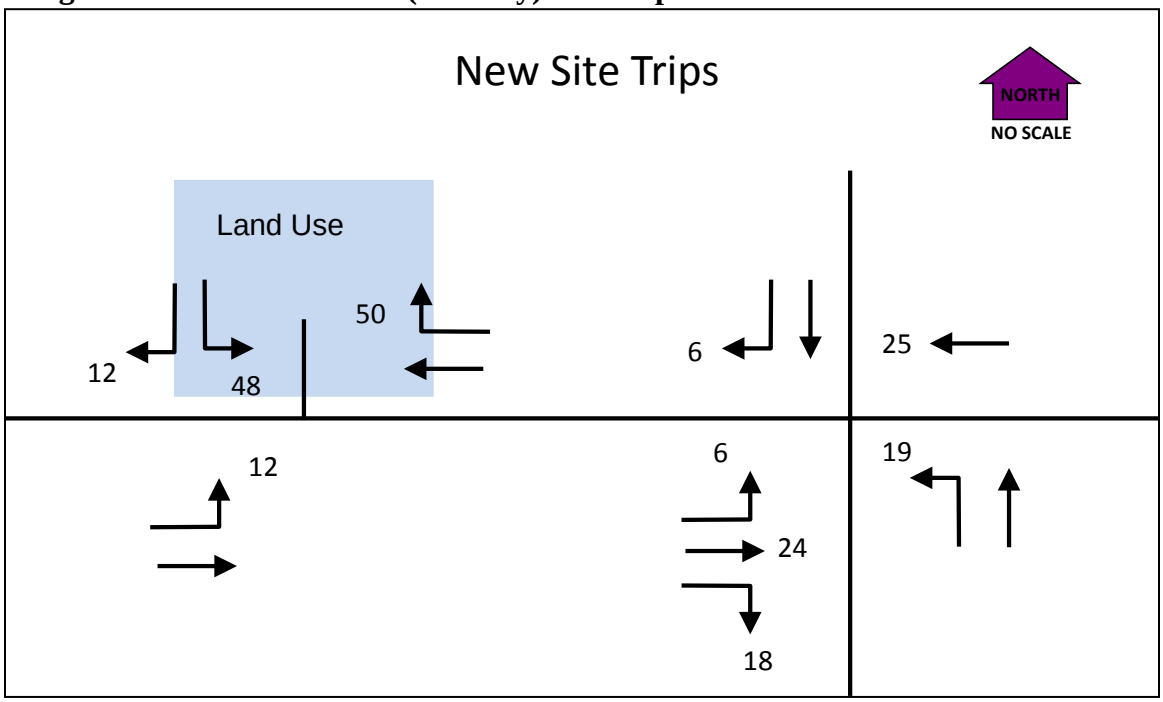
The assignment of new (primary) trips for each turning movement is calculated by multiplying the previously determined number of directional new (primary) trips (trip generation) by the new (primary) distribution percentage applicable to that movement.

Sample calculation for eastbound to northbound left turn movement at the nearby intersection:

This movement is outbound from the site.

Trip generation of outbound new (primary) trips = 60
Trip distribution of outbound new (primary) trips = 10 percent
Trip assignment = 60 x 0.10 = 6 PM peak hour new (primary) site trips

Assignment of PM Peak New (Primary) Site Trips



The assignment of pass-by trips for each turning movement is calculated by multiplying the previously determined number of directional pass-by trips (trip generation) by the pass-by distribution percentage applicable to that movement.

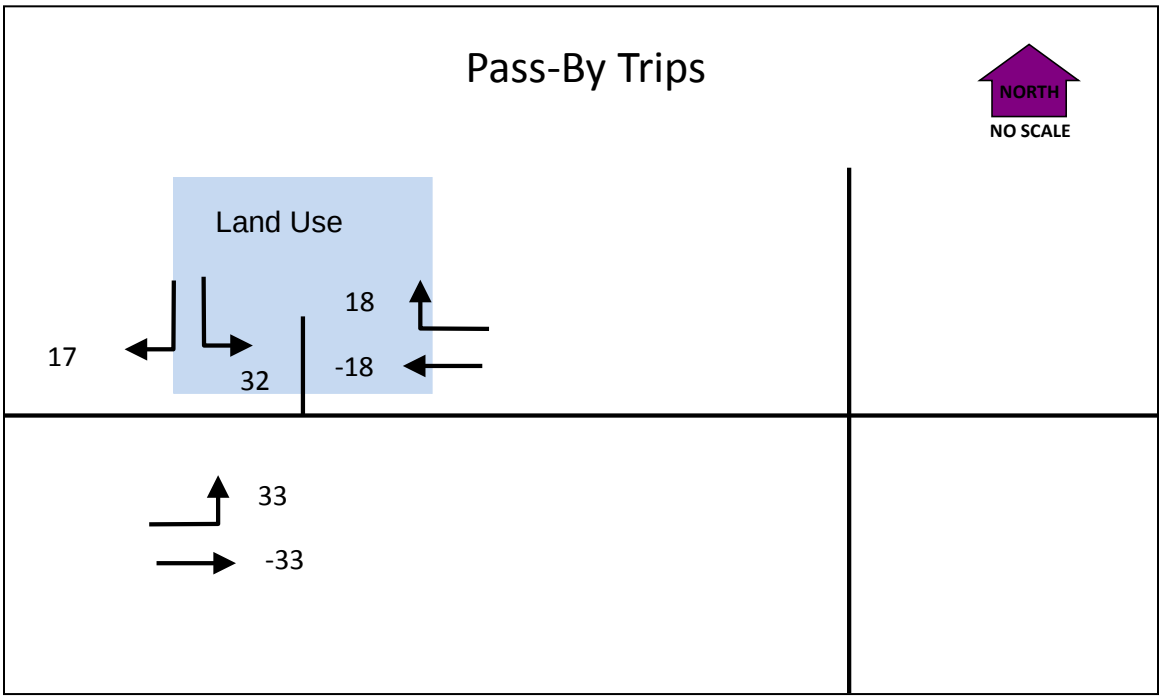
Sample calculation for westbound right turn movement from the adjacent roadway onto the site driveway:

This movement is inbound to the site.
Trip generation of inbound pass-by trips = 51
Trip distribution of inbound pass-by trips = 35 percent
Trip assignment = 51 x 0.35 = 18 PM peak hour pass-by site trips

Note that at the intersection of the adjacent roadway with the site driveway, through movement pass-by trips will have negative values, since they turn into the site instead of traveling through.

Also note that beyond the site driveway intersection, pass-by trips are zero. Pass-by trips do not add new trips to the system; they only change turning movement volumes at the site driveway(s).

Assignment of PM Peak Site Pass-by Trips



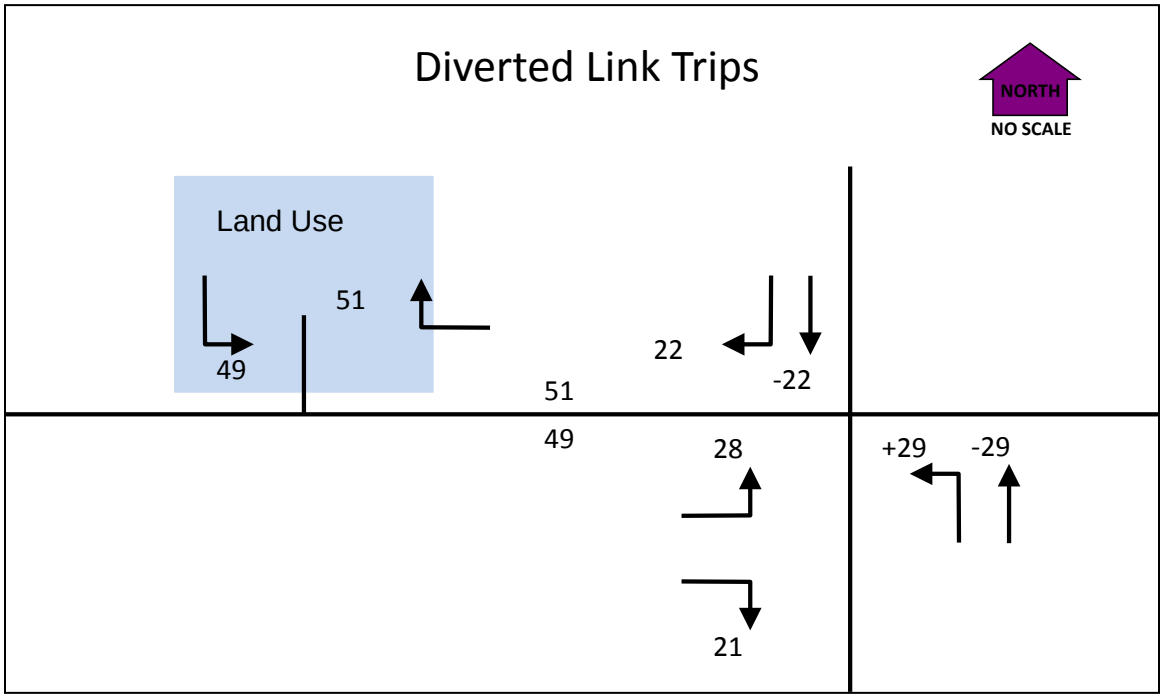
The assignment of diverted linked trips for each turning movement is calculated by multiplying the previously determined number of directional diverted linked trips (trip generation) by the diverted linked distribution percentage applicable to that movement.

Sample calculation for northbound to westbound left turn movement from the non-adjacent roadway to the adjacent roadway:

This movement is inbound to the site.
Trip generation of inbound diverted linked trips = 51
Trip distribution of northbound diverted linked trips = 57 percent
Trip assignment = 51 x 0.57 = 29 PM peak hour diverted linked site trips

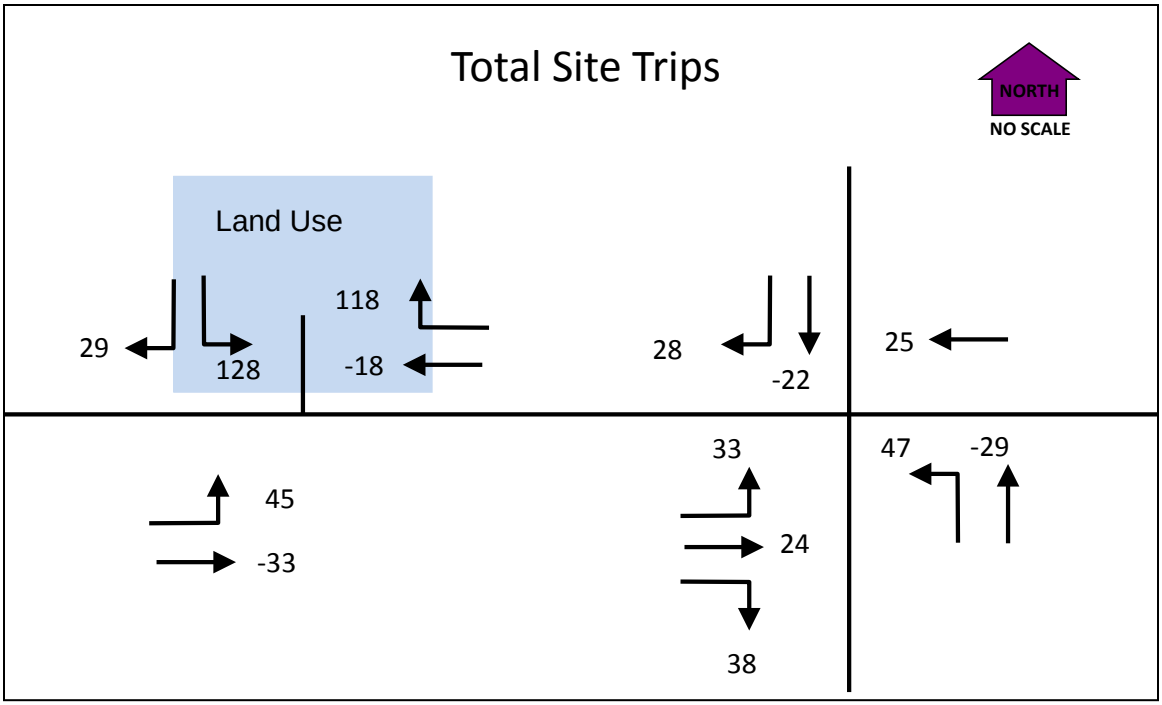
Note that at the intersection of the non-adjacent roadway with the adjacent roadway, northbound and southbound through movement diverted linked trips will have negative values, since they turn onto the adjacent roadway instead of traveling through.

Assignment of PM Peak Diverted Linked Trips



Each of the components of site trips are then summed for each vehicle movement and displayed in a flow diagram of total site trips as shown below.

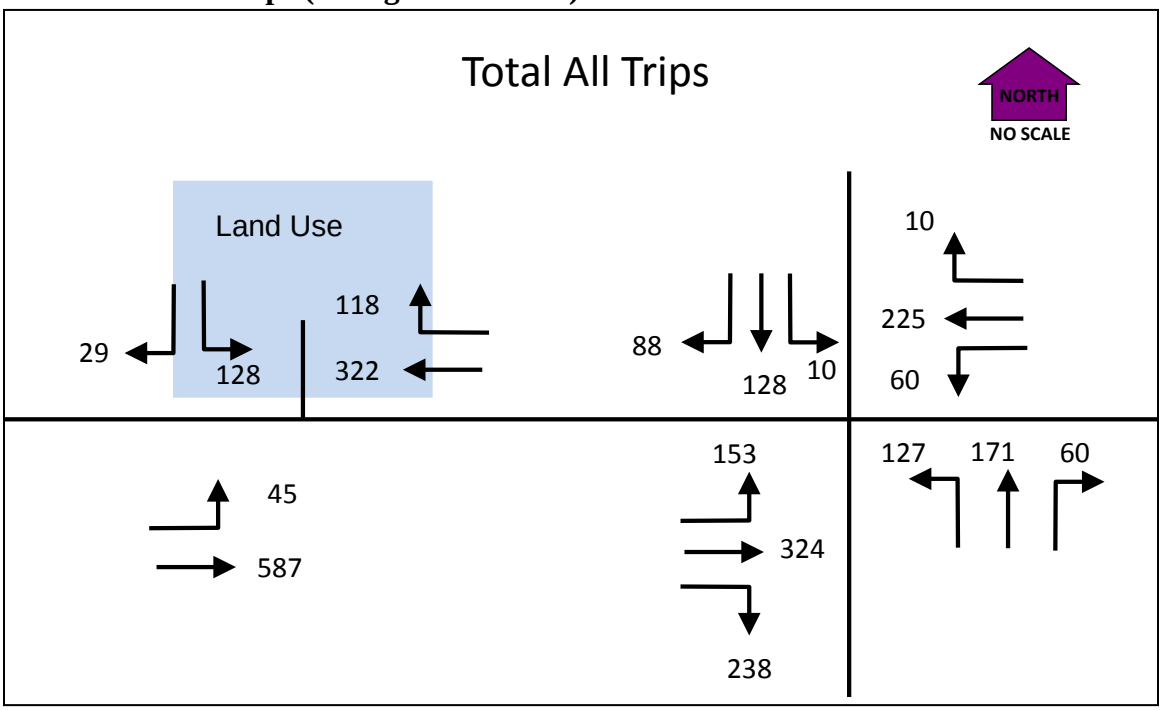
PM Peak Total Site Trip Assignment



The total site trips are then combined with Background Traffic to create Background plus

Site trips as shown below.

PM Peak Total Trips (Background + Site)



6.9 Travel time-based Trip Assignment

Traffic distribution to and from a future development is assigned to specific roadways either manually or using a travel demand model for larger studies (see Section 6.10 as well as the Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012).

Future development trip assignment is often made based on shortest path distance or travel time. Shortest path travel time in some cases may be approximated using segment lengths and posted speeds. However, this method does not account for intersection delay, which can be a significant component of total travel time in some situations. The following methodology identifies path travel times inclusive of intersection delay.

In this method, for a specified origin and destination, competing O-D paths are evaluated iteratively by assigning trips, calculating resulting nodal delay values, computing overall travel times, and repeating the process until the competing paths have roughly the same travel time. It should generally be assumed that if travel times are within 20%, there will be some split of the site trip assignment. If the travel time difference exceeds 20%, all of the site trips can generally be assigned to the shortest travel time path. If the travel time difference is less than 10%, an equal split of site trips can be assumed. The end result is the number of site trips assigned to each route.

Travel time on the paths is the sum of the travel time on links, based on link distance and

posted speed, and control delay at intersections, based on deterministic analysis results such as using Highway Capacity Software (HCS) or Synchro. Note that this method assumes relatively uncongested conditions.

Analysis Steps

1. Develop background traffic volumes.
2. For the initial site assignment, assign 100% of site trips to the shortest distance path.
3. Add the site trip assignment in Step 2 to the background volumes to obtain initial Total Traffic volumes.
4. For each alternative O-D path and direction (inbound or outbound from the site) being studied,
    a. Calculate segment travel times using posted speed and link lengths.
    b. Using initial Total Traffic volumes, apply HCM 2010 methodology to calculate delays for the movements along the path that pass through stop-controlled or signalized intersections.
    c. Sum the segment travel times and delays from Steps 4a and 4b to determine the total travel time for each path. Identify the path with the shortest travel time.
    d. If the shortest distance path travel time is significantly shorter than the next competing path, the site trip assignment is complete (100% of site trips are assigned to the shortest distance/travel time path).
    e. If the shortest distance path travel time is close to or greater than the travel time of the next competing path, further iterations are required.
5. Re-assign some proportion of the site trips to the shortest travel time path identified in step 4c. Using this site trip assignment, sum with Background Traffic to develop second iteration Total Traffic volumes.
6. Repeat Steps 4b and 4c using the revised iteration of Total Traffic volumes developed in Step 4b. Incrementally re-assign a proportion of site trips until each path is equal in travel time. The site trip assignment is then complete.

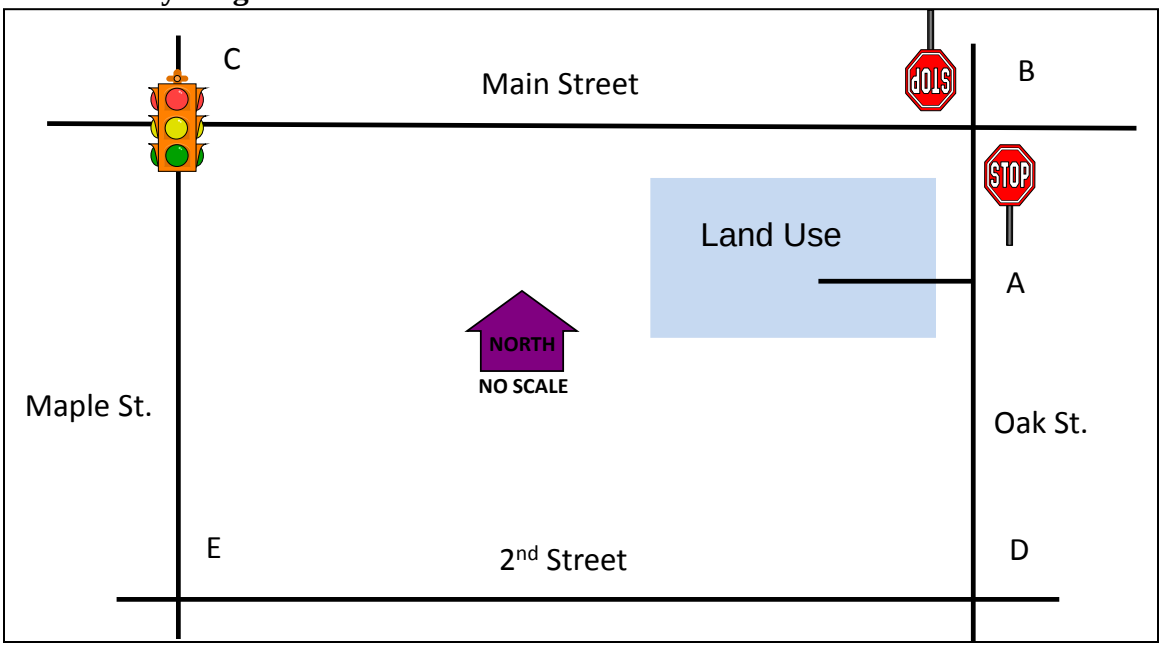
The following example illustrates this method.

Example 6-5 Estimating Trip Assignment Based on Travel Time

A land development is proposed near a state highway. The site is located near the unsignalized intersection of Main Street at Oak Street, as shown below. There are two potential paths for outbound site trips from the development onto the highway in the westbound direction. By inspection, the shortest distance path is ABC. This requires site trips to turn left at the intersection of Main Street at Oak Street, an unsignalized two-way stop controlled intersection. The stop-controlled left turn movement at this intersection experiences high delay. The alternate path, ADEC, is less direct. However, this path has less intersection delay where it accesses the highway at the signalized intersection of Maple Street and Main Street.

It is desired to assign the outbound site PM peak hour trips such that either path will provide an equal travel time from the development.

Site Vicinity Diagram



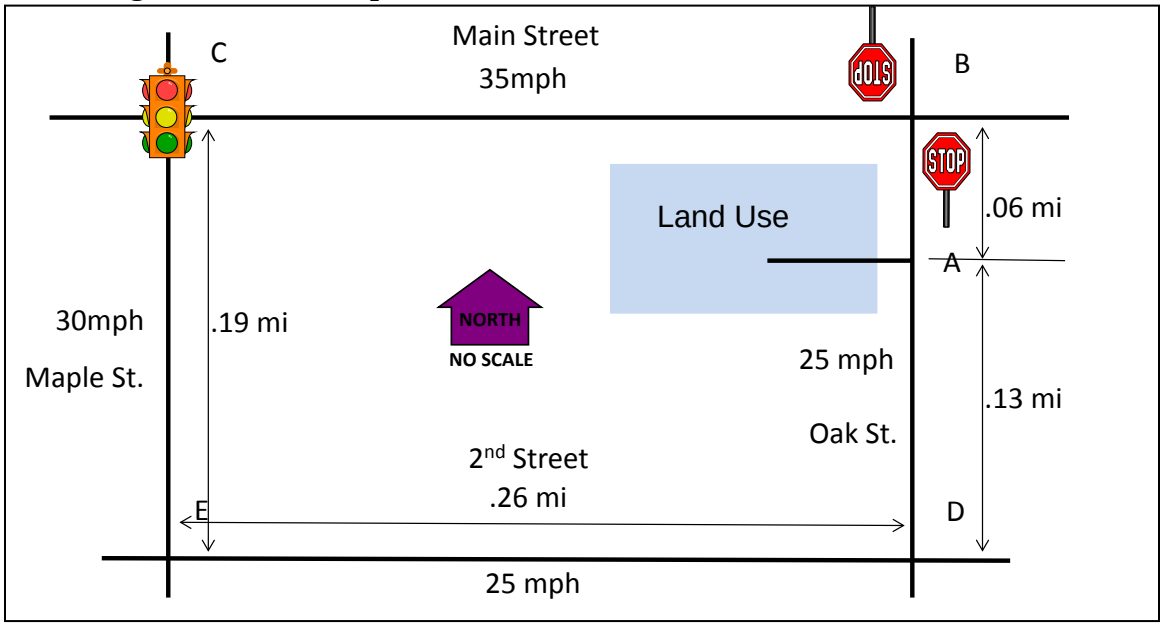
Step 1. For the purpose of this exercise it is assumed that background traffic volumes have been previously developed.

Step 2. Site trips are initial assigned 100% to the shortest distance path, ABC.

Step 3. The initial site trip assignment from Step 2 is added to Background Traffic from Step 1 to create Initial Total Traffic volumes.

Step 4a. Link lengths and posted speeds are obtained and shown in the next figure below. Link lengths are typically measured from aerial photos and posted speeds collected from a field visit.

Link Lengths and Posted Speeds



Segment travel times are calculated as follows, using sample segment BC.

$$\text{Travel Time Segment BC} = \frac{0.26\text{ mi}}{35\text{ mi/hr}} \times \frac{3600\text{ sec}}{\text{hr}} = 26.7 \sim 27\text{ sec}$$

Travel times for each segment are summarized in a table:

Roadway	Segment	Segment Travel Time
Oak St	AB	9
Main St	BC	27
Oak St	AD	19
2nd St	DE	37
Maple St	EC	23

Origin-destination (O-D) path segment travel times are calculated by summing the segment travel times.

O-D Path ABC = AB + BC = 9 + 27 = 36 sec
O-D Path ADEC = AD + DE + EC = 19 + 37 + 23 = 79 sec

Step 4b. For the purpose of this exercise, assume that HCM intersection analysis has been previously conducted for background volumes, resulting in the following intersection delays. Please note that the delay values in this example are for illustrative purposes only and are not actual HCM-calculated values. For this example, it is assumed that delay at other intersections along each path is negligible.

Background Traffic Movement Delay

Intersection	Movement	Movement Delay (s)
Main St at Oak St	South to West left turn	44
Main St at Maple St	Westbound through movement	14
Main St at Maple St	South to West left turn	21

Intersection movement delays are summed for each O-D path

O-D Path ABC = 44 + 14 = 58 sec
O-D Path ADEC = 21 sec

Step 4c. Segment travel times and delays are summed to determine the total travel time for each path.

O-D **Path**	**Segment Travel Time (s)**	**Intersection Delay (s)**	**Total Travel Time (s)**
ABC	36	58	94
ADEC	79	21	100

The O-D path with the shortest travel time is path ABC.

Step 3. Site trips are assigned 100% to the shortest path ABC.

Step 4. The site trip assignment in Step 3 is added to the background volumes to obtain initial Total Traffic volumes.

Step 5. HCM methodology is applied to re-calculate intersection delays based on Total Traffic volumes.

Total Traffic Movement Delay (First Iteration)

Intersection	Movement	Movement Delay (s)
Main St at Oak St	South to West left turn	58
Main St at Maple St	Westbound through movement	16
Main St at Maple St	South to West left turn	24

Intersection movement delays are summed for each O-D path

O-D Path ABC = 58 + 16 = 74 sec
O-D Path ADEC = 24 sec

Segment travel times and delays are summed to determine the total travel time for each path.

O-D **Path**	**Segment Travel Time (s)**	**Intersection Delay (s)**	**Total Travel Time (s)**
ABC	36	74	110
ADEC	79	24	103

At this point, the shortest path based on travel time is now path ADEC. Since path travel times are close, the next iteration would be to assign some of the site trips to path onto path ADEC. Step 5 is then repeated. When path travel times are approximately equal, the site trip assignment is complete.

6.10 Zonal Cumulative Analysis

In quick growing areas or for entire cities, where a more accurate analysis is needed of the impacts (differing growth and trip patterns across the study area), the zonal cumulative analysis process should be used rather than the first-level TIA-level cumulative analysis. The zonal cumulative analysis process is essentially a manually-constructed travel demand model. The process includes the major three modeling steps (trip generation, trip distribution, and trip assignment). The major difference between the zonal cumulative and a travel demand model is that the zonal cumulative uses ITE trip generation instead of population and employment, and projects the incremental growth in trips rather than creating separate base year and future year assignments. Generally, this level of effort is too complex for a TIA.

Like with other cumulative analyses, the zonal cumulative method should be limited to cities of 10,000 or less population or a chunk of no more than 10,000 of a larger urban area. Areas larger than these can theoretically be done, but the number of zones and network size becomes overwhelming to do manually. In addition, anywhere multiple analyses (TSP, corridor or refinement plans, projects) are likely in the near (5-10 year) future then construction of a travel demand model should be considered. Re-purposing a zonal analysis for another project can be more time consuming than just building a travel demand model initially. These larger areas would require the enhanced zonal cumulative analysis process shown in Section 6.11 or use of a travel demand model as shown in Section 6.12.

The basic steps for a zonal cumulative analysis are:

1. Identify the study area and divide into transportation analysis zones (TAZ)
2. Identify vacant lands, in-process developments, comprehensive plan allowed land uses/densities, and development rates.
3. Estimate future trip generation potential
4. Determining the through trip percentages (external – external, E-E) and E-E trips for the external stations
5. Determining the internal – external (I-E) and external –internal (E-I) trips at each external station (external zone)
6. Determining the trip distribution for the internal – external (I-E) and external – internal (E-I) trips for each internal TAZ.
7. Determining the trip distribution for internal-internal (I-I) trips
8. Calculating network link travel times
9. Assigning total trips to the network

The above process is setup for multiple traffic assignments based on a single land use scenario. Doing an additional land use scenario would require repeating of Steps 3-9 or using the more-automated enhanced zonal cumulative analysis. Use of software such as

Vistro and its predecessor, Traffix, may help streamline the accounting of generated trips and the distribution/assignment of them if the network and land uses assumed are not too complex.

6.10.1 Step 1 – Identification of Study Area and TAZ's

The study area should completely cover the project limits and all adjacent land areas that would affect the project area. The study area should be defined such that all relevant facilities are included, since there may be other roadways that could directly influence the traffic patterns on the facilities being analyzed. The location where each relevant roadway facility crosses the outside edge of the study area needs to be noted as an "external station." The external station is where traffic enters/exits the study area and can also be considered an external zone. The study area needs to be broken into homogenous land-use zones (i.e. residential, commercial, or industrial) called transportation analysis zones (TAZ). There generally is no need to break the land use into further sub-categories (i.e. low vs. medium density residential). If zones are not completely homogenous, there will need to be additional accounting of internal trips between residential and commercial for example as there will be trips generated that will never extend beyond the zone boundaries. It is likely that a Geographic Information Systems (GIS) land-use or tax-assessment file is available from the local city or county that will be of great assistance and streamlining of this and the following tasks.

Each TAZ boundary generally needs to follow physical or man-made boundaries. This would include rivers, railroads, and major roadways. Property lines generally break on these major features, and the GIS file can be used to help ensure that the TAZ boundaries do not cross or break up properties.

Example 6-6 Study Area and Zone Identification

This example is based on an actual zonal cumulative analysis done for the US97/South Century Drive project in the Sunriver resort area south of Bend. The overall project area is shown in the figure below. The study area reflects the area that would feed into South Century Drive and eventually to US97. Areas to the south of the project area would most likely feed into the next major road to the south (LaPine State Recreation Road) or into the City of LaPine.

TAZ's were split on land use or on natural or man-made boundaries. Examples for land use:

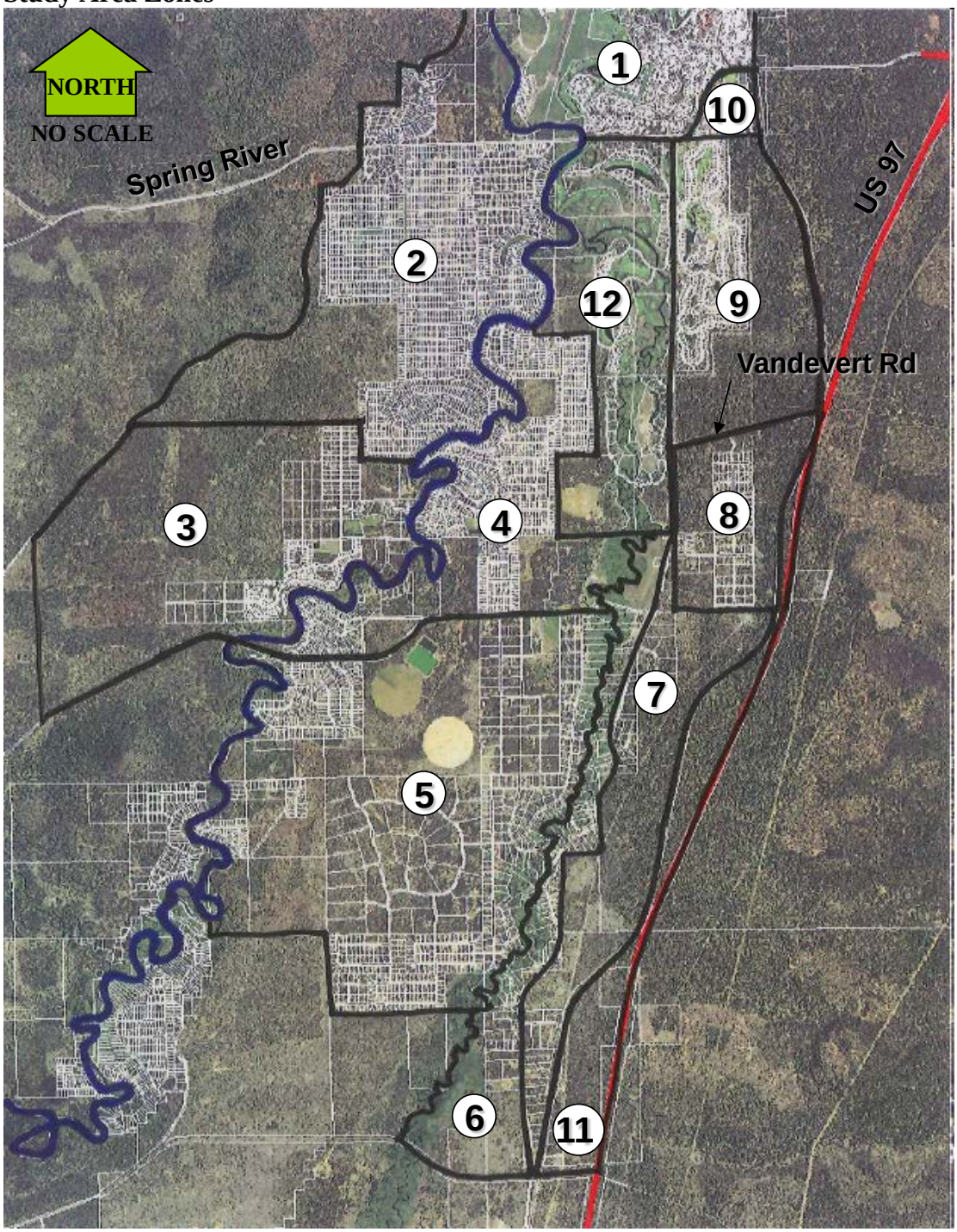
- Zone 1 is the current Sunriver resort development and is generally residential.
- Zone 2 is the existing Spring River residential subdivisions
- Zone 9 is vacant Forest Service forest lands (although zoned for resorts).
- Zone 10 is the Sunriver business district and is generally commercial uses.
- Zone 12 is the Crosswater resort/golf course

TAZ zone boundary splits examples:

- The Deschutes River forms the boundaries between Zones 1 and 2 and Zones 3 and 4.

- The Little Deschutes River forms the boundary between Zones 5 and 6.
- The BNSF railroad tracks forms the boundary between Zones 7 and 11.
- South Century Drive forms the boundaries between Zones 1 and 10, Zones 12 and 9, and between Zones 6 and 7.

Study Area Zones



6.10.2 Step 2 – Identification of Land Use Characteristics and Zoning

After the homogenous TAZ's have been developed, all of the land use characteristics and related zoning needs to be identified. This will create the parameters necessary for estimating the future trip generation in Step 3. The zonal cumulative process assumes that

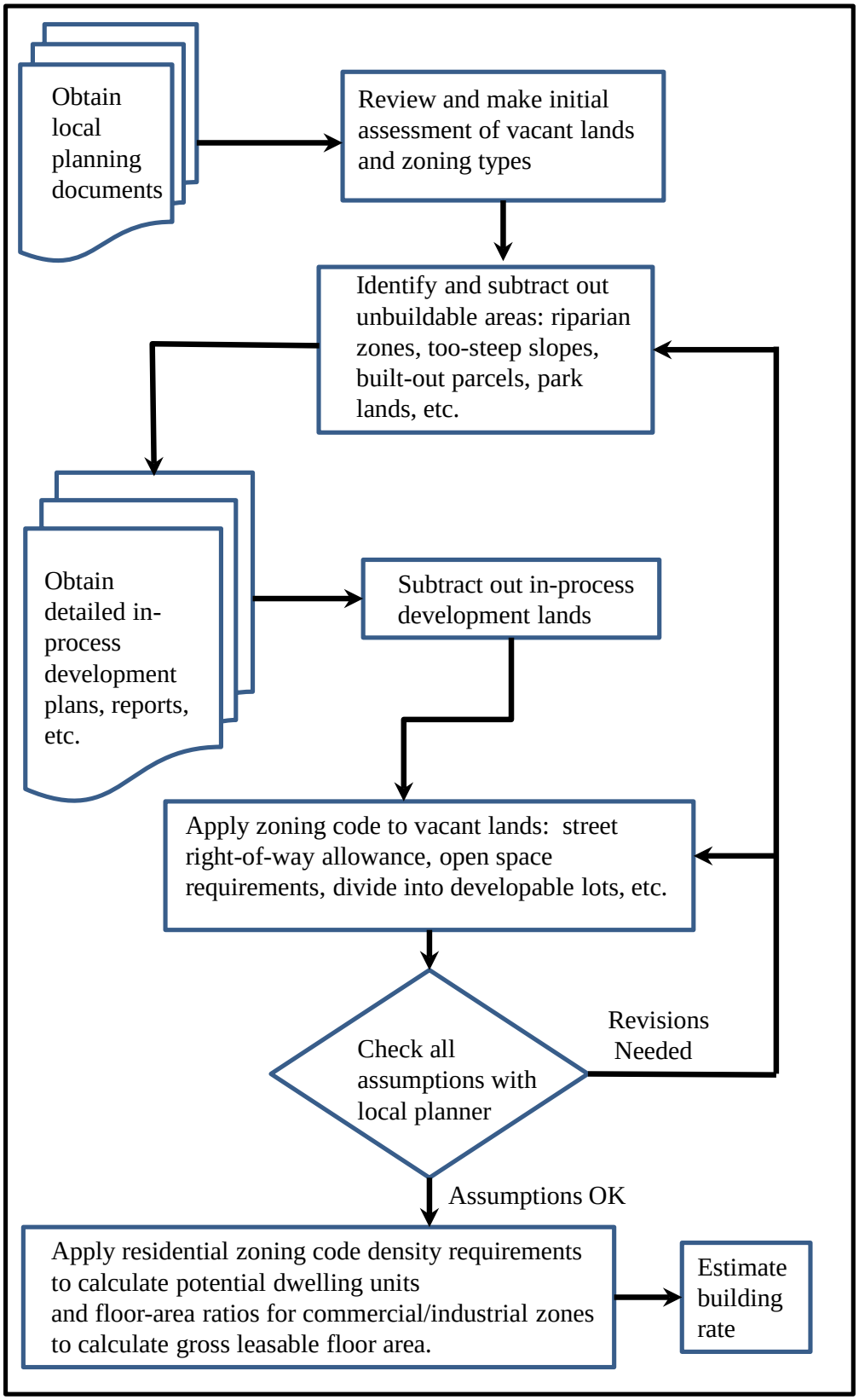
the traffic counts (and the resulting 30 HV) obtained for the study area account for all built properties. The main focus of the process is to determine the total change from the base to the future condition. Areas that are vacant or partially built will need additional data to help determine the future growth potential. Exhibit 6-3 shows the process for determining the TAZ land use data for vacant lands.

Vacant Lands

For each TAZ, any vacant buildable lands need to be identified. This can be facilitated by obtaining the following items:

- Buildable Lands Inventory (BLI) – Not every study area will have an applicable BLI available, but when available, they will limit the amount of data needed. The BLI will specifically identify buildable areas that can be coordinated directly with the study area TAZ's. Detail levels vary but at a minimum, the truly developable vacant lands can be determined. The BLI will help identify areas that are not suited for future development such as wetlands, riparian zones, flood plains, steep slopes, resource areas, etc. The BLI needs to be relatively recent (no more than 3-5 years old for normal growth areas but longer periods might be okay for slow growth areas).
- Comprehensive Plan, Zoning Map and Code – Obtaining the comprehensive plan, zoning map and zoning code is the minimum information needed in order to do a zonal cumulative analysis. The comprehensive plan and related zoning code (see Exhibits 6-4 and 6-5.) will tell what the allowed (permitted outright and through the conditional use permit process) uses are, and lot requirement details such as minimum/maximum sizes, development densities, building heights, floor-area-(coverage) ratios, green/open space requirements, etc. The zoning map allows for easy identification of where the different zoning is applied (see Exhibit 6-6). Generally, land uses should be limited to outright permitted uses only as there is no guarantee that a conditional use would be granted. Exceptions need to have concurrence with the local planning staff.
- GIS-based land-use/property/tax assessor's database – If available, a GIS-based property database will greatly streamline the identification of zoning and whether a property is vacant. These databases generally include, location, tax-lot numbers, zoning, acreage, ownership, improvements (structures), and year of improvement (building permit issued). Use of GIS allows the properties to be grouped by TAZ.

Exhibit 6-3 TAZ Land Use Data Process



- TSP – Newer TSP's may show environmental baseline information such as wetlands, park lands, greenways, historic properties, etc. that can be used to further identify non-buildable areas (especially if a BLI is not available). The TSP will also show future road improvements that can be used to modify the road network.
- Other land-use plans – These cover a wide range of planning maps such as subdivision plats and development master plans that can identify in-process or future developments. Certain areas may not have BLI's so park plans, school district plans, wetland plans, park plans, and other plans of this type fall into this category. All of these can be used for identification of future growth potential. Contacting the local planning office is the best source for this information.
- Current aerial photos – If current aerial photos are available, identification of vacant lands can be easily done with a GIS database or comprehensive plan. However, use of aerials can be a potential pitfall if the aerial has not been verified to be recent. Please note that commercial aerial mapping such as Google Maps could be 3-5 years out of date and is not recommended to be used (unless extensively field-verified) for this process.

Exhibit 6-4 Urban Standard Residential Zone Excerpts

(1) Purpose. The RS Zone is intended to provide for the most common urban residential densities in places where community sewer services are or will be available and to encourage, accommodate, maintain and protect a suitable environment for family living.

(2) Permitted Uses. The following uses are permitted:

(a) Single-family dwelling.

(b) Agriculture, excluding the keeping of livestock.

(c) Rooming and boarding of not more than two persons.

(d) Home occupations subject to the provisions of Subsection (15) of Section 25.

(e) Park rehabilitation, minor betterment and repairs.

(f) Accessory dwelling in a subdivision or Planned Unit Development (PUD) approved after December 2, 1998, provided that overall density in subdivision or PUD does not exceed 7.3 dwelling units per gross acre.

(5) Lot Requirements. The following lot requirements shall be observed, provided that the approval authority may allow smaller lots of different housing types in a new subdivision or Planned Unit Development (PUD) approved pursuant to this ordinance and consistent with the Comprehensive Plan designations for preservation of areas of significant interest when these lots or housing types are internal to the subdivision or PUD.

(a) Lot Area: A lot in a subdivision or planned unit development approved after (date of adoption) shall have a minimum area of 4,000 square feet provided that the overall density does not exceed 7.3 dwellings gross per acre, and provided that where new subdivisions abut lots of 20,000 square feet or less the exterior lots shall be at least 75% of the abutting lot sizes and lot lines or be approved through a hearing process. All other lots shall have a minimum area of 6,000 square feet.

Exhibit 6-5 Mixed Employment Zone Excerpts

(1) Purpose. The zone is designed to provide for a mix of uses such as office, retail, services, light manufacturing and warehousing that offer a variety of employment opportunities in an aesthetic environment and having a minimal impact on surrounding uses.

(2) Permitted Uses. The following uses are permitted in the ME Zone subject to the provisions of Design Review and Site Plan review in Section 23 and Section 23 A.

(a) Automobile and truck repair and service, provided wholly within an enclosed building.

(b) Automobile, truck, and recreation vehicle sales of new vehicles, including service facilities and outdoor storage of vehicles.

(c) Bakery for wholesale and retail distribution.

(d) Banks, savings and loan institutions, credit unions and other financial institutions.

(4) Height Regulations. No building or structure shall be hereafter erected, enlarged or structurally altered to exceed a height of 45 feet, without a Conditional Use Permit approval.

(5) Lot Requirements. The following lot requirements shall be observed:

(a) Lot Area: Each lot shall have a minimum area of 6,000 square feet.

(b) Lot Width: No requirements.

(c) Lot Depth: Each lot shall have a minimum depth of 100 feet.

(d) Front Yard: The front yard setback area shall be a minimum of 10 feet.

(e) Side yard: None except a side yard setback area shall be a minimum of 15 feet when abutting a lot in a residential zone.

(f) Rear Yard: None except a rear yard setback area shall be a minimum of 15 feet when abutting a lot in a residential zone.

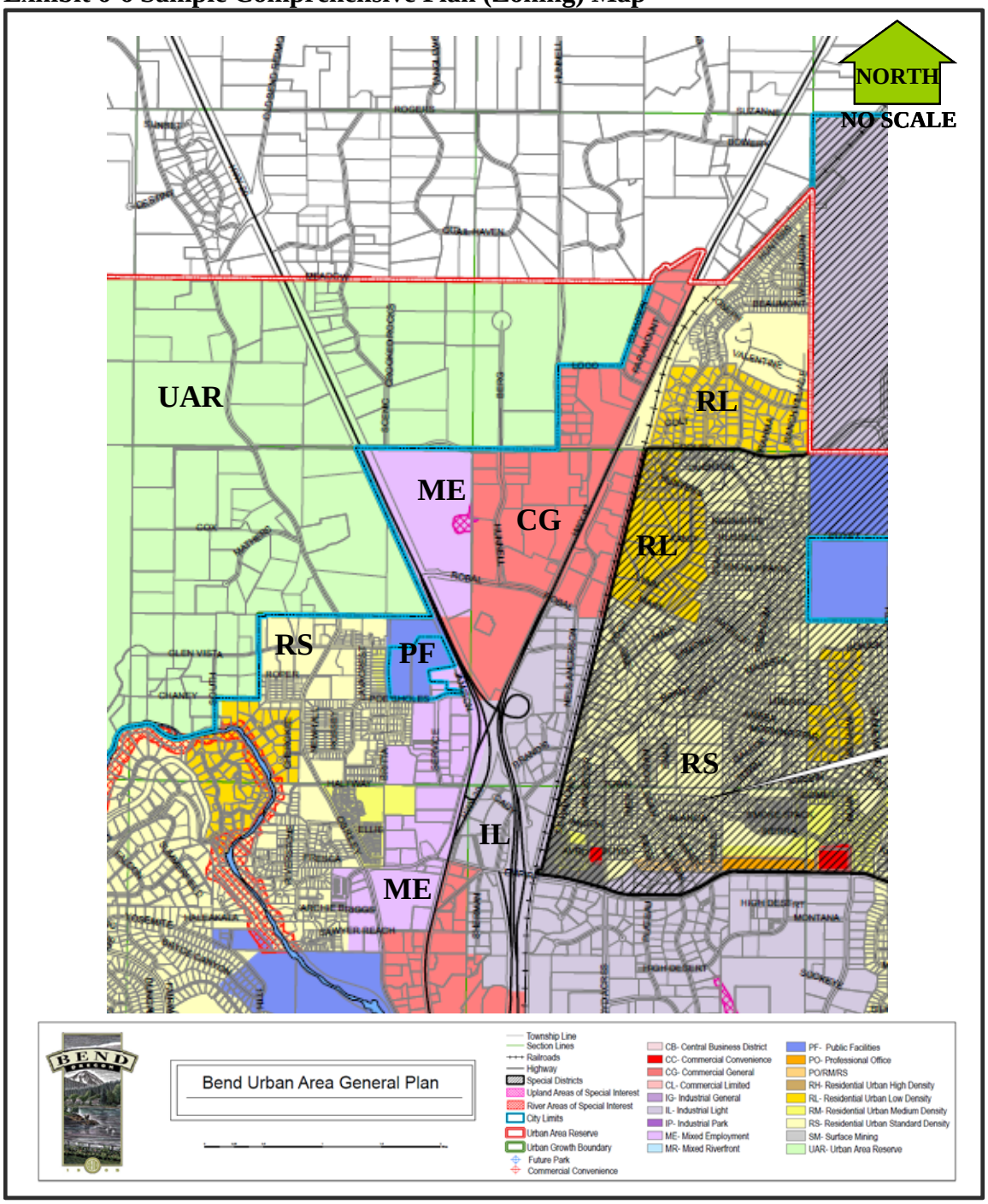
(g) Lot Coverage: The maximum lot coverage by buildings and structures shall be 50 percent of the total lot area.

(6) Off-Street Parking and Loading. Off-street parking and loading space shall be provided as required in Section 24.

The first step to obtaining any of the above is to get in contact and establish a good relationship with the local planning office or local planner. They will know all of the details, recent and past development history, insight on building rates and typical/likely growth patterns. You will need to have them review your development assumptions that you make, vacant lands, and growth potential to make sure that the analysis is reasonable before moving on to more detailed steps.

Once the unbuildable areas have been identified, then any in-process developments need to be identified. Contact the local planning office and ask about any approved but not yet built residential or commercial developments. Obtain documentation such as plats, site plans, or Transportation Impact Analyses (TIA) describing the development. The total number of lots, units, or square footage needs to be noted for the later trip generation calculations. These developments need to be subtracted from the total vacant land to determine the truly vacant buildable land available for future growth.

Exhibit 6-6 Sample Comprehensive Plan (Zoning) Map



Estimating Potential Future Land Use

At this point, the remaining vacant land would be available for future development but is not planned as such. For each TAZ and/or parcel clumps within a TAZ, the zoning code requirements need to be applied.

For residential lands, there will be likely minimum lot sizes or minimum/maximum dwelling unit per acre requirements. A good way to judge what these might be is to take a GIS-based survey of adjacent similarly-zoned single-family home subdivisions and figure out a typical lot size (this is one of those assumptions that the local planner should review for reasonability). About 24% of vacant residential lands should be reserved for local street right-of-ways. The zoning code may indicate additional specific values for green or open space requirements that will need to be accounted for. Buildable residential lands then would be calculated by subtracting the local street and green space requirements from the total land area and then dividing by the typical lot size to determine the number of single-family dwelling units for each TAZ.

Multi-family residential lands such as apartments, condominiums or townhouses need to be figured on a dwelling units per acre basis. The zoning code should tell the range of acceptable densities regardless of building heights. GIS can be used to help determine a typical value by surveying similarly-zoned areas in the local area. The local planning office should be able to give some guidance in this area. Once a typical dwelling unit per acre value is determined then this can be directly multiplied by the vacant buildable multi-family lands to determine the total amount of multi-family dwelling units. The final value may need to be summed from multiple parcels depending on how these lands are spread around in a single TAZ.

Non-residential (commercial/industrial) lands are generally figured on a parcel basis as parcels are generally large. Zoning codes typically use floor-area-ratios (FAR) for determining maximum lot coverage. The typical FAR range is between 25 and 35% of the lot size which covers green/open space, access roads and parking. For denser areas or industrial areas, height requirements may allow more than a single story which would allow more square footage for the maximum lot coverage. However, if maximum square footage requirements are shown, then these apply to the total of all floors. Multiplying the lot size by the FAR or using the maximum square footage per parcel will determine the maximum potential gross leasable floor area. Commercial and industrial lands need to be kept separate as trip generation multipliers will be different.

Example 6-7 Estimating Future Buildable Land Use

For a particular TAZ, there are 100 acres of vacant buildable zoned RM (medium-density single family residential) land. The zoning code indicates that lot sizes are to be 5,000 square feet at a minimum. A survey of recently completed subdivisions in the area shows that the average lot size is about 6,000 square feet. This particular TAZ is covered by additional provisions that require 10% of the total development to be common open space. This TAZ also has 5 acres of neighborhood commercial at a maximum FAR of 35%.

Deduct the common open space from the total land area = 100 ac – 100 ac x 0.10 = 90 ac.

Subtract out the typical 24% allotment for local streets = 90 ac – 90 ac x 0.24 = 68.4 ac

Calculate the total number of potential dwelling units = (68.4 ac x 43,560 sq ft/ac) / 6,000 sq ft = 496.6 = 496 lots (need to round down).

Calculate the commercial maximum gross leasable floor area = 5 ac x 0.35 x 43,560 sq ft/ac = 76,230 sq ft = 76, 200 sq ft.

Building Rates

Typically at this point a spreadsheet is setup by TAZ showing the potential dwelling units for residential and square footage for commercial or industrial areas. These TAZ totals represent build-out which may or may not occur within the study horizon (future or design year). Some TAZ's will be currently mostly built out, so it may only take a few years to reach build-out while other TAZ's are vacant and build-out may be over 40 or more years. Faster growing areas (i.e. Central Oregon) will take less time than historically slower growing areas (South Coast).

For each land use type within each TAZ, a building rate needs to be calculated. This aspect of the zonal cumulative method can be one of the most difficult to obtain accurately. The best way to help determine this is to use a GIS-based tax assessor's database to group properties by TAZ and to indicate in which year an improvement occurred. Non-GIS spreadsheets/databases can also be used, but these will require visual matching of tax- lots with the TAZ's. An alternate source is to use issued building permits assuming that these are available for at least the last 10 years. These values can be plotted over the long-term to determine a curve or best-fit regression line to determine a rate of growth. The rate curve will be the best with a good amount of data points covering at least 10 or more years. Another method is to take the total amount of improved lots divided by the number of years those improvements represent to get an average historical building rate.

There may be areas with little or no historical growth, so these should be estimated by using nearby areas with similar characteristics. If an area is relatively homogenous (i.e.

all residential) then the building rates could be simplified to a few or a single area-wide value. Commercial or industrial areas building rates could be simplified to a few or a single value depending if the characteristics are similar. Keep in mind that if there are a lot of in-process developments, these may skew the historic building rate. Any of these results need to be tempered by the advice of the local planner on the historic or future building rates. At a minimum, there needs to be a single building rate for each land use type used. If a database or permits are not available or available for enough years, then the application of this method becomes difficult at best and the enhanced zonal cumulative method should be used. The enhanced zonal cumulative method uses explicit base and future models and is less concerned with a historical building rate.

Example 6-8 Historical Building Rate

Within a residential TAZ, there are a number of subdivisions that were ready for development in the year 2000. These subdivisions made up a total of 400 lots. The future year for this analysis is 2030. From the county tax assessor's database the following data was obtained from 2000 to 2010:

Year	Number of Permits Issued
2000	20
2001	27
2002	6
2003	4
2004	22
2005	42
2006	37
2007	9
2008	0
2009	0
2010	3

From a review of the data, it is apparent that growth was relatively unsteady and that a regressed trend would not give a good predicted rate. The residential area has the same general characteristics so an average TAZ historical rate is probably the best method.

From 2000 to 2010 a total of 170 lots had building permits issued. This equates to 170 lots / 11 years = approximately 15 lots per year

This TAZ was not built out in 2010 with 170 of the 400 total built. There are 400 – 170 = 230 vacant lots remaining. With a 15 lots / yr rate, this TAZ would be built out in 230 lots/15 lots per yr = approximately 15 years or 2025. Since the future year is 2030 we would use the maximum potential 230 new lots in the analysis.

6.10.3 Estimating Future Trip Generation

At this point, the land uses for each TAZ have been calculated. Use the ITE Trip Generation manuals or Trip Generation software to compute the increase in peak hour trip generation potential for each TAZ as per Section 6.6. Use major ITE land uses (i.e. shopping center, office park, apartments, etc.) that have ideally equations or reasonable data points. For each land use, make sure to specify the split between the entering and exiting trips. Depending on zone structure and land uses, commercial trips should be primary (new trips on the system) trips, unless there is not enough background traffic to accommodate the potential pass-by trips. Trip generation documentation should be in a spreadsheet form.

Example 6-9 Projected Trip Generation

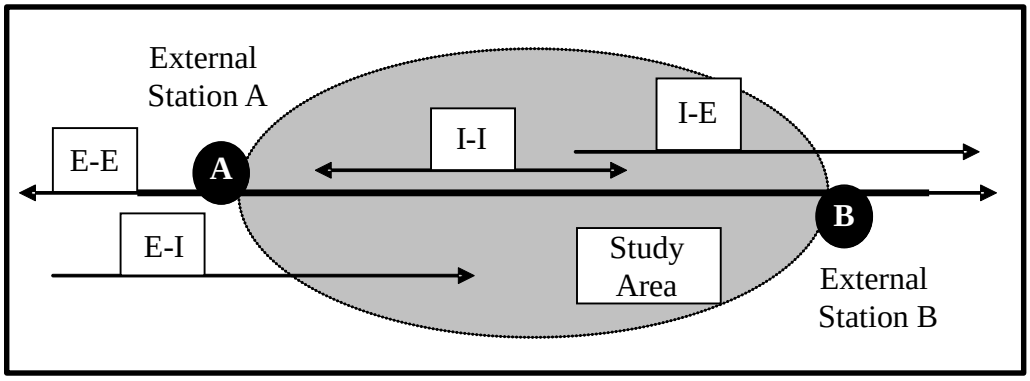
A zonal cumulative analysis was performed for a growing rural residential community along a state highway. This example study area will be used throughout the rest of this section. The study area was split into four zones (1-4). The number of vacant lots and the building rate were estimated following Section 6.10.2. The current year is 2002 with a project horizon year of 2027. All of the zones except for Zone 2 reach build-out. The trip generation is based on the ITE Trip Generation PM peak single family home rates (Category 210) of 1.01 trips per dwelling unit in the peak hour.

(1) Zone	**(2) Vacant Lots (2002)**	**(3) Building Rate (Homes/yr)**	**(4) New Homes built by 2027**	**(5) 2027 Trip Generation Total (Enter/Exit) (vph)**
1	537	80	537	542 (349/193)
2	984	30	750	758 (488/270)
3	167	17	167	169 (109/60)
4	640	35	640	646 (416/230)

6.10.4 Trip Types

The total trips in the study area are made up of internal and external trips. External trips are those trips that have at least one end located outside of the study area, as defined by the study area boundary. Internal trips begin and end within the study area. There are four trip types that make up the total trips that are the focus of the next three sections. The trip types are external-external (E-E), external-internal (E-I), internal-external (I-E), and internal-internal (I-I). See Exhibit 6-7.

Exhibit 6-7 External and Internal Trip Types



6.10.5 Estimating Through (External-External) Trips

External-external or E-E (through) trips are trips that have both ends (origin and destination) outside of the study area. The E-E trips are the first of the four basic trip types that need to be created from the overall study area volumes. The objective of this section is to calculate the proportion of E-E trips compared to the total trips and eventually the total E-E trips.

The point where each study area roadway crosses the study area boundary is known as an external station. This point represents the connection to the outside world. The external stations are shown as the black circled ”A” and ”B” in Exhibit 6-7. External stations are treated essentially as additional zones in this methodology, so number them to not conflict with the TAZ number to avoid confusion. Examples could be using letters (A, B, C…) or a completely different and distinctive number series (500, 501, 502…).

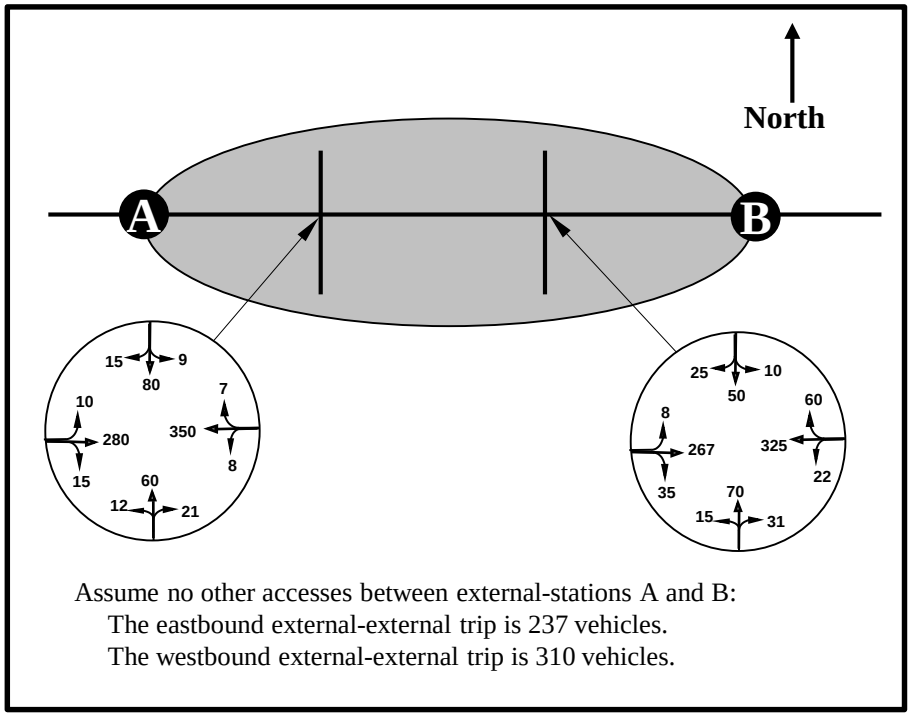
The E-E trips for the base and future years are calculated at each external station. Only roadways with significant volume in the study area should be counted as having external stations. While it is possible to have every local road study area boundary crossing an external station, the complexity of the analysis rapidly increases, the extra work may not be justified, and the necessary detail level needed may not be achievable. Use of origin-destination, license plate matching, or a Bluetooth MAC-address matching study are desired with areas having multiple external stations to simplify finding the E-E trip proportions.

At each external station, the proportion of E-E trips needs to be calculated. This can be obtained directly from an origin-destination or other matching study between each external station pair and for each direction of travel. In most cases, an approximation procedure is necessary to estimate the E-E proportion. Using the directional peak hour (30HV) volumes at an external station, hold that volume and proceed to the other external station by subtracting all turn volumes at each intersection downstream, The remaining volume is the E-E trip volume. This remaining volume is divided by the total directional volume at the external station to determine the percentage of E-E trips. The process is repeated in the other direction and for each external station and for each external station pair (i.e. three external stations: 1-2, 2-1, 1-3, 3-1, 2-3, 3-2).
It is possible to end up with a negative value upon reaching the other external station

especially if there are a large proportion of turning volumes compared to the non-turning volume. The turn movements inside the study area are made up of all the trip types so it is possible that large internal-internal trip patterns skew the turning movements to an extent so a negative value is obtained. A negative value indicates a need to investigate the higher local turn movements to see where they are destined to and to make sure that other external trips are not mixing in. For areas with complex trip patterns or a good amount of external stations, some sort of origin-destination study is recommended for all or part of the study area.

Example 6-10 E-E Approximation Process

In the figure below, there are two external stations, labeled A and B representing the roadway as it enters and leaves the study area. The volumes at intermediate study area intersections are shown below. The initial external station volume is determined from the given volumes. For example, at External Station A, the eastbound volume starts with 305 vph (280 EBT + 10 EBL + 15 EBR) entering the study area.



Starting with the first intermediate intersection and proceeding eastbound, the turning volumes are subtracted from the initial 305 vph value. The resulting value is the total E-E trips for the eastbound External Station A movement. This is repeated for the westbound direction.

Total EB E-E trips = 305 – 10 – 15 – 8 – 35 = 237 vph
Total WB E-E trips = 407 – 60 – 22 – 7 – 8 = 310 vph
At External Station A, the total EB trips are 10 + 280 + 15 = 305
At External Station A, the total WB trips are 12 + 350 + 15 = 377

At External Station B, the total EB trips are 31 + 267 +10 = 308
At External Station B, the total WB trips are 22 + 325 + 60 = 407

The External Station A E-E EB trip percentage = 237 / 305 = 0.77
The External Station A E-E WB trip percentage = 310 / 377 = 0.83
The External Station B E-E EB trip percentage = 237 / 308 = 0.77
The External Station B E-E WB trip percentage = 310 / 407 = 0.77

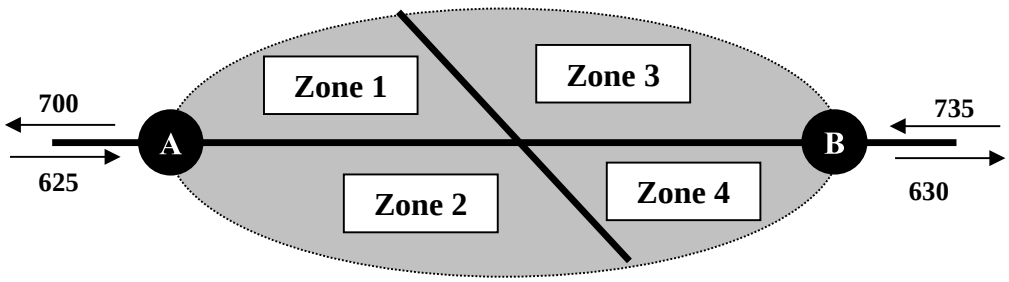
Therefore, there is a 77% chance that trips entering or leaving External Station A are E-E trips. There are 305 total trips on the EB approach at External Station A and it was calculated that 237 of them travel all the way to External station B above. So, 237 / 305 = 0.77 or 77%. In the WB direction at External Station A, there are 377 trips on the approach and it was determined that 310 trips travel from External Station B to A. So 310 / 377 = 0.83 or 83%.

Example 6-10 determined the base year E-E trips. In order to calculate the future year E-E trips, a growth factor needs to be calculated for each external station. This growth factor is computed from the Future Volume Tables for the road segment(s) in question. Non-state roadways can be estimated from historical local counts if available or using a state highway with similar volumes and characteristics as a surrogate. The growth factor is a multi-year factor depending on the number of years between the base and future year. For example, if the base year was 2002 and the future year was 2027, then a 25-year growth factor would need to be computed. See Section 6.5 for more information.

Example 6-11 Future Year E-E Calculations

Given in this example:

- Traffic volumes at the External Station A are 625 entering and 700 exiting.
- Traffic volumes at the External Station B are 735 entering and 630 exiting.



Assumptions:

Growth factors at External stations A and B are 1.83 and 1.53, respectively, over 25 years.

From the figure, the 25-year historical growth factor is 1.83 for External Station A and 1.53 for External Station B and shown in Column (2). The base year 2002 volumes shown in Column (1) are multiplied by the appropriate historical growth factor to obtain 2027 design hour volumes and are shown in Column (3).

The E-E trip proportions were calculated using the method in Example 6-10 for each direction at each external station and are shown in the below table in Column (4):

- External Station A – Entering = 0.83
- External Station A – Exiting = 0.86
- External Station B – Entering = 0.82
- External Station B – Exiting = 0.82

The total new E-E trip growth from 2002 and 2027 is calculated by multiplying the E-E proportions times the difference between the 2002 and 2027 DHV and is shown in Column (5).

Ext. Trip Table	Direction	(1) 2002 DHV (vph)	(2) Growth Factor	(3) 2027 DHV =(1)*(2) (vph)	(4) E-E Trip Prob.	(5) 2027 E-E Trip Growth =(4)*((3)-(1)) (vph)
External Station A	Enter	625	1.83	1144	0.83	431
	Exit	700	1.83	1281	0.86	500
External Station B	Enter	735	1.53	1125	0.82	320
	Exit	630	1.53	964	0.82	274

6.10.6 Estimating External-Internal (E-I) and Internal – External (I-E) Trips

Once the total E-E trips have been determined, the External-Internal (E-I) and Internal-External (I-E) trips can be determined. The E-I and I-E trips have one end of the trip in the study area and one end outside of the study area.

The E-I trip growth is the total external station growth entering the study area minus the directional E-E growth. Conversely, the I-E trip growth is the total external station growth exiting the study area minus the directional E-E growth.

Example 6-12 Future Year E-I and I-E Trip Calculation

From the information in Examples Example 6-10 and Example 6-11, the 25-year growth of E-I and I-E trips are calculated as shown in Column (6).

Ext. Trip Table	Direction	(1) 2002 DHV (vph)	(2) Growth Factor	(3) 2027 DHV =(1)*(2) (vph)	(4) E-E Trip Prob.	(5) 2027 E-E Trip Growth =(4)*((3)-(1)) (vph)	(6) 2027 E-I, I-E Trip Growth = (3)-(1)-(5) (vph)
External Station A	Enter	625	1.83	1144	0.83	431	88
	Exit	700	1.83	1281	0.86	500	81
External Station B	Enter	735	1.53	1125	0.82	320	70
	Exit	630	1.53	964	0.82	274	60

6.10.7 Trip Distribution of E-I and I-E trips

Trips entering a zone are also known as an “attracted” trip while trips leaving a zone are a “produced” trip. The zonal cumulative analysis uses a gravity-based method for determining a TAZ’s distribution of attractions and productions. Larger zones (on a trip generation basis, not geographical area) attract and produce more trips than smaller zones on a relative basis. This process is known as trip distribution.

After the external-external trip growth has been removed from the total external trip growth, the remaining trips are distributed to the internal zones according to the following procedure.

- Distribution of growth in external-internal trips:
    - Calculate the attraction probability of each zone’s new trip attractions by dividing its new trip attractions by the study area’s total new trip attractions.
    - Distribute the growth in external-internal trips for each external station by

multiplying these trips by each zone's attraction probability.

- Distribution of growth in internal-external trips:
  - Calculate the production probability of each zone's new trip productions by dividing its new trip productions by the study area's total new trip productions.
  - Distribute the growth in internal-external trips for each external station by multiplying these trips by each zone's production probability.

When distributing trips, care needs to be taken considering the land use within each zone. For the typical afternoon peak hour analysis, trips will be traveling from employment zones (commercial/industrial) to residential zones; from residential zones to commercial zones (i.e. shopping/eating after work); and from commercial to other commercial zones (trip chaining). Residential to residential trip distribution should be avoided as it will likely cause unrealistic results.

Example 6-13 E-I and I-E Trip Distribution

Distribute the new external-internal and internal-external trips in Example 6-12 to the four zones shown in Example 6-11.

Solution:

The total new trips are obtained from the trip generation done in Example 6-9 (Column 5). All zones are summed up to determine the grand new trip total for the entire study area. The trip attractions and productions are the entering and exiting trips, respectively, also from Example 6-9. The attractions and productions are also summed up across all zones to determine the total attracted and produced trips.

The calculation of the attraction and production probabilities is shown in the external trip attraction and production probability table below. All trips are in vehicles per hour. For example, Zone 1's attraction probability is 349/1362 = 0.256 and its production probability is 193/753 = 0.256.

External Trip Attractions and Productions Probabilities

Zone	**1**	**2**	**3**	**4**	**Total**
Total New Trips (from Example 6-9)	542	758	169	646	2115
Trip Attractions (from Example 6-9)	349	488	109	416	1362
Attraction Probability	0.256	0.358	0.080	0.306	1.000
Trip Productions (from Example 6-9)	193	270	60	230	753
Production Probability	0.256	0.359	0.080	0.305	1.000

The distribution of new external-internal trips is shown in the E-I table below. For example, Zone 1's new external-internal trips at External Station A are 88*0.256 = 23 vph.

External-Internal Trip Attraction Distribution

External Station	New E-I Trips	Zone 1	Zone 2	Zone 3	Zone 4
A	88 (from Example 6-12)	23	31	7	27
B	70(from Example 6-12)	18	25	6	21

The distribution of new internal-external trips is shown in the I-E table below. For example, Zone 1's new internal-external trips at External Station A are 81*0.256 = 21 vph.

Internal-External Trip Production Distribution

External Station	New I-E Trips	Zone 1	Zone 2	Zone 3	Zone 4
A	81(from Example 6-12)	21	29	6	25
B	60(from Example 6-12)	15	22	5	18

6.10.8 Trip Distribution of Internal – Internal Trips

After the new external-internal and internal-external trips have been distributed for each zone, the remaining new attractions and productions are internal-internal trips. While these attractions and productions balance in the examples for simplification, typically they do not. The I-I table would need to be balanced using a Frater methodology (i.e. see NCHRP Report 765). External-External proportions or zone production/attraction probabilities may need to be slightly adjusted for balance to occur. Internal –internal (I-I) trips are trips that both start and end in the study area. The total I-I trips are determined by subtracting the total new E-I/I-E trips from the total new trips for each TAZ.

Example 6-14 I-I Total Trip Calculation

From the previous example, the total new attraction/production trips for each zone in vehicles per hour are shown on the first line of the trip attractions and productions probability table. The total E-I and I-E trips for each zone are summed up and subtracted from the total new trips.

For Zone 1, the total new trips are 542. The total E-I trips (from Example 6-13's trip attraction distribution) are 23 + 18 = 41 while the I-E trips are 21 + 15 = 36 (from Example 6-13's trip production distribution table).

Trip Type	Zone 1	Zone 2	Zone 3	Zone 4	Total
Total New Trips	542	758	169	646	2115
Total E-I trips	41	56	13	48	158
Total I-E trips	36	51	11	43	141
Total resulting I-I trips	**465**	**651**	**145**	**555**	1816

The total I-I trips are calculated by subtracting the total E-I and I-E from the total new trips: Total Zone 1 I-I trips = 542 – 41 – 36 = 465 trips
This is repeated for all remaining zones. Note that the table is balanced as the sum of the total new trips minus the total E-I and I-E trips equals the sum of the column totals. For the above table: 465 + 651 + 145 + 555 = 1816 and 2115 – 158 – 141 = 1816.

To distribute the internal-internal trips for each zone, use the same distribution process as described in Section 6.10.7. Once the total I-I trips are determined for each zone following the process shown in Example 6-13, the total internal attractions and productions need to be calculated. The total internal attractions are determined by subtracting the total external-internal attractions from the total attractions. Likewise, the total internal productions are determined from subtracting the total internal-external productions from the total productions. Attraction probabilities are calculated by dividing the total attractions for each zone by the total attractions. Production probabilities are done similarly.

Example 6-15 I-I Trip Distribution

For each zone, the total internal attractions and productions need to be calculated. For Zone 1, there were 464 total internal-internal trips determined in Example 6-14 and shown below in the internal-internal trip attraction/production probability table. In Example 6-13 the total external-internal trip attractions were 349 while the total external-internal trip productions were 193. The total external-internal trip attraction distribution table has a total of 41 (23+18) trips for Zone 1. Likewise, the corresponding internal-external trip production table has a total of 36 (21 + 15) trips for Zone 1.

Total I-I trip attractions = 349 – 41 = 308 trips
Total I-I trip productions = 193 – 36 = 157 trips

The calculations are repeated for all zones and are shown in the below table. The total I-I trip attractions and productions are summed up across all zones for a grand attraction and production totals. Attraction and production probabilities are also calculated for all zones. For Zone 1 the 308 internal attracted trips are divided by the total 1204 attracted trips = 308 / 1204 = 0.256 Production probabilities for Zone 1 are 157 / 612 = 0.256.

Internal Trip Attractions and Productions Probabilities

	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**Total**
Total Internal-Internal Trips	464	650	145	553	1812
Internal Attractions	308	432	96	368	1204
Attraction Probability	0.256	0.358	0.080	0.306	1.000
Internal Productions	156	218	49	185	608
Production Probability	0.257	0.358	0.081	0.304	1.000

The distribution of new internal-internal attractions is shown in the table below. For

example, the attraction trips to Zone 1 from Zone 2 are 308*0.358 = 110.

Internal Trip Attraction Distribution

Zone	I-I Attraction	Zone 1	Zone 2	Zone 3	Zone 4
1	308	79	110	25	94
2	432	111	155	34	132
3	96	25	34	8	29
4	368	94	132	30	112

The distribution of new internal-internal productions is shown in the table below. For example, the production trips from Zone 1 from Zone 2 are 156*0.358 = 56.

Internal Trip Production Distribution

Zone	I-I Production	Zone 1	Zone 2	Zone 3	Zone 4
1	156	40	56	13	47
2	218	56	78	18	66
3	49	13	18	4	15
4	185	48	66	15	56

6.10.9 Initial Trip Assignment

Following trip distribution, the next step in the procedure is trip assignment, which involves placing the growth in trips on the road network. Trip assignment is the process used to estimate paths the trip will take, which ultimately results in traffic flow on the network. It assigns the trips to specific routes and establishes volumes on links, taking into consideration network characteristics to find the shortest path between origins and destinations.

The trip assignment is based on the shortest path in the network by time. A travel time needs to be identified for each link on the network. At the minimum, each route should be traveled at least once in each direction during the analysis hour to help estimate a travel time for that direction on the link. The ideal method to determine travel times would be following the procedures in Chapter 3 for travel time studies. For roadways that do not exist, speeds should be estimated using distance and likely travel or posted speed.

The analyst has to establish the travel times for the four trip-types. For each production-attraction pair in the trip table, the likely paths need to be identified. There is likely to be more than one path for each pair, depending on the network. The link travel times are summed to create the total path travel time.

Where there are multiple paths for an individual production-attraction pair, the appropriate path needs to be selected. The selection should be based on the smallest travel time. If the path travel times are within 10% of each other, the trips can be assigned equally across those paths. When the times are more than 50% different then assign the trips all to the shortest path. When the difference is between 10 and 50 %, the

trips should be assigned on a weighted average based on the inverse proportion. For example, assume that the paths were 4 minutes versus 3 minutes. Since the 4 minute path is 33% longer than the 3 minute path, the trips are assigned 33% to the longer 4-minute path and 67% to the shorter 3-minute path. Engineering judgment must be used when review travel times of closely spaced parallel paths to assure that actual driver behavior is modeled and not just a mathematical difference.

The analyst must now assign the trips by trip types starting with E-E and progressing to E-I, then I-E and finally I-I as illustrated in the example.

6.10.10 Total Trip Assignment

Once all the trips have been assigned by trip type, the analyst must check for links that have been over assigned based on capacity. The analyst should first review the base year analysis to determine whether certain links are below, near/at or over capacity. For links in the base year that are approaching or over capacity, a flag for possible trip reassignment is identified. Also, links with a large amount of growth in traffic should be identified as needing a check for over capacity conditions.

Any flagged linked may require that the assignment of the growth trips be reassigned to links with available capacity. The analyst needs to use an HCM segment methodology to determine the link capacity. The analyst will need to convert the base year intersection volumes into link volumes. The growth trips need to be added to the base year trips to determine total trips assigned to a link. The analyst then identifies any links that have trips assigned in excess of the capacity. For the over-capacity links, the excess trips above capacity from growth need to be reassigned to other logical paths. This iterative process should be continued until the excess trips have been assigned logically onto the network. Depending on the network, there may be limited additional paths so the excess trips cannot always be completely reassigned.

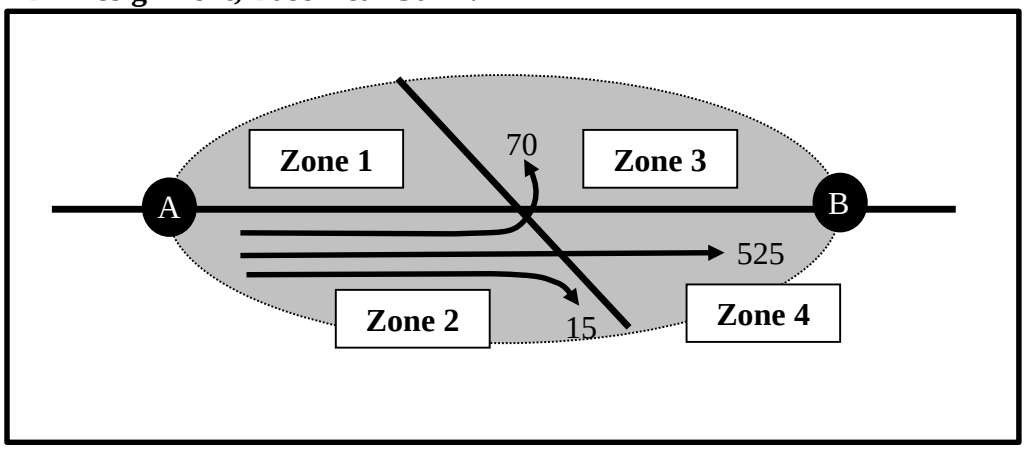
Example 6-16 Trip Assignment for Eastbound Through

This example illustrates the aggregation of the individual trip types for the future for one movement on one approach at an intersection within the study area. This would need to be repeated for the other movements and other intersections. This example focuses on the eastbound through (EBT) movement.

Base Year Trips

The process starts with the existing year (base year) 30HV volume previously calculated using procedures from Chapter 5. From the figure below, there are 525 base-year trips to be assigned to the EBT movement.

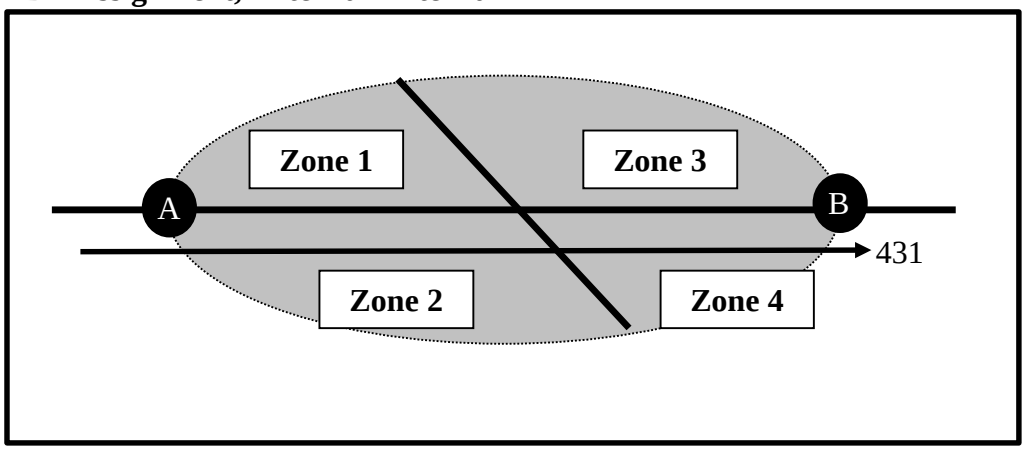
EBT Assignment, Base Year 30 HV



External-External Trips

Next, the external-external trips are added. From Example 6-11, the future year eastbound E-E trips are 431 and are shown in the next figure below.

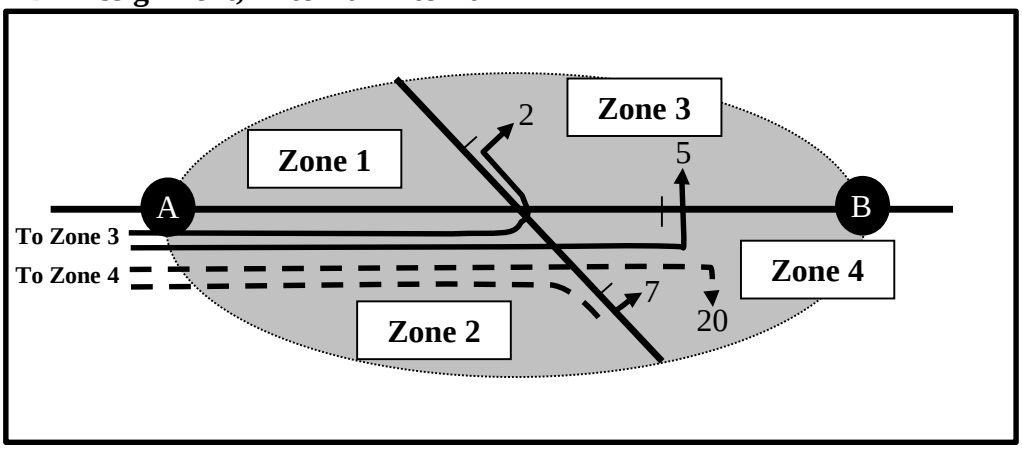
EBT Assignment, External-External



External-Internal Trips

From the figure below, note that Zone 1 and 2 E-I trips will leave the roadway before the intersection at access points or turning left or right at the side street. Both of these do not add to the assignment for the eastbound through (EBT) movement. However, they would be part of the assignments for the eastbound left and right.

EBT Assignment, External-Internal



There are seven total external-internal trips from External Station A to Zone 3. These seven trips can access to Zone 3 by turning left at the intersection or through downstream accesses via the mainline based on assignment assumptions. Two of the seven trips will travel to Zone 3 by turning left at the intersection and the remaining five trips will travel to Zone 3 through downstream accesses via the mainline.

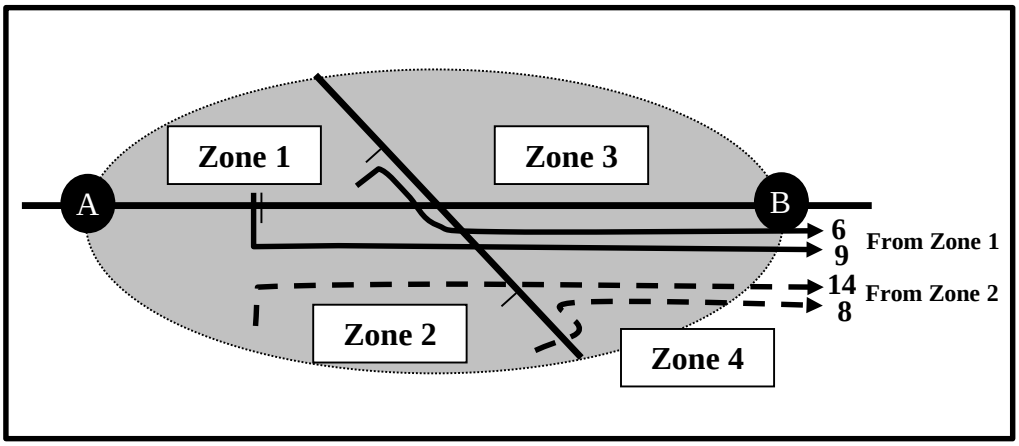
The same process is followed for trips from External Station A to Zone 4. The total external-internal trips from External Station A to Zone 4 are 27. The same accessibility assumptions from Zone 3 apply to Zone 4. Here, assuming 20 out of the 27 will access to Zone 4 by downstream accesses on the mainline and seven via the side street.

The resulting total E-I trips for the EBT movement is 25 (20 +5).

Internal-External Trips

From the figure below, note that Zone 3 and 4 I-E trips will turn onto the mainline roadway at the intersection or access it downstream of the intersection. These movements would not be counted into the EBT movement assignment. They would be part of the assignment for the northbound right and southbound left movements.

EBT Assignment, Internal-External



The total internal-external trips from Zone 1 to External Station B are 15. The assignment of these trips depends on the accessibility from Zone 1 to the external station B. Nine (9) of the 16 trips (depending on the accessibility from Zone 1 to the road network) will travel to External Station B by using upstream access points. The remaining six trips will travel to External Station B by turning left at the intersection.

The total I-E trips are 23 (9+14) for the EBT movement.

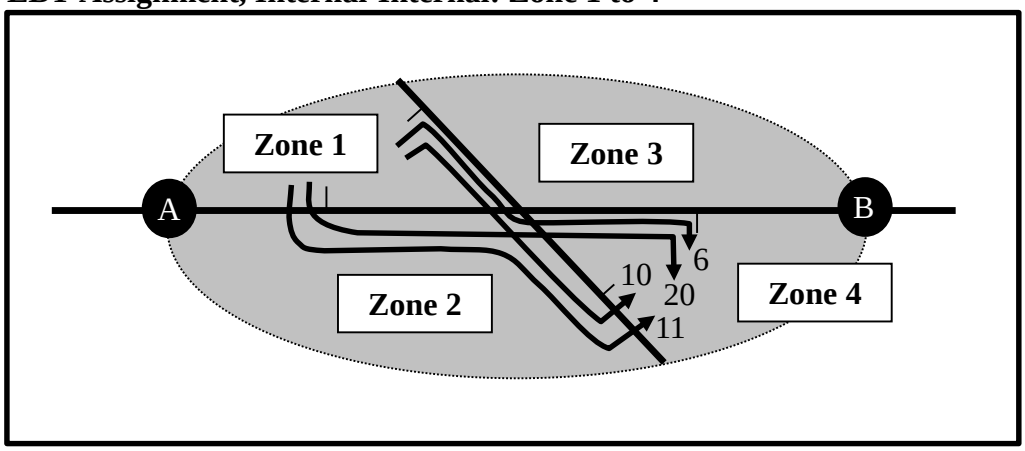
Internal-Internal Trips

There are internal-internal production trips from Zone 1 to Zones 2, 3 and 4, and from Zone 2 to Zones 1, 3 and 4. The internal-internal production trips from Zone 1 to Zones 2 and 3 and from Zone 2 to Zones 1 and 4 do not go through the subject intersection as they use other smaller connectors or accesses. The only applicable internal-internal production trips are between Zone 1 and 4 and Zones 2 and 3.

The total internal-internal production trips from Zone 1 to Zone 4 (See Example 6-11) are 47 trips and from Zone 2 to Zone 3 are 18 trips. The internal-internal trip assignment from Zone 1 to Zone 4 and from Zone 2 to Zone 3 is based on the network accessibility assumptions.

On the side street, I-I trips from Zone 1 to 4 will take a couple different paths by either traveling through the intersection southbound (10 trips) or turning left (6 trips) as seen in the figure below. On the mainline, the I-I trips from Zone 1 to 4 will access the mainline mid-block and travel through the intersection eastbound (20 trips) or turn right at the intersection (12 trips). Of the 48 total I-I trips from Zone 1 to 4, only 20 trips are assigned to the EBT movement.

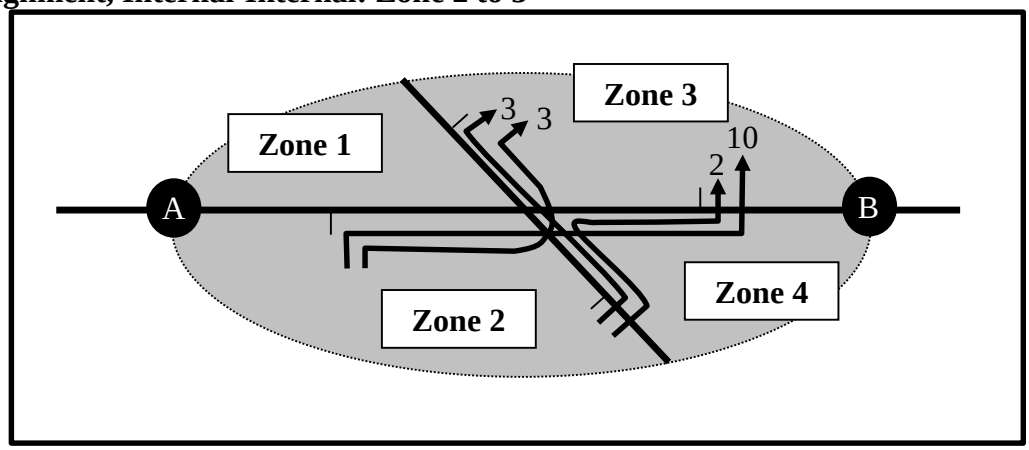
EBT Assignment, Internal-Internal: Zone 1 to 4



Likewise, between Zone 2 and 3, the I-I trips will either travel between the two zones by the side street or the mainline. On the side street, I-I trips from Zone 2 to 3 will either travel northward through the intersection (3 trips) or turn right (2 trips) as seen in the figure below. On the mainline, I-I trips from Zone 2 to 3 will turn left at the intersection (3 trips) or travel through the intersection to downstream accesses (10 trips). Of the 18

total I-I trips between Zone 2 and 3, only 10 trips are assigned to the EBT movement.

EBT Assignment, Internal-Internal: Zone 2 to 3



The total I-I trips on the EBT movement is 30 (20 + 10) from both zones.

Total Trip Assignment

The resulting total trip assignment is created by summing up the base year trips, the external trips and the internal trips as seen in the table below.

Total Trip Assignment – EBT (vehicles per hour, vph)

Trip Type	Trips (vph)
Base Year 30HV	525
E-E	431
E-I	25
I-E	23
I-I	30
Total	**1034**

For Build Alternatives, the trip generation and distribution are fixed, so only the trip assignments need to be modified. The travel times would have to be determined for the new roadway network and then the trips assigned by the methods above.

6.11 Enhanced Zonal Cumulative Analysis

Enhanced Zonal Cumulative Analysis (EZCA) is not and shall not be considered the equivalent of a travel demand model, even though it uses similar techniques and tools. It should not be used for analysis other than the original use without coordination with TPAU to determine if significant re-evaluation and possible updating of information is required.

The EZCA methods provide a series of enhancements to the typical application of zonal

cumulative analysis methods. The purpose of the EZCA application is to enhance traffic circulation and operations analysis that can account for details that are otherwise not captured in the cumulative analysis approach. The full application of these enhancements has also been referred to as the small community forecast tool (SCFT) methodology. The EZCA methods can be used wherever the regular zonal cumulative analysis process is used, as well as larger areas (greater than 10,000) that do not have a travel demand model in place[15]. The development and application of the EZCA methods can be cumbersome and labor-intensive; however, the methods provide significant refinements and application beyond the typical zonal cumulative analysis. Larger areas will still require the manual spreadsheet-based setup, however, the enhanced zonal cumulative allows greater automation in trip assignment using VISUM (or other modeling assignment software). By using assignment software tools, the process can be streamlined to more closely resemble a travel demand model.

The creation of an enhanced zonal cumulative analysis should be weighed against the creation of a full travel demand model. As with a travel demand model, analysts should coordinate with TPAU to determine if subsequent project application (i.e., use for project analysis beyond the original study) is appropriate for the scope and development of the EZCA. Appendix 6A provides a sample application of the EZCA process that was performed for Canby.[16]

6.11.1 Process

The general process for developing an EZCA tool follows a similar process to the zonal cumulative analysis, while adding enhancements that address some of the key limitations. Primary enhancements include:

- Scope of land use and trip assignment - The major difference (enhancement) is to include an estimation of base year and future year total land use (and trips), instead of only using a growth increment. This allows redistribution and reassignment of existing trips that may occur due to adjacent changes in land use or the transportation network. For example, an existing trip from a residence to a grocery store may use a different route (assignment change) if a new street connection is build. Similarly, if a new grocery store is built and is located closer, the driver may decide to travel to this store instead of the other store (distribution change). This fundamental difference provides additional flexibility and options for project application.
- Trip Matrix – All trips in the network are typically assigned using a trip matrix, including existing trips. Fixed trips (such as driveway pass-by trips) can be added, but doing so removes trip assignment flexibility and routing effects due to network condition and changes. Existing count data is used for calibration

[15] While larger areas may trigger development of travel demand model, in some cases full model development may not be feasible given project application needs and schedule. In these areas, EZCA may still provide an alternative tool for forecasting traffic volumes or other project application. An example of a larger area with EZCA application is Canby, Oregon, which had a population over 15,000 in 2010.
[16] Technical Memorandum #3: Canby TSP – Future Forecasting, DKS Associates, March 31, 2010.

purposes, but is not considered "background" trips.

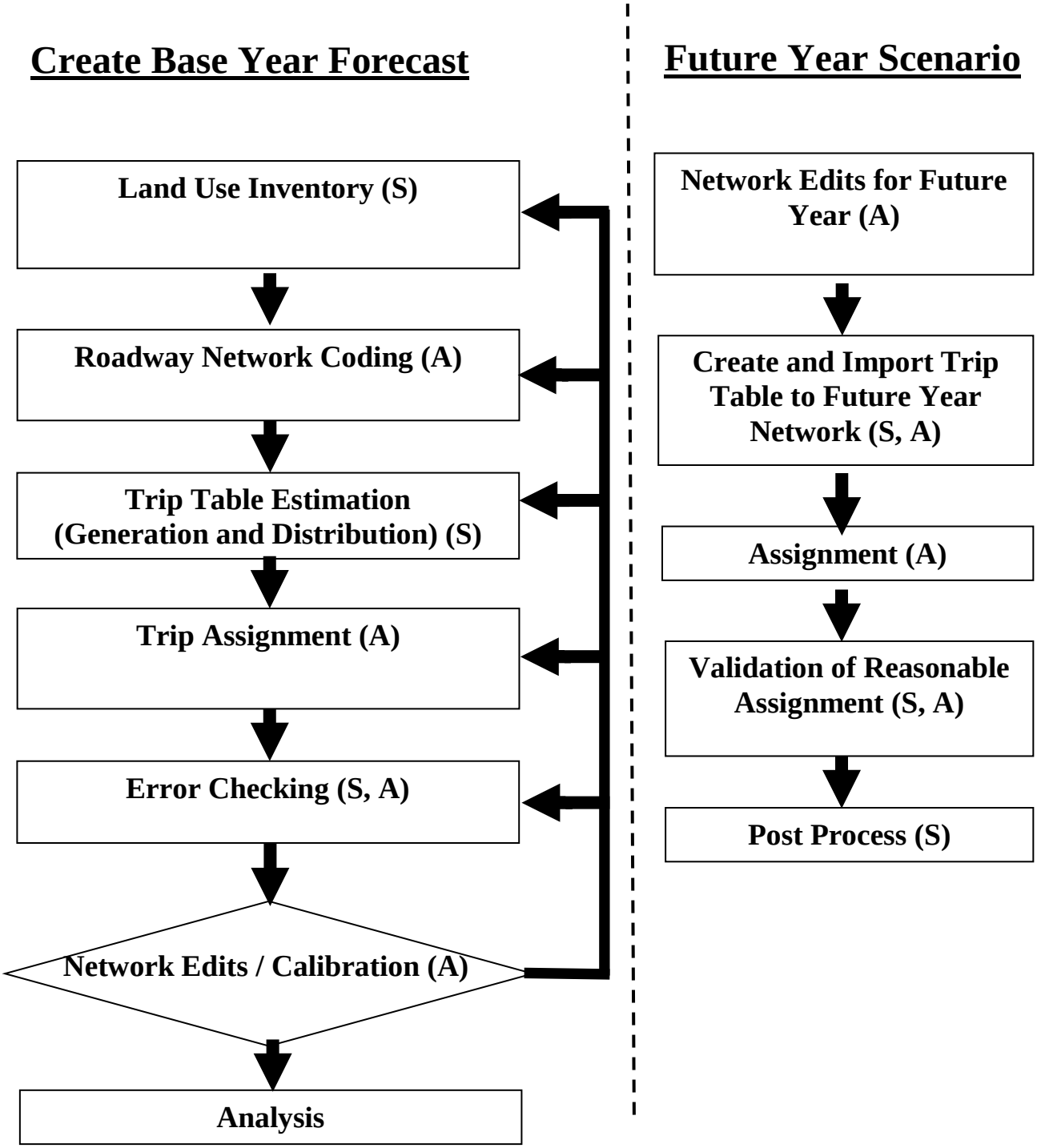
- Trip assignment approach - The EZCA utilizes an equilibrium assignment procedure that automates the routing choices with improved accuracy over manual assignment. Depending on the assignment software tool used, more detail such as link and/or nodal delay can be added to better represent the effects of congestion. This will allow a more responsive, accurate and comprehensive analysis of the base and future conditions. This approach provides two key benefits:
    - Fundamentally, assignment and routing is automated based on a comprehensive, analytical check of available routes and travel times.
    - Network detail (connector loading, street system, traffic control, etc.) can be scaled by project need, as described in Chapter 8 (Mesoscopic Analysis)[17].
- An iterative process of checks, back-checks, and balances – The use of spreadsheets (land use summaries and matrix development) and assignment software (trip assignment) allows for a semi-automated process that can be used to perform iterative checks and testing.
- Calibration of a base year "tool" – Since all internal trips (rather than just the growth increment) are being estimated through land use, trip generation, trip distribution, and trip assignment, the network coding and analysis assumptions (including land use and trip generation) can be validated in a way that is not feasible with the standard TIA level and zonal cumulative analysis methods.
- Various other enhancements that may be performed to refine a standard zonal cumulative analysis application, such as data to refine land use development (Section 6.8.2) collection of Bluetooth data (Section 6.8.5) to inform external trip patterns.

The overall EZCA Process (Exhibit 6-8) is generally similar to the typical zonal cumulative analysis method. However, subtle differences exist as listed in Exhibit 6-8.

The analysis results are impacted by the combined effects of the integrated EZCA components (land use, trip rates, loading locations, network coding, etc.). For this reason, it is important to balance the level of detail and effort that is put into each component to minimize compounded errors. For instance, trip generation relies on both land use and trip rates. A perfect inventory of land uses will not provide true enhancements to this procedure unless trip rates are also appropriate.

[17] Typical applications of EZCA will include an all-street system reflecting comprehensive traffic control, as described in Windowed Area Models.

Exhibit 6-8 EZCA Process



Note: Typical tools for the above process include spreadsheets and the traffic assignment software. Steps noted with (S) are typically conducted in a spreadsheet, while those marked with (A) are typically performed in the assignment software.

Exhibit 6-9 Comparison of Standard Zonal Cumulative Analysis and EZCA

Zonal Cumulative Analysis Step (Standard Approach)	**Enhanced Zonal Cumulative Analysis (EZCA)**
General Set Up	
1- Identify the study area and divide into transportation analysis zones (TAZ)	Study area typically whole community or large subarea
(Step not used)	Set up the transportation network coding
Land Use & Trip Generation	
2- Identify vacant lands, in-process developments, comprehensive plan allowed land uses/densities, and development rates.	Determine all existing and future land use totals (not just growth)
3- Estimate future trip generation potential	Estimate existing trips using ITE average trip rates as the initial assumption.
Trip Distribution	
4- Determining the through trip percentages (external – external, E-E) and E-E trips for the external stations	Approximation by subtraction procedure is difficult due to larger network size, and typically need OD data such as Bluetooth.
5- Determining the internal – external (I-E) and external –internal (E-I) trips at each external station (external zone)	Completed for all trips, not just growth increment.
6- Determining the trip distribution for the internal – external (I-E) and external – internal (E-I) trips for each internal TAZ.	Complete for all trips, not just growth increment.
7- Determining the trip distribution for internal-internal (I-I) trips	Complete for all trips, not just growth.
Trip Assignment	
8- Calculating network link travel times	Not done manually. Assignment software uses the “free flow” travel time as the initial assumption (updated through an iterative assignment process) based on link and/or nodal travel times. Link delay may be needed to account for congestion on free-flow facilities.
9- Assigning total trips to the network	Not done manually. Assignment software is used.
Additional Steps for EZCA	
(Step not used)	Calibration of tool estimation of traffic volumes compared to counts

Although this process is not a travel demand model, many of the elements are similar so general background information can be obtained from the Modeling Procedures Manual for Land Use Changes (MPMLUC) on the Transportation Planning website under

General Papers which is available at: (See Chapter 8 for related information for developing traffic networks for subarea models)
http://www.oregon.gov/ODOT/TD/TP/Pages/Reports.aspx

The following sections provide details for each component of the ECZA process, with a focus on methods that differ from the standard zonal cumulative analysis approach. Unless otherwise noted, the approach generally follows Section 6.8.

6.11.2 Land Use

Land use inventories for EZCA are required similar to the standard zonal cumulative analysis approach (typically collected at the parcel level and aggregated to the zonal level), with the following differences:

- Inventories include all land use, not just the growth increment. For this reason, both base year and future year inventories are developed for the study area.
    - Base year inventories should be consistent with traffic data that was collected for calibration.
    - Future year inventories include not only development, but potential redevelopment as well.
- The study area is typically comprised of a large area, and may even represent an entire community. Larger study areas that encompass the entire community provide the ability to compare to coordinated population projections that may not provide as much value to a smaller area.
- The land use data is typically grouped into five main categories – households (which may be split between single family and multifamily uses), retail employment, service employment, education employment, and other employment. However, these categories may vary by application depending on the community, allowed zoning uses, and context. These land uses should generally correlate with ITE categories or combinations of ITE categories based on related uses that exist in the community. For instance, a community may have the following uses, grouped as shown:
    - Single Family Residential Household
    - Apartment/Condo
    - Retail Employment (Gas station, Fast Food, Bank, Shopping Center)
    - Service Employment (Strip mall offices, auto shops, and specialty shops that do not generate as many trips as active retail uses)
    - Education Employment
    - Other Employment (Office Park, Industrial Uses)
- Land use inventories are aggregated to transportation analysis zones, as shown in Exhibit 6-10.
- For future conditions, the future population projection from the analysis must be consistent with the county-coordinated population forecast for the city. The future employment needs to be at a level that can be supported by the population

in the study area[18]. The future employment and population must be consistent with the local jurisdiction's comprehensive plan. The analyst will need to consult with the local jurisdiction to determine where future growth is to be allocated. The local jurisdiction will also need to review the final allocations for consistency. The modular integration of the EZCA elements allows the ability to easily test different land use scenarios (update trip generation and copy resulting trip matrix to assignment software).

[18] The *Modeling Procedures Manual for Land Use Changes*, ODOT Transportation Planning Analysis Unit, February 2012 identifies employment ratios that are reasonable.

Exhibit 6-10 Sample Land Use Totals (Households and Employees) by TAZ

TAZ	HH_BASE	RETL_BASE	SERV_BASE	EDUC_BASE	OTHR_BASE
101	26	0	0	0	0
102	9	8	0	0	0
103	295	0	0	0	0
104	68	0	0	0	40
105	0	0	0	0	25
106	149	0	0	0	0
107	175	0	0	0	0
108	162	0	0	0	0
109	163	0	0	0	0
110	131	0	0	0	0
111	70	0	0	0	0
112	109	0	0	0	0
113	66	0	0	0	0
114	164	0	0	0	0
115	140	0	0	0	0
116	85	0	0	0	0
117	63	0	0	0	0
118	124	0	0	0	0
119	121	0	0	0	0
120	105	0	0	0	0
121	45	0	12	0	29
122	214	0	1	0	62
123	0	0	0	0	0
124	134	0	0	0	0
125	1	0	25	0	300
126	133	0	0	0	0
127	213	0	0	74.9	0
128	193	0	0	0	0
129	111	0	0	0	0
130	75	30	105	0	13

6.11.3 Roadway Network

The standard application of zonal cumulative analysis can require rigorous manual calculations and checks to determine appropriate assumptions about travel time and vehicle routing. As an enhancement, assignment software can be used to provide a

platform for assigning the trip matrix in place of manual assignment methods. This enhancement provides a technical basis (such as travel time or other factors) for assumptions related to trip routing. For this reason, the roadway network needs additional detail that is not typically included in a standard travel demand model (See network details in Chapter 8 regarding mesoscopic modeling and subarea models).

The network should include, at a minimum, arterial and collectors within the study area. Local streets may also be desired. Additional details can be added which include posted speeds, traffic control, lane geometries and the number of travel lanes. The analyst in consultation with the local jurisdiction must determine whether committed (funded), financially constrained and/or all planned projects are to be added to the future network. Elements of the transportation network should include:

- Link (Street) Detail
  - Location – the more roadways included the more flexibility of assignments is included, specifically roads that are subject to cut-through traffic and any roads that are parallel to major routes. Some software allows for importing GIS shapefiles from sources such as local agency inventories, or the Open Street Network which has much of this information. However, the amount and accuracy of this data needs to be (field) verified or edited. More links in the network does not necessarily increase the accuracy of the assignment results, and care should be taken with calibration.
  - Speed – free flow speeds initially based on posted speeds. In some cases the addition of a volume-delay-function (vdf) may be needed to account for delay accrued on uncontrolled facilities.
  - Lanes – number of lanes based on field conditions. This input affects the number of fully developed approach lanes at intersections and is utilized for intersection geometry and delay.

- Node (Intersection) Detail
  - Control – type is specified based on field inventory and is used to calculate the turn-based travel delay using HCM methodology for the given control type. Calibration may require modifying the control (i.e. yield to stop) to better match field operations.
  - Lane Configuration – (turn lanes) based on field inventory to determine the intersection turn delay

- Zone Detail
  - Centroid connectors represent the non-modeled minor streets and accesses within a zone to load trips from a TAZ centroid onto the network. Extra connectors should be added, as needed to represent a particular network scenario, to distribute trips from the TAZ to match the loading of the trips onto the network such as from new roads, minor streets and off-street parking.

6.11.4 Trip Table Estimation

Trip table estimation is a component that appears generally similar, yet is fundamentally different between the zonal cumulative analysis and EZCA. One notable deviation from the zonal cumulative analysis is including all trips in the forecast rather than just the growth component. This develops volumes for the base year that can be used to calibrate the analysis tool, as well as providing more reasonable trip distributions. The approach of distributing only new growth does not allow for the redistribution of existing trips. For this reason, all trips, including those that are currently part of the roadway system, are estimated in the trip table as E-E, E-I, I,E, or I-I trips (see Section 6.8 for additional information about trip types and distribution).

Trip Generation

External Trip Ends

- There are three steps to prepare for the distribution of external trips. First, the number of external trip ends is estimated based on design hour volumes at external nodes. Second, these external trip ends are separated into external-external (E-E), external-internal (E-I), and internal-external (I-E) trips. Third, projected future growth rates are applied (to determine future trips levels). The base year external trip ends are based on 30th HV design volumes at key gateway locations (Design Hour Volumes at External Nodes).
- Traffic counts should be collected at major external gateways
- The impact of low volume external gateways (typically minor rural roads serving less than 50 vehicles during a peak hour[19]) that do not serve as major regional connections may be important to the overall estimation of the trip table, but it may not appropriate to consume data resources collecting detailed traffic data at each location. The total number of external gateways needs to be coordinated and agreed upon with TPAU. For example, many communities have rural roads that extend outside the UGB that connect to outlying homes but do not provide regional connections to other communities. The traffic volumes at these gateways may be initially estimated based on agreement and coordination with TPAU and a combination of the following resources, as available:
    - An inventory of the land uses (typically number of homes) that are likely to be served.
    - Adjacent traffic counts with an assumption made about the difference in demand that would result. While traffic counts may not be collected at these specific gateways, there should be other internal network counts that are collected at key junctions that can be used to estimate if the inventory is reasonable. Counts that are too far away with many intersecting roads may result in overestimation at the gateway and a tube count should be obtained at these locations.
- Future external trip ends are estimated based on forecasted growth at each of the external gateways. The FVT growth projections are utilized to estimate the growth rate at the external gateways.

[19] This general threshold may vary based on the context of the area and system connectivity.

Internal Trip Ends

- The number of internal trip ends is determined using land use trip generation methodology by applying ITE trip rates to the land uses described in Section 6.9.2. In some cases, combinations or "blended" rates that represent multiple ITE uses and trip rates may be used depending on the grouping of land use categories. For instance, if a single category is used for households and both single family and multifamily homes are present, a blended rate that combines both the single family rate and multifamily rate may be used. For these cases, combinations of trip rates should be used that are representative of the land uses occurring in the community and reflected in each general land use category.
- National average ITE trip rate data may not reflect the unique characteristics of the study area. When sufficient data is available, trip rates may need to be adjusted during the calibration process. Any adjustments to the ITE trip rates need to be documented and reviewed by TPAU. (See calibration section for additional detail). Exhibit 6-11 shows a summary of land use and trips (inbound) for each zone.

Exhibit 6-11 Sample Internal Trip Generation (Trips Inbound) by Zone and Land Use

	Land Use (HH, EMP)						Trips (Inbound)					
TAZ	**HH_BASE**	**RETL_BASE**	**SERV_BASE**	**EDUC_BASE**	**OTHR_BASE**		**HH_BASE trips**	**RETL_BASE trips**	**SERV_BASE trips**	**EDUC_BASE trips**	**OTHR_BASE trips**	**Total Trips**
101	26	0	0	0	0		12	0	0	0	0	**12**
102	9	8	0	0	0		4	15	0	0	0	**19**
103	295	0	0	0	0		139	0	0	0	0	**139**
104	68	0	0	0	40		32	0	0	0	2	**34**
105	0	0	0	0	25		0	0	0	0	1	**1**
106	149	0	0	0	0		70	0	0	0	0	**70**
107	175	0	0	0	0		83	0	0	0	0	**83**
108	162	0	0	0	0		77	0	0	0	0	**77**
109	163	0	0	0	0		77	0	0	0	0	**77**
110	131	0	0	0	0		62	0	0	0	0	**62**
111	70	0	0	0	0		33	0	0	0	0	**33**
112	109	0	0	0	0		52	0	0	0	0	**52**
113	66	0	0	0	0		31	0	0	0	0	**31**
114	164	0	0	0	0		77	0	0	0	0	**77**
115	140	0	0	0	0		66	0	0	0	0	**66**
116	85	0	0	0	0		40	0	0	0	0	**40**
117	63	0	0	0	0		30	0	0	0	0	**30**
118	124	0	0	0	0		59	0	0	0	0	**59**
119	121	0	0	0	0		57	0	0	0	0	**57**
120	105	0	0	0	0		50	0	0	0	0	**50**
121	45	0	12	0	29		21	0	11	0	1	**35**
122	214	0	1	0	62		101	0	1	0	3	**105**
123	0	0	0	0	0		0	0	0	0	0	**0**
124	134	0	0	0	0		63	0	0	0	0	**63**
125	1	0	25	0	300		0	0	24	0	14	**38**
126	133	0	0	0	0		63	0	0	0	0	**63**
127	213	0	0	74.9	0		101	0	0	59	0	**160**
128	193	0	0	0	0		91	0	0	0	0	**91**
129	111	0	0	0	0		52	0	0	0	0	**52**
130	75	30	105	0	13		35	58	102	0	1	**196**

Trip Distribution

Trip distribution estimates the percentage of trips from any one zone to another. In this analysis, trip distribution and generation are used to define the vehicle trip tables that are incorporated into the existing and future tools.

Distribution is based on the trip ends generated as either productions or attractions for each zone. The productions and attractions are used to determine an attraction probability and production probability for each zone relative to other zones in the network.

Trips are distributed between TAZs using two trip tables:

1. Production Trip Table – Each zone's productions are multiplied by the other zone's attraction probabilities resulting in a set of trips from one TAZ to every other TAZ.
2. Attraction Trip Table – Each zone's attractions are multiplied by the other zone's production probabilities resulting in a different set of trips from each TAZ to every other TAZ.

The distribution procedure includes the following steps:

1. Distribute E-E trips based on data collected from origin-destination study (such as Bluetooth data collection)
2. Allocate remaining external trips to E-I and I-E, based on directionality, as applied to zonal cumulative analysis.
3. Allocate remaining internal trips to I-I based on the attraction and production probabilities as done in the zonal cumulative analysis, resulting in a productions trip table and an attractions trip table. These steps need to be performed for trips generated by household land uses and then for trips generated by employment land uses. Household-based trips should use only employment land uses to calculate attraction and production probabilities.
4. Unlike a zonal cumulative analysis, this method requires the creation of a single I-I trip distribution table. To balance the trip productions and attractions and avoid double counting (since the trip generation process identifies trip ends, and every trip has two trip ends), the production and attraction trip tables must be averaged to result in a final I-I trip table.
5. The I-I trip table is combined with the I-E and E-I trip tables to address all identified internal growth. The E-E trips are then added to complete the trip table for all growth. The resulting trip table will be used as the input into the trip assignment tool. This procedure was followed for both the base and future years.

6.11.5 Trip Assignment

The use of Visum (or other assignment software) facilitates this trip assignment process by incorporating intersection delay which allows for the higher level of detail for approach delay. Route selection is set by the shortest path based on travel times between locations. The Visum travel times include both link (street) and node (intersection) components. The intersection delay in Visum is based on Highway Capacity Manual (HCM) methods. Including the concept of intersection turn delay allows for a greater level of detail than zonal cumulative analysis, and allows for comparing future network alternatives. Because this process has more HCM intersection level-detail, less calibration of and post-processing adjustments of turn movements are needed. In some cases link delay (in addition to free flow travel time) may also be considered using a volume delay function (vdf) to account for delay on uncontrolled facilities.

Other link-based tools like EMME can be used in place of a turn-based delay component, but requires more detail in the vdfs than is typically included. The route selection is also set by the shortest path based on travel times between locations. Because this is link-based delay, this method will take more calibration to match field conditions. Traffic assignment is applied in an iterative process until equilibrium is reached, similar to a travel demand model.

6.11.6 Calibration

The calibration process requires an iterative approach that assesses how well the EZCA tool is performing relative to real-world data (such as traffic counts). The integrated enhancement components allow for feedback in the form of "model error" if the tool is not performing well. Such error could be a result of many individual or combined factors, so it is important to have a systematic approach for calibrating and validating the tool prior to project application.

The calibration process includes three tiers, which should be approached *in the following order*:

1. Error Checking – Check for indication that an entry error has been made. Potential errors may include an allowable turn being closed in the travel network, incorrect stop sign orientation, or missing zone connectors, etc.
2. System Issues – Check for issues related to overall system assumptions. These issues may include system-wide trip generation rate used for all households in the system.
3. Spot Location Issues – Issues that are localized and do not have a greater system effect (such as local circulation patterns in the assignment that that do not match turn movement data and local circulation patterns).

Calibration Measures

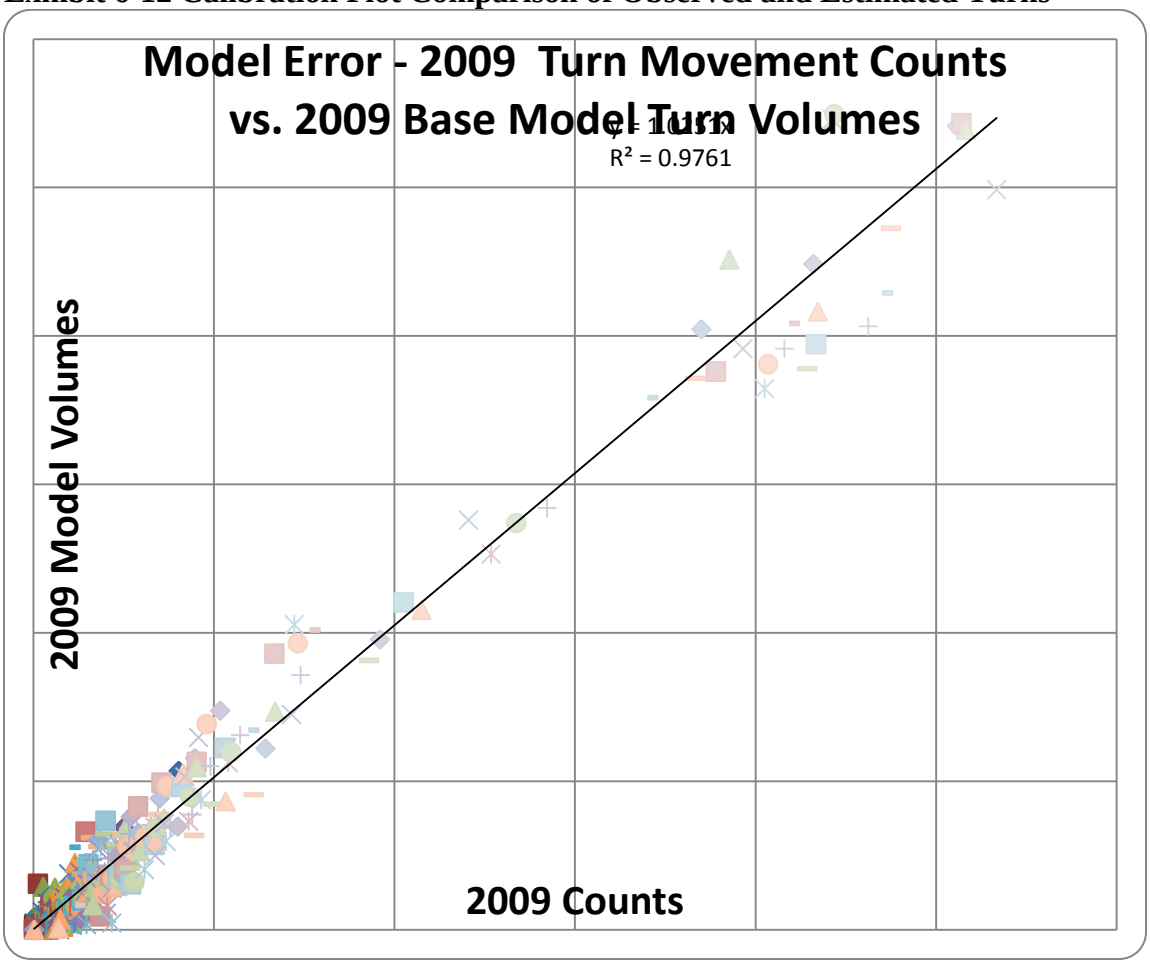
Qualitative calibration checks outlined in Chapter 8 (Mesoscopic Analysis) should be used depending on the scale of the traffic assignment network. Typically, a windowed subarea-model will provide a similar approach. However, since the EZCA is not based on a travel demand model, there are additional checks and considerations.

The following series of checks should be used through the calibration process.

- Do assigned traffic patterns match general routes that are observed?
- Do traffic counts match data for roadway segments and the specified intersection turn movements? Calibration compares assigned volumes to the base year 30th Highest Hourly Volumes (30th HV) on links and nodes. Typically the volumes should be within 10% of each other. Major outliers should be investigated and remedied, as feasible.
- Do systematic comparisons of model error indicate that the tool is generally reflecting count data? A plot comparing the existing traffic counts and the base year tool volumes for all study intersection turn movements should be analyzed to evaluate the accuracy of the tool. In addition to a visual verification of the goodness of fit, the following quantitative measures should also be considered:
    - The slope of the fitted curve should be close to 1.0. This value is generally indicative of how the overall magnitude of traffic estimated by trip generation compares to the traffic counts. A value of 1.2 would indicate that the estimated volumes are generally skewed 20 percent higher than the existing counts.
    - The R^2 value should also be close to 1.0. This value generally indicates how well the estimated volumes fit the observed, target volumes.

Exhibit 6-12 demonstrates a plot of the estimated turn movement volumes with the observed (counted) volumes. The slope of the fitted curve is 1.025, indicating that the model volumes are generally only two percent higher than the existing counts and that the trip generation is appropriate and does not require further refinement. Furthermore, the R^2 value of 0.976 indicates that the model volumes are consistent with the target volumes.

Exhibit 6-12 Calibration Plot Comparison of Observed and Estimated Turns



Both system metrics are equally important and should be considered. An R2 value of 1.0 with a slope of 1.5 does not indicate a calibrated tool (since volumes are consistently being overestimated by 50%).

Calibration processes may include the adjustments to account for the following items. The resulting impacts of adjustments to these parameters can easily be measures using the calibration measures to determine if the adjustment is beneficial to the overall calibration of the tool. Model calibrations are performed in an iterative process to determine the relative effect of each calibration measure.

- Pedestrian Conflicts - The pedestrians crossing a roadway influences the capacity and travel time of the corridor. The additional delay attributed to vehicles stopping for pedestrians can be emulated using "dummy traffic signals" at midblock locations.
- Street Speeds – Speeds on some links may need to be adjusted to account for driver behavior, such as increasing the speed on a downtown link to have it remain as a primary attractive route. Conversely, lowering the speed on a link will make it less attractive, so trips use other routes.
- Centroid Connectors – These connections may be needed to added, deleted or

changed to match the field operations within the study area. It may be determined that an initial approximation for centroid loading did not provide adequate detail and additional refinements (such as additional spreading of demand within the zone) may be needed.

- Trip Generation Rates – It may be that an individual land uses (such as residential or industrial uses) are isolated in the network with limited access, in a way that allows for determining how many actual trips (from count data) are being generated by the use. If the land use is sufficiently intense, it may provide adequate data to determine that a modification or reconsideration of the trip generation rates are needed. Any modifications of rates or uses need to be reviewed by TPAU. The following adjustments may need to be explored, in the following order:
    - Consideration for a "special trip generator" in unique cases that a location exists that isn't reflected in the overall land use and trip generation estimates. These uses could include major landmarks, recreational areas, or tourist destinations that have more traffic than would be otherwise estimated using typical land use categories and rates. An example could be a waterfront area or park that is regionally popular. Sufficient traffic count data should be available to estimate the trips generated by such uses. The application of such uses and rates would generally be limited to a single zone or small set of zones, relative to the overall number of zones in the network.
    - For more comprehensive or system-wide trip rate adjustments, the assumptions about representative ITE uses and rates (Section 6.9.4) may need to be reexamined. Such assumptions could include both the selected types of representative land uses as well as the overall share or weight within the category.
    - Finally, it may be determined that a local trip generation rate is a better fit than the national average rate[20]. Adjustments to account for local trip rates that differ from the ITE national average should be taken with care and only performed in cases where there is sufficient traffic data to support the adjustment. Such traffic data would typically include a combination of a network-wide calibration measure (slope) that indicates an overall trend of traffic estimation being too high/low and specific traffic count locations that serve to somewhat isolate a homogenous set of land use (for example a gated community or other large development, residential or commercial, with limited, consolidated access points). Adjusted rates should typically stay within 25% above/below the average ITE rate and include data that was used for the basis of the adjustment.
- Zone Trips (Land Use or Trip Rates) – Origin-Demand Matrix Estimation (ODME) can be used as a general tool to indicate zones or O-D pairs that are skewing the calibration of the model. While the raw results of the ODME should not be applied directly to the model, running ODME can be used to discover

[20] Adjustments made to trip rates should be made on the basis of traffic count data and taken with care. Areas that are forecasted to have larger amounts of land use growth have a higher sensitivity to adjustments that are made to trip generation rates.

zones that may require additional investigation into assumed land uses and/or trip rates for those land uses.

Because the EZCA process uses travel demand assignment software, the resulting volumes must be appropriately post-processed like other travel demand model outputs for formal traffic alternatives analysis[21]. However, depending on the amount of data and calibration success, turn-based post-processing may be feasible. See Section 6.12.1 for additional detail on post-processing traffic volumes.

6.12 Urban Travel Demand Models

6.12.1 Post Processing Methods

Growth Method

The Growth Method uses growth equations to calculate future design hour volumes. Caution should be used with the method as it may severely overestimate growth on links that have little volume in the base year and significant volume in the future year. The basic form of the growth method (per NCHRP Report 765, the replacement for the old Report 255) is:

Future model year / Base model year = Future DHV / Base 30 HV

Example 6-17 Post-Processing – Growth Method, No Build

- Example: 2035 DHV = (2035 Model / 2014 Model)* 2014 30 HV
- If the 2035 Model had 800 vph, the 2014 Model had 50 vph and the 2014 30 HV had 550 vph, the growth method using a simple linear method would be:

2035 DHV = (800/50)* 550 = 8,800 vph

Note that the future model year link volume is 16 times that of the base model year. Large differences like this will result in a volume overestimation and indicate that another method should be used.

Difference (Incremental) Method

The Difference (Incremental) Method should be used in areas where large differences in base and future model link volumes exist. This method is preferred in NCHRP Report 765. The basic form of the difference method is:

Future DHV = Base 30 HV + (Future model year – Base model year)

[21] Some preliminary alternative testing may be conducted within the forecast tool to inform a set of alternatives for further evaluation.

Example 6-18 Post-Processing – Difference Method, No Build

2035 DHV = 2014 30 HV + (2035 Model -2014 model)

Using the same numbers from the growth method above, using the difference method would be: 2035 DHV = 550 + (800 – 50) = 1,300 vph.

Comparing the results between this and the above example show that this example represents the more appropriate, truer value to use.

Selection of Method to Use

Both methods should be compared in a spreadsheet on a directional link basis using percent and absolute difference. Areas with large percent and absolute differences (greater than 10-15%) should use the difference method. Areas that compare favorably can use one or the other or an average of the two (a.k.a. Average or Combined Method). The analyst will need to analyze the data to find the natural breakpoints of when and where to use each method.

The two previous examples show the large difference between the growth and difference methods where the growth method overestimates the future 2035 volume because the base year model volume is much smaller than the future model year volume. In this case the difference method would be used.

If the 2014 Model had 600 instead of 50, the growth method would result in 733 vph and the difference method would result in 750 vph. When the base and future models are closer, the results from the two methods are much closer. In this case, the growth method or an average of the growth and difference method would be used.

Adjacent link growth rates can be averaged together to reduce the number of calculations/adjustments necessary if they are close together (less than 10%).

Spreadsheet Application

A spreadsheet is necessary to track the post-processing calculations, especially on larger networks. A sample spreadsheet area is shown in Exhibit 6-13. Directional links are represented as rows. Columns represent the post-processing calculations through Step 4. In this case, since the model base and future years do not match the project existing and future years, they are adjusted according to the following formula:

Existing Year Model Volume = Base Year Model Volume x (1+ Annual Growth Rate x (Project Existing Year - Model Base Year))

The growth and difference methods are then applied. In the spreadsheet, conditional formatting was used to help identify links where the difference in future year volumes

between the difference and growth methods exceeded 10 percent, in which case the difference method was selected, or where it is less than or equal to 10 percent, in which case the average of the two methods was used.

Exhibit 6-13 Post-processing Spreadsheet, No Build

Post-Processing - No Build Directional Link Volumes

Existing Year	2008
Project Design Year	2034
Model Base Year	2009
Model Future Year	2034

Link Identification				Existing 30HV	Model Volumes					Post Processed Volumes Future No Build Project Year			
					Model Assignment		Adjustment to Project Years						
Route	Direction	From	To		Raw Model Base	Raw Model Future	Annual Growth Rate	Base Adj. to Existing Year	Future Adj. to Project Year	Difference Method	Growth Method	Percent Difference[1]	Selected Method
Blackwell Rd	SB	Tolo Rd	Kirtland Rd	255	110	154	0.02	108	154	301	364	17%	301
Blackwell Rd	NB	Kirtland Rd	Tolo Rd.	400	228	291	0.01	226	291	465	515	10%	490
Blackwell Rd	SB	Kirtland Rd	I-5 NB Ramps	360	295	466	0.02	289	466	537	580	7%	559
Blackwell Rd	NB	I-5 NB Ramps	Kirtland Rd	465	303	402	0.01	300	402	567	623	9%	595
OR 99	SB	I-5 NB Ramps	I-5 SB Ramps	310	157	194	0.01	155	194	349	388	10%	369
OR 99	NB	I-5 SB Ramps	I-5 NB Ramps	575	435	665	0.02	426	665	814	898	9%	856
OR 99	SB	I-5 SB Ramps	Eric Ave	400	218	354	0.02	214	354	540	662	18%	540
OR 99	NB	Eric Ave	I-5 SB Ramps	495	380	562	0.02	372	562	685	748	8%	717
OR 99	SB	Eric Ave	Seven Oaks Rd	395	218	383	0.03	211	383	567	717	21%	567
OR 99	NB	Seven Oaks Rd	Eric Ave	485	380	574	0.02	372	574	687	748	8%	718
OR 99	SB	Seven Oaks Rd	Jaybee Ln	385	218	383	0.03	211	383	557	699	20%	557
OR 99	NB	Jaybee Ln	Seven Oaks Rd	480	380	574	0.02	372	574	682	741	8%	712
Kirtland Rd	WB	High Banks	Blackwell Rd	395	216	362	0.03	210	362	547	681	20%	547
Kirtland Rd	EB	Blackwell Rd	High Banks Rd	340	133	202	0.02	130	202	412	528	22%	412
I-5 WB	WB	I-5 OFF RAMP	Blackwell Rd	180	201	235	0.01	199	235	216	213	1%	215
I-5 WB	WB	Blackwell Rd	I-5 NB ON Ramp	395	443	737	0.03	430	737	702	677	4%	690
Willow Springs	EB	RR	OR-99	145	99	95	0.00	99	95	141	139	1%	140
Willow Springs	WB	OR-99	RR	115	82	78	0.00	82	78	111	109	2%	110
Willow Springs	EB	OR-99	I-5 SB Ramps	125	137	162	0.01	136	162	151	149	1%	150
Willow Springs	WB	I-5 SB Ramps	OR-99	280	236	424	0.03	229	424	475	518	8%	497

[1] Shaded cells indicate use of the Difference method. Non-shaded cells indicate use of the Growth method.

Basic Steps - Build Alternatives

The basic steps to developing future Build link volumes links are outlined below.

1. Start with Future No-Build DHV directional link volume set.
2. Review the Build Alternative assignment plots to see whether any manual reassignments are needed.
3. Compare the model future No-Build and Build scenarios. *Note that No-Build as used here may not be the exact same scenario as the typical Model No-Build that does not have any projects included. The requested output needs to have the appropriate projects identified and included in the scenario run.* To facilitate comparisons, difference plots (between Build and No-Build scenarios) may be obtained. If differences are within 10-20 percent, no further adjustments are needed and No-Build DHVs may be used for Build DHVs. Otherwise proceed to next step.
4. Adjust model year volumes to match project future year. The model future year must be adjusted up or down to match the project future year.
5. Apply growth and difference equations between No Build and Build scenarios (see examples below). For each directional link, select growth, difference or averaged methods following the guidance provided previously. This will result in preliminary directional link volumes.
6. Use screenlines to determine volumes on any links that are not in both No-build and Build model scenarios
7. Calculate the inflows and outflows at each intersection based on link volumes. Determine the difference between the flows. The inflows and outflows must be equal for each intersection. Split the difference (typically 50-50) to each of the flows by increasing or decreasing link volumes in proportion to the total flow volume.
8. Determine intersection turn movements using a tool such as TurnsW32.
9. Re-balance network and round volumes to obtain Future Build DHVs.

Determining the Latent Demand Effect

Future Build link volumes are developed by comparing model assignments between the future Build alternative and the future No-Build. It is important to check for any latent demand effects where the Future Build volume is significantly greater than the Future No-Build volume, for the same year. Latent demand can occur where the Future No-Build demand has exceeded capacity, and a portion has shifted to other routes, destinations, modes, or time periods to avoid congestion. Once the facility is at capacity, peak hour volumes no longer increase over time, while latent demand may continue to grow. When a Build alternative alleviates the congestion, a portion of the shifted demand may return, which is reflected by an increase in the Future Build volumes.

Determining latent demand may be facilitated by requesting a model plot that compares the two model scenarios, such as plotting the difference or ratio between the Build and No-Build scenarios for each directional link. If the volume difference on each link is not

significant, i.e., less than 10-20 percent, then the future No-Build DHVs may be assumed to be the future Build DHVs. If the difference is significant (meaning that there is a latent demand effect), the appropriate growth or difference method should be determined and applied to the Future No-Build DHVs as shown in either of the two processes shown.

Growth Method:

1. Divide the Future Year Build model scenario volume by the Future Year No-Build model scenario volumes to derive the factor.
2. This factor is then multiplied by the Future Year No-Build Design Hour Volume to arrive at the Future Year Build Design Hour Volume (DHV).

Example 6-19 Post-Processing – Growth Method, Build

- Example: 2025 Build DHV = (2025 Model Build/ 2025 Model No-Build)* 2025 No-Build DHV
- If the 2025 Model No-Build had 800 vph, the 2025 Model Build had 1,000 vph and the 2025 No-Build DHV had 1600 vph, the growth method using a simple linear method would be:

2025 Build DHV = (1000/800)* 1600 = 2,000 vph

Difference Method:

1. Subtract the Future Year No-Build model scenario volume from the Future Year Build model scenarios volumes *(Note: this change in volume can be either positive or negative).*
2. Add the difference to the Future Year No-Build Design Hour Volumes (DHV).

Example 6-20 Post-Processing – Difference Method, Build

2025 Build DHV = 2025 No-Build DHV + (2025 Model Build - 2025 Model No-Build)

Using the same numbers from the growth method above, using the difference method would be: 2025 Build DHV = 1600 + (1000 – 800) = 1,800 vph.

6.12.2 Screenlines

Screenlines can be used for calculating overall growth rates or used for calculating volumes on new links (links that only exist in one of the scenarios that you are comparing).

Screenlines are useful where there are significant differences in growth within the study area. Screenlines should be strategically placed to cross the major links of the different growth areas. Screenlines are drawn the same in both the base model year and the future

model year on the model volume plots. The link volumes crossing each screenline are summed. The summation of each future screenline is divided by the corresponding base screenline summation. This provides the growth rate for the different areas cut by the screenlines.

New Links

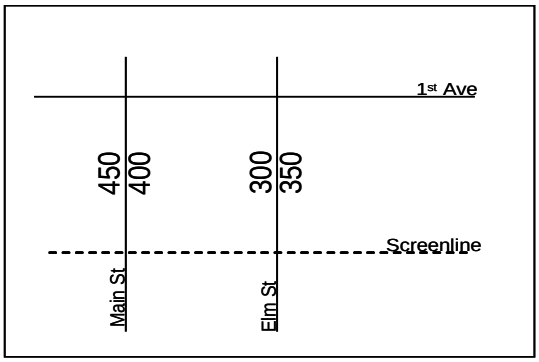
The main use of screenlines is to determine the future design hour volume of links that exist only in one scenario. This comes up when a new route is added to a scenario. This can occur with both future no-build and build alternative scenarios.

Example 6-21 Post-Processing – Use of Screenlines

For example, assume a roadway network in the future no-build year had two north-south links at Main Street and Elm Street, but a build alternative added a new north-south link at Oak Street for a total of three north-south links. The analyst has the model outputs for the scenarios with and without the new connection and the future no-build DHV diagram (without the connection).

1. Draw a screenline across Main and Elm Streets in the future no-build model scenario, and sum up the future no-build model volumes for each street as well as the total north-south future model volume.

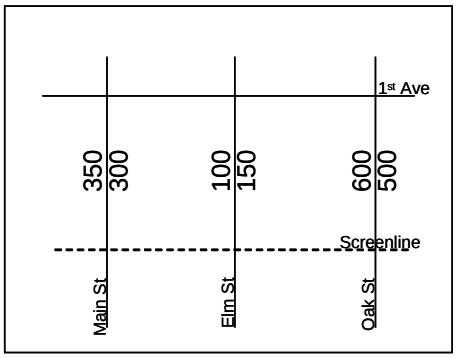
Future No-Build Model Scenario



Main Street Total = 450 + 400 = 850 vph
Elm Street Total = 300 + 350 = 650 vph
Total North-South Volume = 850 + 650 = 1500 vph

2. Draw a screenline across Main, Elm and (new) Oak Streets in the build alternative scenario and sum up the build alternative model volumes for each street as well as the total north-south build alternative model volume. Calculate the street (link) splits and directional (northbound and southbound) splits for all three streets.

Build Alternative Model Scenario



Main Street Total = 350 + 300 = 650 vph
Elm Street Total = 100 + 150 = 250 vph
Oak Street Total = 600 + 500 = 1100 vph
Total North-South Volume = 650 + 250 = 2000 vph

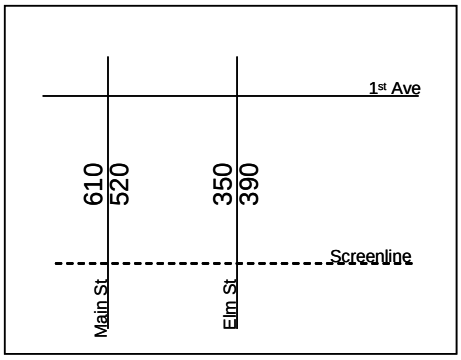
Note: in this example, the build alternative scenario pulls in 33% more traffic (2000 vph vs. 1500 vph) than the future no-build model scenario. This is a result of previously diverting traffic returning to the route that it wants to use. In this case the analyst must use the build alternative model scenario to create the future design hour volumes. If the difference was less than 10%, then the analyst could use the future no-build volume distributed on the build network.

Link Split Calculation:
Main Street split = 650/2000 = 0.325 (32.5%)
Elm Street split = 250/2000 = 0.125 (12.5%)
Oak Street split = 1100/2000 = 0.55 (55%)

Directional Splits Calculation:
Northbound Main Street = 300/650 = 0.46
Southbound Main Street = 1 – 0.46 = 0.54
Northbound Elm Street = 150/250 = 0.60
Southbound Elm Street = 1 – 0.60 = 0.40
Northbound Oak Street = 500/1100 = 0.45
Southbound Oak Street = 1 – 0.45 = 0.55

3. Draw a screenline across Main and Elm Streets in the future DHV diagram, and sum up the total future DHV volumes for each street as well as the total future north-south DHV volume.

Future No-Build DHV



Main Street Total = 610 + 520 = 1130 vph
Elm Street Total = 350 + 390 = 740 vph
Total North-South Volume = 1870 vph

4. Calculate the total north-south build alternative DHV by creating a ratio by dividing the build alternative screenline grand total (Main/Elm/Oak Streets) by the future screenline grand total (Main/Elm Streets) and then multiplying this ratio with the future DHV screenline total (Main/Elm Streets).

   General equation form:

$$\frac{Build\ \ Alternative\ Model}{Future\ No-Build\ Model} = \frac{Build\ \ Alternative\ DHV}{Future\ No-Build\ DHV}$$

   Modified equation to solve for the total Build Alternative DHV:

$$Build\ \ Alternative\ DHV = \frac{Build\ \ Alternative\ Model}{Future\ No-Build\ Model} \times Future\ No-Build\ DHV$$

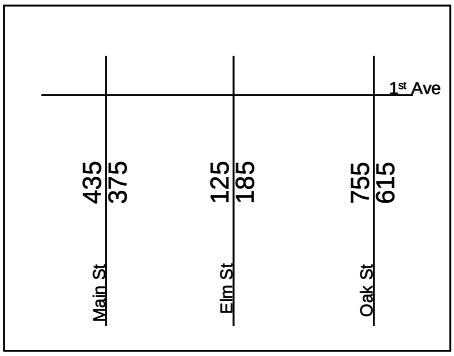
   Build Alternative DHV = (2000/1500) x 1870 = 2493 vph

5. Using the Build Alternative DHV (from Step 4) and the link splits (from Step 2), determine the volumes for each of the streets. Oak Street would be calculated by:
   Build Alternative DHV (Oak) = Oak Street split (from Step 2) x Build Alternative DHV total (from Step 4)

   Build Alternative DHV (Oak) = 0.55 x 2493 = 1371 vph
   Build Alternative DHV (Main) = 0.325 x 2493 = 810 vph
   Build Alternative DHV (Elm) = 0.125 x 2493 = 312 vph

6. Compute the directional DHV for each street by applying the directional splits from Step 2 to the DHV totals for each street calculated in Step 5.

Future Build DHV



Main Street DHV (NB) = 0.46 x 810 = 373 vph (rounded to 375)
Main Street DHV (SB) = 0.54 x 810 = 437 vph (rounded to 435)

Elm Street DHV (NB) = 0.60 x 312 = 187 vph (rounded to 185)
Elm Street DHV (SB = 0.40 x 312 = 125 vph

Oak Street DHV (NB) = 0.45 x 1371 = 617 vph (rounded to 615)
Oak Street DHV (SB) = 0.55 x 1371 = 754 vph (rounded to 755)

6.12.3 Turn Movements

Once all the link volumes have been determined from the standard or screenline post-processing methods, turn movements need to be calculated for each intersection.

Intersection volumes are represented at the turning movement level. It is important to note that the model is built and calibrated at the link level, not the turn level. Turn movement outputs from the model shall not be used directly in software for analysis. TPAU will not provide turning movement volumes for model requests; as they are typically misused to directly post-process turn movement volumes instead of following the link based post-processing procedure. Turn volumes should be developed from post-processed link volumes according to the procedures below.

Base Year turn movements should follow ground count patterns unless projects or other network differences are present in which case turn percentages are obtained from select-link runs. Future Year Turn movement percentages can be determined from select-link runs.

Future No-Build Turn Volumes

The volume of traffic entering each intersection must balance with the traffic leaving the intersection. If an imbalance exists, then inflow/outflow volumes will need to be balanced proportionally.

Typically the future no-build turning movement volumes are the same as the existing (base) year movements with a growth factor applied. Impacts from other projects should show up in the future no-build model run, and would impact the growth rate or methodology used to calculate the future no-build design volumes.

There are times when another project is expected to impact the travel patterns in the study area, and the turning movements would have to be manually adjusted to reflect this. The turning movement percentages provided by the Future Year No-Build model select link runs can help point out some of these impacts. *(Note: A capacity constrained demand model should indicate the shift in travel patterns and the directional link volumes from the model should be used as a starting point to arrive at a future DHV. Arriving at a post-processed set of volumes requires a method such as described above or in NCHRP 765).* The origin and destination matrix can also be a helpful tool to obtain the distribution of trips between zones. Model runs with and without committed/STIP projects can be run to determine the impacts, if any, from nearby financially constrained future projects. After turn movements have been developed, the network needs to be re-balanced and volumes rounded to obtain Future No Build DHVs.

Future Build Turn Volumes

At this point the directional design hour volumes have been calculated for each link so the intersection approach volumes are known. The volume of traffic entering each intersection should balance with the traffic leaving the intersection. If an imbalance exists, then inflow/outflow volumes will need to be balanced proportionally.

Build turning movements are a combination of the known travel pattern changes and the existing turning movements. Model select-link assignments can be used as a starting place. Select-link plots will need to be requested to verify or modify the turning percentages. Developing the build turning movements in some cases is not a straightforward process. It may involve looking at all the possible movements and using the best judgment and knowledge of the area. Changes to turn volumes are also made as the intersection is balanced to hold the link volumes. The link volumes need to be held as much as possible to preserve the future growth ratios and/or differences. After turn movements have been developed, the network needs to be re-balanced and volumes rounded to obtain future Build DHVs.

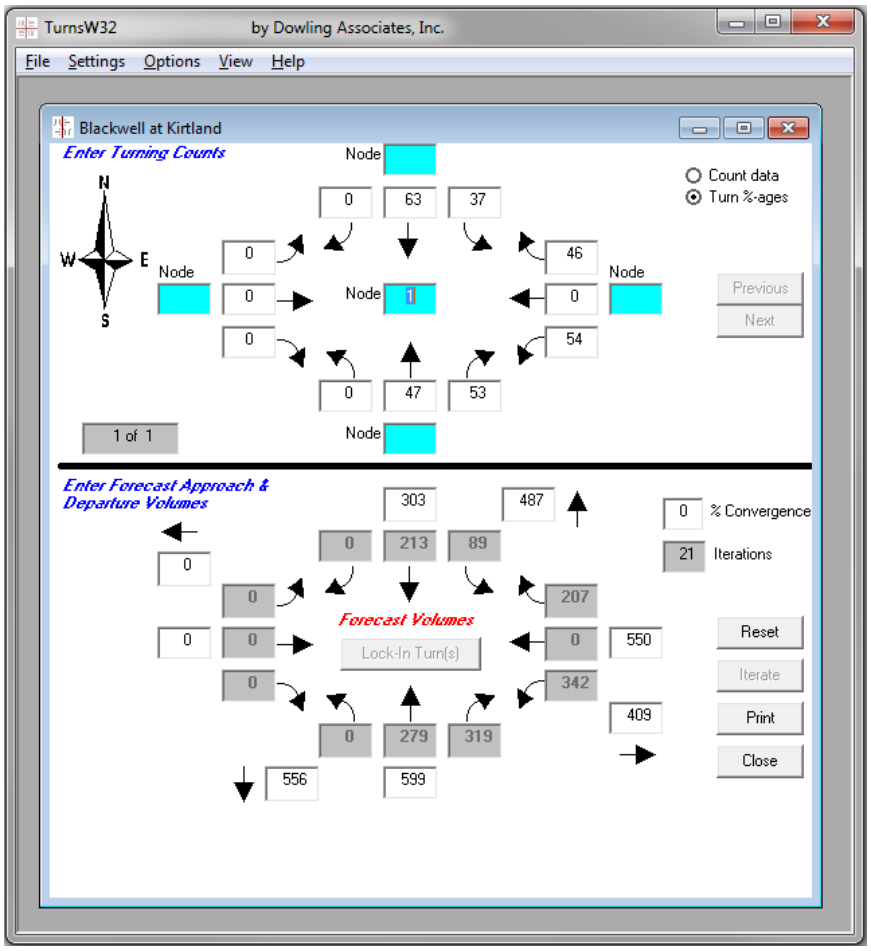
There are matrix-based programs such as Turns W32 that assign turning volumes based on the link volume. These automate the NCHRP Report 765 Chapter 5 (Fratar volume balancing method) turning movement process, which can save considerable time over a hand calculation. The intersection approach link volumes and the exiting link volumes are entered. The programs typically assume that more traffic is attracted to the higher volume links and will weight the movements accordingly. The program goes through an iterative process to closely match the data that was entered. Most of these matrix-based programs require that inflows equal outflows for each intersection. If an imbalance exists, then inflow/outflow volumes will need to be balanced proportionally.

Turns W32

Turns W32 is a tool developed by Dowling Associates, Inc., which converts directional link volumes into turn movement volumes at intersections. Prior to use, flows in and out of the intersection must be balanced so that inflows equals outflows.

As shown in Exhibit 6-14, turn percentages are input into the upper part of the screen in Turns W32 rather than actual turn movement volumes. Preliminary future link volumes with balanced inflows and outflows are input on the lower part of the screen. The program will not process unbalanced inflows and outflows. The convergence value should be set to 0 percent. This value represents the tolerance between successive iterations. A solution is achieved when the results of iteration differs less from the results of the previous iteration by this value. After iterating, the lower screen displays the preliminary future year turn movements. These turn movements need to be adjusted in the final step, which is to re-balance the network while holding the model link growth values as much as feasible.

Exhibit 6-14 Turns W32 Screen



Example 6-22 Turns W32

This example is based on the previous post-processing spreadsheet application shown in Exhibit 6-13. It is desired to determine Future Year turn movement volumes at the intersection Blackwell Road at Kirtland Road. In this example, Kirtland at Blackwell Road is a tee-intersection. Future year directional link volumes at the intersection have been previously determined and are shown in the intersection diagram below.

Initial Future Year Directional Link Volumes

Initial Future Volumes
Unbalanced

	301	490	
0			547
0			412
	559	595	

The first step is to ensure that the directional link volumes produce equal intersection inflows and outflows at the intersection, and to adjust them if they do not. In this case, the inflows are greater than the outflows. As shown in the table below, the inflows total 1443 and the outflows total 1461. Typically, an average of the two values is used.

In this example, the average of the inflows and outflows is 1452. Individual directional link volumes are then adjusted as follows for the EB outflow.

Initial EB outflow = 412.
Proportion of total outflows = 412 / 1461 = 0.28
Reduction needed = 1461 – 1452 = 9 vph
Adjustment = 0.28 x 9 = 2.5 ~ 3 vph
Adjusted outflow = 412 – 3 = 409

The adjusted intersection inflows and outflows are shown in the table below.

Initial Future Volume			Adjusted	
	Inflow	**Outflow**	**Inflow**	**Outflow**
EB	0	412	0	409
WB	547	0	550	0
NB	595	490	599	487
SB	301	559	303	556
Total	1443	1461	1452	1452
Average	1452			
Difference	9	-9		

The next step is to determine the initial turn movement percentages. In this example, the Base Year 2008 turn movement percentages are used. These turn percentages are summarized in the table below.

Direction	Movement	2008 30 HV	Movement Percent of Approach Volume
EB	Left	0	NA
EB	Thru	0	NA
EB	Right	0	NA
WB	Left	215	54%
WB	Thru	0	0%
WB	Right	180	46%
NB	Left	0	0%
NB	Thru	220	47%
NB	Right	245	53%
SB	Left	95	37%
SB	Thru	160	63%
SB	Right	0	0%

The final step is to input the balanced directional link volumes and the turn percentages into Turns W32. As shown in Exhibit 6-14, the turn percentages are entered into the upper half of Turns W32, while the balanced directional link volumes are entered into the lower half. The percent Convergence is set to **0%**. Upon selecting Iterate, the program computes and displays updated turn movement volumes and directional link volumes. The analyst may need to make further adjustments to turn movements as part of re-balancing of the network.

6.12.4 Automated Post-Processing

Certain software tools perform post-processing internally. However, no tool can substitute for the need to manually check results for reasonableness. The analyst should have a good understanding of the internal methodology used in the software.

VISUM has an internal post-processing module. TPAU evaluated VISUM 10.0 by

comparing its outputs to the manual method. VISUM provides an acceptable level of post-processing to determine preliminary link volumes. These volumes are sufficient for sketch planning level analysis or as input to further manual post-processing of turn movements for facility level analysis. However, VISUM's internal turn movement post-processor was found to be inconsistent with the manual procedure since it does not balance intersection inflows and outflows prior to determining turn movements. For facility level analysis VISUM internally post-processed link volumes can be used if turn movements are post-processed manually.

There are other proprietary products from consultants (JRHMoves from JRH Engineering and Furness from CH2MHill) that have been evaluated and found to be consistent with NCHRP 765 for links and turn moves.

6.13 Forecasting Truck Volumes for Pavement Design

Because pavement design is based on the number of axle-loadings experienced on the roadway, heavy vehicle information needs to be furnished in a specific format. The pavement designer will contact the project traffic analyst for this truck information. The Pavement Services Unit (PSU) does all of the pavement designs for all ODOT projects, unless consulted out. Most of these projects are small operational improvements, pavement preservation or bridge replacement projects.

Pavement design volume requests either are at a scoping or project-specific level. All scoping-level requests are done internally by the PSU. A project-level request will need to be done by the project traffic analyst who could be a region project analyst, a consultant, or a TPAU analyst. These requests should be routed through the Transportation Systems Monitoring Unit (TSMU). TSMU will then forward the request to the appropriate project leader and then from there to the project analyst.

Requests of heavy vehicle volumes are e-mailed by PSU. These requests should include the project name, project limits, project type (scoping or project-level) highway name, and route number. They should also include any special needs such as breakouts on one-way facilities. In addition, the analyst should discuss factors that may influence the outputs and therefore the design with the pavement design staff involving the pavement designer. The discussions can help clarify the level and precision of the data required which may streamline the process.

Responses are typically transmitted via e-mails with a spreadsheet-formatted attachment showing: current and 20 year future ADT, a 20-year growth factor, and the current heavy vehicle volume by class (see Exhibit 6-16). If one-way ADT is requested, state direction and intersection leg, if applicable.

General information and special considerations

General truck growth rates are assumed to mirror the overall growth rate on a segment as calculated by methods described previously in this chapter. Vehicle classification specific growth rates are not available due to the lack of commodity and routing information. The

trucking industry introduces new products, with different axle configurations, which have insufficient highway count data.

Before reporting out any data, the analyst should verify that there are no special considerations that need to be accounted for such as having count information that may reflect an average and not a typical vehicle mix. Sometimes a specific generator may not be directly accounted for that might require splitting a segment. Other considerations might include:

- Variations in vehicle classifications that are not accounted for such as vehicles with drop-axles that change the vehicle classification or the different configuration for a logging truck – 5-axle loaded logging trucks versus a 3-axle when the empty trailer is piggy-backed.
- Having a count taken in the summer on a route that services a local school, so it is missing the school bus volumes.
- Heavy generators such as mills, industrial areas, distribution centers, truck stops, or intermodal transfer facilities
- Periodic users, such as material/construction sites, logging or agricultural

The Federal Vehicle Classifications are shown in Exhibit 6-15. All vehicles are classified into one of the 13 categories. For example, class 6 is described as 3-axle, single unit which can be reported out as shown in Exhibit 6-16 with the information including the number of axles and trailers of each class. The truck volumes are also shown.

Exhibit 6-15 Federal Vehicle Classifications

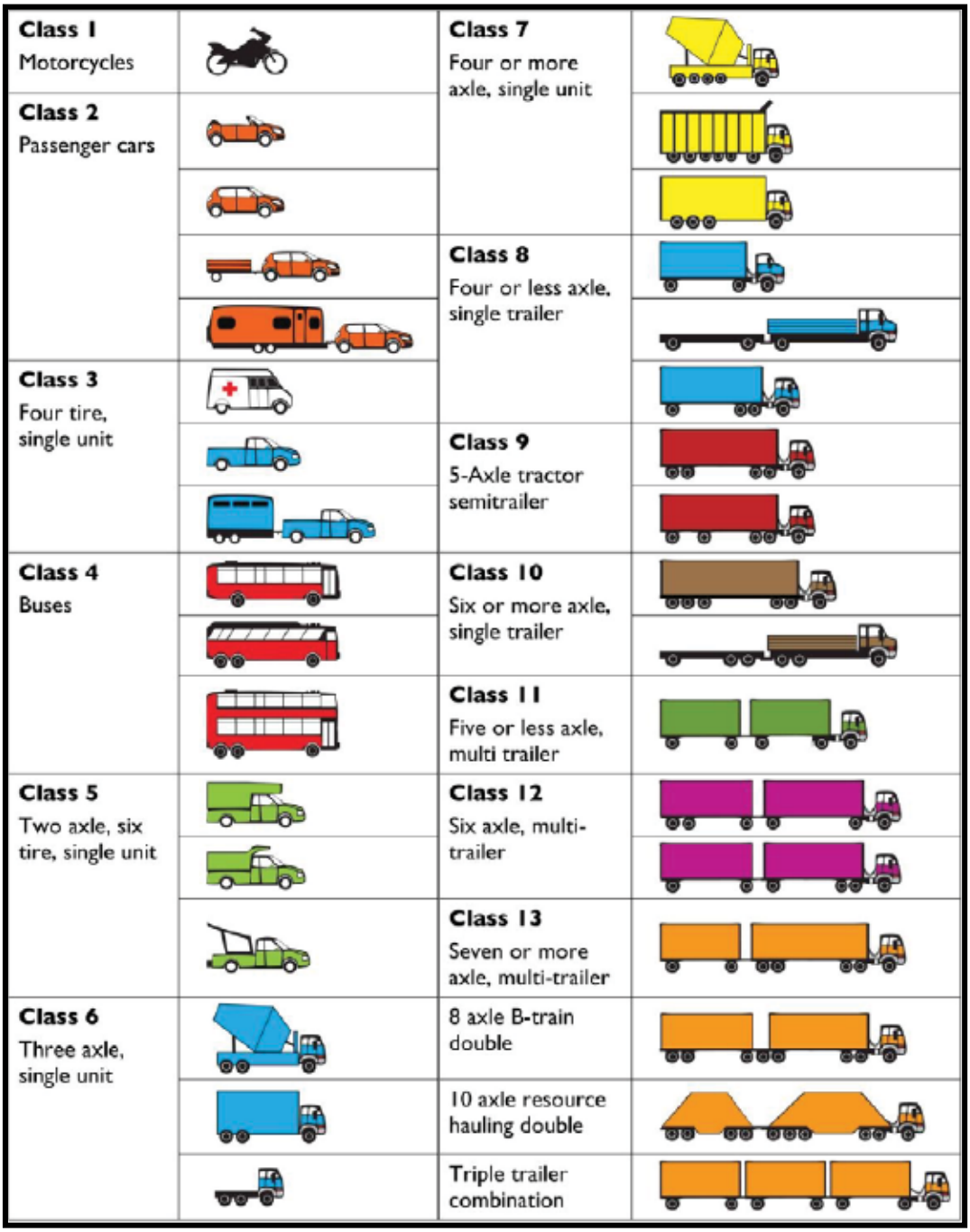


Exhibit 6-16 Example Response Spreadsheet Attachment

Project	Hwy 500 (OR 795) MP 77 - MP 83			
				Count
Class	Descript.	# Axles	# Trailers	2010 Vol
4	buses			18
5	2ax	2		40
6	3ax	3		25
7	4ax	4		2
8	4ax trl	4	1	0
9	5ax trl	5	1	12
10	6ax trl	6	1	4
11	5ax dbl trl	5	2	2
12	6ax dbl trl	6	2	0
13	7ax dbl trl	7	2	0
Total Trucks				103
Future Volume Tables 2010 AADT = 3000, 2030 AADT = 200				
% Trucks 3.43% 20-year growth factor = 1.4				

The percent truck calculation is the total number of trucks divided by the base year AADT. For this exhibit this would be 103 / 3000 = 3.43%. The 20 year growth factor is the future AADT divided by the base year AADT or 4200 / 3000 = 1.4.

Process

To prepare the data, knowledge of the highway characteristics in the area is helpful. While a field investigation is likely not practical, use of the ODOT video log, Transviewer GIS or other mapping aide should be used. There likely is more information readily available for use on state highway segments than on local jurisdiction roadways. The general state highway process takes advantage of currently available formatted outputs. The scoping-level process is used for scoping level requests or simpler projects. The project specific process is more detailed. These requests include intersection or straightaway classification counts and may involve local road segments or state highway segments that need special considerations are applied. A spreadsheet calculator, Heavy Vehicle Pavement Design Spreadsheet, has been developed to streamline the process for both scoping and project level request.

6.13.1 Scoping Level

Using the state highway number, milepoint and other locational data, refer to the Traffic Volumes and Vehicle Classification Report available at:

http://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm

This report provides overall and vehicle AADT volumes and vehicle classification by the

specified segment. The segments are determined by major intersections and other characteristics. Using this information, enter the following into the output spreadsheet (see Example 6-23) for each identified segment:

- Highway/road name
- Beginning mile point
- Effective date of data
- AADT
- AADT 20-YR
- Volumes for Class 4-13

Example 6-23 Scoping Level Project Forecast

As part of a pavement preservation scoping project process, the section of Highway #7 (US20) from M.P. 40 to M.P. 48, heavy vehicle counts were downloaded from http://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm. The AADT Volume, AADT 20-year Volume, Beginning M.P., and the volumes for Classes 4 through 13 were copied into the Heavy Vehicle Pavement Design Spreadsheet in the Scoping Level tab. The data is shown in the next table and the future forecasted results are shown in the following table.

Project	Hwy 7 (US20) M.P. 40-48			
				Count
Class	Descript.	# Axles	# Trailers	2013 Volume
4	buses	2		22
5	2ax	2		123
6	3ax	3		2
7	4ax	4		0
8	4ax trl	4	1	111
9	5ax trl	5	1	132
10	6ax trl	6	1	29
11	5ax dbl trl	5	2	10
12	6ax dbl trl	6	2	9
13	7ax dbl trl	7 +	2 +	33
Total Trucks				471
AADTs 2013 ADT = 1200, 2033 ADT = 1300				
20-year growth factor = 1.08				

Project	Hwy 7 (US20) M.P. 40-48			
Class	Descript.	# Axles	# Trailers	**Forecast** 2033 Volume
4	buses	2		24
5	2ax	2		134
6	3ax	3		2
7	4ax	4		0
8	4ax trl	4	1	121
9	5ax trl	5	1	144
10	6ax trl	6	1	32
11	5ax dbl trl	5	2	11
12	6ax dbl trl	6	2	10
13	7ax dbl trl	7 +	2 +	36
Total Trucks				514

The following example is a relatively simple project level analysis that does not involve local roads or projects with special considerations.

While the following example used future forecasts from the Future Volume Tables for the purpose of illustration, the volumes could have just as likely been derived from a cumulative analysis or a post-processed travel demand model. Choice of future forecasting methods is dependent on the study area, the project requirements, and the tools available. See earlier sections in this chapter.

Example 6-24 Simple Project Level Forecast

As part of a pavement redesign project, a new pavement structure needs to be designed. The pavement engineer on the project first needs to know the heavy vehicle volumes that need to be designed for. The engineer had a 2011 24-hour traffic count available at the project site and recorded the following data from it. The project base year is 2014 with a 2034 future year. The engineer also recorded the 20-year ADT from the Future Volume Tables.

Project	Hwy 2 (US730) M.P. 190 - 195			
Class	Descript.	# Axles	# Trailers	**Count** 2011 Vol
4	buses	2		96
5	2ax	2		475
6	3ax	3		57
7	4ax	4		8
8	4ax trl	4	1	316
9	5ax trl	5	1	724
10	6ax trl	6	1	442
11	5ax dbl trl	5	2	74
12	6ax dbl trl	6	2	38
13	7ax dbl trl	7 +	2 +	245
Total Trucks				2475
Future Volume Tables 2011 ADT = 2500, 2031 ADT = 2600				
% Trucks 42.3% 20-year growth factor = 1.04				

The count information and Future Volume Tables' information were entered into the Heavy Vehicle Pavement Design Spreadsheet and the results found recorded from the spreadsheet into the table below.

Project	Hwy 2 (US730) M.P. 190-195			
Class	Descript.	# Axles	# Trailers	**Forecast** 2034 Vol
4	buses	2		101
5	2ax	2		497
6	3ax	3		59
7	4ax	4		8
8	4ax trl	4	1	331
9	5ax trl	5	1	757
10	6ax trl	6	1	463
11	5ax dbl trl	5	2	77
12	6ax dbl trl	6	2	40
13	7ax dbl trl	7 +	2 +	256
Total Trucks				2589

The Heavy Vehicle Pavement Design Spreadsheet calculator used in this example is shown below.

Heavy Vehicle Forecast for Pavement Design Spreadsheet: Project Level Analysis				
Project	Name	APM Example		
	Description	Cold Springs Automatic Traffic Recorder,		
	Additional Identification	Sta. 30-002, Hwy No. 2 (US730): 0.24 mile east of Pendleton-Cold Springs		
	Hwy #	36		
	M.P.	193.70		
	Base Year	2014		
	Forecast Year	2034		
Count	TCM # (If available)	480		
	Duration	24 hr		
	Factor	1.00		
	Year	2011		
Future Volume Table	Base Year / Future Year	2011		2033
	Base Year AADT	2500		
	Future Year AADT	2600		
20-yr Growth Rate (per yr.)		0.18%		

Class	Description	# Axles	# Trailers	2011 24 hr Count Volume	2011 24 hr Count Volume	2014 Base Year Volume	2034 Forecasted Volume
4	buses	2		96	96	97	101
5	2ax	2		475	475	478	495
6	3ax	3		57	57	57	59
7	4ax	4		8	8	8	8
8	4ax trl	4	1	316	316	318	330
9	5ax trl	5	1	724	724	728	754
10	6ax trl	6	1	442	442	444	460
11	5ax dbl trl	5	2	74	74	74	77
12	6ax dbl trl	6	2	38	38	38	39
13	7ax dbl trl	7	2	245	245	246	255
13	triples	7 +	2 +	0	0	0	0
Total				2475	2475	2488	2578

6.13.2 Detailed Process for Local Roads or Highway Segments with Special Considerations

A more comprehensive process is required when pavement traffic data is needed for non-state facilities or when special considerations exist. This process should also be used when recent classification counts are available. This process is based on intersection or straightaway classification counts.

Note: Additional classification counts may be necessary for longer preservation projects (or where there are no ATR/Automatic Vehicle Classifier (AVC)'s on a particular highway) as counts are not typically obtained for this project type.

Identifying Segments

To determine segments on state highways, use the Traffic Volumes and Vehicle Classification Report available at:

http://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm.

Break roadway into segments if AADT volumes change by more than twenty percent (20%). These initial segments need to be reviewed to see if the truck classifications (4-13) change by more than ten percent (10%). The higher classifications have more impacts of the road surface (since these are the heavier vehicles and/or have multiple axles). Note that the review needs to consider where an absolute number versus the percent change is significant. If there are questions whether a change is significant, the analyst should work with the pavement designer to determine if the segment break is necessary. The analyst needs to put greater importance on changes to the higher classifications. For example, an increase of five triple-trailer trucks (class 13) could cause a 50-100% increase with greater impacts than a 50% increase in delivery/ panel trucks (class 5). When this occurs, the analyst may need to subdivide the segments to better identify the truck volumes.

For local roads, using the count/classification available, determine volumes at different points in the project. Break into sections if volumes change by more than twenty percent (although this changes on a case by case basis) or the project includes more than one highway. While the project may involve only one road, there may be differences in heavy vehicle volumes on each side of a major intersection or urban/rural environment change. A change, such as road classification, may not be reason to split a section, but may be a good place to look for a difference in heavy vehicle volumes. When a count is not available on a specific roadway, counts from similar facilities that serve the same areas may be used as a basis for an educated assumption of the truck percentages.

Count Data

To forecast truck volumes, obtain a 24-hour (less than three years old) full classification count(s) within or near the project. Since truck volumes typically increase overnight as a percent of total vehicles, every attempt should be made to obtain a 24-hour count. If the project has an AVC, then that data can be used as a count. Internal staff may look in the TCM or the count logs on the 6210 share to determine if counts are available. Consultants should contact the TSM staff. If a recent count is not available, and time permits, a full classification count could be requested. Counts on interchange ramps do not have classification data unless specifically requested (such as a freeway to freeway interchange where there are not any ramp terminal intersections), so this is generally obtained from a ramp terminal intersection count.

Determining Classification Volumes

For each intersection count, total the volumes by class for each leg that data is desired. A full classification count is shown in Exhibit 6-17.

Exhibit 6-17 Traffic Count Sheet

Traffic Count Axle Factor Sheet
Transportation Development Division

Site:	2082012	Date:	5/30/2012
County:	Benton	Hours:	6:00 AM-10:00 PM
City:	RURAL	Highway #:	027
Milepoint:	53.59	Location:	OR27 @ Decker Rd. site 1846 - s leg 1848 - n leg
Count Number:	1.00	Weather:	Clear

Direction From-To	Car	Lt Truck	Sgl. Unit Truck			Sgl. Trailer Truck			Multi Trailer Truck			Bus	Motor-cycle	Total All Vehicl	
			2 Axl	3 Axl	4+ Axl	4- Axl	5 Axl	6+ Axl	5- Axl	6 Axl	7+ Axl				
North-East	31	38	2	9		1						2	1	84	
North-South	309	437	22	67	1	1	4	13				1	16	871	
North-West		4												4	
East-North	23	48	5				12						1	89	
South-North	344	363	21	52		9	31	15				2	13	850	
West-North		5												5	
Total Volume	707	895	50	128	1	11	47	28	0	0	0	5	31	1903	
Axle Factor	1.1	1.1	1	1.5	2	2	2.5	3	2.5	3	3.5	1.1	1	0.839	North Leg
Veh O/Coun	778	985	50	192	2	22	118	84	0	0	0	6	31	2268	
North-East	31	38	2	9		1						2	1	84	
East-North	23	48	5				12						1	89	
East-South	14	28	1	6		1							7	57	
East-West		1												1	
South-East	18	29	1										3	51	
West-East														0	
Total Volume	86	144	9	15	0	2	12	0	0	0	0	2	12	282	
Axle Factor	1.1	1.1	1	1.5	2	2	2.5	3	2.5	3	3.5	1.1	1	0.847	East Leg
Veh O/Coun	95	158	9	23	0	4	30	0	0	0	0	2	12	333	
North-South	309	437	22	67	1	1	4	13				1	16	871	
East-South	14	28	1	6		1							7	57	
South-North	344	363	21	52		9	31	15				2	13	850	
South-East	18	29	1										3	51	
South-West														0	
West-South														0	
Total Volume	685	857	45	125	1	11	35	28	0	0	0	3	39	1829	
Axle Factor	1.1	1.1	1	1.5	2	2	2.5	3	2.5	3	3.5	1.1	1	0.844	South Leg
Veh O/Coun	754	943	45	188	2	22	88	84	0	0	0	3	39	2168	
North-West		4												4	
East-West		1												1	
South-West														0	
West-North		5												5	
West-East														0	
West-South														0	
Total Volume	0	10	0	0	0	0	0	0	0	0	0	0	0	10	
Axle Factor	1.1	1.1	1	1.5	2	2	2.5	3	2.5	3	3.5	1.1	1	0.909	West Leg
Veh O/Coun	0	11	0	0	0	0	0	0	0	0	0	0	0	11	

For each leg, there should be a total for each classification (4-13). Note this needs to

include both directions (all the “to” and “from”) on the approach. This means that at a 4-legged intersection there are six movements to be summed. Once the table is filled out, the columns must be totaled to report the number of trucks by classification. If the manual count is less than 24 hours, an expansion factor (see Exhibit 5-19) needs to be applied (typically a 1.1 converts a 16-hour count to 24-hour volumes). These classification subtotals are then combined to report the total truck volume(s). The truck total is then divided by the ADT to give the percent trucks. The Heavy Volume Pavement Design Spreadsheet can be used to streamline the individual segment calculations.

Growth Rate

For state highways, record each year and its volume for the road segment from the FVT into the calculation spreadsheet which will compute the growth factor. The analyst will need to review the FVT segments to determine which have appropriate r-squared values and can be averaged together to arrive at a segment growth rate (see Chapter 5).

Off-system growth rates would need to be determined with county or city data (off system data source), such as historical tube counts, travel demand model growth rates, similar facilities or other project information in the area (see Chapter 5). If historical data, state highways with similar characteristics, or a travel demand model does not exist for the particular site, use 2% for rural areas and 1% for urban areas per year.

Appendix 6A – Sample Application of Enhanced Zonal Cumulative Analysis (EZCA)

7 SYSTEM PLANNING ANALYSIS

7.1 Purpose

The purpose of this chapter is to illustrate the different types of system planning analysis and related tools, applications, limitations, and data needs. These methods are recommended for use in larger scale planning studies.

- System Planning Analysis
- Highway Economic Requirements System (HERS-ST)
- Statewide Integrated Model (SWIM)
- Travel Demand Models
- Regional Strategic Planning Model (RSPM)
- Land Use Scenario Tools

7.2 System Planning Analysis

The following is a list of the different kinds of system planning from a low to a high level of detail.

Strategic Planning

Strategic Planning is a way to understand the first order effects of a broad array of policies with less required input detail (e.g., doubling transit service miles), to understand the tradeoffs of different futures (e.g., operational strategies vs. transit investment). Because these models may be less detailed, they run quickly and thus are able to make lots of runs to test plan resilience under a variety of future uncertainties (e.g. changing fuel price and income forecast). Strategic planning level of detail is limited to a state or regional scope. The key ODOT tools areis the RSPM (Regional Strategic Planning Model), and the HERS-ST tool for roadway investment/policies.

Statewide Systems

Statewide system planning generally is policy or economic-based, such as relating to the Oregon Transportation Plan and/or state modal plans such as the Oregon Highway Plan. Statewide system planning is conducted to explore alternative futures related to greenhouse gas (GHG) emissions, land use development, population demographics and economic forecasts as they relate to use of the transportation system. Statewide system planning is used to develop investment strategies associated with different budget options, policy goals and legislative concepts evaluating the best options to meet statewide objectives. Tools used for statewide system analysis include SWIM, HERS-ST model, and the RSPM.

Regional Systems

Regional system planning generally focuses on specific areas like Metropolitan Planning Organizations (MPO), individual cities, or unincorporated or rural areas. These will

involve creation or analysis of Regional Transportation Plans (RTP) or Transportation System Plans (TSP). Typical tools used could be regional or urban travel demand models.

Corridor Systems

Corridor system planning can involve an individual route which can be made up of one or many different highways. This also can be just a small segment in a regional or urban area. A commonly used tool would be HERS-ST (Highway Economic Requirements System).

Exhibit 7-1 shows the typical tool applications for each type of system planning analysis.

Exhibit 7-1: System Planning Analysis Tool Applications

	Strategic	Statewide	Regional	Corridor
HERS-ST	X	X	X	X
SWIM		X	X	X
Travel Demand Models			X	X
RSPM	X	X	X	
Land Use Scenario Tools			X	

7.3 Highway Economic Requirements System (HERS-ST)

HERS was first developed by the FHWA to examine the relationship between national investment levels and the condition and performance of the Nation's highway system. FHWA uses the model to estimate future investment required to either maintain or improve the nation's highway system. FHWA provides this information to the U.S. Congress on a biennial basis. The HERS-ST model is a direct extension of the national level model. HERS-ST has been used to conduct analysis for the 1999 Oregon Highway Plan, Congestion Management System, and other analyses as shown on the ODOT HERS-ST website. The model focuses on motor vehicle modes. The state system dataset is updated annually. Non-state roadways can be added to the dataset in order to analyze a road network. This section is based on the current HERS 4.5 version but this still compatible with other versions.

HERS-ST offers a high-level identification of needs (deficiencies) on roadway segments over a specified number of periods. HERS-ST can report out numerous performance measures like speed, delay, and travel time. The biggest advantage of HERS-ST is that it forecasts future conditions and quantifies these impacts on an alternative into costs and can calculate relative benefit-cost ratios in comparisons between alternatives. HERS-ST can forecast needs or performance, depending on the study.

The state version of the Highway Economic Requirements System (HERS-ST) uses an input dataset formatted in the standard Highway Performance Monitoring System (HPMS), where each data record represents a unique roadway segment. For each funding

period, the HERS-ST model evaluates each data record one at a time, independent of all other records, to determine whether a road segment has a deficiency as defined by the user. For each deficiency, the HERS-ST model uses a benefit-cost analysis process to evaluate a number of potential improvements to determine the best economical solution to correct the problem. The most economical improvement is then implemented in the dataset and simulated during future funding period analysis.

The analyst defines the timeframe for the HERS-ST analysis period. The general analysis consists of four five-year funding periods for a total 20-year analysis period.

The HERS-ST model consists of a number of individual complex sub-models: Fleet Composite, Widen Feasibility, Capacity, Pavement Deterioration, Speed, and Travel Forecast. The Fleet Composite, Capacity, and Speed sub-models are the most useful for a typical HERS-ST analysis.

7.3.1 Fleet Composition

HERS-ST categorizes the AADT into three vehicle categories which include a total of seven vehicle types. These data on fleet composition are used by HERS when estimating speed, operating costs, travel-time costs, gallons of fuel used, section capacity, and pavement deterioration (used as interim measure only as noted in Section 7.3.4). The progression from the entire fleet to the seven vehicle types is shown (proceeding from left to right) in Exhibit 7-2. It should be noted that HERS-ST fleet composition does not currently reflect the anticipated shift to a lower emission vehicle mix in future years.

Exhibit 7-2: Fleet Composition

Fleet	Weighing Factor	Vehicle Category	Weighting Factor	Vehicle Type
All Vehicles	Section data item: Percent Combination Trucks	Combination Trucks	Prorated from HPMS Vehicle Classification Study	Five or More Axle Combination Trucks
				Three/Four Axle Combination Trucks
	Section data item: Percent Single Unit Trucks	Single Unit Trucks	Prorated from HPMS Vehicle Classification Study	Three or More Axle Single Unit Trucks
				Six-Tire Trucks
	100% less percent of Single Unit and Combination Trucks	Four Tire Vehicles	Prorated from HPMS Vehicle Classification Study	Pickups & Vans
				Medium/Large Automobiles
				Small Automobiles

Source: Table 2-3. Fleet Composition, HERS-ST Highway Economic Requirements System - State Version: Technical Report, August, 2005

The fleet is divided into vehicle categories based upon section-specific percentages of single unit and combination truck classifications. The four wheel category consists of the percentage of total traffic which is not part of either truck category.

7.3.2 Capacity

HERS capacity routines are based upon Appendix N, "Procedures for Estimating Highway Capacity," of the HPMS Field Manual. Appendix N was revised in February 2002 and incorporates algorithms from the Highway Capacity Manual 2000.

For each section, HERS develops separate estimates of capacity for the peak and off-peak periods; and the peak-period estimates are developed separately for the peak direction and the opposite, or "counter peak," direction. These three capacities are referred to as peak, counter peak, and off-peak capacity. Differences in the three capacities result primarily from differences in the number of available travel lanes.

For urban and rural multi-lane facilities, the capacity is defined as the total capacity per direction. The capacity for rural two or three-lane facilities with two-way operation is defined for both directions.

7.3.3 Speed

The speed procedure within HERS-ST is based on the Aggregate Probabilistic Limiting Velocity Model (APLVM) and covers two distinct processes:, free-flow speed (FFS) and average effective speed (AES). The FFS estimation is developed to reflect the average unconstrained speed that exists on the highway system in the absence of any other traffic or geometric influences. Then, the FFS estimates are adjusted to account for the effects of congestion delay and traffic control devices to produce the AES for each roadway segment.

Several key data elements affect speed, including vehicle type, curves, grades, pavement surface quality, speed limits, congestion, and traffic control devices. There are three controlling factors in the APLVM that potentially limit the free speed on a roadway section: curves, pavement roughness and posted speed limit. All of these factors have the potential of lowering the sectional speed estimate.

A vehicle traveling through a curved roadway section is subject to a centrifugal force that acts against the vehicle, forcing it to leave the curve path of the roadway. The higher the vehicular speed entering the curve, the heavier the vehicle, and the sharper the curvature of the road, the greater the external force acting upon the vehicle. This results in a reduced FFS for the roadway section.

When the pavement is smooth and the curvature is low (below two degrees) the average speed is governed by the posted speed limits. This model does not explicitly consider enforcement.

7.3.4 HERS Scenario Development

HERS-ST is intended to be used for high-level studies such as corridor plans or as a screening tool in more detailed plans or project development. HERS-ST can be used to determine numerous outcomes or to answer different questions depending on the particular analysis purpose. It can be used to screen alternatives in a TSP or a RTP, identify needs in a policy or corridor plan, compare performance between alternatives in a plan or project, or to perform before/after analysis on a roadway segment.

If a no-build scenario is to be part of the analysis, there are two ways to utilize the HERS-ST analysis. The first process is to create a scenario dataset with the no-build existing conditions and future volume (i.e., historical, model or post-processed), then turn off the improvement and run the typical four five-year funding increments; HERS-ST creates performance metrics for each funding period analysis. The second process is to create a future no-build scenario dataset by using the project/future year as a base year and run the typical analysis. The future year performance metrics can be found in the base year data analysis.

The typical HERS-ST analysis will evaluate pavement and capacities deficiencies and identify segment-based improvement on a roadway facility, such as adding/widening lanes and shoulders. These improvements can form the basis for future alternative solutions. In order to compare alternatives, separate scenario datasets should be created; this includes evaluating other geometric features such as medians, signals, turn lanes, and

interchanges. HERS-ST can also generate pavement needs. Although ODOT does not use this feature because it has a robust Pavement Management System (PMS) that quantifies pavement needs, other jurisdiction that lack their own PMS will find this feature quite useful. Alternative analysis years will be dependent on the particular study's requirements.

Analysis can be done either on a sectional or system analysis. A sectional analysis is based on each funding period which is typically four to five years. For example, a 20-year project can be divided into four five-year periods with output data reported for each period separately. The system analysis aggregates the impacts and costs of each period up into the total for the whole project.

7.3.5 HERS Data Requirements

ODOT has complete state highway HERS-ST datasets available. These are typically updated every five years. Contact the Transportation Planning Analysis Unit (TPAU) to obtain these or for questions on this methodology. HPMS sample data (covering any jurisdiction) can be run through HERS-ST. HERS data sets can be created from HPMS sample datasets by adding in the necessary specific section data for non-sample sections. HERS-ST can also be tied to a travel demand model for supplying volumes.

By following the data needs and formats in the HERS-ST User's Guide, a roadway dataset can be created from scratch for any area. Datasets are typically done in Excel and exported into HERS-ST in .csv format. Depending on the type of analysis, defaults can be used as necessary. For example, if pavement is not a concern, a "perfect" pavement default can be added. However, the following data elements are generally easy to obtain and should not have default values.

- Functional Class
- Type of Facility (One-way or Two-way)
- Number of Lanes
- Lane Width
- Median Type
- Median Width
- Shoulder Type
- Shoulder Width (both Right and Left)
- Terrain Type
- Speed Limit
- Directional Factor
- Peak Number of Lanes
- AADT
- FADT
- K-Factor
- % Truck (both Single Unit and Combined)
- Number of At Grade Signals, Stop Signs & Other
- Turn Lanes (both Right and Left)

Data can be obtained from online databases such as TransInfo, GIS, road inventories, aerial photography, online maps, video logs, and local knowledge. Field inventory may still be necessary to fill in missing data or to verify data (especially if obtained from on-line mapping or aerial photos).

Datasets need to be broken into homogenous segments. Any changes in the key elements

(i.e. speed, functional class, etc.) need to be separate segments. Segments can be broken further as desired. For example a section with two signalized intersections may need to be broken if different g/c ratios need to be entered for each. Short segments of less than a quarter-mile are not uncommon in urban areas. Rural segments can range from many miles to less than a mile.

7.3.6 HERS Analysis Types

Running HERS with unlimited funding creates a financially unconstrained scenario. HERS will identify improvements solely based on geometric/capacity needs and pavement deterioration. HERS will implement needs based on user criteria such as minimum benefit-cost ratio. This will create a list of needs without regard for the future ability to fund those needs.

Adding in funding constraints will limit identification of improvements to the best improvements available up to the funding threshold. Once beyond the threshold, HERS will not identify any improvements (Constrained Fund).

HERS also has a minimum benefit-cost threshold analysis (Minimum BCR). For this analysis, HERS will solve for both the required funding level and the resultant performance levels when improvements are constrained to return a minimum benefit/cost ratio. This type of analysis does not have any funding constraints. This analysis types includes two special cases. The first is an “engineering needs” run (sometimes referred to as “full needs”), which is a minimum BCR run with the minimum BCR set to a very low negative number so that all sections with deficiencies are selected for improvement. The second is a “maintain current conditions” run in which the model first determines the level of system performance at the beginning of the run based on user-specified parameters (for example, current highway-user costs), and selects the least costly mix of improvements to maintain that level of performance.

The last major type of HERS analysis is Performance Constrained. The user can specify what values are to be maintained. Maintaining pavement condition will have a different set of needs and costs than trying to maintain overall delay. In this analysis, HERS will solve for the funding levels required to bring the system to a specified level of performance.

For more information on HERS analysis types, refer to the HERS-ST Technical Report.

7.3.7 HERS Analysis Results

HERS creates a number of results such as delay, speed, volumes, v/c ratios and other performance measures at a roadway segment level. Most of these can be displayed in different kinds of outputs as described in the following sections.

Average Delay

There are three kinds of delays estimated in HERS-ST:

- Zero-Volume Delay is the delay associated with traffic control devices. This is the expected delay that a single vehicle would encounter even if it were the only vehicle on the road. Zero-volume delay only exists for sections controlled with stop signs or traffic signals and is not calculated for uncontrolled sections.
- Incident Delay is the delay associated with crashes. HERS-ST estimates delay due to crashes through a secondary (or inferred) process where the HERS-ST model estimates the delay cost of crashes and then back-calculates the delay estimates due to crash incidents from the cost calculations.
- Other Congestion (or Recurring) Delay is the average delay due to non-incident congestion.

Total daily traffic is broken into three phases, or demand periods, for all capacity, delay and speed analysis:

- Peak period analysis in the peak direction.
- Peak period analysis in the counter peak direction.
- Off peak analysis in both directions.

Speed

HERS computes vehicle speed for three purposes: calculation of travel time costs; calculation of external costs due to vehicular emissions; and calculation of vehicle operating costs. For each section, HERS models speed for each of the seven vehicle types (except for autos and pickup trucks) in each direction of travel. Overall average speed per section is aggregated from the speeds of the individual vehicle types. HERS takes into account the effects of vehicle type, curves, pavement condition, and posted speed limit in calculating free-flow speeds (FFS). Average Effective Speed (AES) is calculated to account for grades, stop signs or traffic signals, and congestion.

V/C Ratio

The HERS capacity model has two functions. The first is the calculation of section capacity; the second is the calculation of the number of lanes needed to accommodate the projected traffic volume in the design year (that is, how many additional lanes are needed). HERS capacity routines are based upon Appendix N, "Procedures for Estimating Highway Capacity," of the HPMS Field Manual. Appendix N was revised in February 2002 and incorporates algorithms from the Highway Capacity Manual 2000. For each section, HERS develops separate estimates of capacity for the peak and off-peak periods; and the peak-period estimates are developed separately for the peak direction and the opposite, or "counter peak," direction. These three capacities are referred to as peak, counter peak, and off-peak capacity. Differences in the three capacities result primarily from differences in the number of available travel lanes.

Volume/capacity (v/c) ratio is HERS' estimate of the ratio of design-hour volume to peak-period hourly capacity.

The traffic growth information is used to forecast traffic and volume-to-capacity (v/cC) ratios. HERS-ST uses this information to estimate the point at which a capacity improvement will be required and the extent of improvement indicated.

Benefit-Cost Ratio

HERS-ST defines the benefit-cost rRatio (BCR) of a highway improvement as the discounted sum of the present value benefits for the user, agency, and environment divided by the implementation costs of the improvement. For BCR analysis, HERS-ST recognizes four broad classes of costs:

- **User costs** are the costs incurred by the highway user and include Travel Time Costs, Operating Costs (including fuel consumption), and Safety Costs.
- **Agency Costs** are roadway maintenance costs borne by the administrative agency responsible for the highway section.
- **External Costs** (emissions costs) are the social costs passed to the non-users of the highway system.
- **Capital Improvement Costs** are the estimated construction costs of the improvement.

The analyst can change many variables and factors[22] within the HERS-ST model that influence User, Agency and External Costs. The HERS-ST procedure estimates the incremental costs and benefits of each potential improvement for each period of the benefit-cost analysis period, as well as the residual value of the improvement at the end of the analysis period. For BCR, the benefits of an improvement are defined as a reduction in user, agency and external costs as the result of implementing an improvement, and are measured as the difference in costs between the no-improved case and the improved case. The cost variable is the estimated capital improvement cost.

The little known part of the BCR equation is in the residual value (RV) of an improvement. The residual value is the capital value of the improvement that still remains at the end of the final analysis period, and is credited back as the unused portion of the investment. The RV for an improvement is discounted back to the initial year of the analysis period and treated as a benefit.

In theory, any project with BCR greater than one is considered a worthy project. However, the HERS-ST BCR is used to reveal the value of a set of alternative projects related to each other even though the BCR may be less than one.

User Costs

For Travel Time Costs, HERS-ST incorporates national U.S. Department of Transportation values of time per person for personal and business travel. The Operating Costs evaluate vehicle operating costs as a function of cost for fuel and oil consumption, tire wear, vehicle maintenance and repair, and mileage-related depreciation due to pavement conditions. The Safety Costs use national crash rates to estimate the number of

[22] User parameters affect deficiency levels, design standards, improvement costs, auto and truck growth factors, funding and performance constrains, and weights for highway performance goals.

crashes and severity for improved and unimproved roadway segments.

The benefits for each variable are defined as a reduction in costs as a result of the implementation of an improvement. Some improvements might show a savings in one variable, such as travel time, while showing an increased cost (disbenefit) in another variable, such as increased fuel consumption. A reduction in the summation of all three costs is defined as the total benefit for the selected improvement.

Agency Costs

Agency Costs include the cost of routine maintenance. A selected improvement may or may not be associated with a reduction in roadway maintenance costs. HERS-ST evaluates this measure for the current funding period and evaluates the potential reduction of improvement costs in future years resulting from the improvement.

External Costs

The HERS-ST model uses national values to estimate the cost of damages from vehicular emissions (air pollutants) resulting from the implementation of a selected improvement. The air pollution costs are measured as the difference between total pollution costs generated by the forecast volumes of travel on the section under unimproved and improved conditions. Because the cost of air pollutant emissions per vehicle-mile varies by both travel speed and vehicle class, this effect can be negative or positive depending on how a proposed improvement influences forecast travel volumes, the mix of vehicle types and travel speeds. It should be noted that HERS-ST does not currently reflect the anticipated shift to a lower emission vehicle mix in future years.

Capital Improvement Costs

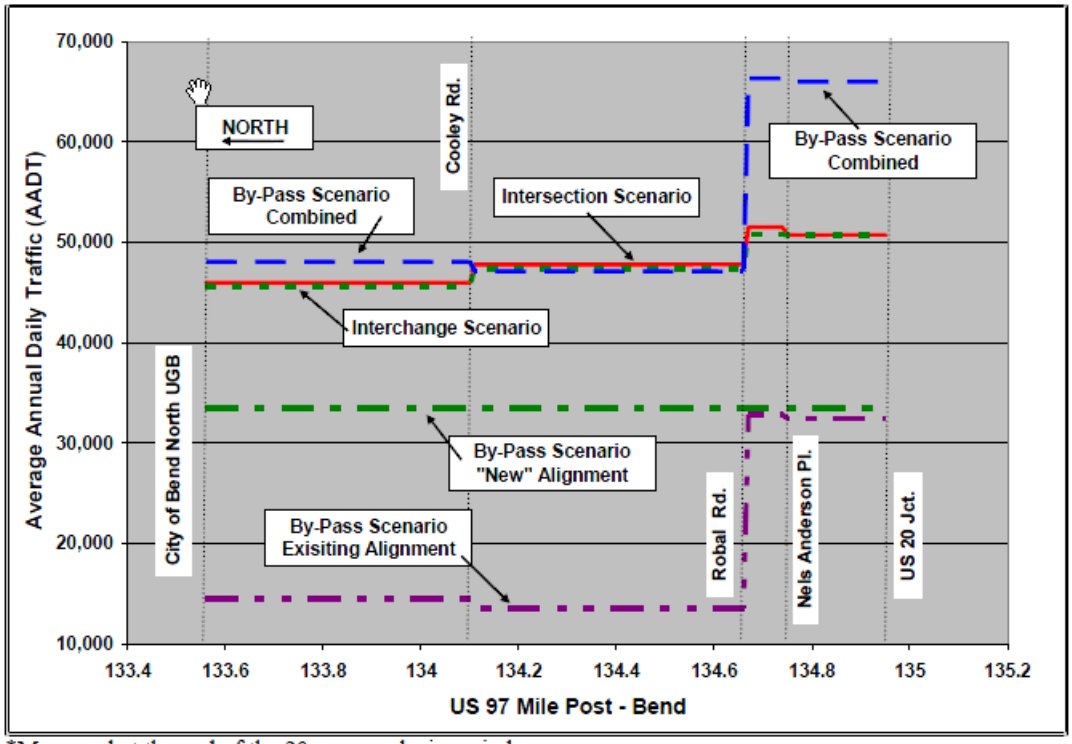
HERS-ST identifies segment deficiencies, evaluates a series of improvements that will correct the condition, and estimates the cost of the highway improvement. The Capital Improvement Costs are simply the construction costs for the selected improvements. When analyzing the economic attractiveness of a potential improvement, the improvement cost is used as the denominator in the benefit-cost equation.

7.3.8 HERS Output

HERS provides a variety of output options. Which output to use depends on the analysis purpose. Benefit/cost analysis leads itself to more tabular output while speed and delay should be plotted via an Excel export. Sectional output also can be exported to GIS for mapping. The ODOT HERS-ST website has example HERS applications, reports and outputs used for presentations. Total User Costs is a major selling point of national HERS use, but for Oregon, this has not been t well received to date and probably should be minimized in report documentation. HERS is very valuable for showing corridor metrics such as v/c ratio, delay, and speed.

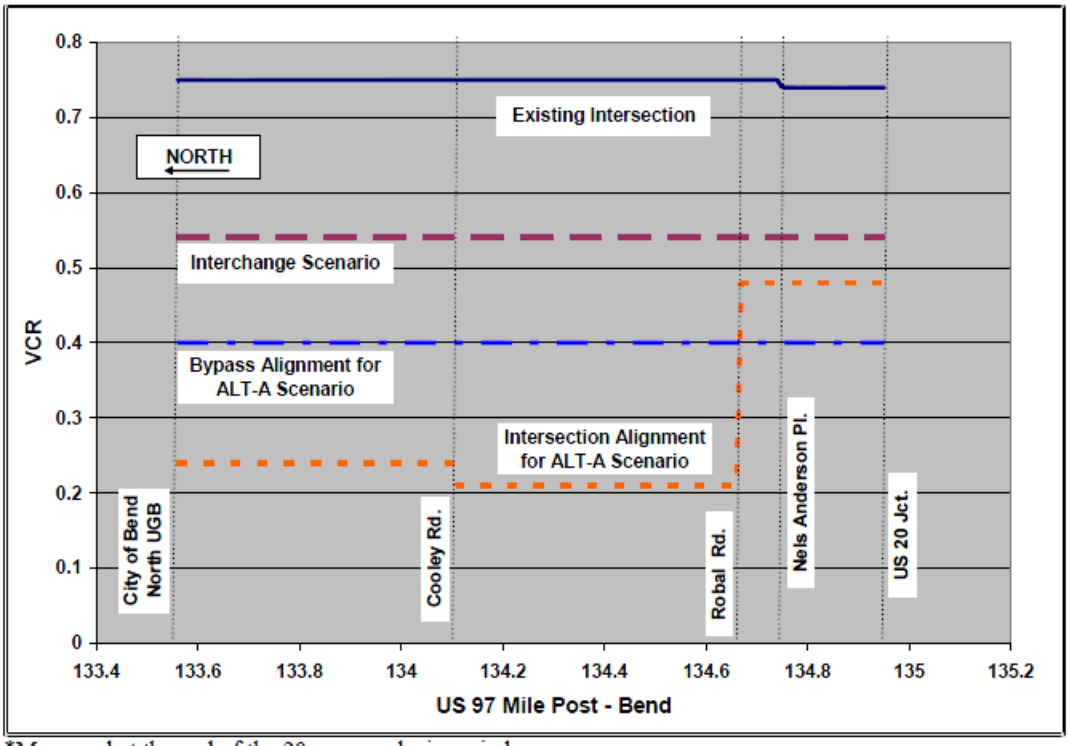
Daily traffic, speed, delay and v/c ratio results can be plotted using color-patterned lines on a profile type graph which will clearly show the differences between alternatives and/or the no-build (as long as care is taken on how many different scenarios are compared at once). Examples of these plots are shown in Exhibit 7-3 through Exhibit 7-9.

Exhibit 7-3: HERS-ST Scenario Comparison - AADT



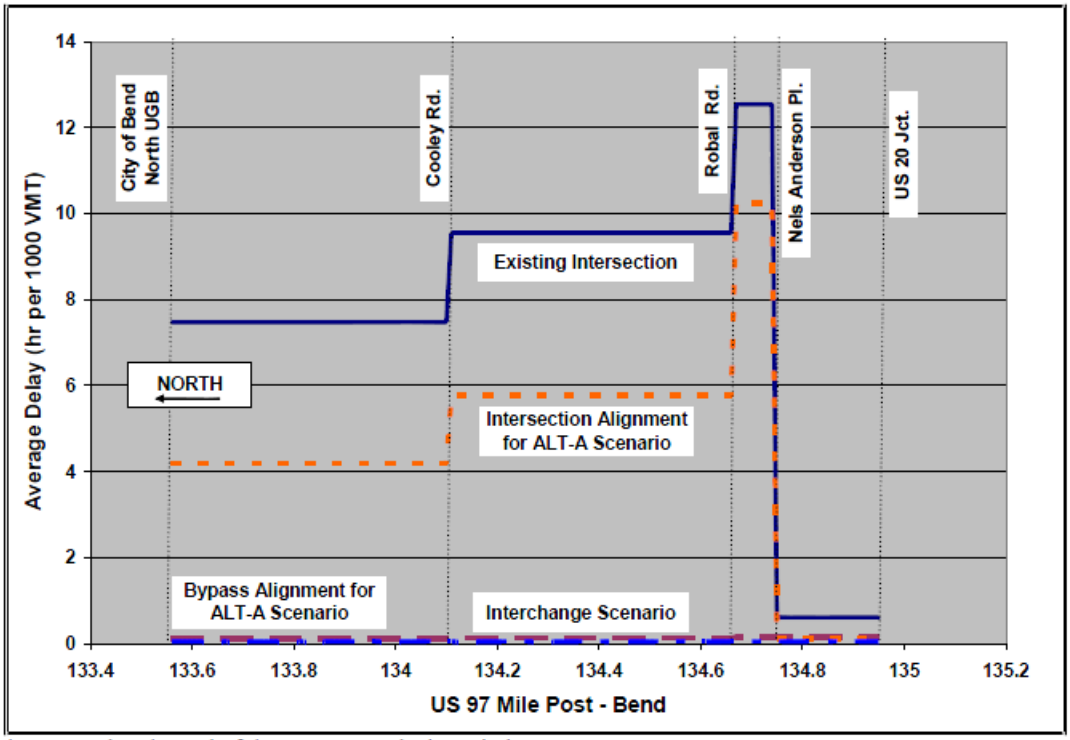
*Measured at the end of the 20-year analysis period.

Exhibit 7-4: HERS-ST Scenario Comparison – V/C Ratio



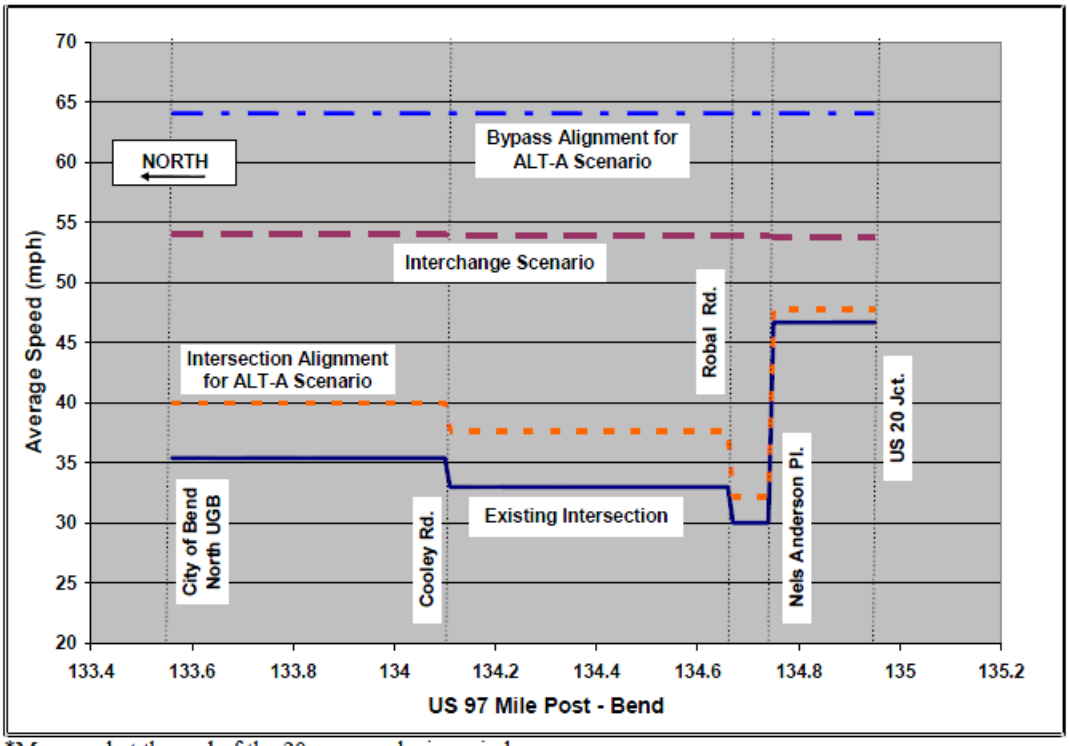
*Measured at the end of the 20-year analysis period.

Exhibit 7-5: HERS-ST Scenario Comparison - Average Delay



*Measured at the end of the 20-year analysis period.

Exhibit 7-6: HERS-ST Scenario Comparison - Average Speed



*Measured at the end of the 20-year analysis period.

Other results are best compared in tables such as VMT or benefit-cost ratio, as shown in Exhibit 7-7 through Exhibit 7-8.

Exhibit 7-7: HERS-ST Benefit/Cost Ratio Summary

Scenarios		Description
Interchange	Bypass	
$149,578,657	$133,893,192	Total Benefit
$18,750,000	$18,750,000	RV for $50m
$50,000,000	$50,000,000	Capital Improvement Costs
3.37	3.05	BCR for $50M

RV: residual value

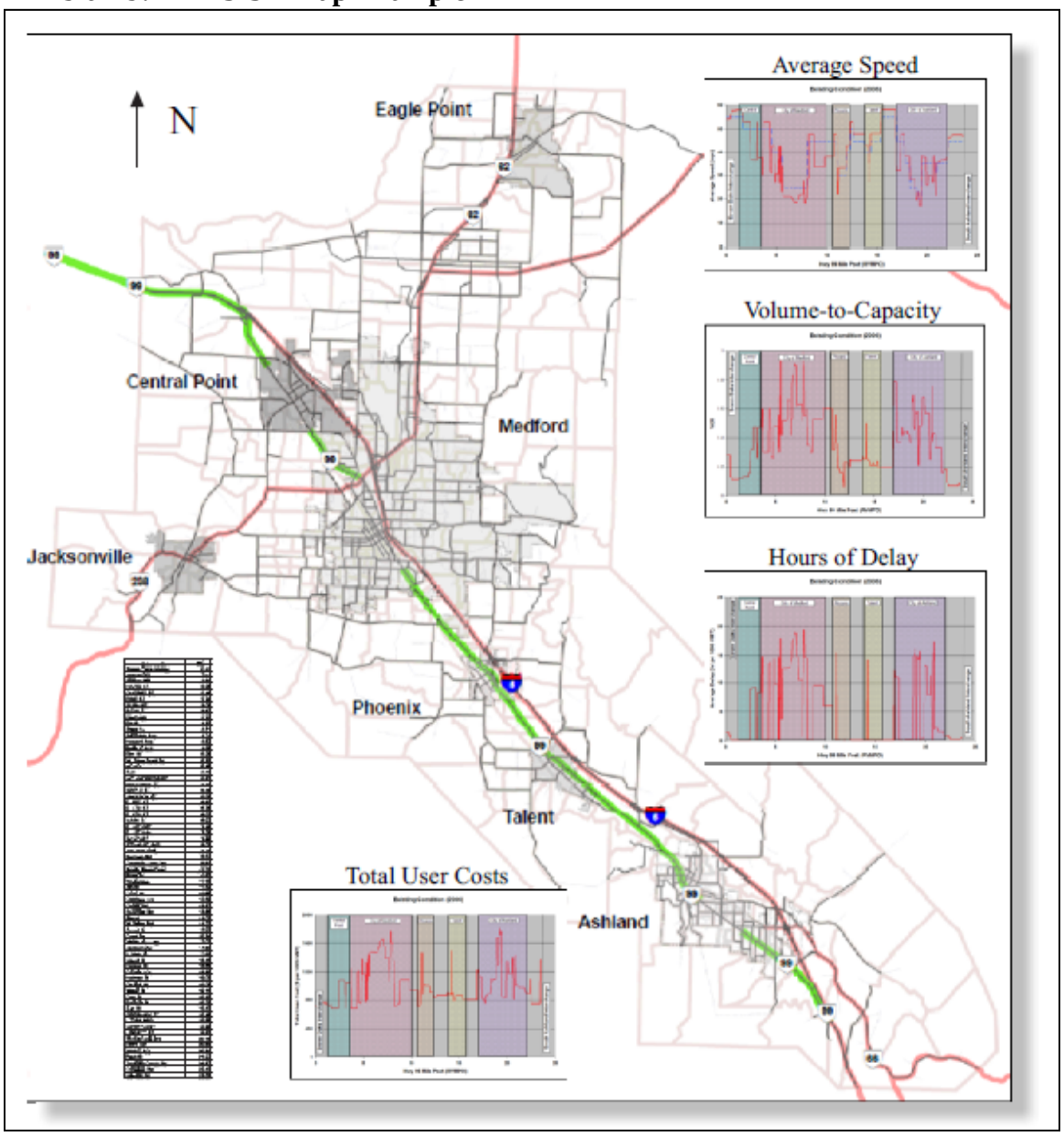
Exhibit 7-8: HERS-ST Scenario Performance Summary

Scenarios	VCR	VMT (million)	Avg. Speed (mph)	Delay (hr/1000 VMT)
No Build: Intersection	*0.75*	*24.4*	*36.0*	*35.1*
Build: Interchange	0.54	24.2	54.0	0.5
Build: Bypass	0.36	26.3	53.1	7.2

*Measured at the end of the 20-year analysis period.

Performance measures are best shown on a map for easy spatial reference since HERS is segment based.

Exhibit 7-9: HERS-ST Map Example



7.3.9 Documentation Requirements

The documentation of the HERS analysis needs to give an adequate discussion of the context and study area that HERS was used for. There should be documentation in the report (or appendix) showing all of the assumptions used in the dataset creation and what inputs were defaulted. Also, the analysis assumptions need to be defined such as funding periods, analysis types, etc.

The documentation of HERS results should include discussions on particular alternatives and between alternatives including any issues or considerations. Since there typically is a large amount of data in a HERS analysis, summaries are critical to reader understanding.

It is easy to create too much data and information through which for the reader mustto sift through.

Additional general information on documentation is in the APMv1 Documentation Chapter 12.

7.3.10 HERS Application Examples

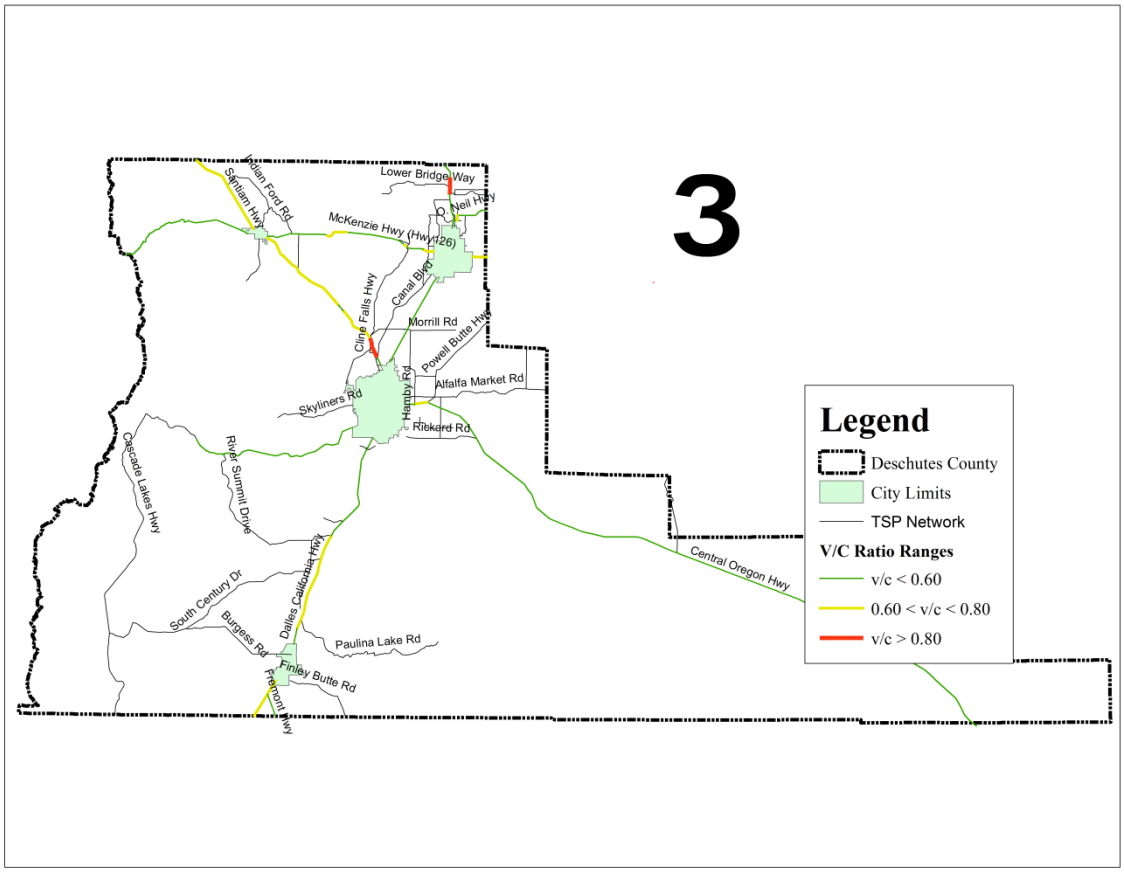
Plans TSP/RTP: Deschutes County TSP Update

Transportation System Plans (TSPs) are to identify needs/risks of transportation systems. Instead of detailed project level analysis outlined in Transportation Planning Analysis Unit's Analysis Procedure Manual (TPAU's APM), a system-level analysis was used for the Deschutes County TSP update. The analysis is based on the Deschutes County travel demand model along with other data to estimate deficiencies with a high, medium and low ranking. A high rank indicates a near-term project will be needed with a combination of the available funding. Medium and low ranks show need of a refinement plan for mid-term and long-term projects to be amended back into the TSP.

Capacity analysis of the TSP's roadways was performed using the Highway Economic Requirements System – State Version (HERS-ST).

- State highways used existing 2006 HPMS data from ODOT's Integrated Transportation Information System (ITIS). Exhibit 7-10 shows the HERS-ST calculated v/c ratios for state highways in the TSP.
- County roadways use HPMS data developed from the base Deschutes County travel demand model (e.g. Annual Average Daily Traffic (AADT) volumes, speeds, number of lanes), data provided by Deschutes County (e.g. truck percentages), an assumed average K-factor of 15 percent and some national default values in the HERS-ST analytical program for unattainable data.

Exhibit 7-10: Scenarios 1 and 2 V/C Ratio[1] Ranges on State Highways



[1] V/C ratios were calculated by HERS-ST

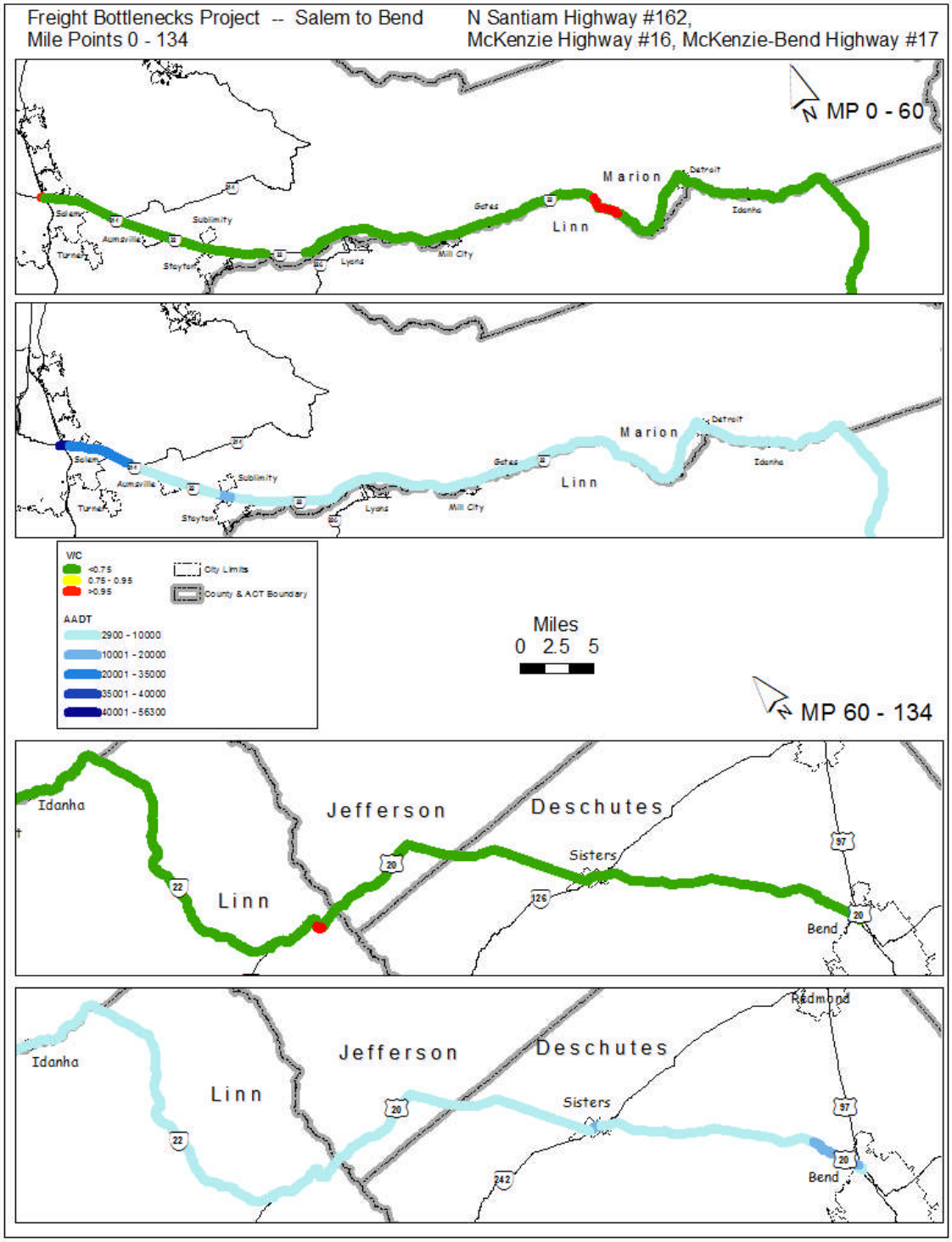
System/Policy: Freight Bottlenecks Project

The Oregon State Highway Performance Data and Metrics Related to Freight study described highway corridor performance and economic use in order to support informed decisions by identifying and prioritizing transportation investments. The study was intended to reveal locations with performance issues related to freight, and support strategic prioritization of additional refined traffic analysis necessary to develop bottleneck solutions. The report was prepared in support of an effort to identify freight bottleneck locations. Nineteen corridors were evaluated.

HERS-ST and the Oregon Statewide Integrated Model (SWIM) were used in the study. HERS-ST was used for this study to provide metrics including average annual daily traffic, daily vehicle miles traveled (VMT), truck share of traffic, annual hours of delay, volume to capacity ratios, highway user costs, vehicle operating costs, and vehicle travel time costs.

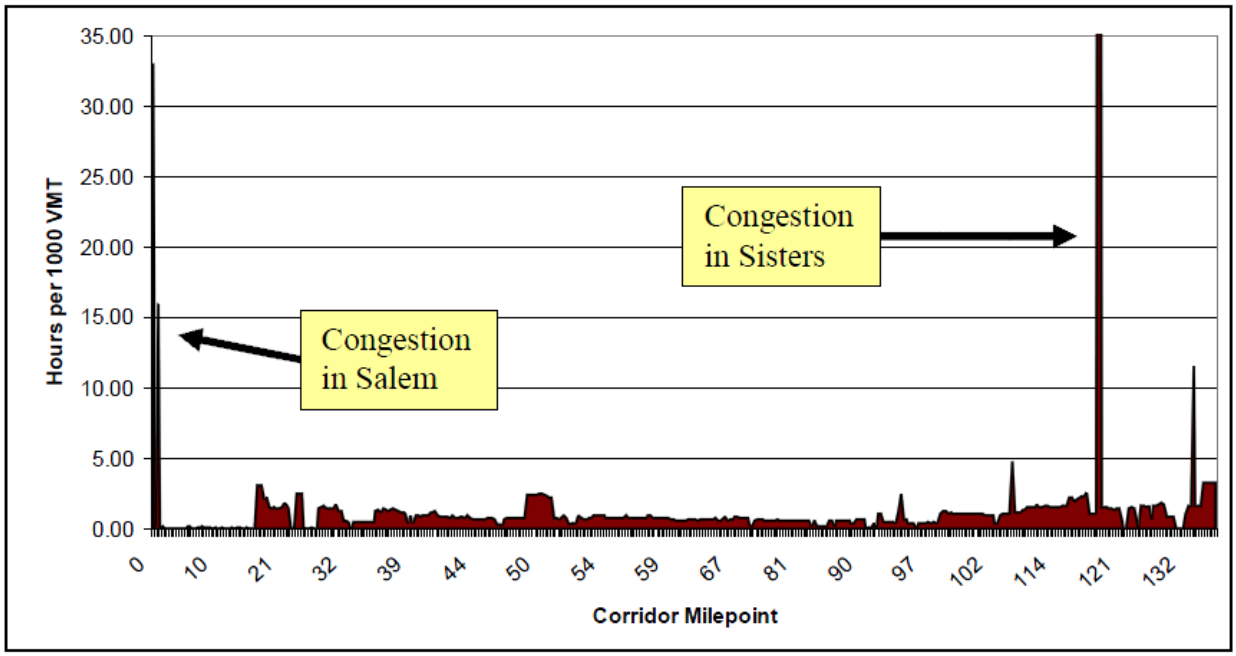
Example HERS-ST outputs from this study are shown below for the OR 22/US 20 Salem to Bend corridor in Exhibit 7-11 and Exhibit 7-12.

Exhibit 7-11: Freight Bottlenecks Project – Salem to Bend



Source: Freight Corridor Study, Figure 46.

Exhibit 7-12: Annual Average Delay: Hours per 1000 VMT (OR 22/US 20 Salem to Bend)

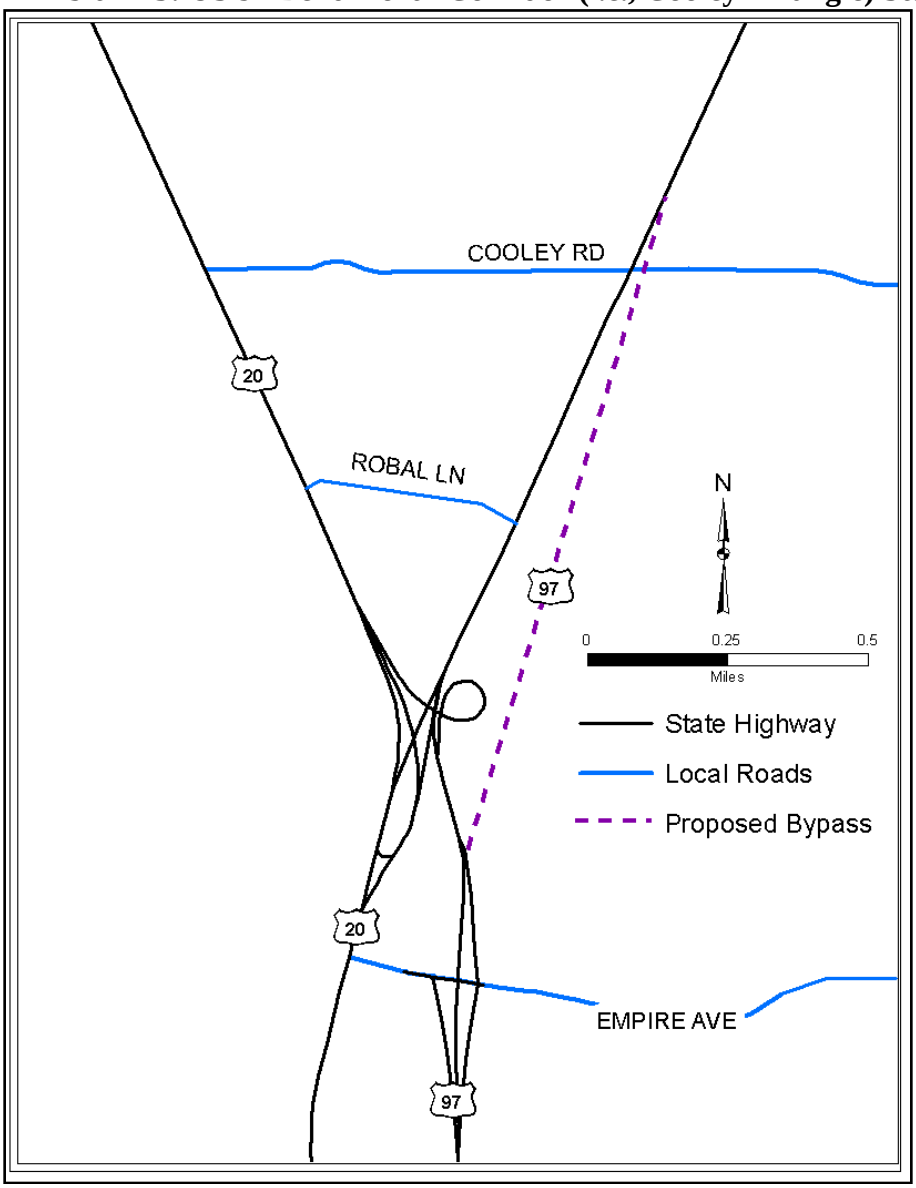


Source: Freight Corridor Study, Figure 47.

Project: Bend North Corridor Bypass Alternative

Over the past decade, the northern area of the City of Bend has undergone considerable business growth and change. The area known locally as the "Cooley Triangle" has been the location of choice for many retail organizations moving into this Central Oregon community (Exhibit 7-13).

Exhibit 7-13: US 97 Bend North Corridor (i.e., Cooley Triangle) Study Area



The original costs for the larger-scale alternative solutions recommended to address the transportation needs were estimated at $350-$400 million, which far exceeded the region's available funding stream for the next 20 years, so the likelihood of full funding seemed unlikely. The project team sought to investigate smaller-scale solutions that would begin to address the system needs at a more reasonable cost. The HERS-ST analysis was undertaken to help inform decision-makers on the range of funding levels that could produce the highest value to the state.

This project analysis evaluated changes in long-range system performance measures and looked at economic benefits for improving the roadway system based on a generic benefit-cost ratio (BCR) concept. A number of system performance measures were evaluated using the state version of the Highway Economic Requirements System (HERS-ST). Based on the BCR concept, the analysis looked at economic benefits for a

no-build and build scenario.

The No-Build Scenario was the existing roadway system, with no signal or widening improvements. The No-Build scenario is the base case that reflects the existing system layout, assuming that no improvements are made other than routine maintenance. Separate HERS-ST input datasets were built for each of the five roadway alignments. The dataset development process began with importing key traffic data elements provided by the Transportation Planning Analysis Unit (TPAU), such as base and horizon year average annual daily traffic (AADT), truck percentages for single units and combinations, peak hour traffic factors, direction factors, signal control locations and lane configurations. The input data was checked using the Oregon Department of Transportation's (ODOT) video log and on-line mapping images to ensure that the data correctly reflects the existing condition.

The pavement condition was defined as "perfect" at the beginning of the analysis period in order to minimize improvement analysis within HERS-ST and to avoid introducing an additional complication factor in the BCR analysis. It was generally assumed that the pavement condition would continue to deteriorate over the 20-year analysis period and that resurfacing would be required at or near the end of the analysis period. The local costs for resurfacing, when warranted, use national improvement costs.

The Build Scenario added a new bypass alignment, as well as some moderate widening and intersection signalization improvements, on several roadway systems within the immediate area. The Build scenario is based on the "Alternative East DS2 Modified" traffic analysis data provided by TPAU. Various data element changes were applied to the Build scenario dataset to reflect the proposed project improvements for the roadway systems. The easterly bypass alignment was coded as an urbanized expressway with full access control, and the number of lanes and speed values were coded as two lanes per direction and 45 miles per hour (mph), respectively.

The HERS-ST model evaluated each scenario as if it were operational at the beginning of the analysis period. The analysis addressed the question, "What is the long-range system user costs and performance for this condition?"

The regional significance of the US 97 bypass project and five roadway alignments were identified as key transportation facilities for analysis within the immediate area of the proposed project. Both Build and No-Build scenario datasets were developed for the five alignments (10 datasets total) and the HERS-ST model was used to evaluate and compare the system condition and performance for each alignment, as well as the total user costs. The average segment peak speed, peak delay, and volume-to-capacity ratio (VCR) analyses showed reasonable improvement for the Build scenario, as compared with the No-Build scenario.

The performance improvements are due to the added bypass alignment and the other improvements to the local infrastructure that enhance the flow in and through the project area. The bypass alignment pulls a large number of trips off the existing US 97

alignment that are considered "pass-through" trips because they do not stop within the project area. Pulling the pass-through trips out of the general flow has advantages both to the general performance of the regional system and to safety and travel cost savings as well. As a result of the improved flow, the travel time, operational costs and crash costs are reduced for the general users of the facilities, which can be directly measured with the BCR analysis.

The capital improvement cost was evaluated using two different contingency costs: 25% and 40%. The analysis showed a BCR range of 1.48 and 1.40 for a 25% and 40% contingency, respectively. Exhibit 7-14 shows the 25% contingency table as an example. These numbers are rough estimates for high level planning purposes. A detailed analysis should be conducted to develop a precise BCR.

Exhibit 7-14: Summary of BCR – 25% Contingency Costs

Roadway	No-Build ($)	Build ($)	Diff ($)
US 97	1,514,900,000	1,456,800,000	58,100,000
US 20	825,100,000	771,500,000	53,600,000
Cooley Rd.	203,000,000	188,700,000	14,300,000
Empire Ave.	244,000,000	230,700,000	13,300,000
Robal Rd.	54,500,000	49,800,000	4,700,000
Total	**2,841,500,000**	**2,697,500,000**	**144,000,000**
Total Net Benefit			$ 144,000,000
Residual Value			$ 111,400,000
Total Capital Improvement Cost (25% Contingency)			$ 172,600,000
Benefit-to-Cost-Ratio (BCR)			1.48

Arterial: Seaside (US 101)

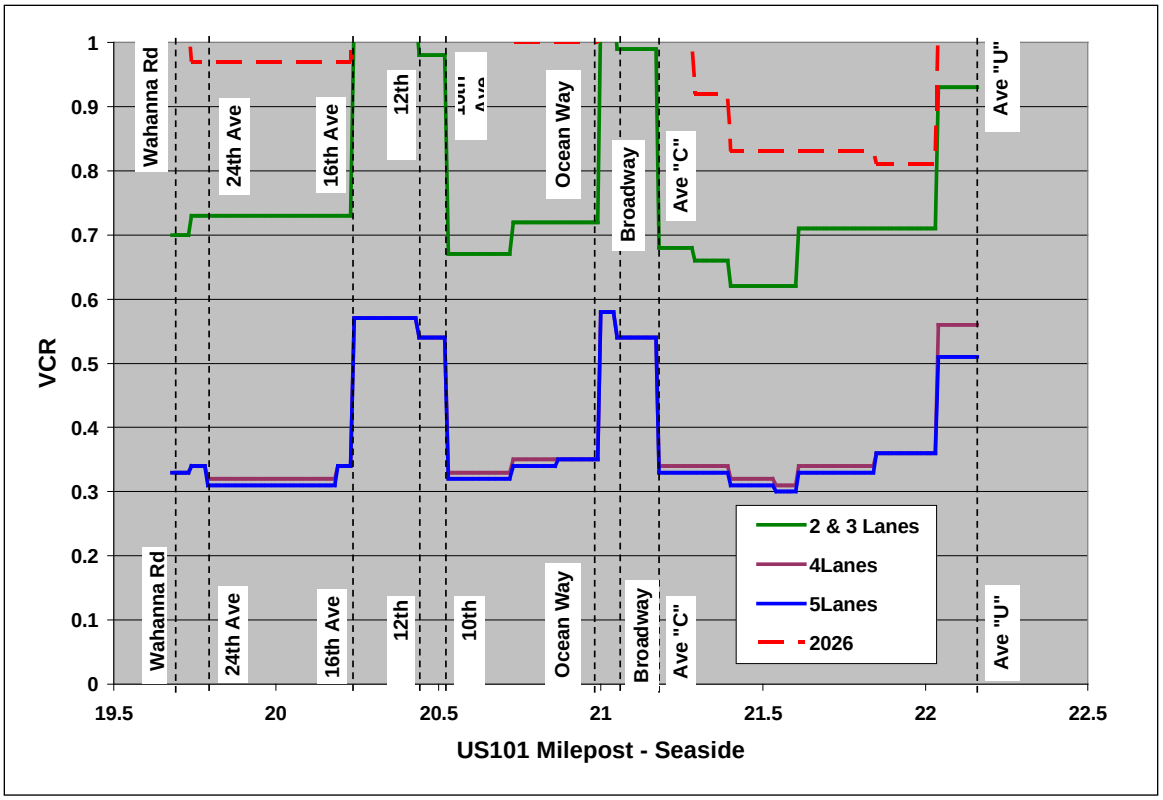
HERS-ST was used to evaluate US 101 performance through Seaside, Oregon. The termini for this project were from Wahanna Rd (M.P. 19.68) at the north to Avenue "U" (M.P. 22.17) at the south. The total length of the highway segment was 2.4 miles.

The HERS-ST dataset was double checked using aerial imagery, such as Google Earth. The checking process verified the intersection locations, the shoulder and median types, and the location and number of through and turning lanes. Three signalized intersections were found on this segment of US 101 through Seaside: at 12th Ave (M.P. 20.44), at Broadway St (M.P. 21.05), and at Avenue "U" (M.P. 22.17).

Four scenarios were developed and run for this project: 2Lane (Existing Condition), 3Lane, 4Lane and 5Lane. For this analysis, average speed, average delay, volume-to-capacity (VCR) and total user costs were evaluated. All four of these measures are outputted individually for each of the 18 segments. The sectional outputs were compiled and graphed in Exhibit 7-15 through Exhibit 7-17, below. By plotting along a profile of US 101, the analyst can see how each performance measure varies along the entire US 101 alignment.

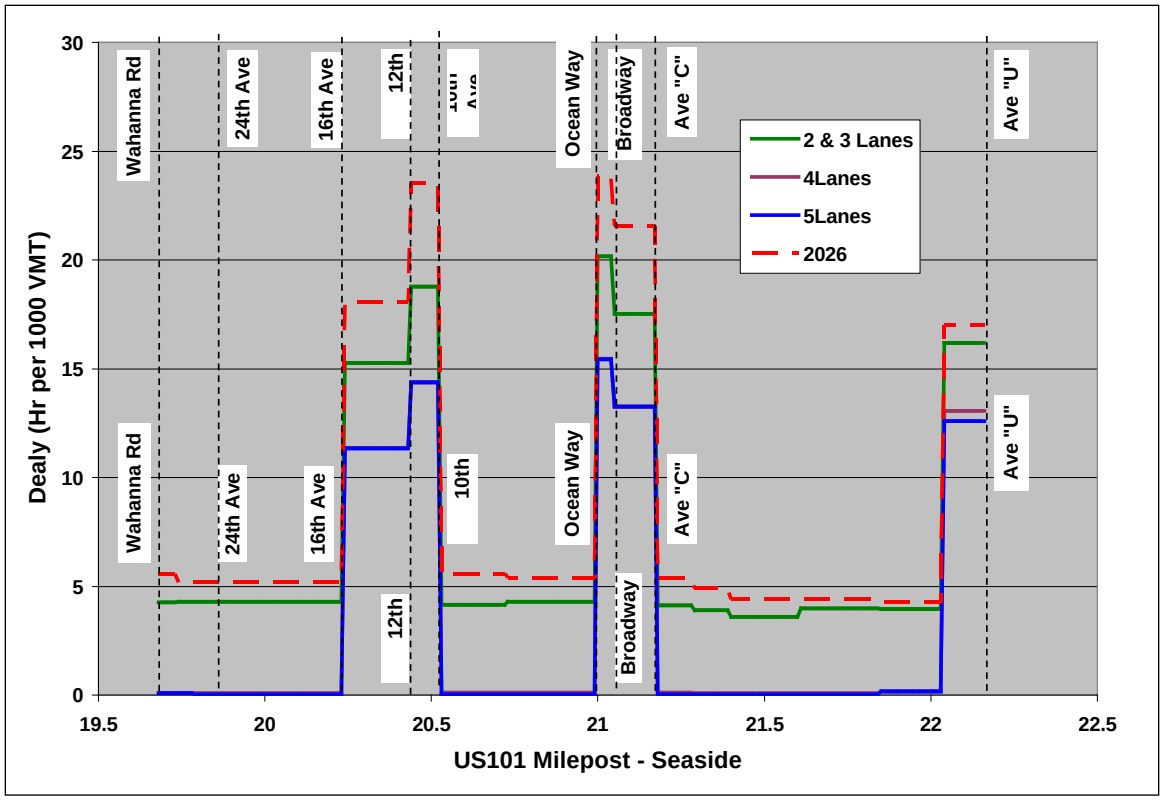
The VCR analysis of all four scenarios is shown in Exhibit 7-15. The volume-to-capacity ratio (VCR) is often used to identify congestion and define performance on the roadway system. The HERS-ST model uses refined HCM formulas to calculate peak VCR for each segment. It should be noted that HERS-ST does not produce intersection VCR.

Exhibit 7-15: US 101 – Volume-to-Capacity



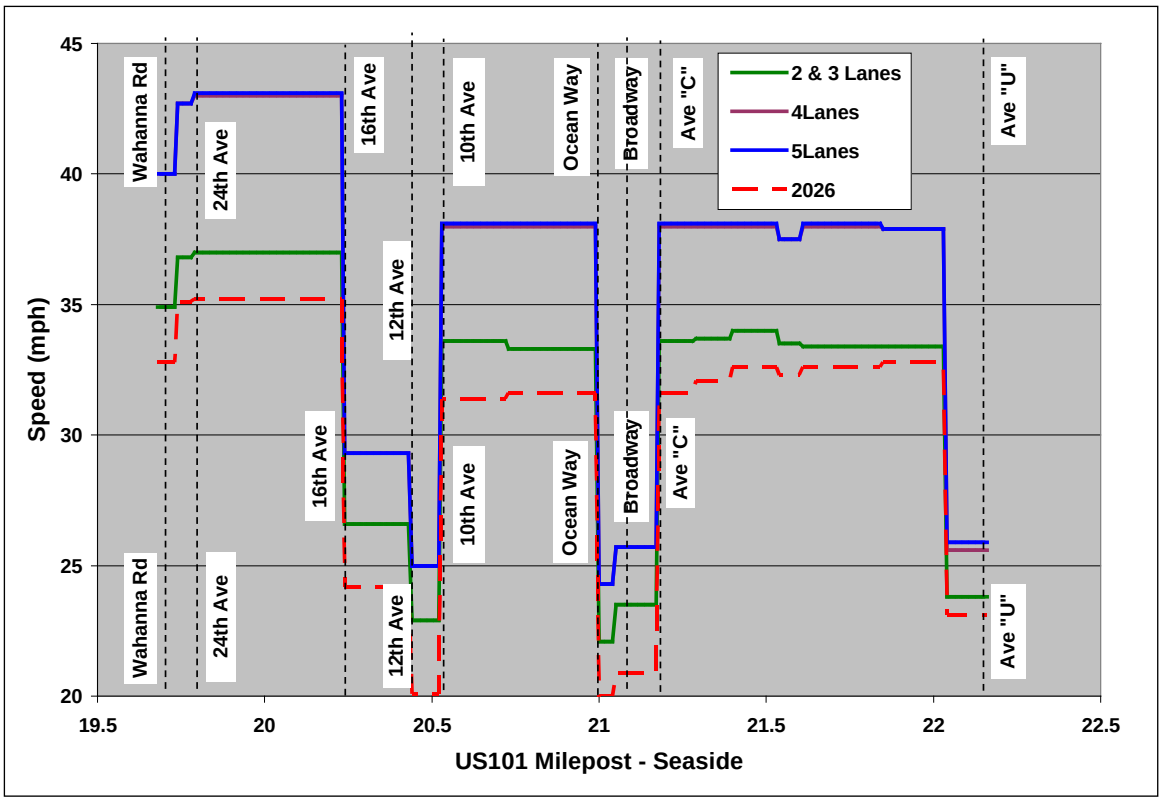
Average Peak Delay is plotted for each scenario in Exhibit 7-16. As expected, the highest level of delay is associated with signalized intersections.

Exhibit 7-16: US 101 – Hours of Delay



The average speed along US 101 for the four scenarios is shown in Exhibit 7-17. As expected, the average speeds decreases around the signalized intersections, suggesting a level of congestion due to restrictions on traffic movement due to the control. As with the VCR and Delay analysis, the Speed analysis shows no difference in the average speed for the Existing and 3Lane scenarios.

Exhibit 7-17: US 101 – Average Speed



7.4 Statewide Integrated Model (SWIM2)

7.4.1 Introduction/Purpose

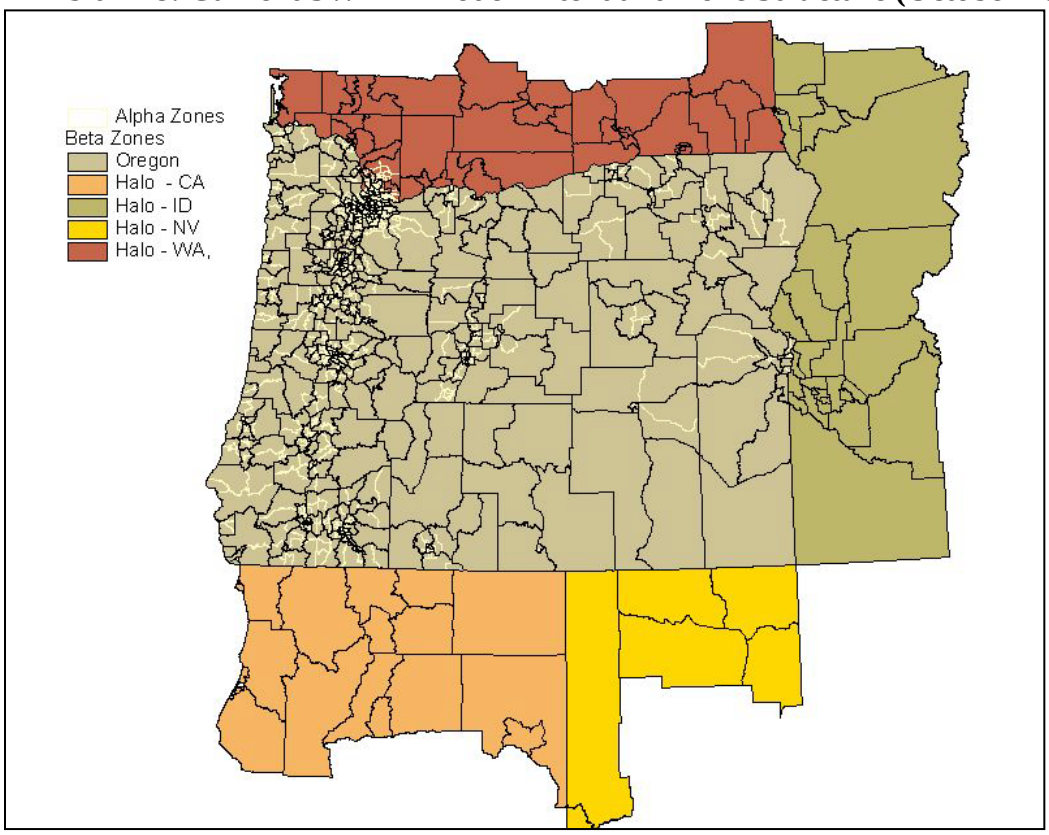
Transportation, land use and economics are all interwoven. Oregon's SWIM2 model allows regional and statewide policies to be tested to inform decision-makers on the complex interactions between land use, the transportation network, and the economy. SWIM2 has been used to examine a variety of transportation and land use policy actions, investments, and their interactions through time. It is designed to answer questions at a larger scale than the typical regional or small urban travel demand model. Unlike typical travel demand models where land use is the major input, the SWIM2 model uses the economy in terms of gross domestic product (GDP) and models land use and its impact on transportation.

7.4.2 Geography, Zone Size and Network Level of Detail

SWIM2 operates at two geographic levels within the model area (Exhibit 7-18). Both levels encompass all 36 Oregon and 39 (Halo) adjacent state counties. The halo encompasses a roughly 50-mile buffer around Oregon. A system of alpha zones used for trip assignment (light and dark lines in Exhibit 7-18) has the finest level of detail. A system of larger beta zones is used for land use allocations. The External Stations

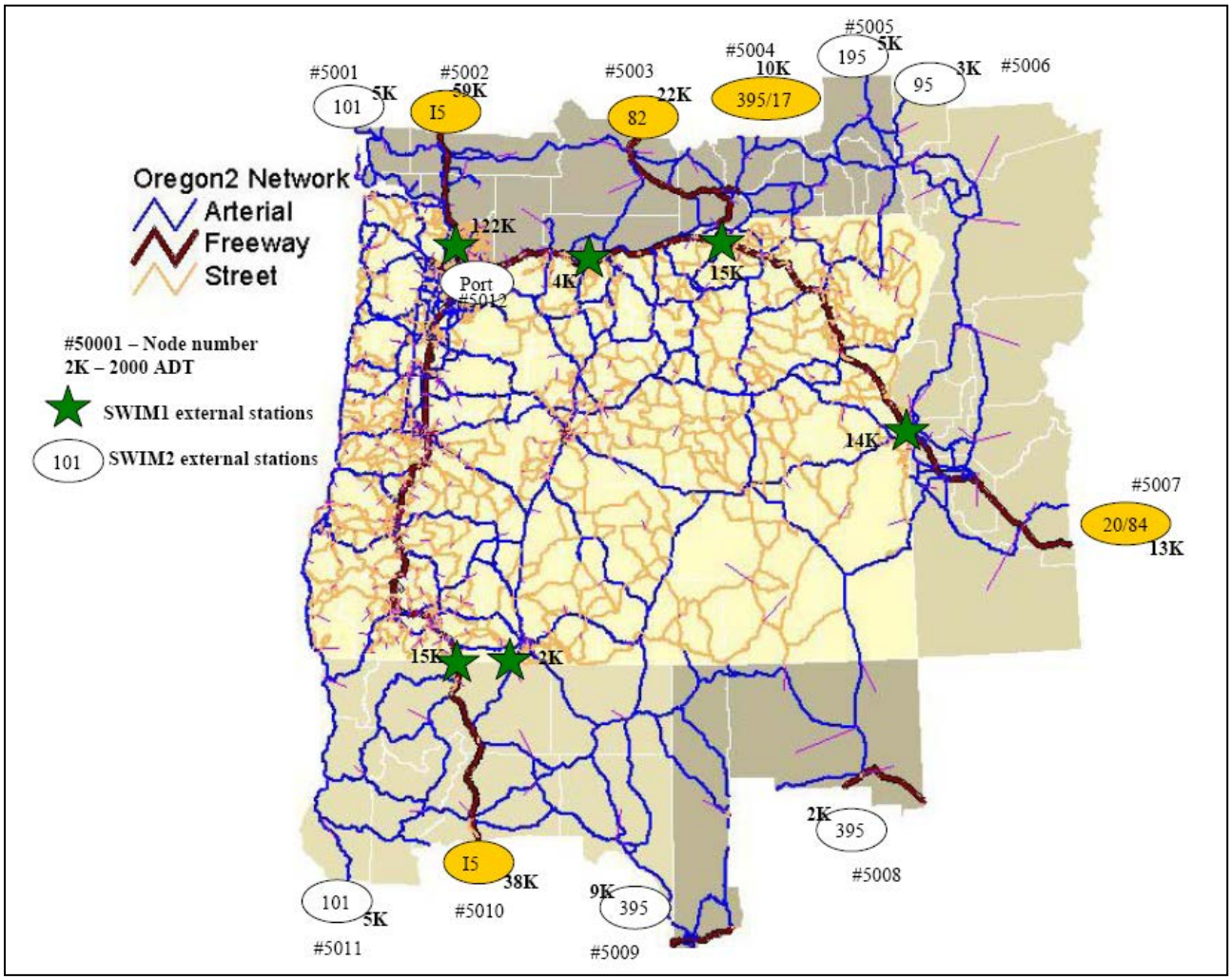
(Exhibit 7-19) serve as model area entry/exit points or gateways to World Market zones.

Exhibit 7-18: Current SWIM2 Model Extent and Zone Structure (October 2010)



Source: 2nd Generation StateWide Integrated Model (SWIM) Model Description - Model Build Documentation November 2010

Exhibit 7-19: Map of SWIM2 External Stations



Source: 2nd Generation StateWide Integrated Model (SWIM) Model Description - Model Build Documentation November 2010

7.4.3 SWIM2 Structure

The SWIM2 model is comprised of the following individually calibrated modules that represent the behavior of the land use, economy and transport system in the sState of Oregon. Because the structure is modular, it allows for updates and improvements to be made with minimal disruption to the full model.

- **ED** – The Economics and Demographics module determines model- wide production activity levels, employment and imports/exports.
- **SPG** – The Synthetic Population Generator module samples household and person demographic attributes (SPG1) and assigns a household to an alpha zone (used for trip assignment) (SPG2).
- **ALD** – The Aggregate Land Development module allocates model-wide land development decisions among study area alpha zones considering floor space prices and vacancy rates.

- **PI** – The Production allocations and Interactions module determines commodity (goods, services, floor space, labor) quantity and price in all exchange zones to clear markets, including the location of business and households by beta zone (used for land use).
- **PT** – The Person Travel module generates activity-based person trips for each study area person in the synthetic population, during a typical weekday.
- **CT** – The Commercial Transport module generates mode split for goods movement flows and generates truck trips, combining shipments and possible trans-shipment locations, for a typical weekday.
- **ET** – The External Transport module generates truck trips from input origin-destination trip matrices representing import, export (within 75 miles) and through movements based on PI and external station growth rates.
- **TS** – The Transport Supply module assigns vehicle, truck and transit trips (separately) to paths on the congested transport network for a 24-hour period, generating time and distance skims for AM and off-peak periods.

The PI module operates on the less-detailed beta zone system (dark lines in Exhibit 7-18) where the external stations are replaced by world markets. The beta zones consolidate (aggregate) the alpha zones, with a focus on the small urban zones. In other urban areas, zones were consolidated based on a sliding population scale (approximately 25,000 persons per zone), respecting similar employment clusters and transportation commute-sheds. In rural areas, homogenous public lands (e.g., BLM, National Forests) were consolidated, while retaining most county and all ACT[23] boundaries.

The world markets assume that goods transport by truck and rail is limited to the US (except Hawaii), Canada and Mexico. Imports and exports to other regions in the world are shipped by barge, either from the Port of Portland or other US east or southeast marine ports.

The ED module estimates production activity, imports/exports and employment exclusively at the model-wide level. Due to data limitations, ED uses an aggregated set of general industry sectors such as Wholesale Trade, Lumber and Wood Products, and Education[24]. ED outputs are disaggregated using fixed relationships into the industry categories used in the SPG and PI modules. These fixed relationships rely on employment and economic data.

7.4.4 Scenario Development

SWIM is intended to respond to large (regional or statewide) projects and policy questions, and is not suitable for fine-grained questions, such as specific land use changes (i.e., a new shopping center) or small network projects (i.e., widening of a 1-mile section of urban road). These kind of smaller requests need to use the appropriate MPO or small

[23] Area Commissions on Transportation (ACTs), used in Oregon transportation planning, provide a convenient way to divide the sState into 12 areas.

[24] For a complete list of Industries and commodities please refer to the Model Build Documentation - 2nd Generation StateWide Integrated Model (SWIM) Model Description

urban model.

Typical inputs would be to make any network modifications like adding a new highway corridor or significant bridge crossing that would affect the regional economy. The inputs are all integrated and provide feedback to each other (i.e. the transport system can affect land use which, in turn, affects the economy). The SWIM2 model network is primarily state highways. City networks are not as detailed as a MPO regional model. Land use inputs involve defining the allowable zoning and capability for each zone type. Economic inputs are based on the GDP by sector at a state level.

Because of its complexity and statewide application, ODOT staff and resources use SWIM2 to develop scenarios. SWIM2 is not to be requested using the standard model request form. Any potential SWIM application requests need to be routed to the TPAU unit manager. Although it is useful for developing and analyzing a wide range of policy alternatives and options, it can require several weeks to run the model to respond to the input changes. SWIM2 outputs are on an annual basis rather than a typical 20-year planning horizon for most travel demand models. Outputs are not intended for post-processing as the model is not to the typical link level of detail. There also is no "official" future no-build to compare to as there is no consistent statewide vision of a future network and zoning. Every SWIM module has generated outputs such as dollars traded by sectors from the PI module or population by zone from the SPG module. These outputs require analysis to be able to "tell the story" of the impacts of a particular scenario.

7.4.5 SWIM Applications

Estimated Economic Impact Analysis Due to Failure of the Transportation Infrastructure in the Event of a 9.0 Cascadia Subduction Zone Earthquake

The purpose of this analysis was to provide high- level estimates of avoidable economic impacts caused by damage to the transportation system from a major seismic event (a 9.0 Cascadia Subduction Zone Earthquake, where the fault breaks along the entire subduction zone – a worst case earthquake scenario). Four alternative scenarios were used to evaluate the impacts of pre-emptive mitigation. This analysis was prepared for the ODOT Bridge Engineering Section, which is evaluating risks and identifying strategies to mitigate seismic vulnerabilities of the state highway system. The scenario approach was designed to provide a general sense of the magnitude and direction of avoidable economic impacts to Oregon from damage occurring on the highway/street transportation system alone (non-transportation losses were not accounted for). This analysis focused on the western portion of the state, defined as the area to the west of the Oregon Cascade Range.

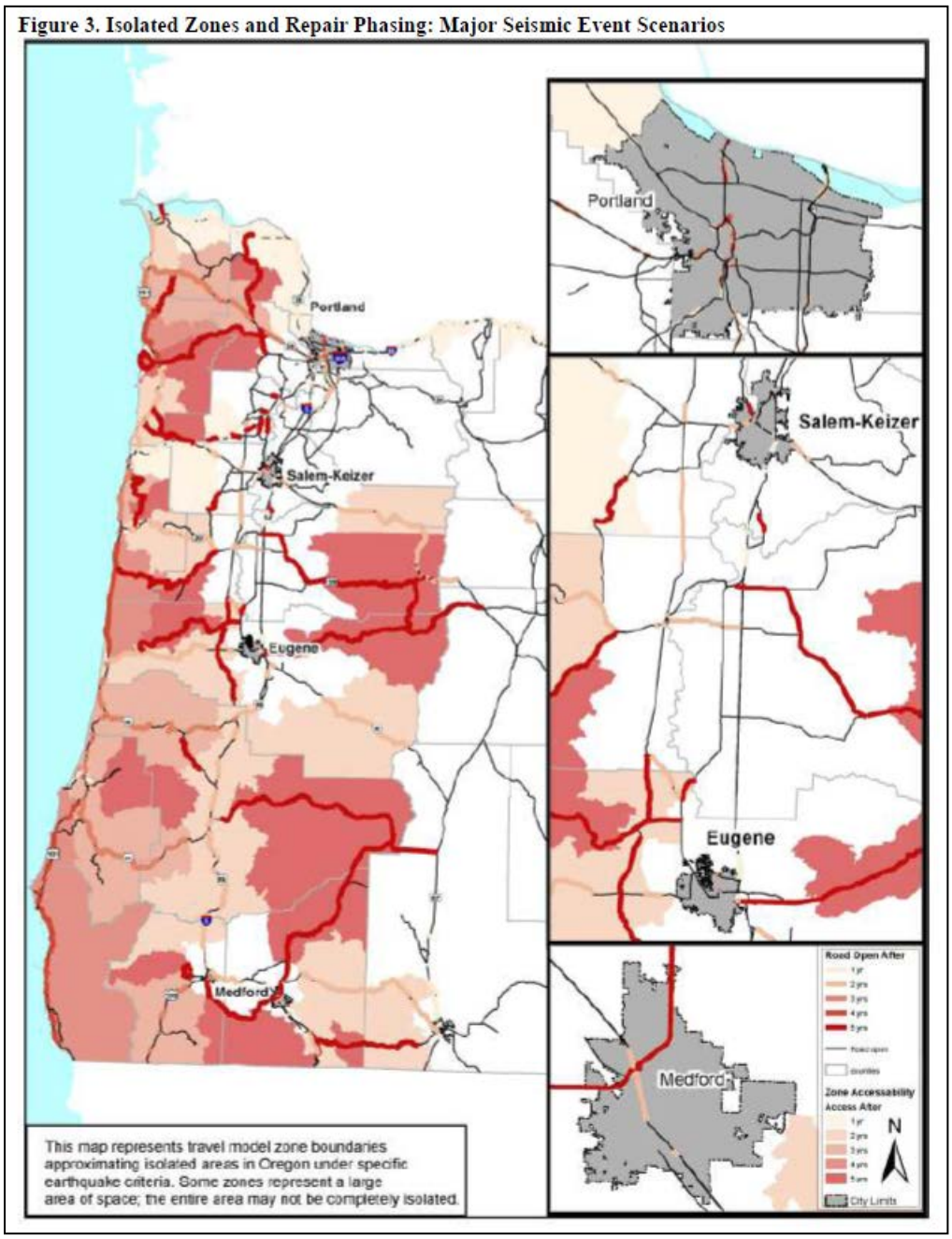
Results of this analysis indicate strengthening corridors before a major seismic event will enable the state to avoid a significant amount of economic loss. Significant economic losses in production activity can be avoided by preparing for a major earthquake ahead of time. With no preparation ahead of time, Oregon could lose up to $355 billion in gross state product in the 8 to 10 year period after the event. Proactive investment in bridge

strengthening and landslide mitigation reduces this loss between 10% and 24% over the course of the eight years simulated for this analysis.

The analysis was conducted using the Oregon Statewide Integrated Model (SWIM). Only the roadway network was altered for the modeled scenarios. Corridors expected to experience damage from a major seismic event were represented as “failing.” The points of failure were identified by the ODOT Bridge Engineering Section for high-use state-owned facilities. For lower use corridors and non-state owned facilities in the SWIM network, adjacent parallel routes within these corridors were altered to maintain consistency in network coding. Nearby facilities with similar proximity and characteristics of those identified to fail were represented to fail in the same manner. The purpose of this analysis was to evaluate the effects of impacts to transportation on economic activity separately, therefore building loss, damage to utilities, other damage or loss of life resulting from an earthquake werewas outside the scope.

Exhibit 7-20 shows the sections of highways affected by failures and areas of isolation. The roadway network is color- coded to illustrate when corridors would be repaired and returned to pre-earthquake conditions. Areas coded with the lightest color regain access to the highway system within one year, where the darkest red areas remain isolated for the full five- year repair period. Isolation means severely limited [(day(s) of travel]) access to markets for the local economy, causing delay in economic recovery.

Exhibit 7-20



Estimated Economic Impact Analysis Due to Failure of the Transportation Infrastructure in the Event of a 9.0 Cascadia Subduction Zone Earthquake Technical Memorandum, ODOT/TPAU, January, 2013.

Eastern Oregon Freeway Alternatives

The 1999 Legislature asked ODOT to look at the results of designating a north-south freeway in Central or Eastern Oregon, from the Washington to California borders. The objectives of House Bill 3090 were to:

- Define a better north-south connection to I-82 in Eastern Oregon
- Increase growth of Central/Eastern Oregon

- Decrease growth in the Willamette Valley
- Decrease travel and congestion on I-5 in the Willamette Valley

The basic approach of this study was to use SWIM to evaluate several alternative freeway scenarios. The alternative scenarios were modeled over a long time horizon because of the amount of time required to build such a freeway and the time would take for land use effects to occur afterward. For the purposes of this study, completion of the freeway was set at 2020 and 2025. Since significant land use effects of major transportation changes take decades to occur, the modeling time horizon was established as 2050. Data for several evaluation measures were extracted from the model outputs in order to determine whether the objectives of the freeway would be accomplished. The objectives and measures are summarized in Exhibit 7-21.

Exhibit 7-21: House Bill 3090 Study Objectives and Evaluation Measures

Objective	Evaluation Measures
• Decrease travel time in Central & Eastern	• Average travel for Central and Eastern Oregon (minutes per passenger mile and minutes per ton mile)
• Increase the amount of travel occurring in Central & Eastern Oregon • Decrease travel and congestion on I-5 in the Willamette Valley	• VMT by region of the state • Average travel time for the Willamette Valley • Traffic growth on I-5 and other selected highways
• Increase growth of Central/Eastern Oregon and decrease in Willamette Valley	• Percent of households by region • Percent of jobs by region

Study of Eastern Oregon Freeway Alternatives Pursuant to House Bill 3090, ODOT/TPAU, April, 2001

The results of the study found that building a new freeway connecting I-82 with California or Nevada to the south would significantly reduce travel time from border to border, but would have little effect on the growth of Central or Eastern Oregon or the Willamette Valley. It would also have little effect on diverting traffic away from the Willamette Valley.

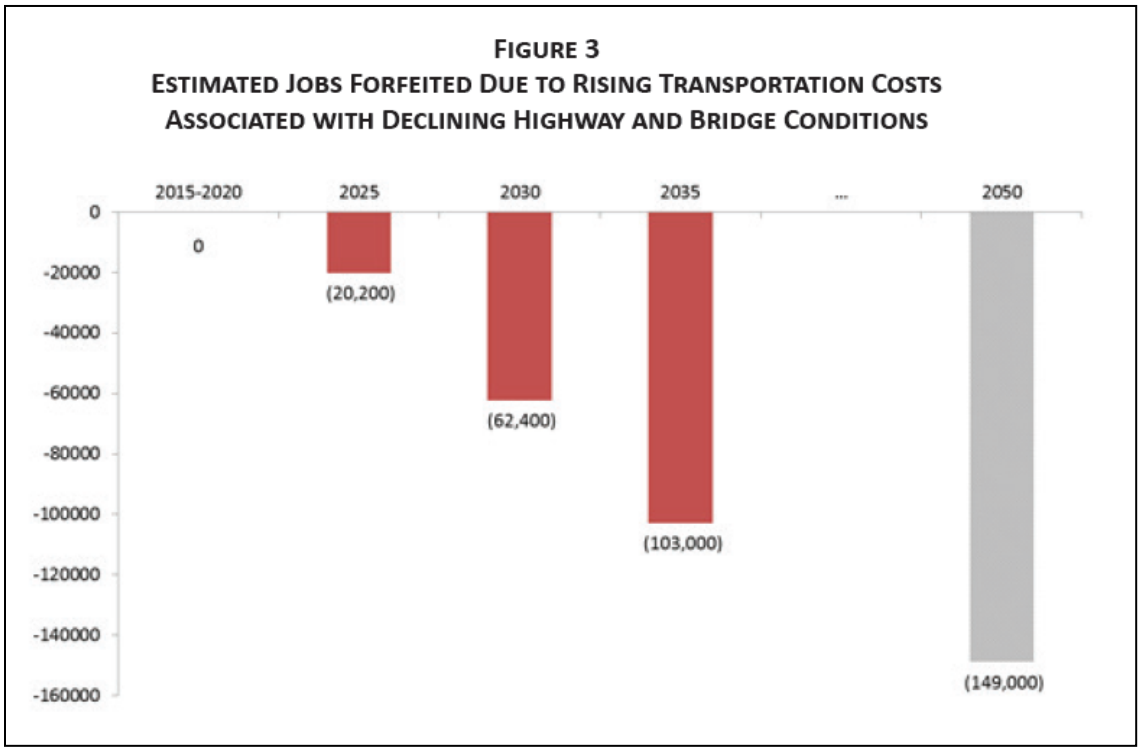
Rough Roads Ahead

The purpose of this analysis is to prepare a high- level strategic comparison between the current forecast budget and an alternative budget designed to preserve current conditions of state highways, roads and bridges. Two funding scenarios were developed for this high- level comparative analysis. The *Current Revenue/Deterioration Scenario* represents the current 20-year ODOT budget forecast for state highway spending. The *Maintain Current Conditions Scenario* represents a 20-year forecast for highway spending designed to preserve current highway conditions. The second generation Oregon

Statewide Integrated Model (SWIM2) is used for the scenario analysis.

One of the results were the estimated number of jobs forfeited due to higher transportation costs imposed in Oregon by declining highway and bridge conditions shown in Exhibit 7-22. Impacts to transportation costs start out small but increase rapidly; within 20 years there is significant impact on the growth of Oregon jobs. The number of estimated jobs lost increases over time. Between year 2025 and 2030 the number triples. By 2035 the number rises another 65 percent.

Exhibit 7-22: Jobs Forfeited



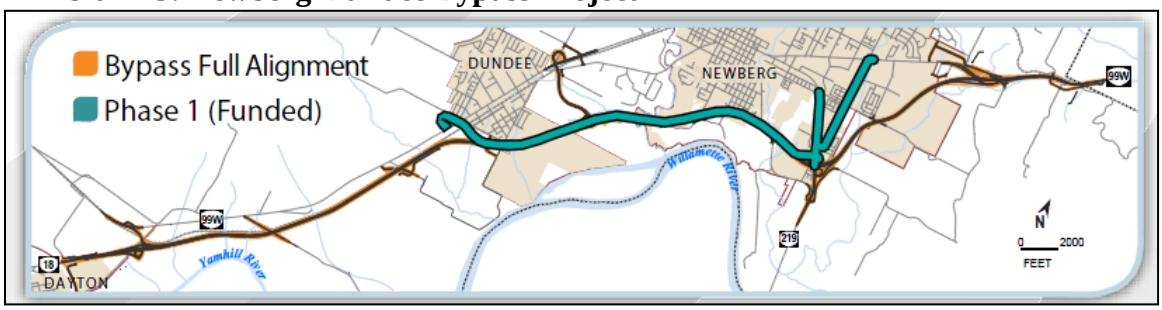
Rough Roads Ahead: The Cost of Poor Highway Conditions to Oregon's Economy, ODOT, 2014
http://www.oregon.gov/ODOT/GOVREL/Pages/Rough-Roads-Ahead.aspx

The results of the study showed that deteriorating state highway conditions can be avoided. ODOT estimates that keeping the state highway system in its current good condition would cost an additional $405 million per year (constant dollars) compared to current budget levels. Given the expected economic losses and additional costs caused by a deteriorating system, the typical household will likely come out ahead with increased public investment in roads.

Newberg-Dundee Bypass

The Newberg-Dundee Bypass project was considered for funding under the Oregon Transportation Investment Act. The project, as shown in Exhibit 7-23, was modeled to assess potential land use, transportation and economic impacts of constructing or not constructing the project.

Exhibit 7-23: Newberg-Dundee Bypass Project



SWIM was used to model two scenarios: a Newberg-Dundee Bypass scenario, and a reference case or No-Action scenario. The distributions of households and jobs for the two scenarios were compared across external zones on the OR 99W/OR 18 corridor representing nearby communities in Yamhill County. Some of the conclusions from this modeling analysis effort were:

- The Newberg-Dundee Bypass will provide better access to McMinnville, which will help to stimulate the economic growth in the community.
- With the Bypass, there will be greater travel for all purposes between McMinnville and the Portland area consistent with the growth of population and jobs in McMinnville.
- Minimal effects will be seen in Newberg and other smaller communities in Yamhill County as a result of the Bypass.

Freight Plan

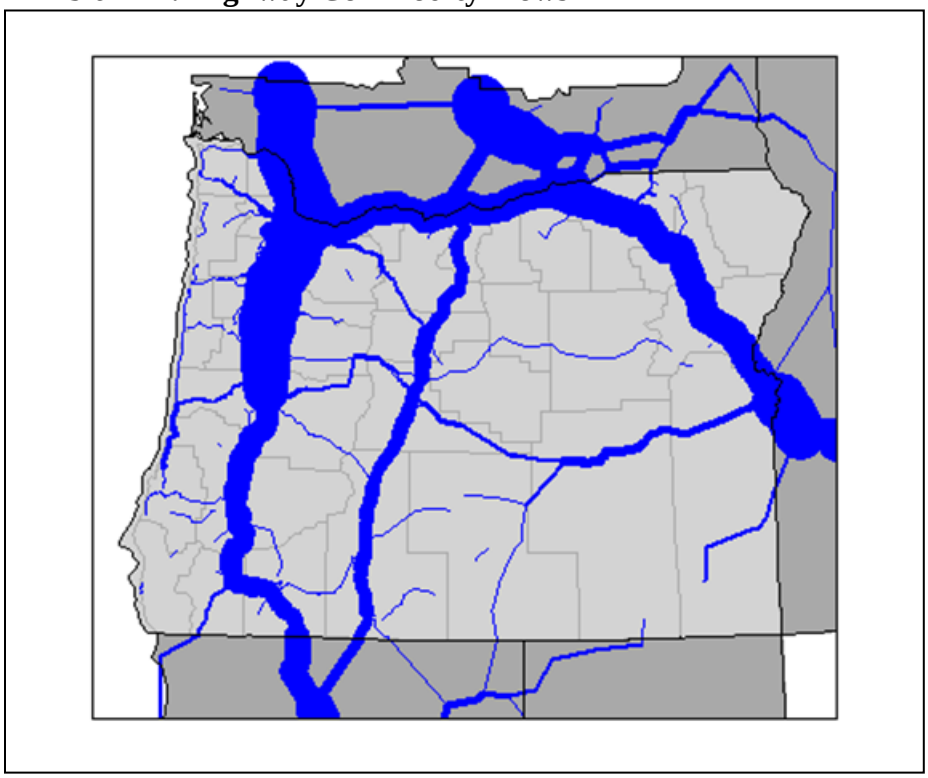
The purpose of the Oregon Freight Plan analysis was to gain an understanding of the spatial land use and transportation implications of different economic conditions. This analysis illustrated the variation in statewide and regional activity and commodity flow in order to help evaluate the risk associated with economic volatility on alternative Freight Plan strategies. As a result of the analysis, decision makers were better able to assess the robustness of freight strategies and avoid the creation of barriers that may prohibit the freight industry from reacting nimbly to economic change.

SWIM was used for this analysis. Four model scenarios were produced: business-as-usual Reference; Optimistic Economic Forecast; Pessimistic Economic Forecast; and High Transportation Cost. Highlights of the analysis findings include:

- Future demands on the freight system will be large, even if economic growth is muted. Economic inertia causes the dominant commodity mix and geographic flow patterns in Oregon to remain intact, with relatively small changes over time under various scenarios.
- Higher per-mile highway transportation costs result in less congestion, providing the impetus for shippers to increase the length of individual truck tours to increase operating efficiency. Higher transport costs result in reduced miles of travel and hours of travel statewide.
- Households relocate to reduce transport costs, causing urban density to rise and statewide auto miles of travel to fall.

- Commodities have unique and diverse patterns and logistics. Transportation services used to move these commodities are just as varied. Maintaining access to markets is key to economic competitiveness.
- The net results of thousands of shippers and buyers of goods and services are complex and, at times, counter intuitive. Modeling the dynamic nature of these forces provides valuable insight into the collective Oregon freight system needs.
- Assessing system performance and economic impacts is multifaceted. Attention must be given to regional issues, commodity characteristics, industry logistics, and employment patterns when evaluating alternative strategies.
- The largest commodity flows are on the I-5 and I-84 corridors, with significant flows on US-97 and US-20. Exhibit 7-24 shows the total commodity flows in the study area.

Exhibit 7-24: Highway Commodity Flows

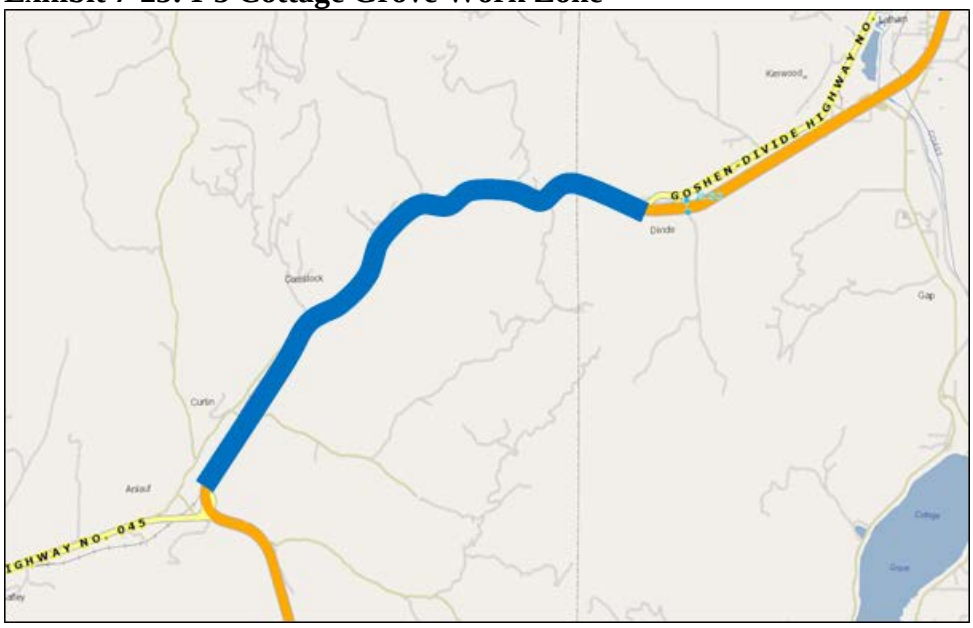


Oregon Freight Plan Modeling Analysis Technical Memorandum, ODOT/TPAU, August, 2010

I-5 Cottage Grove Work Zone

The SWIM network was utilized to answer a question from Region 3 regarding an upcoming pavement replacement project. If VMS signs were in place in the Willamette Valley and in California, what would be the diversion potential away from this section of I-5? Delay was added to the blue portion of I-5 in Exhibit 7-25 below and the model run to determine the potential traffic shifts.

Exhibit 7-25: I-5 Cottage Grove Work Zone



Signage in Eugene and Reedsport has the potential to encourage typical users of OR 38 (, Umpqua Hwy), to use OR 126 (Florence- Eugene Hwy). Signs in Eugene and in California have the potential to encourage trucks and some autos to use OR 58 rather than I-5 when traveling nNorth of Eugene or sSouth into California. Using the statewide model, and engineering judgment it would be reasonable to estimate that with the additional signage there is a possibility to remove between 8%-10% of trucks and 5%-10% of autos from this section of I-5.

7.5 Travel Demand Models (Trip-based)

The intent of the travel demand model is to represent travel decisions that are consistent with the actual travel trends and patterns. The decisions are influenced by the available transportation system, the allocation of households and employment, household socio-economics, and travel costs. Known Oregon travel behavior and relationships from household surveys are used to replicate the impacts on the actual transportation system.

Travel demand models can be used to predict future travel patterns and demands based on changes in the transportation system (i.e., new roads, wider roads with more capacity, closed roads, etc.), changes in the land use (i.e., more residential development, a new industrial site, etc.), and changing demographics (i.e., more or less people in a specific area, access to a vehicle, aging population, etc.).

Travel demand forecasting has the ability to test the impacts of critical “what if” questions about proposed plans and policies. Model results can provide users with a variety of information on travel behavior and travel demand for a specified future time frame, such as forecasted highway volumes for roadways, transit forecasts, the effects of a proposed development or zoning change on the system. They allow planners to analyze the effects of latent demand and other unanticipated impacts to the system.

It is an important tool in planning future network enhancements and analyzing proposed projects and policies. Information from travel demand models is used by decision-makers to identify and evaluate different approaches to addressing transportation issues and to select policies and programs that most closely achieve a desired future vision. See Chapter 17 for more details on model structures, processes, and application elements. RTP

Models can be used to quickly assess the entire MPO planning area which may contain multiple cities and the interactions between them. Use of demand- to- capacity ratios can indicate bottleneck areas or areas that potentially need improvements. Conceptual project scenarios can be added to test impacts of them on the overall network. These can be bundled into groups of projects for specific objectives (capital projects, multi-modal, mobility, etc.). Impacts of land use changes can also be tested, such as in a UGB expansion scenario, nodal development, neighborhood urban centers, etc. Transit and other multimodal benefits can be evaluated depending on the detail of the individual networks (i.e. walk, bike and transit) and zone structure. If the model has enough detail, such as economic sensitivities, items like congestion pricing, parking pricing, and tolling can be evaluated. Models can also be used to create and evaluate accessibility, connectivity, and equity measures. Some operational strategies can be modeled such as TDM or ramp metering. Projects that come out of modeling are generally high level such as “Widen to four4 lanes”, or “Add overcrossing”, etc. which are consistent with the general level of detail available.

TSP-IAMP-Refinement Plans

TSPs, IAMPs and refinement plans typically deal with smaller areas or individual facilities or corridors. Like with the larger regional (MPO) areas, models can evaluate across a single city to determine capacity constraints to eventually determine project concepts. Modeling will be generally more specific such as adding or modifying roadway connections such as a new interchange. Individual facilities can be tested with different speeds or number of lanes or one-way/two-way directions to determine the impact on the city. Land use scenarios with differing levels of growth can be evaluated and compared with a baseline scenario from a localized zone to the whole city.

Some areas have air quality issues that require them to go through an air quality conformity basis which requires improvements on the system not to add more emissions than the specific target values. These can be for CO or particulate matter (PM). Trapped PM from woodstoves has been the focus of most Oregon AQ issues such as in Grants Pass and Klamath Falls. The overall roadway network including any improvements is based on VMT and run through the MOVES emission tool. Models streamline the process by allowing testing of multiple strategies with different mixes of projects. Certain projects could lessen VMT and emissions if trip are shortened or mode shifted or allow travel at faster speeds. Conversely, some projects like a new interchange could encourage travel and increase VMT and emissions. It is this balance that needs to be obtained in the conformity process.

7.5.1 ABM

The Activity-Based Model (ABM) is a computer-based model used to estimate travel behavior and travel demand for a specific future time frame, based on a number of assumptions. It includes elements such as roadway and transit networks, a synthesized population and employment data, socio-economic characteristics, and travel costs. It deals with individual persons with a rich set of attributes that influence travel and linked trips or tours (i.e. home to shop to work) instead of groups of households and separate trips (i.e. home to shop and shop to work). This type of model has the ability to answer questions in finer detail. For example, demographics of individual users (i.e., low-income users) can be forecasted versus just a single number of trips by purpose from a zone. The ABM micro-simulates tours which are groups of linked trips (i.e. trip chaining) as that is how trips actually occur. This provides much more context for trips that do not begin or end at home (e.g., mode for lunch trip depends on if work commute mode), and allows household interactions for shared vehicle use. Microsimulation of households and persons over an entire day of travel enables the evaluation of pricing strategies in the context of a household budget. An ABM does everything the trip-based travel demand model does, but with considerably more behavioral content.

The ABM introduces two levels of zones with the typical transportation analysis zone (TAZ) created at the census block level and the micro-analysis zone (MAZ) at the parcel level. The non-auto modes are captured better because of the smaller MAZ structure which will make shorter trips more evident.

The ABM application is best used for providing the required detail for long range regional transportation plans (RTP) required by the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) for metropolitan areas. Currently, ABM is under development for some MPO areas in Oregon.

7.6 Regional Strategic Planning Model (RSPM) (aka GreenSTEP)

Introduction/Purpose

RSPM allows for strategic planning and testing of policy scenarios. Strategic Assessment is the first step in strategic planning. It assesses financially constrained adopted plans and does sensitivity tests of more ambitious plans and resilience to other future trends (e.g., fuel price). Scenario planning results in a preferred scenario. Metro & Lane Council of Governments (LCOG) were required to develop a preferred scenario by legislation. Metro also had to implement the preferred scenario in plans. CAMPO is to run a number of scenarios with RSPM that precede and inform local plans. These local plans will use more detailed traditional tools to implement the plans. For more information on scenario planning/strategic assessments see
http://www.oregon.gov/ODOT/TD/OSTI/Pages/scenario_planning.aspx

The strategic nature allows a broad view of policies associated with the development of land use, transportation, energy production, and economic development. These policies can be tested for resilience under uncertainties such as changing demographics, new untested technology solutions, and limited funding. The limited detail allows many high-level policy scenarios to be evaluated. RSPM captures policy interactions by micro-simulating reactions of individual households, primarily using relationships found in the National Household Transportation Survey. RSPM uses simplified inputs and relationships in order to facilitate quick run times for the policy tool. It sets the strategic components (e.g., doubling transit service miles), which complements more detailed traditional models (travel demand models, ABMs) that can be used to develop implementation details (e.g., new transit corridors and/or increased stop frequency).

RSPM produces high-level community outcomes (outputs) such as household travel (average daily VMT to all locations, congestion), health (active mode travel, air quality indicator),[25] environment (GHG emissions), economy (travel costs such as fuel, fees/taxes, and parking), etc. RSPM can comprehensively evaluate sets of local strategies, providing measures to help planners and decision-makers assemble programs to achieve the desired community vision/outcomes acceptable to policy-makers. RSPM is sensitive to factors and new policies (i.e. car-sharing) that traditional travel demand models do not include. A key component of RSPM is that it models changes using a budget-based process that enables analysis of policies based on constraints where existing data is limited or does not exist. It also enables analysis of the travel response to pricing (e.g. pay-as-you-drive insurance). RSPM does not include an explicit roadway or transit network, but instead uses supply and demand relationships by functional class to approximate congestion and Intelligent Transportation Systems (ITS) policy impacts.

The RSPM model estimates vehicle ownership, vehicle travel, fuel consumption, and GHG emissions at the individual household level. This structure accounts for the synergistic and antagonistic effects of multiple policies and factors (e.g. gas prices) on vehicle travel and emissions. For example, the battery range of electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) is less of an issue for households residing in compact mixed-use neighborhoods because those households tend to drive fewer miles each day. Modeling at the household level makes it possible to evaluate the relationships between travel, emissions and the characteristics of households, land use, transportation systems, vehicles, and other factors. In addition, household level analysis makes it possible to evaluate the equitability of the costs and benefits of different strategies.

General categories of RSPM inputs are shown in Exhibit 7-26. For more information on the inputs, see the RSPM User Guide Appendix 1 and 2.

[25] RSPM has been connected to the ITHIM (Integrated Transport and Health Impact Modeling) Tool in Portland and Eugene studies, allowing burden of disease (air quality and active mode travel) and safety outcomes.

Exhibit 7-26: General RSPM inputs

Regional Context	Local Actions		Collaborative Actions	
	Community Design	Marketing & Incentives	Fleet & Technology	Pricing
• Demographics • Income Growth • Fuel Price	• Future Housing (Single- & multi-family) • Parking Fees • Transit service • Biking • Roads	• TDM (home & work-based) • Car sharing • Education on Driving Efficiency • Intelligent Transportation Systems	• Vehicle Fuel economy (mpg) • Fuels • Commercial Fleets	• Pay as you drive insurance • Gas taxes • Road user fee

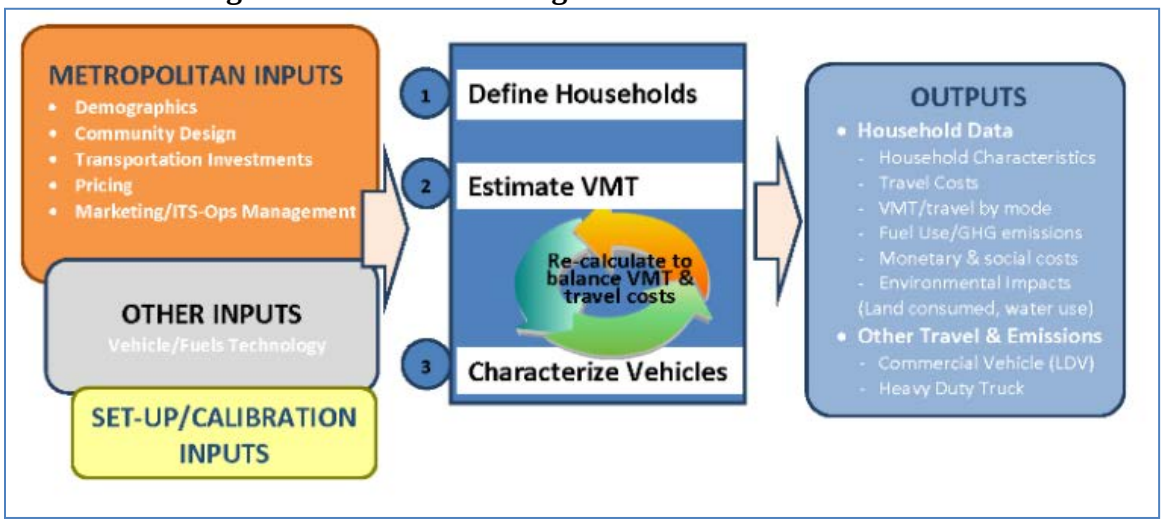
RSPM simulates how the following characteristics could impact the community outcomes:

- Demographics Trends – Household income, age mix, household size, university group quarters
- Community design
  - Urban characteristics, such as land use (density, mixed use), alternative modes (public transit, non-motorized transportation), and parking management.
  - Road characteristics, such as the supply of freeways and other arterials and the management of incident delay.
- Marketing & Incentives
  - Marketing characteristics, such as the deployment of employer-side and household-side travel demand management programs.
  - Efficiency education programs such as eco-driving, low-rolling resistance tires, and pay-as-you-drive insurance.
- Vehicles & Fuels – for personal and commercial service vehicles
  - Vehicle and fuels technology characteristics, such as fuel economy, proportions of electric vehicles, and fuel carbon intensity.
  - Vehicle fleet characteristics, such as the proportions of autos and light trucks and the age distribution of vehicles.
- Pricing
  - Prices, including fuel price, fuel taxes, mileage taxes (e.g., to cover road costs), congestion charges, and recovery of externalities or social costs, e.g, carbon taxes.

RSPM operates at the individual household level. The treatment of assumptions that determine travel characteristics is simplified, enabling the model to have a high degree of policy sensitivity and interactivity and yet be easy to set up and run quickly. RSPM links a series of submodels that forecast outputs, such as vehicle ownership and household daily VMT. The demand side of the model is disaggregate; it includes a synthetic

population generator and an auto ownership model. The supply side is handled in an aggregate way without a detailed transportation infrastructure network. RSPM can be run at a state or MPO level. The MPO level uses census tract level districts to represent different neighborhoods, while the state tools uses county zones to be responsive to regional differences. Exhibit 7-27 illustrates the RSPM process. The model distinguishes between households living in metropolitan, other urban and rural areas to reflect their different characteristics in terms of density, urban form, transportation system characteristics, and demand management programs. The environmental outputs of the model include fuel consumption by fuel type, electric power consumption by electric vehicles, and CO_2 equivalents for fuel and electric power consumed.

Exhibit 7-27: Regional Scenario Planning Model Process



Data requirements are available here in a checklist: http://www.oregon.gov/ODOT/TD/OSTI/docs/Checklist.pdf. For more information on RSPM and its application, please see the User's Guide: http://www.oregon.gov/ODOT/TD/OSTI/docs/RSPM_UG_20140107Draft.pdf

RSPM is intended to be used in an environment where there are many unknown policy implementation details (e.g. doubling transit service-miles) combined with uncertainty about factors that may or may not be controllable. RSPM is intended to be run at the statewide (at county resolution) or MPO (Census tract resolution) level. It could be run on smaller areas if data is available. RSPM requires construction of a base-year scenario using local data which is then calibrated with Census data (i.e. household size and income). RSPM is predicting household travel, so a conversion factor is necessary from a travel demand model or HPMS to create roadway-based travel within the MPO. Contact TPAU for inquiring about use of RSPM for an application.

Outputs

The primary outputs of the RSPM are household travel, fuel and power consumption, and GHG emissions calculations, but other information is produced for households and commercial vehicles as well. The amount of commercial (light-duty) and freight (heavy-

duty) travel is calculated as well as associated fuel, power consumption and GHG emissions for those vehicles. In addition, heavy vehicle travel, fuel and power consumption, and emissions are calculated. The RSPM User Guide Appendix 4 gives the full list of MPO-based outputs and their definitions. Examples of statewide assessment outputs are available in the RSPM User Guide Outputs section (Page 14).
Typically, RSPM scenario development includes a large amount of unknowns and potential combinations to explore the future uncertainties. This can result in hundreds if not thousands of individual runs. Interactive web-based visualization tools have been developed to effectively access a large number of previously run scenarios allowing users to explore the tradeoffs and outcomes of various policy investment mixes.

Applications

The typical MPO application for RSPM is the strategic assessment. A strategic assessment uses the Regional Strategic Planning Model (RSPM) to estimate future GHG emissions and other outcomes based on state and local conditions. ODOT and DLCD staff work with MPO and local government staff to gather the data needed to develop the model inputs, and ODOT staff runs the model. ODOT and DLCD staffs then work with the MPO staff to develop a report of the model outputs. The report also includes possible next steps for the region**.**

A strategic assessment evaluates the region's adopted plans and policies, assesses how far those plans help the region reach its goals over the next 20 years, and identifies alternative paths to achieving those goals. It also identifies the value of state-led actions such as newer clean vehicles and fuels. Largely a technical exercise, the assessment provides information that can help inform decisions about the future, helping communities to understand where the current path leads and what options exist for the region. This can inform plan updates and general decision-making. Additional work may be desired to help answer specific policy questions or to evaluate scenarios to formulate a vision for the region. If additional work is desired, support for scenario planning or additional analysis may be provided. A short video can be viewed about strategic assessments at http://www.oregon.gov/ODOT/TD/OSTI/Pages/scenario_planning.aspx.

The purpose of the strategic assessment is to estimate travel and emissions likely to result if adopted plans are implemented and current trends continue. The assessment can provide information about:

- Household travel costs
- Transportation and energy costs
- Air quality
- Mixed-use development
- Health impacts
- VMT
- Travel delay
- Fuel consumed
- Walk trips and bike miles

- GHG emissions

The results of a strategic assessment can help the region determine whether current plans and trends are achieving the outcomes the region wants to see, and identify potential actions to better meet the region's goals. The results of the assessment can also help local governments better understand issues and quantify the effect of adopted policies as they review and update the area's transportation plans and make investment decisions. It can also bolster collaboration on policies such as transit, parking, and state-led actions such as implementation of pay-as-you-drive insurance, by quantifying the value of such policies. The effort can inform the public of new policies and the tradeoffs of alternative paths to meet regional goals. In addition, the information provided in the assessment is intended to help local officials decide whether to pursue a more comprehensive analysis of land use and transportation options through formal scenario planning.

Examples

Statewide Applications

Statewide Transportation Strategy (STS): A 2050 Vision for Greenhouse Gas Emissions Reduction (OTC accepted in 2011)

RSPM (previously named GreenSTEP) was built for addressing legislative GHG reduction requirements for ground transportation. The STS process evaluated what it would take to achieve a 75 percent reduction from 1990 GHG emission levels by 2050 statewide. Many policy combinations were evaluated in cooperation with a stakeholder committee in three phases. The STS, through hundreds of runs of the RSPM tool, identified the most effective GHG emissions reduction strategies in transportation systems, vehicle and fuel technologies, and urban land use patterns to accommodate future growth and it showed how collaborative efforts in all areas were required to meet these goals. Beyond reducing GHG emissions, these strategies are expected to reap other benefits, including improved health, cleaner air, and a more efficient transportation system, as noted in the various RSPM outputs. The strategies resulting from the RSPM-based analysis and accepted by the OTC serve as guidance to help meet the state's GHG reduction goals while supporting other societal goals such as livable communities, economic vitality and public health. The STS points to promising approaches that should be further considered by policymakers at the state, regional, and local levels. http://www.oregon.gov/odot/td/osti/pages/sts.aspx

MPO Target Rule

One action following from ODOT's STS is the establishment of GHG reduction targets for each MPO by 2035 by the Land Conservation and Development Commission (LCDC). Although the overall reduction target is set by the legislature, RSPM was used to evaluate the share of this target that could be achieved by state-led actions on vehicles and fuel programs, with the remainder the responsibility for GHG reduction attributed to the local MPOs. RSPM was critical in being able to assess the fleet turnover, multi-modal response to the cost of travel, and land use dependencies (e.g., EV range limitations) important in assessing the impact of new vehicle and fuel technologies across the state.

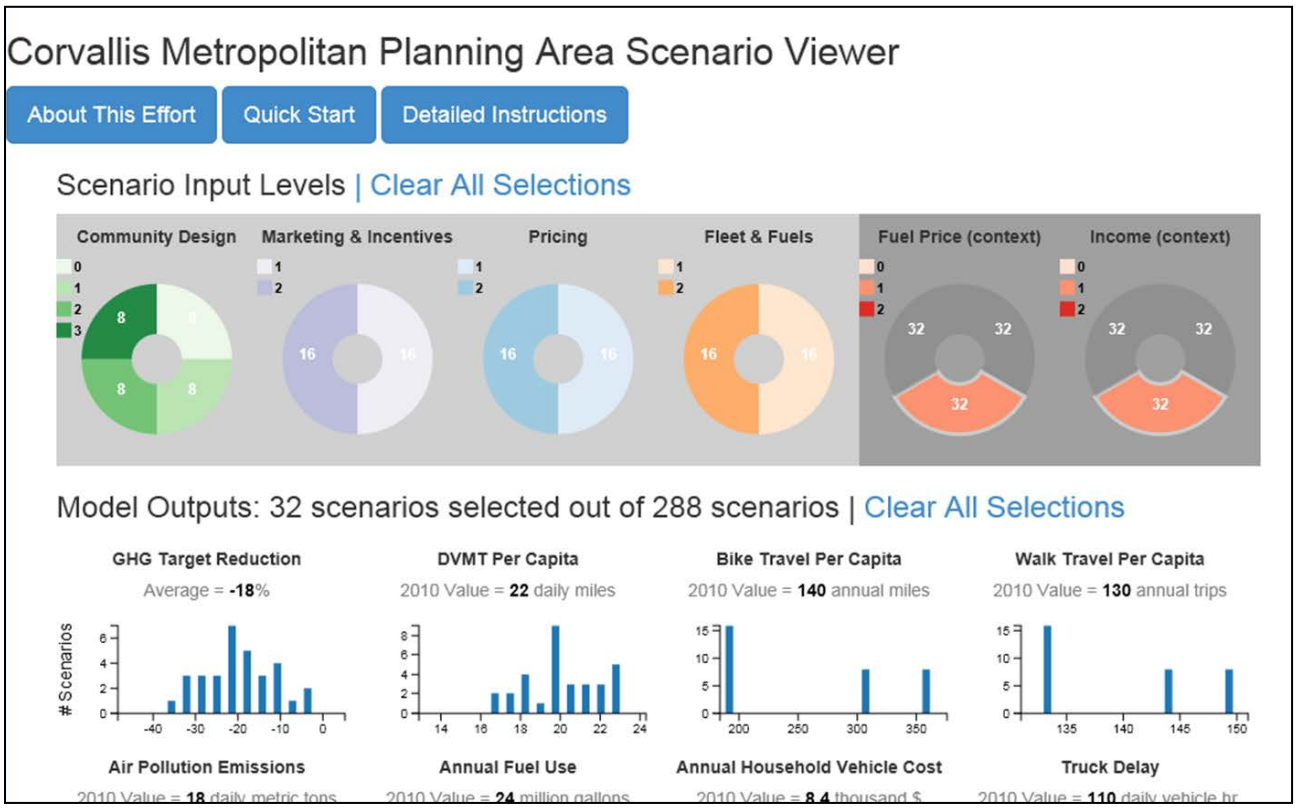
MPO Applications

CAMPO Strategic Assessment and Interactive Viewer

AA Strategic Assessment, as supported by ODOT for mid-sized MPOs, is the first step in Scenario Planning as undertaken by Portland and Eugene-Springfield. Corvallis was the first to volunteer to use the RSPM model in a Strategic Assessment. It assessed their financially constrained adopted plans and performed sensitivity tests of more ambitious plans (e.g., more transit, alternative land use patterns) and resilience to future uncertainties (e.g., fuel price). The RSPM scenarios in this effort precede and inform local plans. The local plans (e.g., RTPs, TSPs) will use more detailed traditional tools to implement the strategic understanding resulting from the assessment.

As part of the Strategic Assessment, an interactive viewer has been created to help simplify exploring the completed runs. Exhibit 7-28 shows a screenshot of the viewer created for the CAMPO Strategic Assessment project. The viewer for CAMPO is available at: http://www.oregon.gov/ODOT/TD/TP/Pages/ORScenView.aspx?sv=CAMPO. The viewer shows how community outcomes (e.g., household travel costs, health, walk and biking travel, vehicle delays) change under adopted and more ambitious policies and investments (user input adjustments). Additionally, the user can identify the desired outcomes (e.g., meet GHG reduction targets, high bike trips), and be shown the policy combinations that reach those goals. The viewer can be customized for a particular area. The scenario data that forms the basis for the viewer can also be mined using data analysis software.

Exhibit 7-28: CAMPO Scenario Viewer



7.7 Land Use Scenario Tools

7.7.1 Introduction/Purpose

Objective: Develop sSet of plausible future LU patterns and demographic consistent with various constraints, for local review. Travel impacts can be ascertained by combining the resulting land use inputs in a travel model, ABM, SWIM or RSPM.

Land Use Scenario Tools should:

- Allow us more thoughtful land use inputs. It is important to tie together the inter-relationships between land use inputs (e.g., dwelling unit type varies with density, income and household size will change with the development of a TOD, population and employment locations are driven by different criteria).
- Be a starting place for framing a land use conversation with local planners using their frame of reference and their resources (e.g. comprehensive plan, jobs-housing ratios).
- Serve as a check on the reasonability of local input variables. - oOur models are only as good as these key inputs.

Land use models are designed to predict the future pattern of population and employment, typically in an iterative fashion with a travel model. By connecting land use and transport models, land use can respond to market forces such as accessibility and congestion (e.g., locations with good accessibility are more likely to develop than remote

locations). Travel can respond to market-driven development patterns (e.g., distributions of residents and employment locations determine activities and create demand for travel on the transportation system). The resulting land use forecast (population and employment by model zone) is a critical input to travel models, including JEMnR, OSUM, SWIM, and RSPM, which assess demand for travel against available infrastructure capacities.

The complexity of most land use models precludes widespread use by planning agencies. However, they are useful tools for forecasting land use inputs to transportation models and for analyzing the land use effects of transportation projects, such as fully considering how a development pattern will impact transportation, induced demand, and the cost of the resulting congestion.

Many tools have attempted various versions of these land use objectives in Oregon. No tool solves the issue fully for all purposes. This section will outline the various applications to date involving alternative versions of several tools, and note future opportunities.

Metroscope:

In Portland, Metroscope serves the role of developing alternative land use inputs for their travel model. Metroscope is a complex land use model that has been developed over decades making use of the extensive Portland- area GIS data and the region's economic/demographic forecasts for the multi-county, and multi-state region. It runs in a connected manner with the Metro travel demand model and has supported a variety of planning studies. The website below provides more information.

Metroscope website: http://www.oregonmetro.gov/forecasting-models-and-model-documentation

7.7.2 LUSDR (Land Use Scenario Developer in R)

LUSDR differs from most land use models in that it is designed to run quickly in order to create a large number (rather than just one) plausible future land use scenarios that meet zoning constraints and respond to market forces (when used iteratively with a travel demand model). This is important because the likely future development pattern can take many forms, the result of many factors that are not easy to forecast. By running many scenarios, one can understand the range of possible development patterns and the likelihood of development for a particular zone. The large number of plausible futures can be used to help evaluate how different possible development patterns will affect the transportation demand and resulting network performance. Using this information, local agencies can have a better sense for how future land use will improve or hinder traffic operation, which can be used to improve land use forecasts that help meet transportation objectives in modeling studies. LUSDR (or variations thereof) can be used to speed up development of land use inputs for travel models by creating a few "bookend scenarios" for local staff to pick from rather than trying to figure out where market forces will combine with available land capacities leading to likely locations for growth 20+ years in the futurefrom now. By making it easier to develop alternative land use futures, LUSDR

gives users the ability to test transportation networks under various future land use patterns. This enables testing transportation investment resilience to different futures, which is a risk assessment approach. It allows users to see how transportation infrastructure will perform under a range of possible future land use patterns, and it provides municipalities with a tool to assist with planning future growth.

LUSDR operates on a zonal (sub-regional) scale within an urban area but not at a parcel or urban block level. It requires substantial data and analytic resources to set up for a specific locality. LUSDR requires local zoning/comprehensive plan parameters (such as compatible development types and densities under the zoning designation) which are used to create a large series of plausible future land use development patterns. These development patterns can then be analyzed in a travel demand model, which provides an evaluation of travel resulting from each land use scenario. LUSDR and the travel demand model can be run iteratively through time, passing this information back and forth to simulate the effects of land use and transportation interactions (i.e., accessibility from the travel model is used to determine land development, while development from the land use model is used to determine travel demand). This process allows the testing of many future possible outcomes, to give local and regional agencies insight into how different land use patterns affect the transportation network. LUSDR can also help in other types of analyses, (e.g., GHG analysis in the RSPM model).

7.7.3 LUSDR Variations

LUSDR-inspired land use scenario methods are now the norm for creating future land use inputs in a new or updated travel demand model scenario. Typically this involves using simplified LUSDR components and inputs. These methods provide an objective method that can simplify the land use development process at the local level by creating plausible scenarios that can be considered and modified rather than a review of TAZ by TAZ to assess the explicit future number of households and employees.

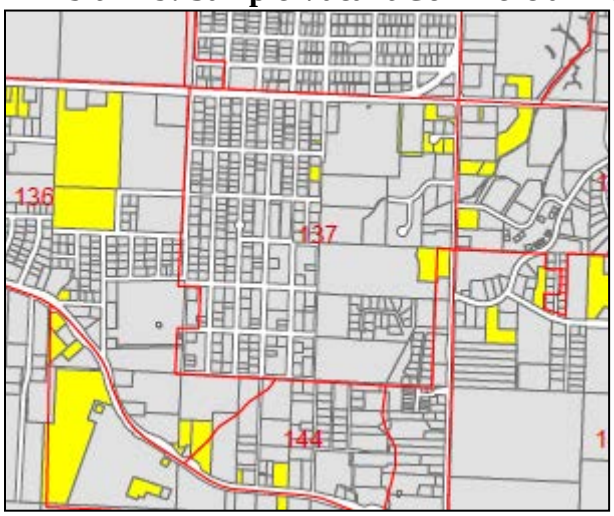
The earliest LUSDR variation was an application in Klamath Falls when a travel model update required new land use inputs. Local staff was challenged by the sheer number of possible future growth scenarios as the available vacant lands within the UGB was so large. A number of household and employment growth scenarios were created and shown to local staff which later picked a couple to average together to create the final future scenario.

Another LUSDR variation was completed in both the Coos Bay/North Bend model update and a new model for The Dalles. The method resulted in a significantly shortened future scenario development process and increased understanding of the planned future on all sides. In this method, the local staff is asked to provide growth potentials for households and employment which is later translated into TAZ values. This allows local staff to be more comfortable with planning- level terms instead of having to deal with TAZ-level detail. Small jurisdictions usually have little or no exposure to travel demand models, so limiting the technical details will make the process much smoother, especially if some introductory outreach is performed initially. The process ends with creating a

single or small set of scenario(s) that the local staff can choose or modify as needed. The general process is as follows:

- Regional Land Use Control Totals - Use the base year land use total and other sources to determine total population and employment within the model area. Population sources include Oregon Office of Economic Analysis (OEA) and Portland State University Population Forecasts by County/Cities. Employment is typically scaled to achieve historic Census (or adjusted) jobs-household ratios.
- TAZ Land Acres by type - Based on the most current GIS parcel-level database available for the jurisdiction, extract the parcel-acres of the existing and vacant parcels by residential, commercial, industrial and other property classes. Exhibit 7-29 shows part of the overall GIS plot for vacant developable commercial lands for the cCity of North Bend staff to which apply TAZ growth potentials to.

Exhibit 7-29: Sample Vacant Commercial Llands in the City of North Bend



- User-defined TAZ Growth Potential - Identify the growth potential by ranking the TAZs with 0, 1, 2, and 3 for no growth (0%), low (50%) , medium (80%) and high (100%) with respective to land uses. Exhibit 7-30 shows part of the TAZ growth potential review that City of North Bend staff did as their part of the Coos Bay-North Bend model update.

Exhibit 7-30: Example Growth Potential Allocation from City of North Bend

COMMERCIAL			
	TAZ	DEVELOP. RATING	NOTES
	101	3	
	107		W. of Hamilton = 0; others = 2
	109		S. of Virginia = 2; others = 0
	110	2	
	111	2	
	112		E. of Hamilton = 1; others = 0
	113		S. of 15th & N. of 11th = 2; others = 0
	118	1	
	121	0	

- Available Residential Capacity - Calculate the current population density of residential land with each TAZ and residential land available for development based on the buildable land inventory and potential growth ranking;
- Allocate New Households - Allocate the future year population total in terms of household total into each TAZ according to the relative potential capacity for residential development;
- TAZ Accessibility - Use the existing base year model to figure out the accessibilities to each TAZ as one of the variable to determine the employment capacity;
- Available Employment Capacity - Calculate the employment capacity by retail, service, industrial and other sectors by TAZ according to the available vacant land (by commercial, industrial and other category) and growth potential rankings; and
- Allocate New Employment - Apply the future total land use forecasts by sector by using the "Long's Model" methodology (a simplified technique that allocates employment growth to zones based on accessibility to potential customers) to allocate the potential employment growth to TAZs based on the buildable land capacity and potential growth rankings.
- Review/Sensitivity Tests - Adjustments can be done by having the local staff review the resulting TAZ plots to see if too much or too little growth by land use sector occurred. By changing the growth potential ranking up or down will re-allocate growth amongst the TAZ's by making certain ones more or less attractive.

The Coos Bay-North Bend model update process ended up with a single land use scenario that was reviewed and slightly adjusted allowing the entire model update to complete on time. Since this process uses more planner-based terms it is important to keep the definitions consistent (i.e. the term vacant means no parcel development, not partially developed).

7.7.4 Place Types

Place Types can be helpful in visualizing and providing a common language for the land use conversation using any of the tools noted above. Adopted for Oregon from SHRP2 C16 RPAT (Rapid Policy Assessment Tool, formerly SmartGAP, a RSPM-derived modeling tool), Place Types provide a criteria-driven topology of land use patterns and allows for ways to visualize and map the different functions and roles of a community. Oregon Place Types are built on TAZ data, consistent with the travel demand model zones, and can be aggregated for use in other models. They use data on the 5Ds (development density, destination accessibility, design, diversity, and distance to transit) built environment of the area, building on TAZ household and employment data (e.g., density, mixed uses), as well as attributes representing urban design/walkability (i.e.., link density) and transit accessibility. From these land use coverages, logic and threshold criteria are applied resulting in the following two Place Type dimensions:

- Regional Role (i.e., accessibility to regional job center)
- Neighborhood Character (i.e., how well the pattern of development supports a multi-modal transportation system)

The full Place Type logic is summarized in Exhibit 7-31 with example outcomes for RVMPO noted in Exhibit 7-32. A visualizer has been developed to enable interactive viewing of the 5Ds and resulting Place Types. Place Types have been shown to be useful in quickly encapsulating the role of different community neighborhoods (e.g., job center, multi-modal main street), identifying locations to best support alternative mode investment (e.g., mixed use areas), and as a check on land use inputs (e.g., expected higher density highlights miscoding of employment data). The use of common Place Type criteria across the state enables useful comparisons for envisioning possible future development patterns (e.g., parts of Rogue Valley are planned to reach the density and multi-modal potential of Corvallis's near-campus districts, with opportunities to support car-sharing and other modes).

In addition to facilitating the conversation and visualization of current and forecast land use patterns and opportunities for growth, Place Types will soon be utilized in RSPM to better model the effectiveness of TDM programs. Efforts to translate the method to census block-group coverage is underway and will allow stratifying out-of-state data by place type for use in Oregon tools that use Place Type land use classification.

Exhibit 7-31: Logic for Developing Oregon Place Type

Place Type Logic

1 BUILT ENVIRONMENT VARIABLES

Built Environment Variables		
Destination Accessibility	Share of Regional Jobs within 5 miles (ratio)	H-M-L-VL
Density	Jobs & Households per acre within 0.25 mile	H-M-L-VL
Design	Multi-modal & Pedestrian-Oriented street density (links per sq mile)	H-M-L-VL
Diversity	Jobs (total or retail- service) to household ratio, within 0.25 mile	H-M-L-VL
Transit Service Level	PM Peak hourly transit service within 0.25 mile	H-M-L-VL

2 REGIONAL ROLE (Area Type)

		Destination Accessibility			
		H	M	L	VL
Design	H	Regional Center			
	M		Close In Community		
	L VL			Suburban/Town	
Density	VL		Low Density/Rural		

3 NEIGHBORHOOD CHARACTER (Development Type)

	Density	Design	Diversity	Transit
Mixed Use	M	M	H	
	H	H	H	
Employment	Not MIXED		Jobs> HHs	
Residential	Not MIXED		HH>jobs	
Transit Supported Development	H	H	H	H
	H	H	Jobs>HHs	H
Low Density/ Rural	VL			

4 LAND USE PLACE TYPES

Area Type + Development Type = PLACE TYPE

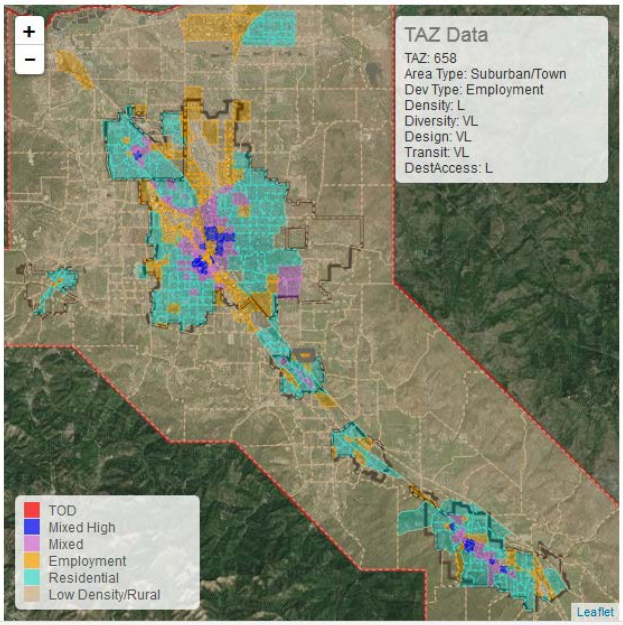
Neighborhood Character (Development Type)\	Regional Role (Area Type): Regional Center	Close In Community	Suburban/ Town	Low Density/ Rural
Transit Supported Development	√	√	√	
Mixed Use - High	√	√	√	
Mixed Use	√	√	√	
Employment	√	√	√	
Residential	√	√	√	
Low Density/ Rural				√

Draft 7/06/15

Exhibit 7-32: Example Place Type Maps for 2010 RVMPO

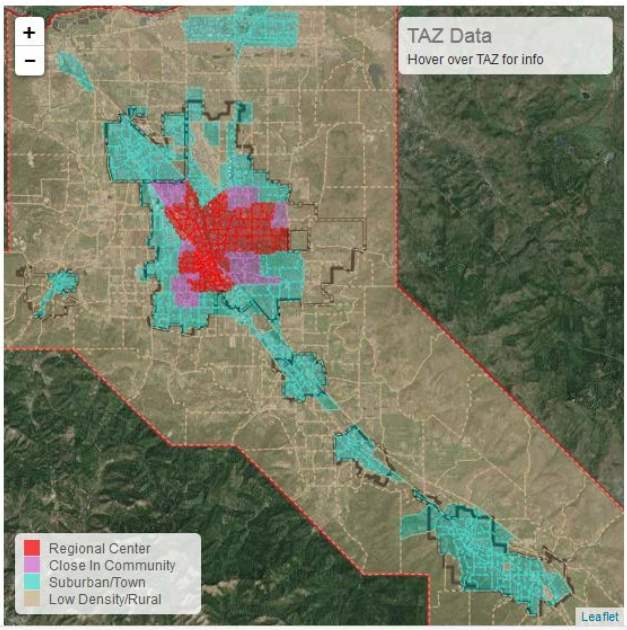
RVMPO 2010 Place Types (V4)

Neighborhood Character (Development Types)



Background Map Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community

Regional Role (Area Types)



, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community

8 MESOSCOPIC ANALYSIS

8.1 Purpose

This APM chapter provides fundamental guidance and overview of an array of methods related to mesoscopic modeling. Mesoscopic methods are rapidly changing based on availability of new tools and data sources, such as the move towards activity based travel demand models. This chapter focuses on methods that have previously been applied in projects involving ODOT and is not intended to be comprehensive for all mesoscopic methods and tools. Other methods not documented in this chapter may be applied, if appropriate, through consultation with TPAU staff.

The purpose of this chapter is to provide an overview of methods and tools available to apply mesoscopic analysis. The information provided in this chapter is intended to provide the user with the information required to understand the general approach for scoping project methodology and understanding the differences between various methods along with limitations and advantages of using each method. For more details on many of the methods in this chapter also refer to NCHRP Report 765.

8.1.1 Overview of Chapter Sections

This chapter covers a broad array of topics related to mesoscopic analysis. Topics included cover:

- Scoping – How to identify approach, tools, and effort based on the analysis needs.
- Subarea Analysis – How to develop subarea models that increase the detail from an existing model.
    - Focusing – General procedures for adding detail and creating a focus area model within a regional model.
    - Windowing – General procedures for selecting an area to "cut" or "window" out into a separate model that can then have additional detail.
- Dynamic Traffic Assignment (DTA) – Analysis considerations and triggers that may lead to analysis that considers traffic routes and travel times that vary by time of day.
- Peak Spreading – General concepts and analysis considerations to identify how congestion spreads from peak periods to larger intervals and the impact on vehicle demand during shoulder periods.

Section 8.1.4 includes references to other chapters of the APM that provide material that may be related to mesoscopic methods covered in this chapter.

8.1.2 Key Definitions

Having a common understanding of the terms in this chapter is necessary for proper implementation of methods and tools. Definitions for terms included in this chapter are included in the Glossary. Selected terms that are needed for fundamental content are shown below.

- **Macroscopic Model**– Aggregate models that have a high-level view of the transportation system and do not include many transportation network details. Macroscopic travel demand models are generally large (potentially regional) in size and focus on general vehicle flows and route choice from one area to another. Streets may be approximated by the average number of lanes, a free-flow speed, and approximate vehicle capacity. Vehicle trips are routed through the network based on algorithms that select paths that minimize the travel time.

- **Mesoscopic Model** – A hybrid model that includes combinations or approximations of elements from both macroscopic and microscopic models. Mesoscopic models may include a routable network similar to a macroscopic model (with a supplementary origin-destination matrix), while also incorporating more detailed operational elements of the transportation network to better estimate travel time based on traffic operations similar to a microscopic model. Elements from either the macroscopic or microscopic models may be generalized or simplified.

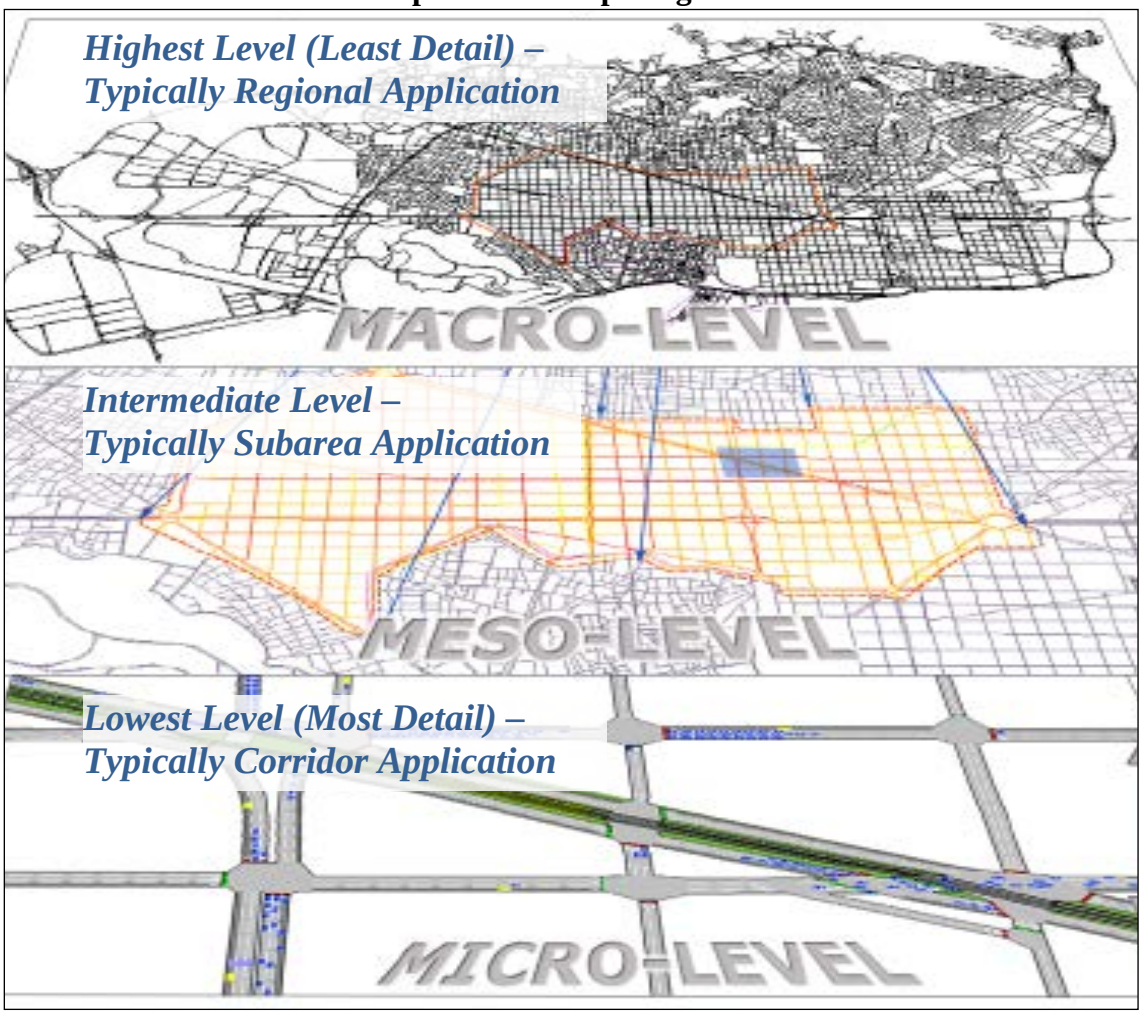
- **Microscopic Model** – Detailed models that are at a fine scale and typically include all streets and components of the transportation system that impact travel. Such elements can include intersection control and striping, pedestrian crossings, transit stops, and even the inclusion of traffic calming measures. Microscopic models typically refer to simulation models that include randomized characteristics and behaviors of an array of drivers and vehicles as they traverse a network. The performance of these models is typically averaged over several "runs" to account for the randomized driver and vehicle characteristics. Unlike macroscopic models, traffic demand values are generally inputs and typically do not result from path choice within the model, therefore, there may not be a predetermined throughput. As a result, assigned traffic volumes at specific locations such as midblock or a turn movement may not match the input demand due to constraints on the network metering flow. For example, queues will build in a microscopic model and only vehicles that can make it through a bottleneck in a given time period will be observed.

- **Multi-Resolution** – The combined framework of an integrated series of models, each built or scaled for the appropriate level of "resolution" and detail given the context for project application and need. The individual model components (resolutions) each can be integrated for a particular project/analysis that benefits from the data analysis and output of the individual tool and level. General levels,

or “resolutions”, that may be used to describe models or application that fit a general context include microscopic, mesoscopic, and macroscopic models as shown in Exhibit 8-1.

Appendix 8B provides a user guide for the PTV Vision Suite software which is an example of a multi-resolution tool. The guide is provided to help infrequent users get a quick start in building, importing and exporting networks for analysis.

Exhibit 8-1Multi-Resolution Spectrum Comparing Various Model Levels



8.1.3 Introduction to Mesoscopic Analysis

Transportation analysis methods have traditionally focused on two levels of detail, macroscopic and microscopic. ***Macroscopic*** analysis is concerned with system-wide travel movements; how much travel, of what types, when, how, and by what modes and major routes. Urban, regional, and statewide travel demand models are the primary tools used to do this level of analysis. These tools facilitate the evaluation of the effects of demographics, economics, land use patterns, transportation network configurations, and prices on travel patterns. These models assess how many trips are moving between areas (zones) and along which routes (links). Because they are not built for focused urban area studies they do not typically account for the influences on delay from turning lanes and signal or stop sign controls at intersections. Likewise, macroscopic models provide no information on the location and duration of queuing. Furthermore, they are not calibrated to the level of local streets and points of access to the network (e.g. parking locations).

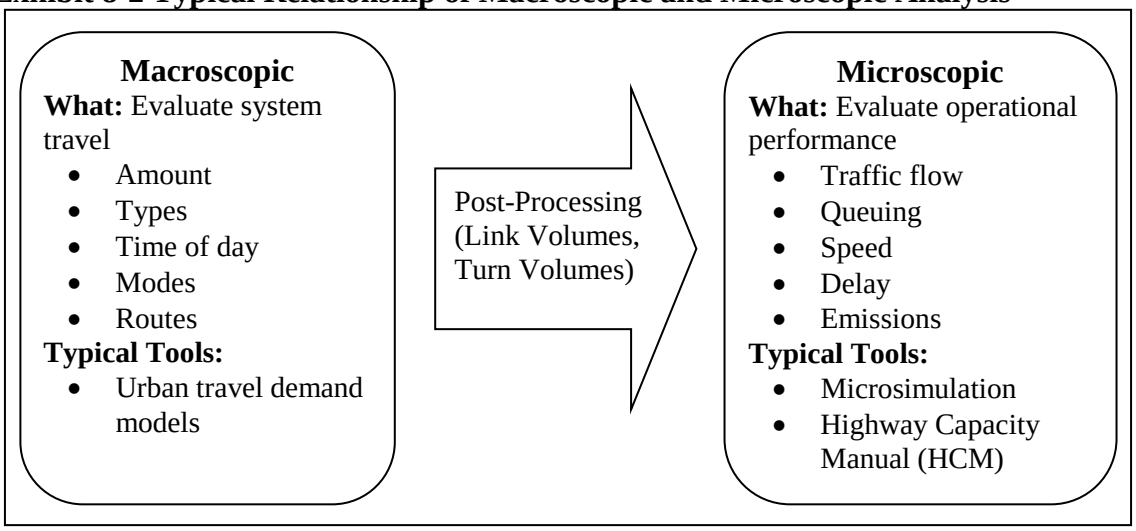
Microscopic analysis is concerned with the operational performance of transportation facilities; traffic flow rates, queuing, speed, and delay. This level of analysis uses micro-simulation models and highway capacity manual methods primarily. These tools facilitate the evaluation of the effects of localized land uses, roadway geometry, and traffic controls on traffic flow characteristics. However, most microsimulation models rely upon fixed post-processed traffic volume inputs from travel demand models to evaluate future year scenarios and are, therefore, only as good as the volumes put into them. Furthermore, project application of microsimulation models typically requires many hours devoted to model development due to the level of detail incorporated in the models. While these models provide a good estimation of traffic operations, they are often not practical to implement as a tool to evaluate or screen a large number of alternatives or a large analysis area.

One major difference between macroscopic and microscopic analysis is that macroscopic models use land use data as the primary input that dictates demand for travel, whereas microscopic use traffic volumes or vehicle trips as the primary input that dictates the demand for travel. The impacts of land use on travel demand are external to microscopic models and assumed to be already accounted for in the microscopic model's traffic volume inputs. Likewise travel costs (e.g. fuel prices, the traveler's value of time, transit fares) are direct inputs to macroscopic models dictating travel mode and route choices. These travel costs and decisions are external to microscopic models, and assumed to be already accounted for in the microscopic model's traffic inputs.

These two levels of analysis (macroscopic and microscopic) are loosely coupled through the transmittal of link and turn volume data and the use of travel demand model post-processing methods. The flow of the data is from macroscopic to microscopic, and there is typically no feedback from microscopic to macroscopic (e.g. queuing calculations do not affect system travel calculations).

The following diagram illustrates these two levels of analysis and their connection.

Exhibit 8-2 Typical Relationship of Macroscopic and Microscopic Analysis



Increasing attention is being given to the combination between the macroscopic and microscopic modeling levels, often referred to as "***mesoscopic***." While the term "mesoscopic" can have various meanings for users in different fields and even to multiple users within the field of transportation, it generally is used to denote a hybrid of microscopic and macroscopic features. Exhibit 8-3 demonstrates the relationship between these three general fields.

Exhibit 8-3 Mesoscopic Overlap between (and Potentially Combining) Macroscopic and Microscopic Modeling Process

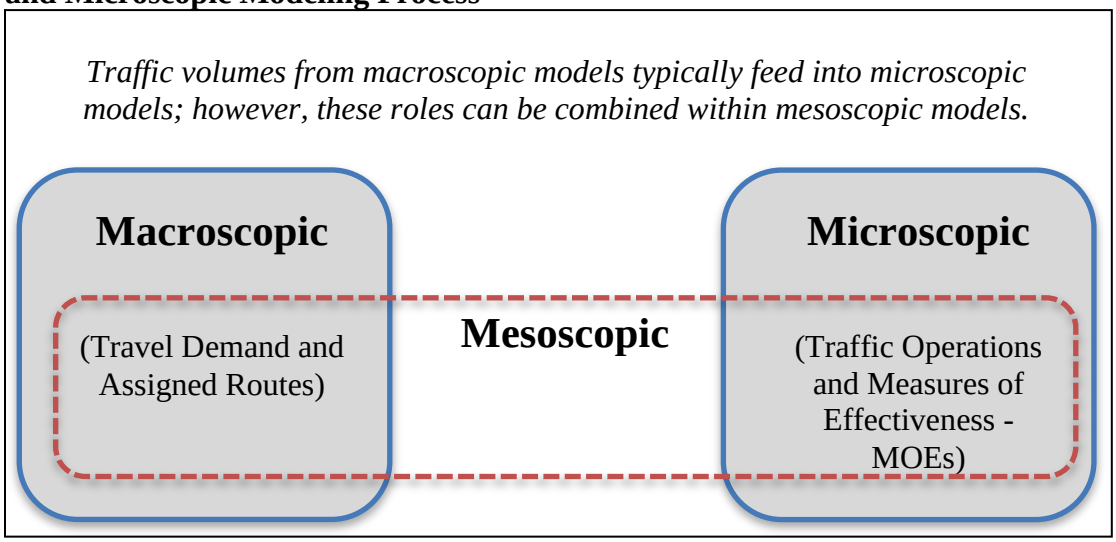


Exhibit 8-4 lists potential examples that summarize key comparisons among typical microscopic, mesoscopic, and microscopic models. These examples are provided for demonstrative purposes and actual characteristics of these models can differ.

Exhibit 8-4 Summary of Typical Differences among Microscopic, Mesoscopic, and Macroscopic Models

	Detail Present		
Model Element	**Macroscopic**	**Mesoscopic (Potential hybrid)**	**Microscopic**
Network Scale (Size)	Region-wide	Varies. Potentially region-wide, but may be smaller, depending on level of network detail and mesoscopic software	Typically a single corridor or small study area
Network Scale (Detail)	Regionally significant routes (generally collector and higher)	Varies. May include all public streets, but could include less depending on network size	All streets and major driveways
Intersection Detail	None (typically a simple node junction of streets without time-penalty and without geometric or control characteristics)	Generally includes types of attributes needed for HCM level analysis (intersection control, lane geometry, basic signal timing, etc.)	Full lane geometry and widths, turn bay lengths, traffic control and striping, signal timing detail for individual phases (if applicable)
Travel Time	Link-based travel times generally rely on volume-delay functions (vdf). Intersection delay is generally ignored or simplified.	Can have a combination of link and intersection travel time, though intersection delay may be less robust than microscopic models	Travel time is based on vehicle interaction and includes acceleration, deceleration, stopped delay, and other associated factors
"Outputs" - Measures of Effectiveness (MOE) / Performance Measures	Vehicle hours of delay, corridor travel time, average distance traveled by users on a link	Provides general MOEs possible in both macro and micro models, without full detail (e.g. queue lengths and impacts) of micro models.	Intersection turn delay, corridor travel time, 95th percentile vehicle queue length, etc.
Routes / Assignment (Is route diversion possible?)	Yes (routes vary based on relative "cost" of all potential routes, typically travel times)	Yes	No (traffic volumes and route paths are typically a fixed input and route options/ diversion are not present)

Needs

Mesoscopic analysis capabilities can help meet emerging analysis needs and overcome limitations of the traditional process and tools (macroscopic forecasts fed into microscopic models). In particular, the following needs can be addressed:

1. Operational Impacts
    - Restricted funding and less interest in making major changes in the roadway system are shifting the focus of planning to system management and leveraging the effects of changes in operations and many small system improvements. In addition, there is increasing interest in modeling operational improvements that improve reliability and reduce incident-related congestion. Macroscopic models are typically not applied in a manner that is precise enough to model the effects of traffic operations or minor improvements. Microscopic models can analyze these effects, but cannot do so at a large-scale systems level. Moreover, microscopic models require a very large amount of data and are impractical to develop for an entire urban road system.
    - The focus on operational improvements and smaller system changes requires the use of more precise performance measures in order to distinguish the relative benefits of alternative choices. Macroscopic models use travel time and speed measures having limited precision (e.g. do not capture the vehicular delays upstream of system bottlenecks). These measures are necessary in order to predict travel patterns, but precision has been limited for reasons of computational tractability and because precision may not have been important for the regional decisions being made. Microscopic models can produce these measures, but only for a relatively small portion of the system.
    - The operational impacts of interactions with other modes (such as bus stops or rail crossings) can impact travel time along a route and thus route choice. For example, the impacts that transit vehicles have on auto travel times are ignored in most macroscopic models (e.g. additional traffic congestion caused by buses on mixed use roadways and vehicular delays occurring at rail crossings). These impacts can be explicitly modeled and evaluated using microscopic models.
2. Congestion Impacts
    - As traffic congestion severity, extent, and duration grow, the travel time and speeds estimated by macroscopic models become less able to reflect actual travel conditions. Macroscopic models have a limited ability to account for congestion on adjacent (downstream) links, as well as within (adjacent lanes) a given roadway segment. Consequently, macroscopic models are less able to account for the effect of traffic congestion on travel patterns. This has been a significant consideration in the Portland metropolitan area for some time, and is starting to become an issue in other areas of the state as well.

    - The effects of severe congestion may not be reliably accounted for by microscopic models. How are the system constrained traffic volume and trip inputs for microscopic models developed for future year scenarios (as the severity, extent, and duration of traffic congestion grows) without the help of macroscopic travel models?
3. Sensitivity/Risk Testing/Alternatives Analysis
    - There is increasing interest in assessing the risks associated with uncertain futures (e.g. amount and distribution of land uses, fuel and other travel costs, government policies, regional economic and funding issues). The assessment of uncertainty and risk requires a more comprehensive analysis than is presently done. In the past, assumptions were made about many factors (such as land use, transportation network changes, etc.) in order to limit the number of alternatives needing to be analyzed. This has been necessary because of the amount of work required to develop models and process outputs from macroscopic models to be input into microscopic models and time required to adequately develop microscopic models.

Mesoscopic modeling has the potential for meeting these emerging needs and overcoming existing limitations by leveraging the strengths of both macroscopic and microscopic modeling:

- Operational performance can be calculated with more detailed metrics than is currently done by macroscopic models in order to account for the effects of smaller changes to the system and to distinguish smaller differences between alternative improvements. The calculations in mesoscopic models are less precise than those of microscopic models; this reduces the data needs and model run-times so that entire regional transportation systems or large portions of transportation systems can be modeled.
- Since mesoscopic models can make more detailed calculations of performance, in some cases they may be a substitute for microscopic models for the purposes of uncertainty and risk analysis. For larger systems with severe congestion issues, a mesoscopic model will allow for realistic results to be generated at a lower detail level but still meet the needs of the project development process. The calculation of the performance measures by a mesoscopic model would reduce the need/use of microscopic models for alternatives testing and greatly increase the number of scenarios that could be analyzed within a given amount of time and resources. Microscopic models would continue to be used for more detailed analysis of a limited number of scenarios.
- Mesoscopic models can provide a mechanism for feeding back better estimates of travel times reflecting very congested conditions to macroscopic modeling processes for forecasting travel demand for successive iterations in the macroscopic models. This might be done by incorporating the mesoscopic model into the macroscopic model, or by using the mesoscopic model as a post-processor of the macroscopic model.

When to Consider Mesoscopic Analysis

Many considerations exist that could lend mesoscopic procedures being applied for an analysis. Some of these considerations for mesoscopic application could include:

- Do a large number of system network alternatives need to be analyzed or screened at a system level? Is it not feasible/cost-effective (or appropriate) to model all alternatives in microscopic analysis? Does macroscopic analysis not provide adequate detail for providing relative comparisons among alternatives?
- Do network alternatives include operational impacts or improvements that may not be captured with a macroscopic model?
- Do network alternatives have the potential to impact system circulation and routing due to the outcome of the resulting traffic operations and flow?
- Does a level of congestion exist that may not be captured with a macroscopic model?

Any of the items listed above may be an indication that mesoscopic analysis would be beneficial for project application. While defined triggers do not exist, generally a mesoscopic approach will provide additional benefit in cases where both macroscopic traits (such as route choice) and microscopic traits (such as traffic operations, performance measures on duration and severity of congestion and queuing) are desired in a hybrid environment.

8.1.4 Related APM Chapters

Several other chapters provide related guidance. These chapters and the relation each has to this chapter are listed here.

- Version 2 Chapter 2: Scoping Projects – Guidance on scoping transportation analysis work. Includes comparisons of analysis tools and guidance on tool selection.
- Version 2 Chapter 3: Transportation System Inventory – Includes information about data collection that may be needed for application of the methods covered in this chapter.
- Version 2 Chapter 5: Developing Existing Year Volumes – Includes information about volume development that may be needed to estimate demand for some of the tools and methods covered in this chapter.
- Version 2 Chapter 6: Future Year Forecasting – Provides information about developing future forecasts and includes subarea assignment methods. The chapter also describes multiple forecasting methods, including use of travel demand models.
- Version 1 Chapter 8: Traffic Simulation Models – Procedures for microsimulation model development and calibration.
- Version 1 Chapter 10: Analyzing Alternatives – Includes information about developing sets of alternatives that may be analyzed or screened using the tools and methods covered in this chapter.

8.2 Subarea Analysis

This section provides an overview of types of subarea analysis and general considerations for application. Two types of subarea analysis, focusing and windowing, are covered in greater detail in following sub-sections.

8.2.1 General Considerations

The analyst has a number of tools and methods available for application. A critical component of any project is first selecting an appropriate tool and then determining how to best apply that tool. In many cases, the best tool available may not be adequately refined for the intended application. In the case of a regional travel demand model, the model may be constructed and calibrated to a regional scale. However, with the appropriate additional refinement, the model (tool) may be applicable to additional uses. Creating a subarea model is a common example of applying model refinement for more rigorous use beyond the original scale of the model.

This subsection describes general subarea refinement and considerations. A ***subarea*** is a specified area that is identified for refined analysis. This may require a model or tool that includes additional detail beyond what is used for areas outside the subarea in order to adequately capture the desired level of analysis. The subarea may be similar to a "study area" identified through the analysis as the general area included in the analysis, but often these areas differ based on the degree of analysis needs and tools present.[26]

Once an analyst is aware of pre-existing models, the decision about model applicability and potential to use the model for another purpose must be made. While this decision process should be coordinated with Transportation Planning Analysis Unit (TPAU) and documented, the following considerations may indicate the potential for applying subarea analysis:

Is the "base model" (agency or regional model) appropriate for further project use?

- Does the model boundary fully include the study area?
- Does the model consider the appropriate time period (hour of day, season, etc.)?
- If land use changes are being investigated, are the scale and type of uses appropriate for the model? Smaller magnitude areas, such as some traffic impact analysis (TIA) for the development review process, may not require land use adjustments in the model if it is being used to forecast background growth. However, larger magnitudes may require land use adjustments or even be beyond the scope of the model. Additional documentation on this matter is provided separately.[27]
- Does the model boundary include key locations outside of the study area that may influence operations within the study area (downstream interchanges, over capacity intersections, etc.)?

[26] Considerations for identifying subarea boundaries are presented later in this section.
[27] Modeling Procedures Manual for Land Use Changes, TPAU, February 2012.

Is subarea refinement needed for model application?

- Does the model include all transportation facilities relevant to the study? This may include study intersections as well as parallel facilities or alternate routes, which may be needed for gauging traffic diversion.
- Is the zone structure detailed enough for the analysis and are centroid connectors placed in a way that will not impact the outcome of the results?
- Is the model sensitive enough to test the range of alternatives under consideration, such as intersection control and geometry or signal timing changes?
- Is a specific zone or unique land use not adequately captured due to the regional scale of the model?
- Is the zone and centroid connector structure detailed enough to perform Origin-Destination (O-D) matrix estimation procedures if needed?
- What will be the ultimate use of the model data? Do HCM procedures need to be performed on study intersections? Will the model be exported to microsimulation?
- Do other modes of travel need to be considered that are not included in the regional model? For instance, do a significant amount of trucks or heavy vehicles need to analyzed separately and/or account for restricted routes? Are there other modal network elements?
- Is a more realistic assignment needed due to extensive peak period congestion?

The considerations above are intended to serve as a general guide for determining model application potential. However, given project context, other considerations may exist and coordination with TPAU is needed. The following sections explore these general considerations in more detail.

8.2.2 Overview of Focusing and Windowing

Focusing and windowing are two general types of subarea models that are commonly applied. These approaches can be applied for both macroscopic and mesoscopic analysis models. While each of the two methods shares similarities, there are also distinct differences.

Focusing is the practice of adding additional refinement and detail to a model within the structure of that model. The additional resolution may be added to the supply (transportation network) or the demand (zone structure or loading). In either case, the full function of the model is maintained.

Windowing involves cutting out a portion or component of a model. Often, this will include a “window” of the transportation network in the subarea that then creates cordon (external) areas at the edge of the subarea. Windowing, like focusing, is applied to allow additional refinement or modification. However, because windowed models are separate

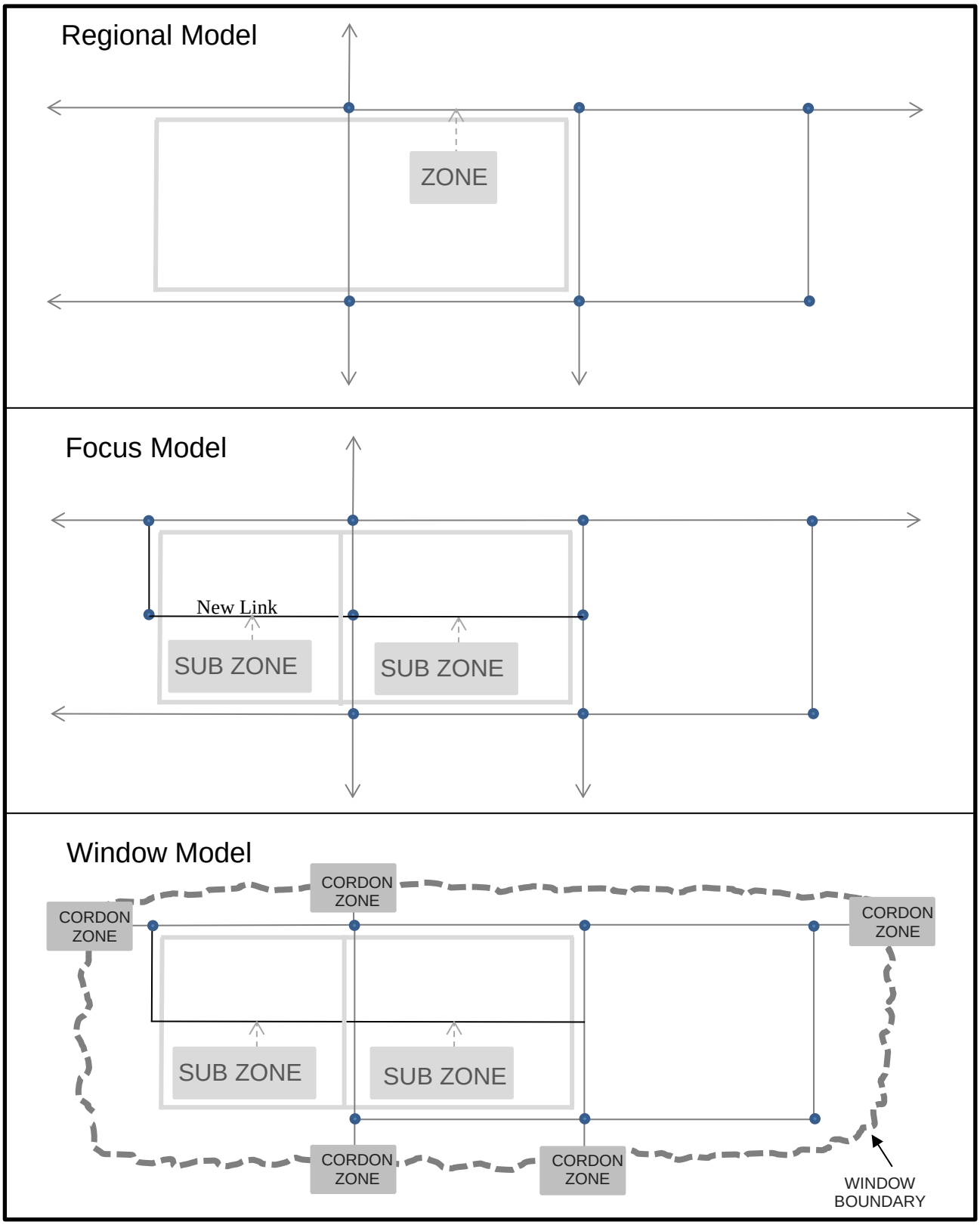
from the original model, they are not held to the same requirements for consistency[28] and integration with the full model. This allows for testing changes from the original model (such as travel demand intensity or trip assignment technique). Results of the windowed model are specific to the window itself and are not necessarily relevant to the original model. In some cases, the entire model area may be windowed in order to test scenarios (or framework) that differs from the base regional model.

Refer to Appendix 8B Section 1 for guidance on windowing using PTV Visum software. If the model is in the Emme platform, see Section 4.1 for guidance on converting the model network to Visum.

Exhibit 8-5 demonstrates the general differences in network refinement that a focus and window subarea model would add to a base model network.

[28] Coordination with TPAU is necessary to determine if the level of adjustments are appropriate and reasonable for the windowed area model.

Exhibit 8-5 Comparison of Base/Regional, Focused, and Windowed Models



8.2.3 Scoping

The following sections provide an overview of scoping subarea modeling efforts, including general considerations for selecting windowing and focusing methods and level of effort for subarea application.

Tool Selection

In some instances either windowing or focusing may be an appropriate approach for refining the model area. However, in other cases one approach may be preferred due to limitations or flexibilities built into each method. Exhibit 8-6 highlights some situations to guide the analyst in selecting an appropriate methodology.

Exhibit 8-6 Considerations to Guide Selection of Subarea Model Methodology

Consideration	Focusing	Windowing
Alternate Traffic Routes	• If alternate (or parallel) traffic routes exist outside the subarea, they may be affected by non-uniform refinements made to the model within the focus area.	• Routes from the regional model will be fixed and constrained at the location of subarea boundary or cordon "cut" lines (outside the windowed area)
Assignment	• Constrained by base (regional) model	• Adjustments to assignment type and parameters allowed
Demand Intensity	• Constrained by base (regional) model	• Adjustments to demand intensity of zones allowed
Model Size	• Can be applied for any size model	• Applying a "cut" of the model and creating new cordon zones may be desired to reduce run time
Model consistency	• Edits require consistency within the framework of the regional model and running the full 4-step model	• Edits are allowed to deviate from regional model framework, however do not provide the ability to re-run the full 4-step model directly.
Future Work	• May be used for future projects	• Generally can only be used for the subject analysis
Intersection Control	• Typically not available in regional models	• Intersection control through nodal delay-based assignment
Level of Effort	• (Varies – see Exhibit 8-7)	• (Varies – see Exhibit 8-7)
Full 4-Step Model Runs	• Full model could be rerun with the additional detail of focus area	• Model generally reassignment only. A full model run (trip generation, distribution and mode choice) is not performed.
Transit	• Typically not affected in subarea focus model.	• Transit assignment and route functionality may break due to unique nature of coding.

Data

Types of data that are necessary to perform subarea analysis (such as focusing and windowing) may include:

- Traffic volumes – Needed to validate the model traffic volumes, particularly if new network is being added
    - Roadway tube counts
    - Intersection turn counts
    - Truck percentages
- Land use – Provides guidance for refining zone structure to allocate land use or trips to new zones.
    - Zoning map
    - Detailed land use metrics (in size of building and/or number of employees)
    - Aerial photos
- Network geometry – Characteristics needed to reflect infrastructure and control
    - Intersection and corridor geometry (lane use and channelization)
    - Posted speed
    - Capacity
    - Intersection control – type, orientation, signal timing plans, etc.
- Traffic operations – Existing traffic operations for model validation/calibration.
    - speed
    - travel time
- Traffic patterns – What is the distribution and what routes are being used?
    - origin-destination patterns
    - routes

Some data may only be needed depending on the detail of the subarea model (such as intersection control and geometry), while other data may only be needed if the subarea model will be later converted to microsimulation.

Resource Needs

The ability to scale the tool for the analysis is an important benefit of subarea modeling. The degree of effort needed to apply a subarea model can vary greatly based on the amount of detail that is put into refinement of the key model elements. Various model elements that may be refined for subarea analysis are listed in Exhibit 8-7 along with a sample of “low”, “medium”, and “high” levels of effort. For the purposes of this table, these levels are defined (as approximations) to be:

- Low Effort – Typically completed within a couple hours
- Medium Effort – Can be completed within a day
- High Effort – May require several days or more to complete

Exhibit 8-7 Subarea Scalability to Identify Resource Needs

	Range of Effort (Refinement and Application)		
Consideration	**Low**	**Medium**	**High**
Network Refinements	Add a link in study area or adjust speed/capacity	Review and refine all existing links and link properties for advanced street network detail. Add key missing links.	Review and refine all links in model and add any missing public streets (local, collector, arterial, etc.)
Zone System	Use existing zone system or split a single zone	Split zones (5 or less) in the immediate study area	Split zones (5+) over a broad area that may expand beyond the study area
Connectors	Use existing connectors, add connectors, or adjust placement to be loading to optimal roadway in study area	Review and refine placement and potentially weights of connector loading in general study area	Review and refine placement and weights of connector loading in broader area
Assignment Method (Window only)*	Use existing assignment method. May still require subarea "cut" of windowed area.	Modify assignment method to incorporate other considerations (such as fixed intersection delay by movement)	Implement detailed intersection operations elements that incorporate HCM intersection turn delay.
Intersection Control	No control setting, or simple node type of signalized/unsignalized	Control includes intersection geometry, specific control type and orientation	Control includes detailed type, geometry, and settings such as signal timing
Data Mining	Daily or peak hour link volumes	Peak hour/period link and turn volumes at key locations in study area	Peak hour/period link and turn volumes at locations in and beyond study area (and cordon zones if they exist)
Validation/ Calibration	Check/observe regional links in study area.	Check/observe regional links and additional subarea link network	Check/observe and plot the differences for all link and turn count locations to measure model calibration

Note: *Applies to Window models only since focus area models do not change assignment methods.

8.3 Focusing

The following sections provide an overview of how to apply focusing:

- Process – What steps are involved?
- Potential Issues – What are issues that may occur?
- Calibration – How to know when the model is "ready"?
- Application – When is this tool needed?
- Examples – When has this tool been used?

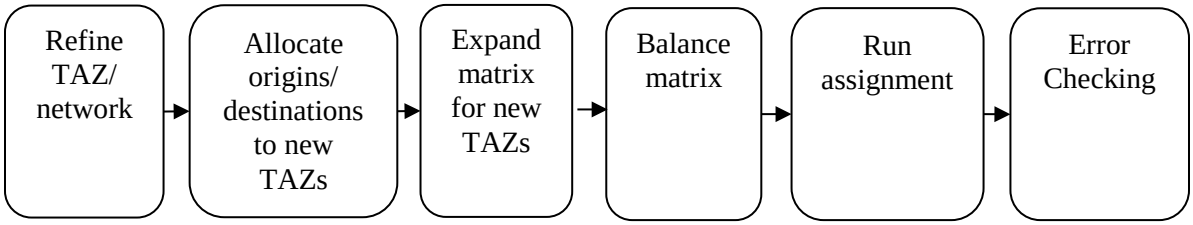
8.3.1 Process

While not explicitly listed as a repeated step below, continuous, on-going error checking and quality control are vital components of the model coding and application process. For purposes of simplification, this on-going component is not depicted.

The following steps, simplified in Exhibit 8-8, are used to apply focusing[29]:

1. **Refine Transportation Analysis Zone (TAZ)/network -** The standard TAZ system and network are refined in the subarea. This may include adding elements that were not included in the base model (such as additional roads), or adjusting elements that were in the base regional model (such as modifying link capacity).
2. **Allocate origins/destinations to new TAZs -** The origins and destinations for the original or "parent" TAZs from the model run are allocated to the disaggregated TAZs using one of several possible weighting schemes (Section 8.4.4).
3. **Expand matrix for new TAZs -** The assignment trip matrix from the model run is expanded to reflect the revised TAZ system.
4. **Balance matrix -** The expanded matrix is balanced using the disaggregated origins and destinations from Step 2.
5. **Run assignment -** A new trip assignment is run with the trip matrix from Step 4 and the refined network.
6. **Error checking –** Compare model output to check for consistency with base model.

Exhibit 8-8 Focusing Process



[29] *Modeling Procedures Manual for Land Use Changes*, ODOT Transportation Planning Analysis Unit, February 2012.

8.3.2 Potential Issues

The following potential issues may arise with a subarea model that uses focusing:

- Additional detail or street network may attract/detract travel demand from the study area. Creating additional transportation system links in the study area may increase the total capacity, thus attracting additional trips. Conversely, adding additional detail (nodes/intersections, traffic control, etc.) may disproportionately increase the travel time through the study area and detract traffic. These potential issues may indicate that windowing is more appropriate.
- Data may not be readily available to validate the traffic volumes on street network that is vital to the focused area.

8.3.3 Calibration (Model Checking)[30]

Analysis Procedure Manual Version 2 Chapter 6 includes additional information on model checks. It is assumed that the subarea models are based on regional travel demand models that have already been subject to a formal calibration and validation process. The following information is provided for calibration of subarea models for project application and may not be appropriate for regional models.

The calibration process is a critical step to ensure that the focused subarea model is compatible with the base model. If issues arise during the calibration process, it may be indicative that another method (such as windowing) may be more appropriate. The calibration process should generally include the following considerations, at minimum:

- Confirm the focus model is consistent with the base model
    - Is the overall demand matrix sum unchanged? There is risk of modification to the overall matrix demand when splitting the zone structure and creating new TAZ. Any change in overall demand (which may result when splitting zones with internal trips) should be minimal (typically less than one percent, unless documented otherwise).
    - Do links outside the focused area generally retain the same assigned traffic volumes? Significant shifts in traffic volumes may indicate incompatibility with the base model and a need to perform windowing as an alternate approach.
- Confirm the focus model is compatible with the base model
    - For a given screenline, do links within the focus area carry the same total assigned traffic as the base model? If the network was refined, traffic assignment may shift within the focus area, but the overall assigned volumes across a screenline should not significantly differ.

[30] The following material includes components of both a validation and calibration process. It is assumed that the regional demand models would have been formally validated and calibrated during model development. The information in this section focuses on the calibration of subarea models for project application.

- Confirm the focus model is providing realistic results
    - Do the sums of connector volumes for a zone match the total zone demand?
    - Does the routing for traffic into and out of new zones make sense? Common checks include a select zone analysis (Emme traffic assignment software) or a zonal flow bundle analysis (Visum traffic assignment software).
    - Do the routes, origins, and destinations for traffic using a new link make sense? Common checks include a select link analysis (Emme) or a link-based flow bundle analysis (Visum).
- Confirm the model reflects existing traffic data
    - Does the magnitude of resulting traffic demand match base year traffic count data? Differences in data are typically present due to:
        - Difference in model year/period and date of data collection (e.g., average weekday model for year 2010 compared to July 2013 count data).
        - Count data collected from various source and time periods. Assigned traffic volumes in the subarea model must balance (unless there is a connector between locations), so unbalanced count data can lead to incompatibility of the data set and create more difficulty for the calibration process.
        - The amount of driveway trips related to pass-by and retail use, or the detail of street network included in the subarea model, may not be captured in the regional travel trends present in the regional travel demand model.
    - If assigning multiple vehicle classes, does the traffic demand match classification data?
    - Does the distribution of traffic match O-D patterns anticipated from license plate, Bluetooth, cell-phone, or other data survey means?

8.3.4 Key Considerations (Application and Issues)

In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements.

The following questions and considerations are intended to help guide decisions regarding application of focus models. In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements. These considerations are not absolute but are intended to function as a general guidance when developing an approach and methodology.

Study Area Size/Boundary
When selecting an area of the model to focus, consider the following:

- Larger focus areas provide more opportunity to refine the model, but also require additional effort.
- Smaller focus areas may limit the effects of focusing.
- Having a constrained focus area with limited connectivity to surrounding areas helps to retain consistency with the base model assignment.
- A focus area should be adequately large that changes within the focus area do not impact areas outside of the focus area.

Network Link (Street) Refinements

- When refining the attributes of the street network, parameters should be consistent with assumptions made about the rest of the network. For example, streets within the focus area should have compatible capacity to similar streets outside the focus area.
- Is the structure of the focus area street network appropriate for the level of detail that is needed for the analysis? Are key streets missing from the model? These may include facilities that affect circulation as well as locations that require detailed traffic forecasts.
- Are the attributes that are used in the regional model appropriate for the focus area? Models are often calibrated to a regional scale and may not include unique details that reflect specific locations. Attributes such as speed or capacity may need to be refined to better reflect true conditions.

Network Zone Refinements

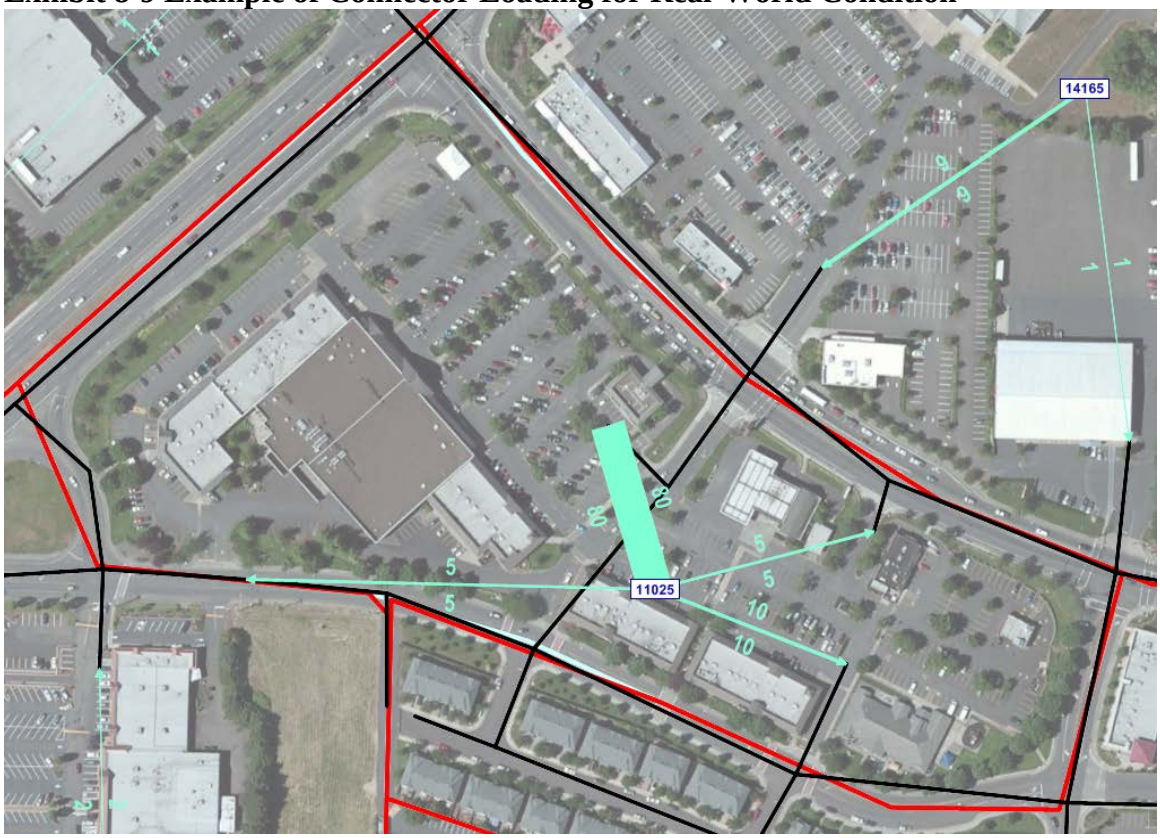
- Can a zone be split based on different land use types? This often can help to allocate the portion of trips from the original zone to the split zones.
- Are there constraints that affect connectivity (such as rail, topography, water, etc.) that drive the need to split a zone to better control loading?

Network Connector Refinements

Depending on the modeling platform, treatment of connectors may be used as a substitute for splitting zones. However, some modeling platforms may not provide the flexibility for multiple connectors per zone with different weighting allocations.

- Location of connector loading should best represent the real-world condition (location of internal streets, driveways, or parking) as is feasible given the model detail. Exhibit 8-9 provides an example of using connector loading to better represent actual network conditions. In this example, each connector for Zone 11025 is placed to represent approximate driveway locations and is given a relative weight based on the amount of trips that are served by the land uses at each driveway. In some cases additional link network and detail may be needed for realistic connector loading.

Exhibit 8-9 Example of Connector Loading for Real-World Condition



- The amount of connectors may need to be increased depending on the magnitude of zone trips and the uniformity of real-world loading throughout the zone. Commercial zones typically have less loading points due to the location of specific (high volume) driveways. Residential zones that may not require specific loading points that represent major driveways but instead multiple connectors that distribute these trips along the edge of the zone as local street circulation would provide.
- The weighting or portion of trips loading to each connector may be set based on the configuration and available data. A common case may be a commercial zone that includes multiple driveways. If traffic counts are available for the driveways, connectors can be weighted to replication these driveways and better reflect actual conditions. In other cases it may make sense to uniformly load (equal weight) connectors across the zone area to distribute demand more evenly – as in the case of a residential zone with uniform house coverage.
- What is the real-world circulation within the zone and should all connectors be used? Is internal circulation possible and is connector (driveway) use based on driveway delay or some other attribute? If so, movement within a zone may occur and trips (in some cases) may not use a given connector and/or connector weights may change. The level of internal circulation also may impact the amount of crossing driveway traffic (e.g., traffic from an eastern driveway heading to the west and traffic from a western driveway heading toward the east, versus all

western driveway traffic heading to the west and all eastern driveway traffic heading to the east).

Intersection Control

- What methods are applied to determine intersection capacity and impedance (delay) in the regional model? If none are applied, application of intersection control is likely beyond the scope of focusing and may be better suited for windowing (which provides more flexibility and deviation from the regional model).
- What level of detail is appropriate given the fidelity of other model elements? Models generally fit into one of the following levels of intersection control:
    - Level 1 – intersection control is ignored
    - Level 2 – some control types are coded (e.g., signalized intersections are flagged) with an equal delay given to all movements
    - Level 3 – all control types are coded and a look up delay is applied for all/some turns. This may consider influences of major and minor street approaches.
    - Level 4 – all control types (and potentially geometric details) are coded and delay is calculated at each intersection movement by a method such as HCM.

Section 8.5.4 (Windowing Key Considerations) includes additional information on application of intersection control and node delay.

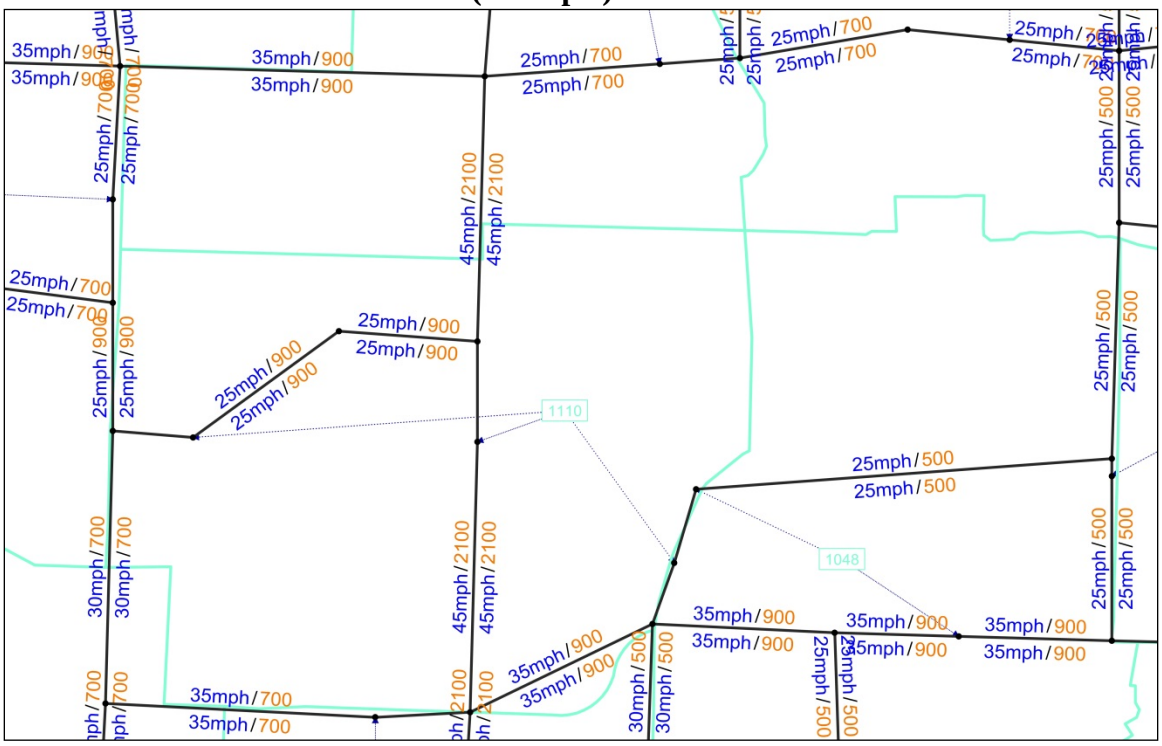
Ramp Meters

- Ramp meters can create bottlenecks that can significantly restrict the throughput based on timing parameters. To reflect this "hard" capacity restriction, a volume delay function that has significantly more delay when over capacity may be an option for emulating a ramp meter.
- Additional solutions for reflecting ramp meter impacts may be available depending on the presence of intersection control elements in the model.

8.3.5 Examples and Scaling

As listed in Exhibit 8-7, the focusing methodology can be applied in varying degrees and scaled to fit the needs of each project and analysis. The following examples demonstrate different scales of application. For reference, Exhibit 8-10 provides a sample of a typical regional base model. This model includes a sparse system of links that represent the major roads (typically collectors and arterials), a zone network, and limited connector loading.

Exhibit 8-10 Base Network Model (Example)



Examples for different scales of applying focusing are shown in Exhibit 8-11 and Exhibit 8-12.

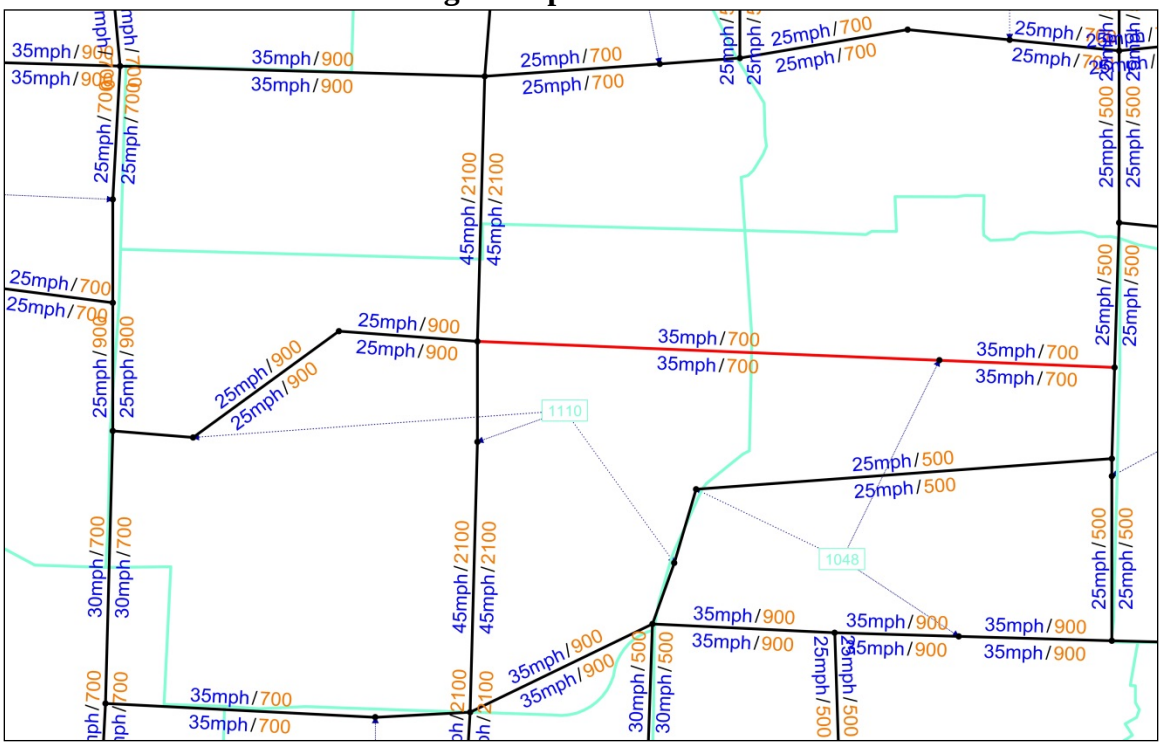
Focus Model Example 1: Low Effort

A low effort application may include making a minor refinement to the travel demand model, including any combination of the following:

- Add a new link or adjust the attributes of a link
- Add connector location or weighting
- Split a zone

Exhibit 8-11 shows an example of adding an additional link and centroid connector to refine the network. The new link (relative to the base network shown in Exhibit 8-10) is shown in red. These two refinements (new link and new centroid) may be all that are needed to focus the subarea model, and represent a minimal, low effort application. Low effort applications may also involve adjustments to the zone system (disaggregation), or minor additional link and centroid connector edits.

Exhibit 8-11 Low Effort Focusing Example – One New Link



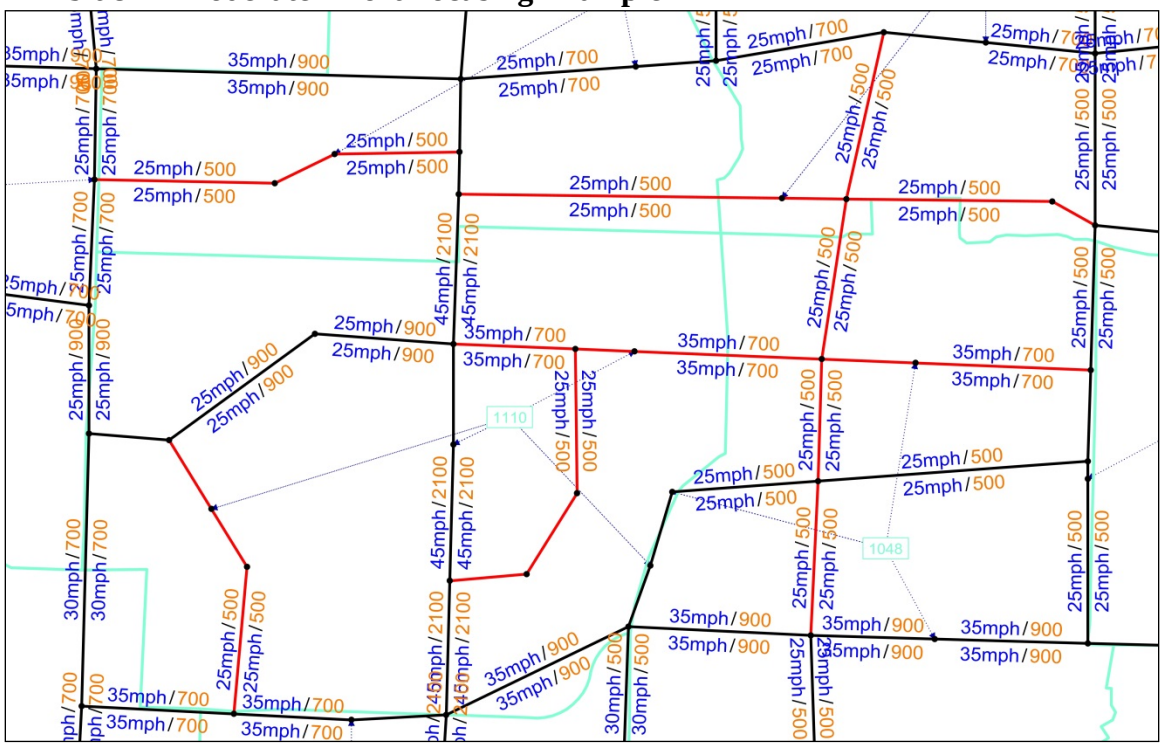
Focus Model Example 2: Moderate Effort

A moderate effort application may include making refinements to several elements in the travel demand model, including any combination of the following:

- Adding several new links or adjust the attributes
- Add connector location or weighting for several zones
- Split several zones

Exhibit 8-12 shows an example of adding several additional links and centroid connectors to refine the network. Similar to the previous example, the new links (relative to the base network shown in Exhibit 8-10) are shown in red. These additional refinements (beyond the level of detail shown in Exhibit 8-11) represent a moderate effort application and would further refine the assignment of traffic in this subarea. Moderate effort applications may also involve adjustments to the zone system (disaggregation).

Exhibit 8-12 Moderate Effort Focusing Example



8.4 Windowing

Windowing is primarily intended to be a motor vehicle reassignment exercise to improve traffic circulation routing and analysis within a subarea. It is likely that continuity of certain elements of the full regional model, such as the ability to perform full 4-step model runs and assigning transit, will be broken by windowing a subarea model. If these components are critical for the application, consider performing a focus model or other methods.

The following sections provide an overview of how to apply windowing:

- Process – What steps are involved?
- Potential Issues – What are issues that may occur?
- Calibration – How to know when the model is "ready"?
- Application – When is this tool needed?
- Examples – When has this tool been used?

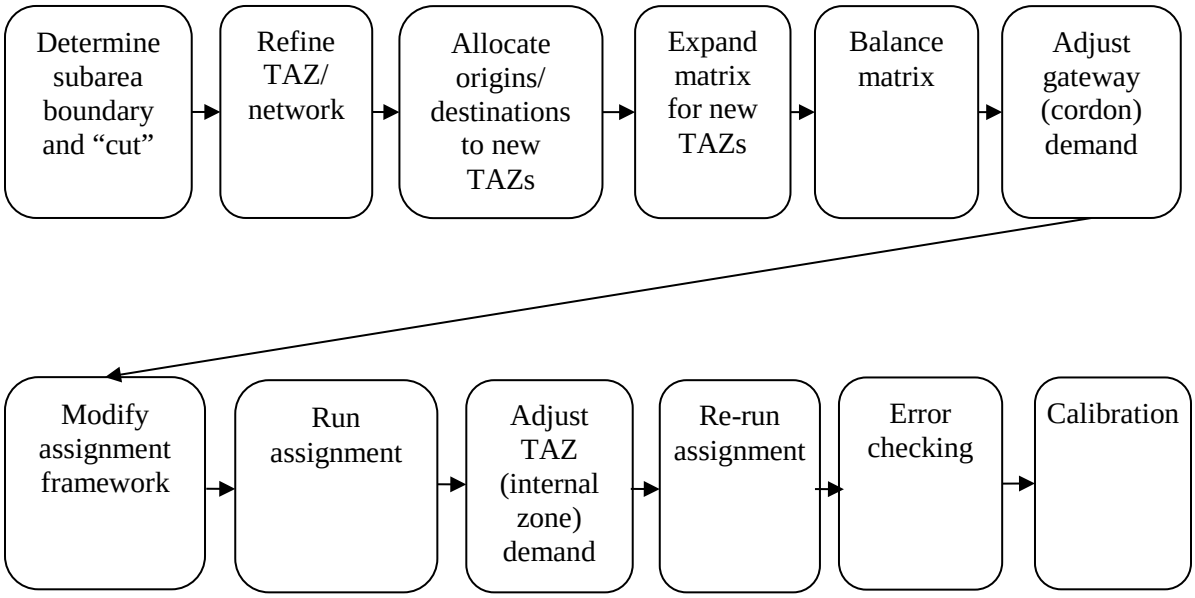
8.4.1 Process

The following steps, simplified in Exhibit 8-13, are used to apply windowing. Note that the windowing process contains more steps than the focusing process shown in Exhibit 8-8. Steps that are also included in the focusing process may have more details in Section 8.4. Additional information, including key considerations and checks, is provided in the following sections.

1. **Determine subarea boundary and "cut" –** Identify locations (links) that will become "cordon" zones with fixed demand from the regional model run. The selection of the boundary is a key decision since demand will be fixed.
2. **Refine TAZ/network -** The standard TAZ system and network are refined in the subarea. This may include adding elements that were not included in the base model (such as additional roads), or adjusting elements that were in the base regional model (such as modifying link capacity).
3. **Allocate origins/destinations to new TAZs -** The origins and destinations for the original or "parent" TAZs from the model run are allocated to the disaggregated TAZs using one of several possible weighting schemes.
4. **Expand matrix for new TAZs -** The assignment trip matrix from the model run is expanded to reflect the revised TAZ system.
5. **Balance matrix -** The expanded matrix is balanced using the disaggregated origins and destinations from Step 3.
6. **Adjust gateway (cordon) demand –** Adjust the demand at the windowed gateways as appropriate for analysis needs (such as adjustment to another analysis year or season).

7. **Modify assignment framework –** Adjust the assignment parameters[31] (such as assignment type and method for determining cost or travel delay), as appropriate, to meet the analysis needs.
8. **Run assignment** - A new trip assignment is run with the trip matrix from Step 5 and the refined network.
9. **Adjust TAZ (internal zone) demand –** Adjust the demand for internal zones as appropriate for analysis needs (such as scenario testing and scaling for additional growth or development). Verify that the resulting demand matches the target values.
10. **Rerun Assignment** - A new trip assignment is run with the updated demand parameters.
11. **Error checking –** Compare model output (such as link and/or turn assignments and general routing patterns between zones) to check for consistency with base model.
12. **Calibration** – Compare model output to data sources and make adjustments to calibrate model.

Exhibit 8-13 Windowing Process



8.4.2 Potential Issues

The following potential issues may arise with a subarea model that uses windowing:

- The subarea needs to be sufficiently large to capture variations in traffic circulation patterns among alternatives. Since the edge of the subarea becomes

[31] While windowing provides some flexibility to add additional detail and refinements that may support using different assignment techniques than the regional model (such as moving from a link-based volume-delay function to an intersection turn-based delay calculation), it is critical to coordinate with TPAU and ODOT regional staff to confirm these methods and assumptions are appropriate for the network detail.

fixed demand, traffic circulation that may be impacted outside the study area is not considered.

- The additional flexibility ("more knobs to turn") with windowed models can require more care and make them more difficult to calibrate. The iterative process that considers adjustments to the network, demand, assignment parameters, and other elements, often requires that those elements are revisited after subsequent adjustments have been made to other parameters. Conceptually-sound adjustments are critical.

8.4.3 Demand Adjustments

Demand adjustments (scaling or changing the demand for a zone or specific O-D pairs) allow a layer of flexibility not present in focus area models that can be used to account for subarea demand magnitudes and traffic patterns that may not be captured in a regional scale model. While subarea models should typically stay consistent with the regional demand model, there may be cases where demand adjustments are needed. Section 8.5.5 includes additional considerations for demand adjustments.

- Demand adjustments may be needed for a number of reasons (including, but not limited to, adjusting to count data for another analysis period/year, or capturing internal trips ends and driveway counts along a corridor) to represent demand well enough that the model has the ability to adapt to network modifications and alternatives.
- A sample application of a demand adjustment could include the following analysis scenario:
    - The purpose of the analysis is to test a variety of transportation improvements, which include operational improvements such as intersection control and lane configurations.
    - A windowed area model is created that includes a high level of detail for the traffic network in order to capture the operational behavior and impacts in the model. This model uses intersection-level turn delay based on HCM methodology.
    - Traffic circulation in the model depends on the delay calculated for turn movements in the system. In order to capture existing traffic flow patterns, a realistic approximation of the travel demand between zones is needed to produce accurate turn delays in the model.
    - A comparison of the subarea model and traffic count data indicates that some of the gateway (cordon) traffic volumes in the model do not match well with count data.
    - A demand adjustment is performed in order to scale the gateway traffic volume (or other isolated internal demand that is not related to routing errors) closer to actual count data. By having a model demand that reflects actual count data, the model will be able to better account for traffic circulation patterns that result from changes in the transportation system. By better estimating the traffic circulation, the model will also better estimate actual traffic volumes on the road system.

- Demand adjustments typically rely upon having traffic count data that demonstrates the basis for the adjustment. However, it is important to be mindful of daily traffic fluctuations, which may be 10% on a day-to-day basis.
- Demand adjustments (as noted in Section 8.5.4) should only be performed after exhausting other model checks and calibration items related to assignment routing in the model.
- Demand adjustments should not be performed indiscriminately without a conceptual basis for why the adjustments are being made.
- Demand adjustments require existing year count data or similar thresholds to act as constraints to determine the degree of adjustment. Demand adjustments made to future year models should be applied in such a way that the resulting model growth (difference between the original base and future models and differences between the adjusted base and adjusted future models) does not change. Demand adjustments are performed to better fit traffic data and routing behavior in the model, not to influence the growth projected by the model (unless analysis year is changed).

8.4.4 Calibration (Model Checking)

Analysis Procedure Manual Version 2 Chapter 6 includes additional information on model checks.

The calibration process is a critical step to ensure that the focused subarea model is compatible with the base model. If issues arise during the calibration process, it may be indicative that another method (such as focusing) may be more appropriate. The calibration process for windowing is similar to the process used for focusing (Section 8.4.3); however, some key differences exist due to additional allowances and flexibility that the modeler has through the windowing process. The calibration process for windowing should generally include the following considerations, at minimum:

(Before demand adjustments or network refinements)

- Confirm the window model is consistent with the base model
    - Are demands at cordon zones or gateways on the edge of the windowed model consistent with the assigned link volumes at these locations in the base regional model?
    - Do internal TAZ retain their original scale of demand (total trips in and out)?
- Confirm the window model is compatible with the base model
    - Does rerunning the assignment procedure for the windowed area give similar assignment results as the regional base model?

(After network refinements)

- Confirm the window model is providing realistic results
    - Do the sums of connector volumes for a zone match the total zone demand?

    - Does the routing for traffic into and out of new zones make sense? Common checks include a select zone analysis (Emme) or a zonal flow bundle analysis (Visum).
    - Do the routes, origins, and destinations for traffic using a new link make sense? Common checks include a select link analysis (Emme) or a link-based flow bundle analysis (Visum).
- Confirm the model reflects existing traffic data
    - Does the magnitude of resulting traffic demand match base year traffic count data?
    - If assigning multiple vehicle classes, does the traffic demand match classification data?
    - Does the distribution of traffic match O-D patterns anticipated from license plate, Bluetooth, cell-phone, or other data survey means?

(After demand adjustments)

- Confirm the demand adjustments had the intended effect
    - Are adjusted totals for in and out trips by zone consistent with the targets?
    - Does the overall matrix sum change by the intended amount (if applicable)?
    - Do demand levels at zones that weren't intended to change remain the same?
- Confirm the window model is providing realistic results (again)
    - Do the sums of connector volumes for a zone match the total zone demand?
    - Does the routing for traffic into and out of new zones make sense? Common checks include a select zone analysis (Emme) or a zonal flow bundle analysis (Visum).
    - Do the routes, origins, and destinations for traffic using a new link make sense? Common checks include a select link analysis (Emme) or a link-based flow bundle analysis (Visum).

Given the unique characteristics and applications of subarea models, an appropriate level of calibration (e.g., metrics such as R^2 values for observed versus modeled link or turn volumes) for one model may not be sufficient for another model. For that reason it can be difficult to determine when a model is calibrated "enough", since it ultimately depends on how the model is applied and the decisions that will be made with the analysis. However, at a minimum, the above process and qualitative checks should be followed to ensure that due-diligence is performed, though additional checks and actions may be required. In addition, the analyst/modeler should provide documentation that shows that convergence criteria (such as R^2) were tracked through the calibration process.

8.4.5 Key Considerations (Application and Issues)

The following considerations are intended to help guide decisions regarding application of window models. In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements.

These considerations are not absolute but are intended to function as a general guidance when developing an approach and methodology.

Study Area Size/Boundary

When selecting an area of the model to window, consider the following:

- The boundary of the windowed area creates gateway or cordon zones that have fixed demand based on the assigned link traffic in the regional base model.
- Refinements to the regional base model may be needed before applying the windowed cut in order to refine demand at the cordon zone locations.
- Since demand is fixed at cordon locations, ensure that the model is sufficiently large to test the set of alternatives that will be analyzed. Running a sensitivity test in the regional base model that includes the most extreme network alternative can be used to determine the area of impact and potentially the size of windowed area model that may be needed.
- Since demand is fixed at cordon locations, it is generally beneficial to minimize the number of cordons and select a boundary that has less network redundancy. Constraints to network connectivity (rail, water, extreme topography, etc.) can provide physical boundaries that serve windowed models well.

Network Element Refinements (Links, Zones, Nodes)

When adding refinement to the network elements in a windowed subarea model, many of the same considerations for focusing should also be applied and are provided in Section 8.2.4. Additional considerations that result from the added flexibility that windowing allows:

- Do other attributed need to be considered and coded in the windowed area that may not be included in the regional base model? Unique elements within the windowed area (downtown parking, pedestrian activity, etc.) may be considered and added to the network attributes. These elements may also need to be accounted for in the assignment process.

Demand Adjustments

When applying demand adjustments, consider the following (and items noted in 8.5.3):

- Applying network refinements before demand adjustments aids in error-checking these edits before introducing additional changes (demand).
- What is the demand adjustment trying to achieve and what is the appropriate level of detail to meet this need? Some adjustment scenarios may require simply applying a factor to a single zone, while other adjustment scenarios may include a more elaborate process that considers changes to distribution.
- What type of demand needs to be adjusted? Will all model trips be adjusted, or will adjustments be made to specific internal zones and/or cordons?
- Do the trip length frequencies of the adjusted demand matrices remain similar to the original demand matrices?

Future Year Scenarios

When preparing future year scenarios, consider the following:

- What is the most appropriate method for combining the windowed area network with the future year demand? The most efficient process often includes windowing the future demand matrix and inserting it into the windowed base year model network and then adding additional improvement projects (if any) to reflect the future model road network.
- Were demand adjustments made to the base year model that needs to also be applied to the future year model? Section 8.5.2 provides additional information about conducting demand adjustments and application for future year models.

8.4.6 Examples and Scaling

As listed in Exhibit 8-7, the windowing methodology can be applied in varying degrees and scaled to fit the needs of each project and analysis. The following examples demonstrate different scales of application.

Window Model Example: Astoria Downtown

The Astoria-Warrenton model was windowed to capture potential circulation impacts related to potential traffic control changes in the Astoria downtown area. The base regional model is shown in Exhibit 8-14 and includes Astoria, Warrenton and the surrounding rural areas.

Exhibit 8-14 Astoria Warrenton Regional Model

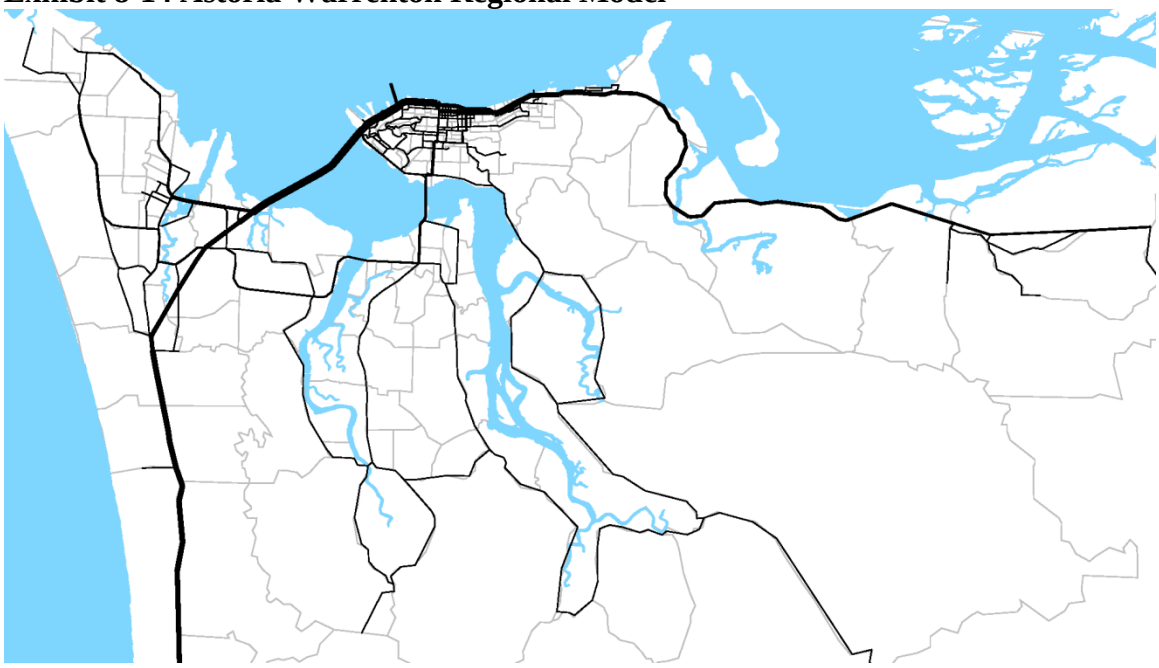


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Exhibit **8-15** shows the Astoria downtown area in the regional model, as well as a sketch showing the proposed window boundary and cordon zones. This area was selected to minimize the amount of streets in the regional travel demand model that would be cut,

while allowing for a large enough area to sufficiently capture potential traffic circulation changes due to future transportation network alternatives. Specifically, the window boundary was selected to account for and balance the following needs:

- Adequate size to include subset of study intersections and circulation impacts
- Minimize the number of cordon zones (cut base regional links)
- Zone boundaries were retained and not split (windowed matrix retained total trips for internal zones)

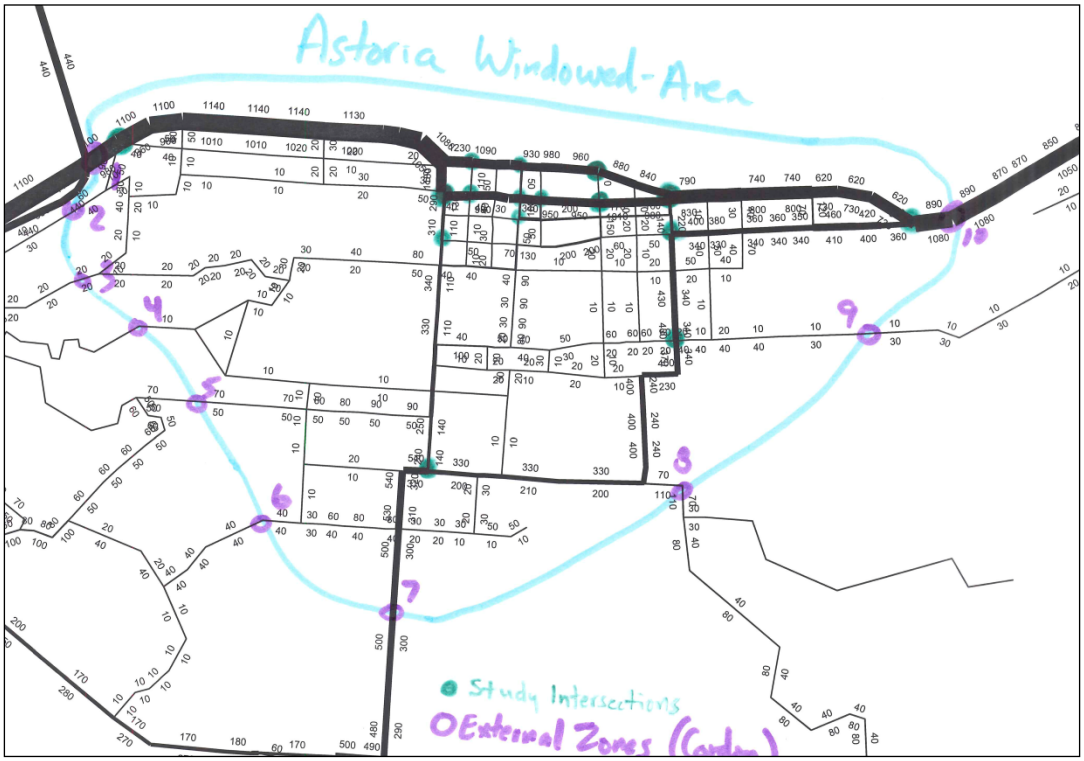


Exhibit 8-15 Astoria Warrenton Regional Model and Sample Window Area

The resulting windowed area model is shown in Exhibit 8-16. The windowed model included the following refinements to capture circulation impacts:

- Assignment – Incorporated HCM intersection delay for intersection turns.
- Link Network – Added all public roadways in windowed area
- Zone Network – Added centroid connectors to reflect major driveways and parking locations.

Exhibit 8-16 Astoria Downtown Windowed Model

8.5 Dynamic Traffic Assignment (DTA)

This section provides an overview of Dynamic Traffic Assignment (DTA) concepts and general considerations for application in Oregon. DTA tools and software packages are still relatively new, emerging tools that have the potential to improve forecasting and analysis and are becoming more widely used around the country. Due to the potential benefits of these tools, they may become more prevalent as they become better known and understood. While this section provides a general overview of DTA, additional information about DTA is provided by the Transportation Research Board[32].

8.5.1 DTA General Concepts

Traditionally, travel demand models have generally included a "static" assignment – one that provides a fixed path (or paths) for each origin-destination (O-D) pair during a given time interval. The time interval is generally the duration of the model period (such as a full day or a one-hour evening peak hour), or may be divided into shorter durations (such as one hour intervals within a day, or 15-minute periods within an hour). Generally, these static models have four common characteristics:

1) The O-D trips for each time interval are a function of input static time-of-day factors that are unrelated to the modeled assignment results. This means that the trips planned for each time interval are largely insensitive to how congestion varies through time.
2) All O-D trips are assumed to be completed during the time interval. That is, the travel time for each O-D pair is less than or equal to the time interval (generally one hour). In the event that a trip exceeds the time interval, demand is still forced through the system, leading to unreasonable demand-to-capacity (d/c) in highly congested networks.
3) The assigned path (or paths) for each O-D pair are not affected by the volumes in earlier time periods. Therefore, preexisting congestion on the roadway (from previous time periods) is ignored.
4) The representation of intersection Level of Service (LOS) is very simple (or non-existent) as the network usually lacks intersection geometry and signal timing. This significantly limits the static assignment model in its usefulness for traffic operations analysis.

Such static assignment models tend to work fairly well as long as recurring congestion is not present in a network with multiple alternatives routes (i.e. a redundant network). In addition, static assignment models are not able to fully capture additional details related to the complex effects of congestion that causes traffic to:

- Divert to another route (spatial spreading),
- Leave earlier or later (during another time period – peak spreading), or
- Travel through the congestion (with a significantly higher realized travel time).

[32] TRB Transportation Research E-Circular E-C153: Dynamic Traffic Assignment: A Primer, Transportation Research Board, Washington DC, June, 2011. http://www.trb.org/Publications/Blurbs/165620.aspx

Beyond traditional aggregate trip-based demand models, activity-based demand models (ABM), are a better framework for integration with DTA. ABMs microsimulate a day's worth of travel for each individual in a region, operate at a finer temporal resolution (such as 30 minutes), and include improved models for scheduling trips (both departure and durations). Unlike aggregate trip-based models which output matrices by time period, ABMs output a list of individual trips with departure times. Integrating an ABM with a DTA therefore looks significantly different than integrating with a trip-based model. Currently, ODOT is in the process of developing ABMs.

In addition, static assignment models are not designed for dynamic changes in network capacity related to temporary closures, changes in traffic control, or non-recurrent diversion related to an incident. Other tools are needed for application in these scenarios. To better understand the potential impacts of the above cases, DTA can provide a more comprehensive assessment.

Unlike static models, DTA models allow travel routes to change through time. Traffic that is existing on the system (and its impacts on travel time) is considered, much like a seeding interval for a traffic simulation model. While there are many differences between different DTA platforms, the following general characteristics are common:

- Time-dependent paths; the path through the network is influenced by travel times that vary depending on when travelers arrive at a given network link, as opposed to assuming that travel times are constant throughout the period being simulated.
- Travel routes typically change at shorter intervals than static models (typically minutes instead of hours).
- Network congestion estimates, which are often based on traffic operations, are typically more detailed than a static model to account for travel time difference between routes.
- Vehicles queue on the network and are not forced through over-capacity conditions due to a timer interval constraint. Thus some demand may remain unserved during the analysis period.
- Individual vehicle "simulation" (whether visualized or not) is generally present to account for vehicle interaction and operational impacts.
- Like static assignment, multiclass assignment (including trucks) can be captured in DTA tools, which allow for different path sets and attributes among vehicle classes.
- Transit elements are included in varying degrees based on each DTA tool, but may include the ability to include service information including routes, stop locations, and schedules. Next generation DTA tools are starting to model individual transit persons as well.

DTA models assign demand in a much shorter time interval than static equilibrium traffic assignment models; often demand must be segmented into 15, 10 or even 5 minute time slices. This shorter interval duration is a feature that allows for better reflection of traffic flows, but it is also a requirement that necessitates better trip estimates than typically provided by demand models. Developing the initial set of OD trip tables by time period

that are fed into the DTA is an important task that needs to be done with care, and is discussed later in this section.

In mesoscopic modeling, DTA models represent the application that comes closest to achieving the same details that microsimulation models achieve. While microsimulation models maintain more advanced driver behavior algorithms and settings, DTA models usually provide individual vehicle simulation, car-following logic, intersection delay and queuing components, and the ability to introduce vehicle and/or driver profiles, all while maintaining trips to load onto a routable network.

A key differentiator among DTA models is the overall fidelity and detail for which traffic flows are captured along a road. The two types of models are referred to as "link-based" and "lane-based:"

- **Link-Based Models** – Traffic flow along a roadway is analyzed macroscopically, where the total number of lanes is considered as an overall link capacity. Differences among individual lanes (including the amount of traffic demand for an individual lane), interactions among individual vehicles, and friction related to movement and lane changing are not directly modeled.
- **Lane-Based Models** – Traffic flow along a roadway is analyzed for each lane, using car-following algorithms that account for interactions among vehicles and flow differences in each lane. Storage of vehicles related to turn bay lengths and other differences between lanes along a given link may influence operations at the adjacent node/junctions/intersections.

As discussed in later sections, the fundamental differences between these model types should be considered when selecting a DTA tool for project application.

8.5.2 DTA Scoping

The following sections provide an overview of scoping DTA modeling efforts and an introduction to various tools and software packages.

"…DTA models are not the universal cure that can cost-effectively address all types of problems at hand. DTA models take more time and resources to construct and calibrate (as compared with static traffic assignment models) and represent traffic dynamics in a coarser granularity (as compared with microscopic traffic simulation models.) Practitioners are advised to match the choice of modeling approaches to the problem at hand. For long-term planning, for example, the available level of input data required for DTA may not be available, so that one may have to make many assumptions in order to construct such models. If the additional detail and precision in their output data compared to conventional network forecasting is not beneficial for the modeling question in mind, then it may not be worth the additional modeling effort. For a smaller bounded area in which a detailed representation of multiple modes (e.g., auto, transit, pedestrians) and facilities (roadways, parking, crosswalks, etc.) are required, microscopic models may be more appropriate and useful" [1]

[1] TRB Transportation Research E-Circular E-C153: Dynamic Traffic Assignment: A Primer, Transportation Research Board, Washington DC, June 2011.

Tool Selection

Unlike static demand models that typically can achieve similar analysis under different graphical user interface (GUI), DTA models generally have many more fundamental differences related to model structure, network detail, and assignment algorithms. Section 8.5.3 provides an overview of DTA tools and includes additional information comparing key differences among some of the DTA tools and software packages. It is important to consider these fundamental differences when selecting the correct tool (among DTA software or other tools) to address the transportation question.

Data

The general types of data needed to code and calibrate a DTA model are similar to a subarea model (Sections 8.2 through 8.4) and require the following general types of data:

- Network Data – Attributes of the transportation network such as traffic control, lane geometries, and signal timing information.
- Demand Data – Data such as initial O-D trip matrices by time period, land use inventories and/or traffic counts to estimate the level of overall traffic demand.
- Calibration/Validation Data – Data that can be used to compare traffic flows and operations from the model, such as tube or intersection turn counts, and travel time runs along a corridor.

However, the key differences are that DTA traffic datasets (demands, flows, and operations) typically need to address finer-grained resolutions of traffic volume and travel time data over sequential time periods. For instance, data (such as traffic volumes, speeds, etc.) may be needed for individual 15-minute intervals (3:00 to 3:15 p.m., 3:15 to 3:30 p.m., … 6:45 to 7:00 p.m.) rather than a single, aggregated 5:00 to 6:00 p.m. one-hour period. Key differences in the type and resolution of data needs include:

- O-D Trips (travel demand)
    - Finer time resolution trip matrices
    - Trips matrices that will not overload the DTA network (i.e. the overall magnitude of traffic demand is appropriate for the network)
- Traffic Volumes (intersection turn or roadway tube)
    - Flow profiles that cover the modeled time period (which may exceed a simple peak hour)
    - Flow profiles in time intervals of an appropriate resolution to be compared to the DTA model (such as 15-minute periods)
    - Flow profiles at key locations upstream, downstream and/or within bottleneck areas to understand differences in traffic demand and actual supply output
- Traffic Operations
    - Average speed profiles along a corridor (may come from Bluetooth and/or third party vendor speed data such as INRIX or TomTom)
    - Average delay for intersection movements (may be compared to an HCM intersection model)
    - Actual signal timing (such as observed average phase durations and cycle lengths) to develop the network model (traffic control details).
    - Queue lengths to understand the vehicle spacing and jam density

Given the duration and resolution of datasets identified above, it can be difficult (if not cost-prohibitive) to acquire complete data coverage of the model area. For that reason, it is important to strategically make use of existing data sets and focus new data collection efforts on key locations that capture real world behavior and attributes that need to be reflected in the model. The following types of answers should be addressed in model validation and calibration and may guide the collection of data:

- Is the overall magnitude of traffic demand appropriate? If not, then a common correction (for current and short term forecast years) is to adjust the O-D trip matrix to better match traffic counts (see Section 8.5.3) (Check volumes at network entry points and/or screenlines)[33]
- Is the correct routing being reflected in the model? (Check volumes on screenlines and turn movements at key junctions)
- Is the correct volume profile (and peaking) being realized on key network links? (Check volume profiles at key locations as well as upstream/downstream of bottlenecks)
- Is the correct travel time profile being realized on key network links? (Check traffic volumes and determine if delay estimates are being applied appropriately)

Resource Needs

Section 8.3.3 reviewed the level of resources needed to apply windowing and subarea models. In many cases a DTA model may be applied as a windowed model. For reference, application of a DTA windowed model will generally fall under the "high"

[33] There are some DTA model development projects that rely upon activity-based demand, provided in the form of trip lists (simulation output) rather than an ODO matrix.

range of effort listed in Exhibit 8-7.

Due to the additional refinements and details available in a DTA model, the time needed to set up a DTA model (like a microsimulation model) is probably best summarized as weeks or months, rather than hours or days.

Since DTA models typically require additional effort to build and calibrate beyond a typical static macroscopic model, it can be helpful to approach the process from the perspective of scoping a microsimulation model. While DTA models may be used for a variety of purposes ranging from developing better demand volumes for microsimulation to using operational measures to screen alternatives, the details and data needed to build and calibrate the models can emulate a microsimulation model. ODOT has developed a process[34] for building Vissim microsimulation models that provides a general structure for how to approach and scope a microsimulation effort. Depending on the DTA application and similarity to a microsimulation model, some of the framework of this approach may be able to provide a generalized resource for a DTA modeling endeavor.

8.5.3 Overview of DTA Tools and Software Packages

There is a wide array of tools available to perform DTA at varying scales and resolution levels. These tools range from enhancements of macroscopic models to application within microsimulation – essentially covering the full spectrum of mesoscopic modeling in terms of network detail and level of effort. The various types of tools available and the range of these tools allows for broad application ranging from enhancing volume development for separate traffic analysis to performing the actual traffic analysis in place of microsimulation. The following section provides an overview of some of tools used in the Portland metropolitan area. This list is not meant to be a review of all the DTA tools on the market; instead it is meant to illustrate the spectrum of DTA tools. Exhibit 8-18 summarizes the DTA tools that have been applied in the Portland metropolitan area.

[34] *Protocol for Vissim Simulation*, Oregon Department of Transportation, June 2011. http://www.oregon.gov/ODOT/TD/TP/APM/Add15A.pdf

The following tools are grouped along the spectrum of mesoscopic modeling, ranging from those closer to macroscopic models to those that are more similar to microscopic models. Each tool has numerous features and fundamental differences that provide opportunities and limitations that ultimately impact the analysis results. This list is grouped for demonstrative purposes only and analysts are encouraged to understand the full abilities and limitations of these tools before project application. Groups closer to macroscopic models would require less detail and resources to use, while those closer to microsimulation would be more data and labor intensive to apply.

DTA tools within **macroscopic framework** (individual vehicles are not modeled):

- Visum Dynamic User Equilibrium (DUE) – A model within PTV's macroscopic Visum model that constrains vehicle flow due to out-link intersection capacity and allows spreading of vehicle demand to adjacent routes. If other routes are at capacity (for a given time period), demand can be spread to originate during adjacent time periods. DUE is a link-based model and does not require coding intersection geometry or signal timing.

DTA tools with **link-based traffic flow** (individual vehicles modeled):

- DynusT – An open-source stand-alone DTA package that models individual vehicles but does not model individual travel lanes. Because of its simplifications in network representation, it can be applied to larger network sizes. See Exhibit 8-18 for additional details.

DTA tools with **lane-based traffic flow** (individual vehicles modeled):

- Dynameq – This stand-alone DTA package developed by INRO models individual vehicles and lanes, includes car-following logic that (due to the lane-based nature) models interactions in a more advanced manner than the link-based models but is more simplified than a microsimulation model. See Exhibit 8-18 for additional details.

DTA tools within **microscopic framework** (individual vehicles modeled)

- Vissim DTA – A model within PTV's Vissim microsimulation package that allows for dynamic routing of individual vehicles. This application makes use of the fine-grained car following logic within the microscopic model.

Exhibit 8-17 Continuum of DTA Tools and Typical Level of Detail

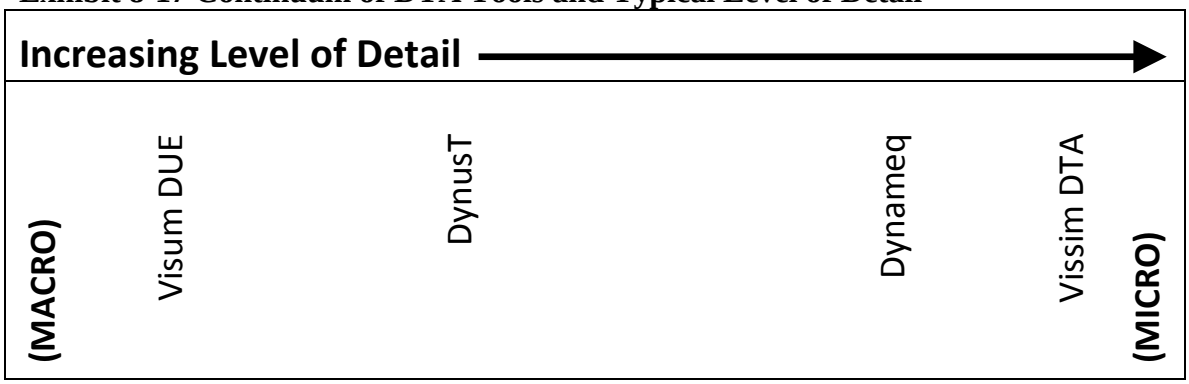


Exhibit 8-18 Comparison of DTA Tools Applied in Portland Metropolitan Area

Element	DynusT	Dynameq
Segment Geometry and Control	**Link**-based (overall capacity of the cross-section is considered)	**Lane**-based (individual capacity for each lane and interaction with adjacent lanes and vehicles are considered)
Intersection Geometry and Control	Intersection turn bays are based on single global distance parameter.	Allows specific lane storage via creation of new links at any change in cross section.
Traffic Signals	Includes general traffic signal settings as well as actuated timing on a cycle by cycle basis.	Includes general traffic signal settings as well as actuated timing on a cycle by cycle basis. (beta feature)
Typical Model Size/ Application	Regional application for major roads is common.	Typically more restrictive model size that may be smaller scale subarea due to increased detail (all streets).
Includes Vehicle Simulation	Vehicles simulated at specific time steps (every 3 seconds or other duration)	Vehicle interaction is simulated for events and calculation is performed when there is a change
Visualization	Synthetic visualization of individual vehicles based on link-level information.	Macro flow (density, speed, etc.) at link level - individual vehicles not shown (but are simulated).
Randomness	Stochastic – allows multiple runs to reflect system variability (similar to microsimulation)	Deterministic model (profiles are applied for characteristics)
Ability to Import and Export Data	Allows network import/export with travel demand models and microsimulation. Direct integration may be difficult since network may be modified based on geometries.	Allows network import/export with travel demand models and microsimulation. Direct integration may be difficult since network may be modified based on geometries.
Output	Data/Measures can be visualized in GUI or raw data exported for processing.	Data/Measures can be visualized in GUI or raw data exported for processing.
Scripting / Application Programming Interface (API)	Custom dynamic-link library (DLL) for ramp metering and signal control; full API planned	Python API
License	Open source without support; support for a fee	Purchase (includes software updates and support)

8.5.4 DTA Calibration

Analysis Procedure Manual Version 2 Chapter 6 includes additional information on model checks. Calibration information in section 8.5.4 may also be relevant, particularly when applying a DTA model as a windowed subarea model.

Model Checking

An important aspect of DTA calibration is finding and fixing network coding problems and performing a model checking process. In the case of a DTA model, miscoding signal timing, approach geometry, intersection connectivity, turn prohibitions, etc. can have major impacts on the simulation. Very often the calibration process requires detailed network coding checks, and network defaults must be revised where they are found to be insufficient to reflect true operations in key locations. In addition, any O-D demand adjustment should be re-done if significant network errors are corrected.

Calibration

In general, the following broad observations are common to DTA model calibration:

- DTA models include more settings and "knobs" to turn (which may or may not be appropriate to adjust) than a traditional static assignment model. This makes the calibration process more complex, costly and time consuming.
- More data is needed than a typical static model (see Section 8.6.2)

Due to the varied level of detail and application of DTA tools, it is important to consider the resolution of the model and what is an appropriate level of calibration. In addition to information provided for calibration subarea models, some strategies for calibrating DTA models include:

- If specific targets are used for traffic volumes and/or travel times, consider thresholds that vary by project priority. Corridors that are the primary focus of the analysis should have the tightest calibration targets while other roads in the model that compose the supporting network may not be as critical. These targets should be developed through coordination with agency staff.
- Signal timing can be a critical element that affects calibration on non-freeway facilities. Spending the time to code signal timing at an appropriate level of detail will facilitate calibration.
- Flow models (relationship of vehicle speed, density and flow) are an important component of freeway segments. Be sure that the settings are reasonable and appropriate for the model area.
- Understand the basis, limitations, and location-dependency of data that was used to develop the model, specifically in regards to if data represents a total traffic demand or an actual (potentially capacity-restricted) traffic volume that is realized in the network.
- Consider if bottlenecks and capacity constraints are being correctly reflected in resulting flow profiles. Gateway adjustments may be necessary to approximate bottleneck effects.

- Depending on model resolution and purpose, calibration may be sufficient at aggregate levels.
- Review high-level items (such as total volume magnitude of a screenline) and general routing patterns before focusing on network details.
- Check for unserved demand or "lost trips" on the travel network. These are vehicles that cannot actually get on the network or cannot make it from their origin to their destination according to their chosen route because of congestion. Many DTA packages report these trips and the analyst must address them by changing the demand profile or fixing the network.
- O-D demand adjustment may be needed to fit a demand matrix to the network conditions (as observed by traffic counts). However, such action should be approached with caution and should be re-done once the network is error free. . Related guidance for demand adjustments is provided in Section 8.5.3.

Some parameters (such as vehicle flow densities and signal timing) have the potential to greatly influence the model network capacity and the resulting traffic assignment and overall results. These parameters should be verified before focusing on and adjusting gateways or micro-level details for calibration.

8.5.5 Measures of Effectiveness (MOE)

The fundamental nature of DTA models and core differences from traditional static models allows for an expanded set of model data and reportable measures of effectiveness. The increase of available measures reflects the key differences introduced by DTA models in level of detail (such as intersection operations) and changes over time that are typically not available in static models.

The amount of MOE that are available directly through the GUI of the DTA platform may vary by software version and type of DTA model (link-based versus lane-based, see Section 8.5.3). However, additional measures are typically available indirectly by processing raw data that is produced through the model runs. These possibilities leave the analyst with a wide selection of potential MOEs. It is important to select MOEs that are relevant for the decisions being made and are appropriate for the level of detail coded into the model.

Some potential types of MOEs include:
*(Note: additional detail may also be available for individual lanes in lane-based DTA models when denoted with *)*

- MOEs typically produced by a static model
    - Roadway segment (link) traffic volume during a time period *
    - Roadway segment (link) average travel time during a time period *
    - Roadway corridor average travel time during a time period *
    - System MOEs (vehicle hours of delay, etc.)
- MOEs typically produced by a DTA model
    - Available due to additional operation detail

        - Average delay by intersection movement
        - Vehicle queuing or link occupancy (available on a lane basis for lane-based DTA models) *
    - Available due to nature of model simulation (individual vehicles)
        - Reliability metrics related to range of travel time for all vehicles along a corridor during a time period (Exhibit 8-20) *
        - Individual travel time trajectories along a corridor *
    - Available due to differences between time periods
        - Map-based simulation of traffic volumes, occupancy, or other metric shown on a link by link basis (Exhibit 8-19) *
        - Segment or corridor travel time profile (for each hour of the day or model time interval) (Exhibit 8-20)
        - Space-time ("brain scan") heat maps showing changes in travel time, occupancy, speed, etc. along a corridor (Exhibit 8-21) *

Some MOEs or outputs that are commonly produced using static models (such as model difference plots) may not be as easy to reproduce in DTA packages. The summary of this output may require additional processing rather than being directly available/automated through the model interface.

The following exhibits demonstrate some of the MOEs that are possible with DTA models.

Exhibit 8-19 DTA MOE Sample 1 – Map-based Shockwave Animation (Regional or Subarea) Shown for Four Sequential Time Periods

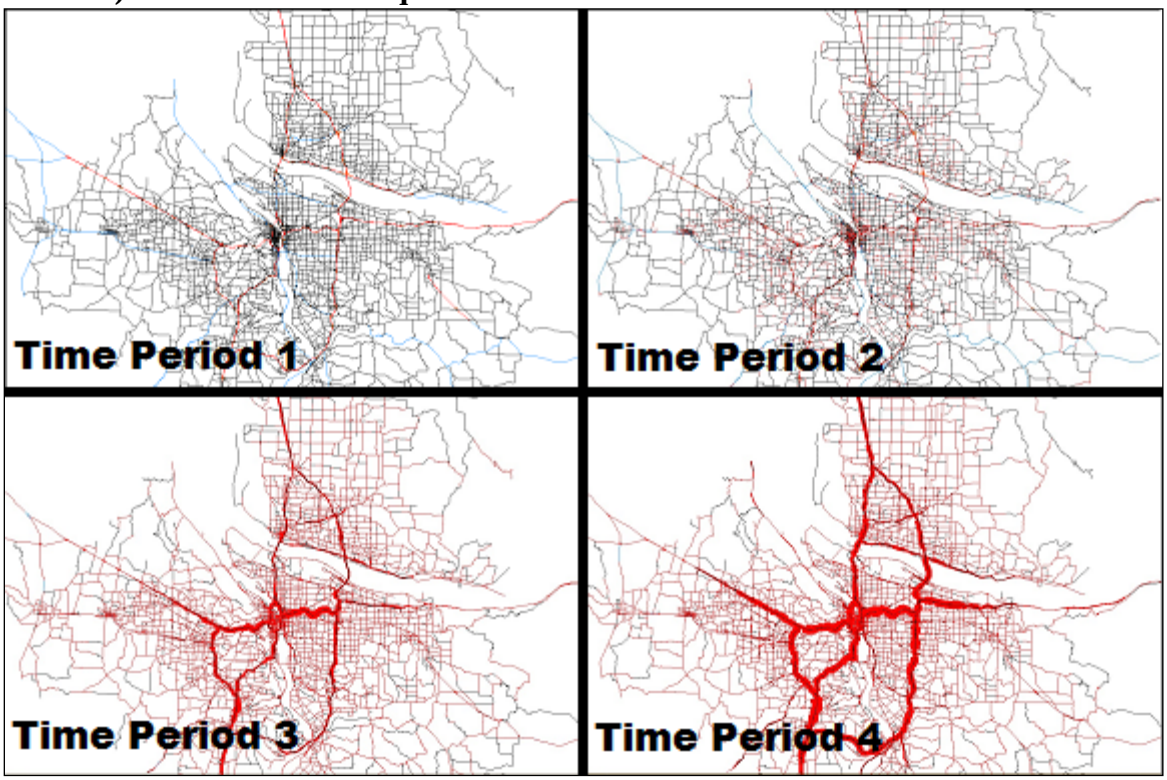


Exhibit 8-20 DTA MOE Sample 2 – Travel Time Profile along a Corridor

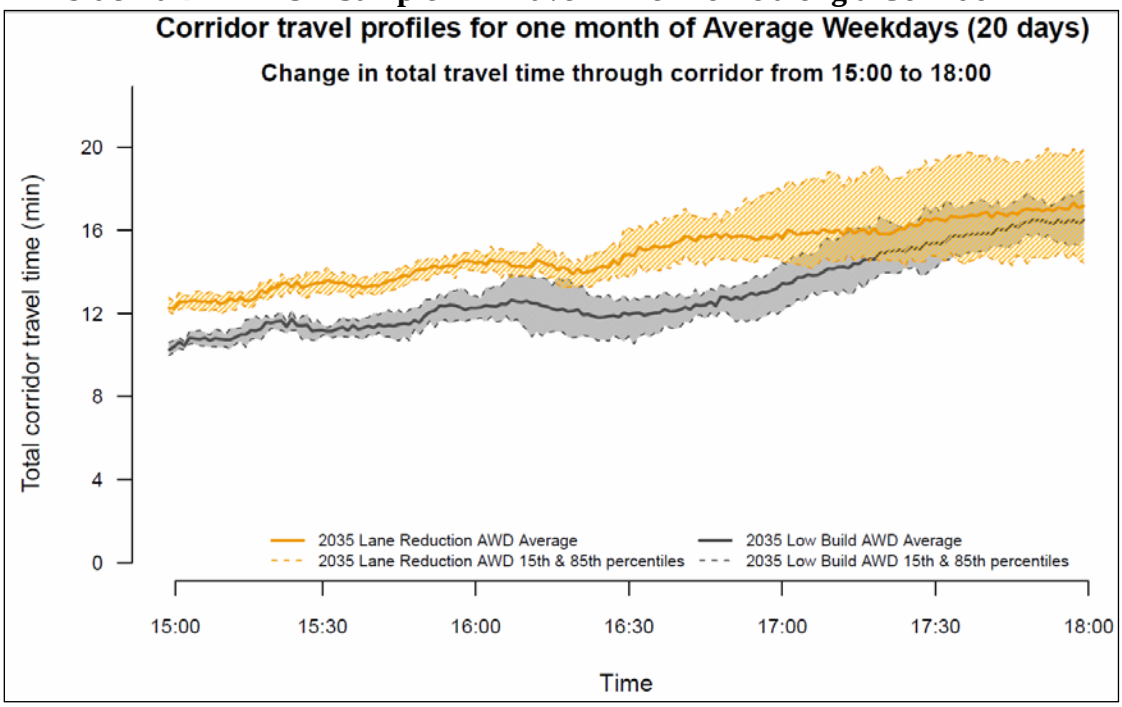
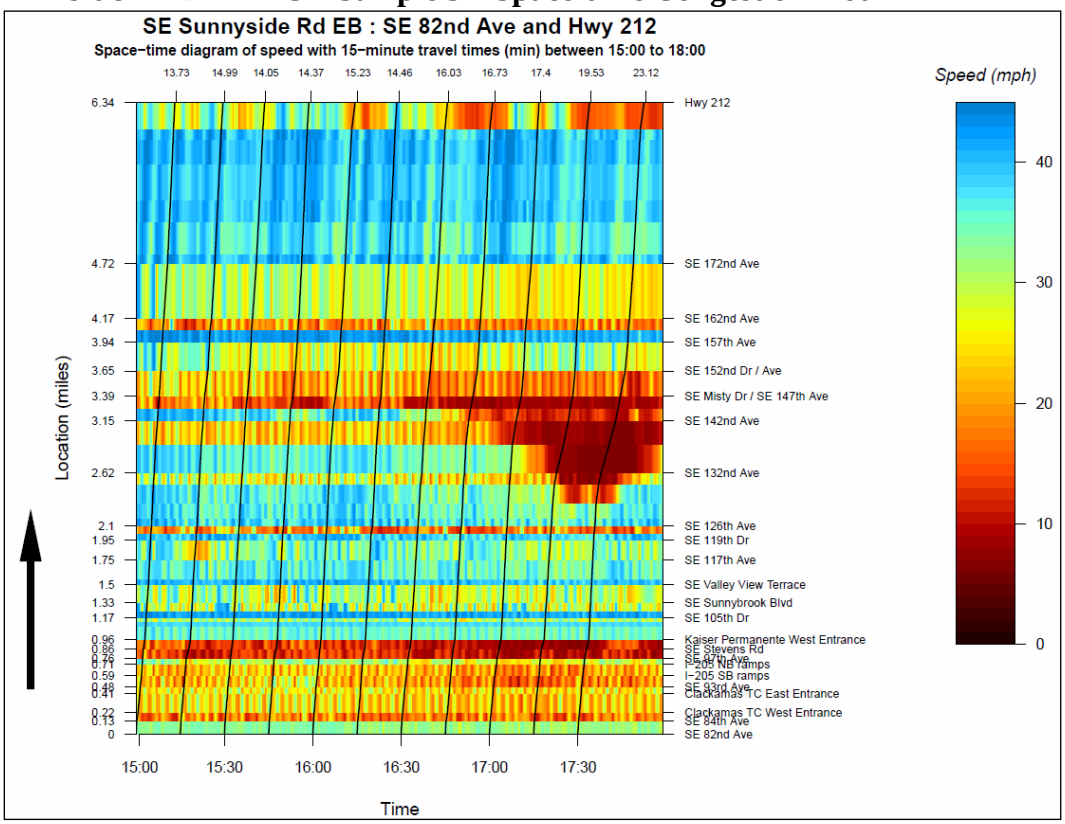


Exhibit 8-21 DTA MOE Sample 3 – Space-time Congestion Plot



8.5.6 Key Considerations (Application and Issues)

The following considerations are intended to help guide decisions regarding application of DTA models. In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements. Since application of a DTA model may be applied as a windowed subarea model to a regional static model, many of the same considerations for windowing would apply. However, due to the fundamental differences for DTA models (including increased resolution for traffic operations), additional considerations would apply. These considerations are not absolute but are intended to function as a general guidance when developing an approach and methodology.

General considerations related to windowing a DTA subarea from a regional static model (see Section 8.5.5 for additional detail)

- Study Area Size/Boundary
- Network Element Refinements (Links, Zones, Nodes)
- Demand Adjustments
- Future Year Scenarios

The following considerations reflect those that are introduced by DTA models that may not be primary issues when dealing with static models.

- Balancing model refinements with overall purpose - The ultimate purpose of the DTA model will application will vary from project to project and will ultimately guide the level of refinements needed in the model. Some examples of the range of typical applications include:
  - Volume development (may include higher level model)
    - Developing base year alternative volumes for operations analysis
    - Forecasting future year volumes
  - Operations analysis (may include finer resolution and detail)
    - Screening alternatives within the DTA model (relative comparisons)
    - System measures
    - Corridor/Intersection measures

- Understanding Traffic Flow Theory and Operations Concepts - DTA models introduce traffic flow details that are not generally present in static models. These elements may vary from those that are simplified in static models (such as traffic control types), to those that are non-existent in static models (flow model and jam density values). In order to correctly understand and use the models, the analyst needs to have an understanding of traffic flow theory that goes beyond what is generally needed for regional-scale travel demand modeling using static models. Some of these key concepts include:
  - Intersection control and movement priority
  - Traffic signal timing (and realistic settings)
  - Speed/Flow/Density relationships (including jam density[35])

Fundamental knowledge in these areas is needed to correctly code operational elements in the model and to consider the reasonableness of model results.

- While DTA software generally include the ability to import and export data, these abilities, and the differences in the underlying network data models, vary by platform and can make it difficult to transfer data between packages in an efficient manner. For this reason, the analyst should consider these differences when considering application of multi-resolution models and combinations of DTA platforms for project application.
- Applying DTA models for future conditions introduces several other considerations for the future year model:
  - Assumptions for traffic control, specifically future traffic signal timing parameters for existing or proposed traffic signals. In some cases (such as a fixed timed grid network or along a coordinated corridor) it may not be reasonable to assume that signal timing parameters would change in the future. However, depending on the intersection location, ownership, and potential for growth, it may be reasonable to anticipate that traffic signal timing would be updated in the future to reflect changing needs. For example, an intersection on the urban fringe that currently runs free and

[35] Jam densities vary by location and vehicle mix but generally range from a spacing of 25 to 30 feet per vehicle or 175 to 210 vehicles per lane per mile)

has low average splits and cycle lengths may have longer average splits and cycle lengths as demand increases in the future. However, for intersections that are part of a coordinated system, particularly when located along a highway route that maintains a green band, future signal timing modifications may not be as likely. These assumptions should be coordinated with TPAU and/or ODOT Region traffic group.

- Adjusting demand through O-D matrix demand adjustment is problematic for future year models because it assumes the relationships that exist between the seed demand matrices from a regional travel demand model and the traffic counts hold true in the future (see Sections 8.5.3 and 8.6.4)
- Method used for developing traffic analysis volumes. Many factors (such as the type of DTA model used, the amount of data available, the effectiveness of the calibration process, the amount of pre -processing of traffic demand, etc.) will influence the balance of traffic analysis that is performed within the DTA model versus the use of external tools (including HCM or microsimulation).

8.6 Peak Spreading

This section describes the concept of peak spreading and summarizes different analysis methods, needs, and considerations based on location and context (type of study and implications such as short term development impacts for a TIA or long-term regional planning needs). Peak spreading (as described in the following sections) occurs when there is travel demand for a sustained period that exceeds the available capacity of the transportation network. For this reason, peak spreading is unique to congested conditions, and is unlikely to exist for an extended period in a relatively uncongested network.

8.6.1 Peak Spreading General Concepts

While peak spreading methods can be used to estimate how traffic routing, assignment, and/or travel time may be influenced by congestion during different periods of the day, the existence of peak spreading may indicate that other facets of the travel estimation (such as trip generation and trip distribution) may need to be reconsidered. As Oregon moves towards activity based models (ABM) and Dynamic Traffic Assignment (DTA) models the integrated abilities of these tools will limit the need for separate peak spreading processes described in this section.

The following sections provide an introduction and overview of general peak spreading concepts. For the purposes of the following material, it is important to understand the differences between two terms that are commonly used interchangeably but have very different meanings:

- **Travel demand** – the amount of unconstrained traffic that wants to travel on a road or make a turn movement during a specified period of time. An example of traffic demand would be the amount of traffic that a static travel demand model reports wants to use a road in the future. In reality, there may be constraints (such as capacity of a downstream intersection) that prevent this amount of travel demand from being achieved in the real world. However, this demand" can still provide insight for planning purposes. Travel demand is sometimes reported as a ratio to available capacity as demand/capacity (D/C), which can exceed a value of 1.0.
- **Traffic volume** – the amount of traffic that is actually served on a road during a specified period of time. An example of a traffic volume would be the number of cars that are observed travelling in a lane or making a turning movement during a vehicle count data collection. These volumes are the actual amount of vehicles that are able to use the system, given constraints that exist. The traffic volumes may be equal to the travel demand, but in congested conditions the traffic volumes will be less than the travel demand due to constraints (insufficient green time at the signal, downstream bottlenecks, etc.). Traffic volumes are commonly reported as a ratio to available capacity as volume/capacity (V/C). By definition, these ratios cannot exceed a value of 1.0.

How Travel Demand Models Deal With Time-of-Day
Before defining peak spreading in detail, it is important to understand how travel demand models generate traffic demand forecasts since traffic demand is often revised during peak spreading procedures.

Aggregate trip-based models create time period specific travel demand trip matrices based on static user defined time period factors. These factors usually vary by trip purpose and direction of travel (production to attraction and attraction to production). By applying these time-of-day factors, the estimated daily travel demand is split into time period specific demand. As a result, travel demand models are largely insensitive to peak spreading since the user specifies how demand is spread across the hours of the day.

Activity-based models (ABM), such as those being developed for the Portland metropolitan area regional government (Metro) and ODOT, take a much different approach to modeling time-of-day. ABMs have explicit trip departure time and duration models that operate at the hourly or half-hour time period that are sensitive to a much more comprehensive set of information, including differences in network congestion by time-of-day. As a result, ABMs can produce more reasonable travel demand by time period and are much more able to model peak spreading.

What is Peak Spreading?
Traffic demands and traffic volumes constantly fluctuate based on many factors. While traffic is always changing, traffic analyses generally consider peak traffic conditions to assess the needs of the roadway system. Traffic analyses commonly account for traffic peaks or profiles in three general ways.

1) Annual traffic profile - Daily traffic volumes for a given location may be assessed to determine how they change over the year. These considerations are used to adjust for seasonal factoring, which account for changes in daily traffic demand throughout the year. (see APM Section 5.4 for additional information)
2) Daily traffic profile and "peak hour" occurrence - Traffic volumes by time of day (generally divided into an hour) are considered to determine at what time the traffic is generally highest. These periods are commonly referred to as peak periods and (based on land use and transportation factors[36]) generally occur during a "peak hour" in both the morning and evening periods that correspond to commute patterns. In order to account for this peaking, traffic counts may be conducted during both periods for a traffic impact analysis, such as the 7:00 a.m. to 9:00 a.m. and 4:00 p.m. to 6:00 p.m. periods to identify the peak hour.

[36] Such as proximity to land uses that may have atypical trip generation peaks (schools, major employment centers with off-peak shift changes) or variable elements of the transportation system (time of day control or meters that influence other network options) that cause routing patterns to change.

3) Traffic peaking during the highest hour and peak 15-minutes[37] – Traffic analysis following HCM procedures further accounts for peak traffic demands during a peak 15-minute period. This is measured as the peak hour factor (PHF), which corresponds to the ratio of: (peak hour volume / (4 * peak 15-minute volume)). A PHF of 1.0 indicates a uniform traffic volume during each 15-minute segment of the peak hour, while lower values indicate a sharp peak (such as a shift change near a major employer or end of school day near a school).

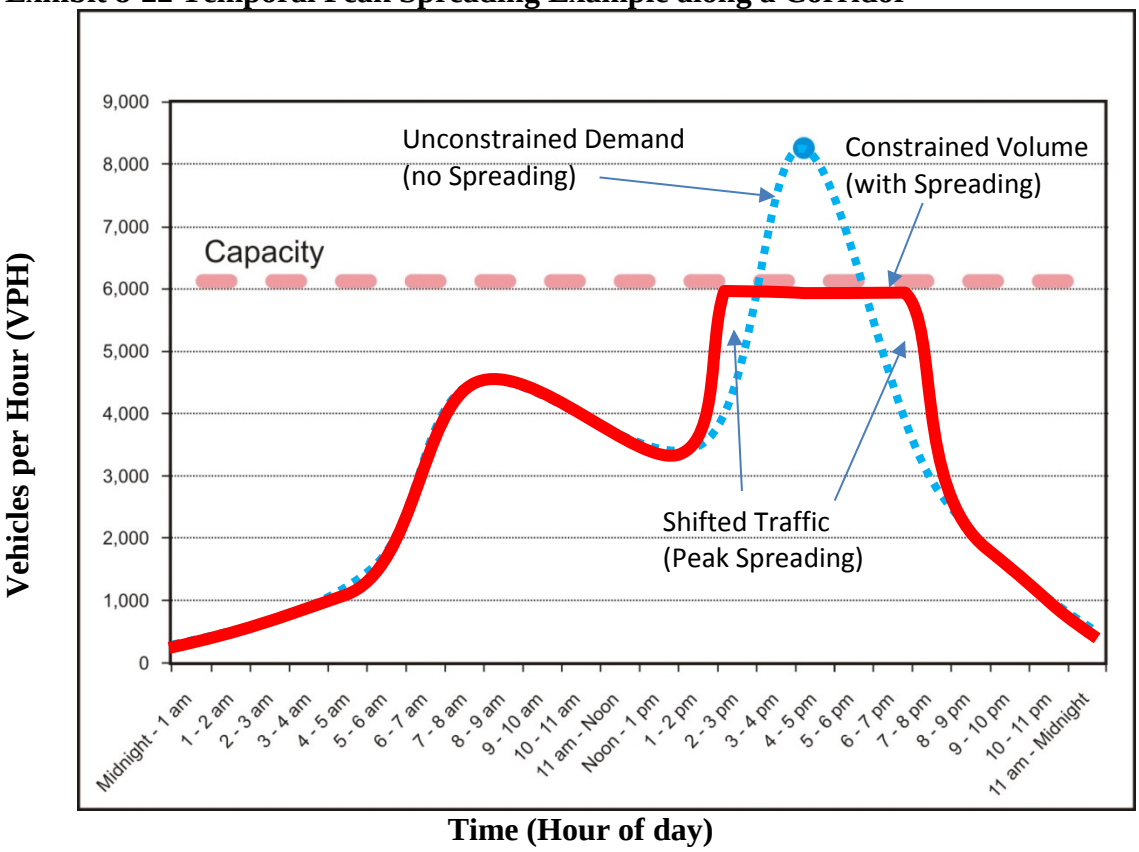
On a smaller scale, the example of a PHF at or near 1.0 is indicative of the general concept of peak spreading within the peak hour. **Peak spreading** is when traffic demand exceeds capacity and the resulting traffic volumes are served over a longer peak duration (temporal spreading) or may shift to other routes (spatial spreading).

Exhibit 8-22 demonstrates temporal peak spreading along a corridor. First, the x-axis represents the hour of the day and the y-axis represents the traffic on the freeway segment. The example includes four primary elements:

- The capacity of the segment is approximately 6,100 vehicles per hour (VPH), represented by a dashed red line.
- The unconstrained traffic demand (shown in dashed blue) is the amount of traffic that wants to travel on the corridor. This demand may be the result of applying a growth factor (resulting from historical trend or travel model forecast to an existing profile. The unconstrained demand is highest around 3 p.m. with a value of 8,200 vehicles. This unconstrained demand is well above the capacity of 6,100 vehicles per hour.
- The constrained traffic volume (shown in solid red) is the amount of traffic that can actually use the corridor given the capacity constraints. The constrained traffic volume does not exceed the capacity of 6,100 vehicles per hour. During early hours of the day and late hours of the night (when traffic demand is low), the traffic volume is the same as the traffic demand. However, when traffic demand exceeds the capacity, the traffic volume is limited at the capacity.
- The peak spreading (shown as the area above the unconstrained demand and below the constrained volume) is traffic volume that is using the system earlier or later than the unconstrained peak in order to be accommodated by the capacity. In this case, some of the traffic volume would occur later (approximately between 6 p.m. to 9 p.m.) due to congestion and longer travel times. In addition, some of this traffic may have desired to use the system between 2:00 p.m. and 5:00 p.m. but may have chosen to plan their route differently to leave later. In addition, the peak spreading shown to occur between 5:00 a.m. and 11:00 a.m. would be caused by traffic that would be leaving earlier to avoid congestion later in the day.

[37] Refer to APM Chapter 3 for additional information regarding traffic counts and congested conditions.

Exhibit 8-22 Temporal Peak Spreading Example along a Corridor

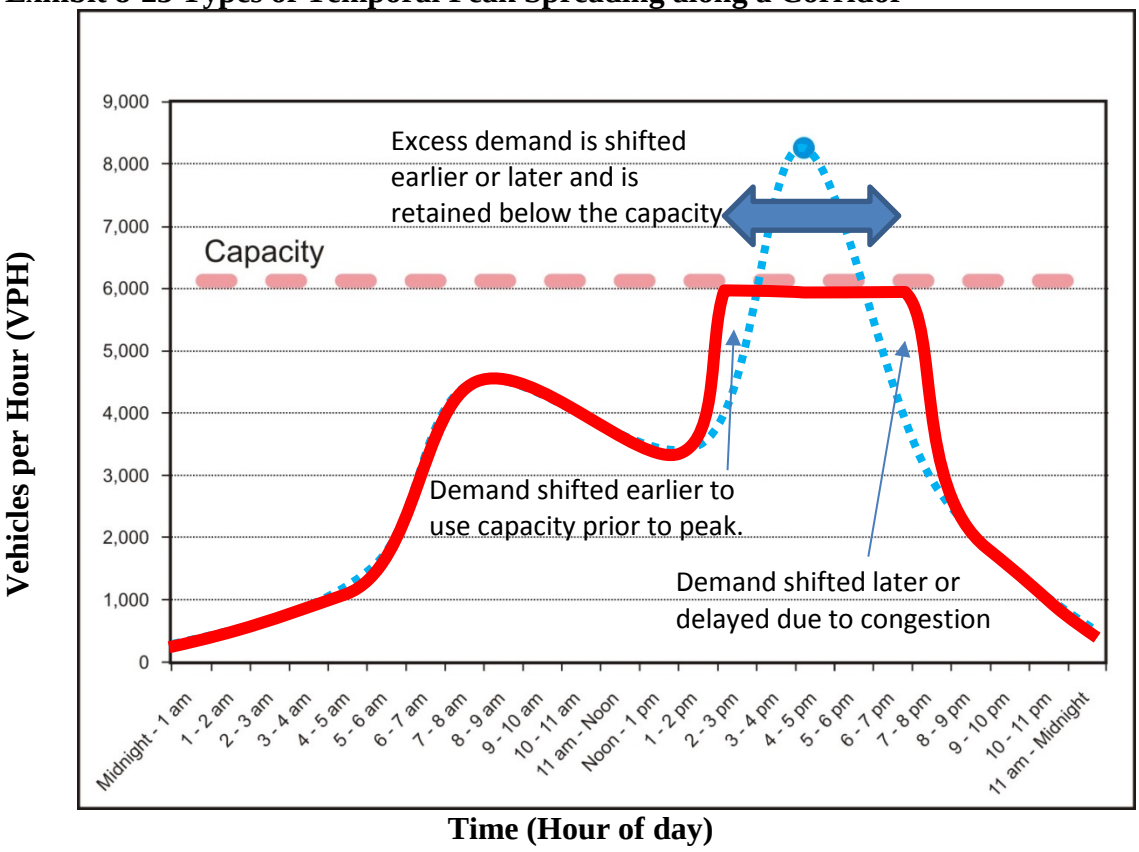


What Causes Peak Spreading?

As demonstrated in Exhibit 8-23, peak spreading is generally caused by one or both of the following conditions related to congested traffic conditions:

- Driver decision making - A driver changes their travel behavior to leave before/after the peak conditions to decrease the overall travel time and avoid waiting longer in congestion.
- Bottleneck capacity - A driver does not change their travel behavior and leaves at the desired time to start their trip. However, congestion prevents the driver from completing their trip in a timely manner and they do not reach a downstream location until later due to upstream bottlenecks.

Exhibit 8-23 Types of Temporal Peak Spreading along a Corridor



Why Does Peak Spreading Matter?

Peak spreading as an outcome of congested traffic conditions can influence the amount and distribution of actual traffic on the system. In some cases, the traffic volumes may be less than the travel demand that was projected (during the peak period), but in other cases the traffic volumes may be greater than the projected travel demand due to the effects of peak spreading. In cases where actual traffic volumes are required for an analysis (which is the majority of all traffic analysis), and there is potential for congestion and peak spreading, considerations for peak spreading are important to ensure that findings are reasonable.

In particular, peak spreading considerations are critical for the following use cases:

- Realistic operational analysis (including microsimulation analysis) – Realistic traffic demands are necessary to produce realistic traffic operations results. In order to derive more realistic operations (such as v/c or LOS), appropriate consideration needs to be taken for other network elements and behavior that may influence the traffic demand. Microsimulation models generally function poorly (and may reach a gridlock state) when estimates of O-D trips are not reasonable to account for upstream metering or capacity constraints. In addition, by not correctly accounting for peak spreading, the analysis may lead to unrealistic conditions, misidentification of traffic impacts and queues, and poor design decisions.
- Understanding duration of congestion (and implications of potential improvements) – As new performance measures and policies are explored, it is critical to have a better understanding of what congested conditions will result. By portraying the actual conditions that people will experience, analysts and decision-makers will have a better context for choices related to transportation improvements and policy needs. This consideration will also provide a means for assessing the implications for potential improvements outside the traditional design hour case.

8.6.2 Peak Spreading Scoping

The following sections provide an overview of scoping peak spreading considerations.

Peak spreading analysis and approach depends highly on the preexisting tools (such as the type of travel demand and assignment model) that exist for a location as well as the level of detail needed. Some sketch level analysis may be completed in a matter of hours while more in-depth questions may require additional travel surveys and/or (further) development of a travel demand model.

Identifying Analysis Needs

When analyzing congested conditions, peak spreading may need to be accounted for in the following conditions:

- Developing travel demand volumes for microsimulation
- Determining peak hour factors for future intersection capacity analysis
- Evaluating compliance with OHP mobility targets and possibly identifying alternate mobility targets

Tool Selection

Ultimately, the tools and methods available to assess peak spreading will vary greatly for each unique application based on a variety of factors, including:

- Purpose of the analysis
    - What questions are being asked and what level of detail and precision is needed? Having a sketch level estimate of congestion duration at one

location is much different than producing peak period travel volumes along a corridor for microsimulation analysis.

- Location and context
  - Single road location versus network level demand
  - Commuter travel base that may adjust travel patterns and driver behavior versus recreational trips that may not have information (the knowledge of regular occurrence) to change travel behavior.
- Availability of existing data sources (see Data section)
- Availability of existing modeling tools (travel demand models or other tools)

Exhibit 8-24 provides an overview of peak spreading tools and methods that are covered in additional detail in the following section.

Exhibit 8-24 Overview of Peak Spreading Tools and Methods

Element	Cursory Method (No Model)	Travel Demand Model (OSUM[1]/ JEMnR[2])	Metro Hours of Congestion (HOC)	Metro Peak Spreading	DTA
Area	Areas without models	Urban areas with models (outside Portland)	Portland region	Portland region and other OSUM/ JEMnR models	Portland region
Location Scope	Manually applied on link by link basis	Systematic for model area	Systematic for model area	Systematic for model area	Systematic for model area
Data Needed	Existing traffic counts and profile	Depends on application and post-processing	Depends on application and post-processing	Depends on application and post-processing	Depends on application and post-processing. See Section 8.6.2
Output	Scaled volume profile for a location	With additional processing - regional matrix and systematic link level travel demand by hour	Systematic link level travel demand by hour	Regional hourly demand matrix from 2-7 p.m. that can be assigned	Link by link or O-D pair travel time for time intervals.

[1] Oregon Small Urban Models (OSUM) - Population under 50,000
[2] Joint Estimated Model in R (JEMnR) Population over 50,000 (MPOs)

Data

The following types of data may be useful or necessary to conduct peak spreading analysis:

- Existing travel profiles – existing profiles can provide some insight into how peak spreading currently occurs or could develop given additional traffic growth or transportation network changes.

- Bottleneck data – data that indicates the maximum capacity for bottlenecks such as intersections. Saturation flow studies may be needed to determine actual capacities.
- Travel survey – Driver decision making has the potential to influence peak spreading characteristics. The decisions people make related to how much congestion they are willing to endure, the flexibility of their schedule, and the likelihood to leave earlier or later to avoid congestion can all affect the degree of peak spreading.
- Travel time data – The collection of existing travel time data may be used to calculate a travel time index (TTI) or other measure to better understand existing congestions levels (the degree to which travel time is impacted by existing congestion) and consider when estimating driver sensitivity and the future potential for peak spreading.
- Seasonal count data – In absence of specific data about the share of system users that are aware of recurrent system conditions (such as commuters) and those that are not (such as recreational travelers), a comparison of seasonal count data may provide insight into the portion of travelers that are seasonal users. This data can be used to inform assumptions about whether trips would occur at other periods in the presence of congestion. (See Section 8.7.3).

8.6.3 Peak Spreading Application and Procedures

The following sections provide an overview of tools and methods available to analyze peak spreading. Each tool is location-based and therefore options and methods may be limited. In all cases, it is appropriate to coordinate with TPAU or Region 1 Traffic staff to ensure that the method and application is appropriate based on the analysis requirements. In some cases existing tools and data may limit the degree and certainty of peak spreading analysis.

Areas without Travel Demand Models (Cursory Method)

The following section provides an overview of a cursory method to estimate peak spreading in the absence of a travel demand model. While this method can provide useful estimation on peak spreading potential, locations that are projected to be congested to the degree that trip generation, distribution, or route choice are affected may require a travel demand model to better assess this impacts.

At a cursory level, peak spreading can be assessed for locations that do not have a travel demand model. The application may vary based on the specific location, context or purpose of the analysis (such as short-term analysis or long-range planning needs), and availability of data. However, the general process would be the same. While additional processing and adjustments may be needed and applied, the following method is intended to be applied at a cursory level as an informative approximation of peak spreading.

To manually assess peak spreading, three elements are needed to first develop the un-

spread profile, including:

- **Reference traffic volume at location to be analyzed** – This may be an existing traffic count or a projected future traffic volume, typically for a peak hour. This value is needed to determine how to appropriately scale the traffic profile.
- **Traffic profile at a generally representative location** – This may be data from an ATR or data collected from a multi-hour (typically 16-hour or daily) traffic count. The location would optimally be at the same location that is studied for the effects of peak spreading. However, it may be determined that other locations may be representative (or may be all that is available) and may be sufficient for analysis. Other representative locations would typically be along the same corridor either upstream or downstream of the analysis location. Depending on the use of the cursory analysis, other locations may be considered.
- **Relative comparison (or scaling factor) to adjust ("fit") the traffic volume to the representative location on the profile** – A factor to convert the traffic profile to the profile for the analysis condition is needed. This factor is derived from the following method and will generally vary by location:
    - **Reference volume / Profile volume during period = Profile Factor** For a like time period (such as 5-6 p.m.) (Exhibit 8-25):
        - **For same location -** This factor may be equal or near 1.0 depending on when the profile data and reference data were collected. However other values may result from impacts such as seasonal factors or annual growth.
        - **For different location -** This factor may be more or less than 1.0 depending on where the data was collected and the relative difference between the two locations (e.g., the profile data may be located upstream of the study location in an area that generally has higher traffic volumes). Like data collected from the same location, variability also may result from impacts such as seasonal factors or annual growth.

Exhibit 8-25 Profile Factor Calculation

$$\textbf{Profile Factor} = \textbf{Volume}_{\textbf{(Reference)}} / \textbf{Volume}_{\textbf{(Profile)}}$$

Profile Factor: Scalar factor that will be applied to each hour of the existing profile to achieve the demand profile, which is representative of another location or another analysis period (or year)

Volume $_{\textbf{(Reference)}}$: Volume that represents the analysis volume (peak count or post-processed) for a given time reference time period. This may be the 30HV traffic volume

Volume $_{\textbf{(Profile)}}$: Volume that is indicated in the daily profile during the same reference time period as the Volume $_{\text{(Reference)}}$.

In addition, a general assumption about spreading behavior is needed to determine how the excess demand will be spread:

- **Capacity or maximum traffic flow that can be served –** At the location being analyzed, determine the maximum traffic flow. This may be based on an HCM intersection or other types of capacity analysis.
- **Seasonal data/user system familiarity, or assumptions related to the propensity for drivers to shift earlier, later, or not at all –** Roadway context, location, and fluctuation in seasonal demands have an influence on peak spreading. The decisions made by a traveler (destination, route choice, and time of departure) have the potential to greatly influence the observed peak spreading trends. The outcomes of these decisions can vary greatly based on the characteristics of the travelers, particularly with respect to how familiar the traveler is with the system condition and their level of flexibility. Commuters or other drivers that know the system conditions may choose to leave earlier or later, or may select a different route, based on their expectation of the system condition. This could include unfamiliar drivers if they have access to traveler information on congested conditions. Thus, they may tend to make peaking spread both earlier and later. However, trips made by users that are not familiar with the system (such as regional/recreational trips) may not have the ability to leave at a different time (being committed to a longer regional or interstate trip) or may not be aware of the local conditions before committing to a route. These users would tend to cause peak spreading to occur with a bias towards later. Therefore, the types of drivers on the system and the mix of seasonal and daily users can have an influence on how peak spreading occurs. Related discussion about data is provided in Section 8.7.2. In the absence of other data, the following spreading trends could be applied based on the traffic user:
    - Commuters – Assume that these users that are familiar with the reoccurring system conditions would be evenly likely to change their daily behavior to leave before and after the peak period - half of the travelers would leave before the peak and the remaining half would leave after the peak.
    - Recreational Users (Portion derived from seasonal data) – Assume that these users, which are not familiar with the reoccurring system conditions, would not spread to other periods (i.e., these users would not leave before or after the peak period in order to reduce their overall travel time).

To manually apply the cursory method, the following two steps are needed:

1) Determine the projected (un-spread) traffic profile (each hour) of the profile
2) Determine the method used to develop the adjusted (spread) traffic profile by the following method::
    a. No shifting - Trips leave at original times, but take longer to complete due to congestion. (Trips over capacity will be shifted to later period of arrival)

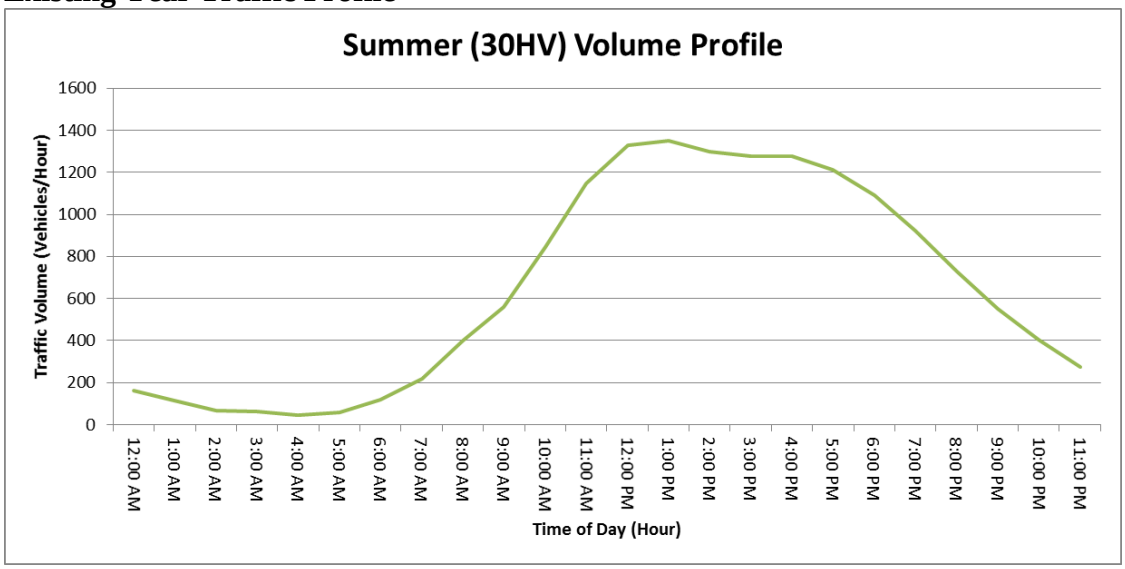
b. Shifting – A share of commuter or other users may shift their trip-making to an earlier and/or later period. (Determine portion to shift)
    i. Identify the portion of trips that will be shifted earlier or later based on the familiarity with the system.
    ii. Based on the split of excess demand that will be shifted earlier and later than the peak, identify when this period occurs. This will serve as the "divide" where excess demand is shifted before or after the peak.

Example 8-1 Cursory Method for Estimating Peak Spreading (To Determine Duration of Congestion)

In this example, the Cursory Method is applied to determine the duration of "congestion" at the US 101/ D River intersection in Lincoln City. This example assesses the southbound direction in the peak summer month (August). The duration of congestion, accounting for peak spreading, is estimated using the following steps:

- **Step 1: Determine the base year volume profile.** An Automatic Traffic Recorder (ATR) exists near the study intersection (D River Wayside ATR) and used to determine the base year volume profile. To determine the summer volume profile, each hourly volume is averaged for the entire month of August. The resulting profile is shown below.

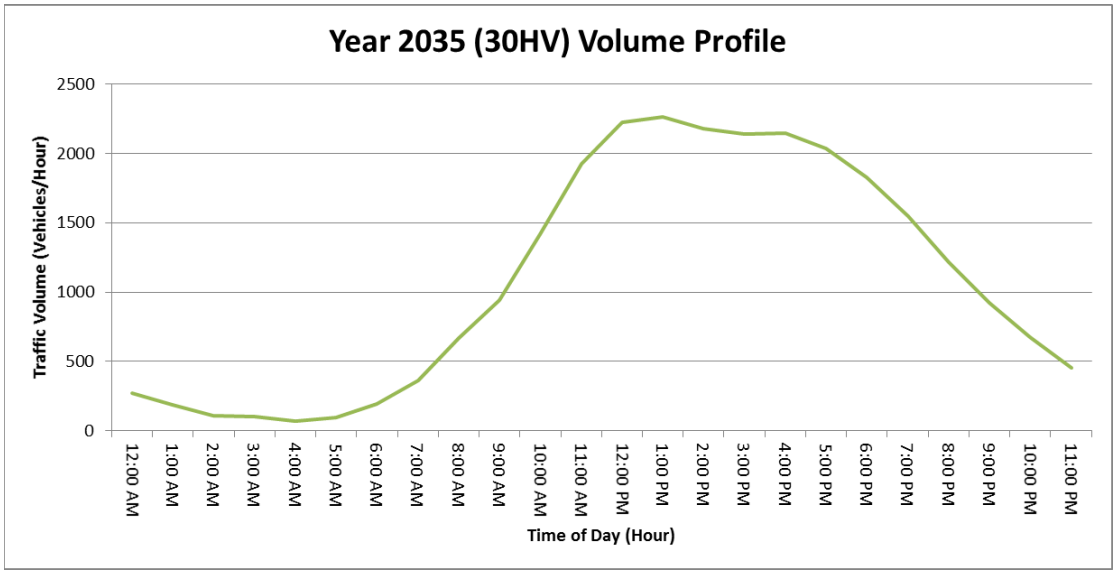
Existing Year Traffic Profile



- **Step 2: Factor the volume profile to the year 2035 p.m. peak hour volumes.** Through the forecasting process, the resulting year 2035 p.m. peak hour volume for the southbound approach is 2,145 vehicles/hour; the peak hour is 4 p.m. The corresponding base year volume at 4 p.m. (determined in Step 1) is 1,279 vehicles/hour. The resulting factor is 1.68 (i.e., 2145/1279). To determine the

2035 volume profile, each hour of the base year volume profile is multiplied by 1.68. The resulting year 2035 volume profile is shown below.

Factored Future Year Unconstrained Demand Profile



- **Step 3: Determine capacity constraint.** Through HCM analysis (e.g., Synchro HCM report), the southbound mainline approach capacity is 2,091 vehicles/hour. The same value of capacity is assumed for each hour of the 24-hour volume profile.

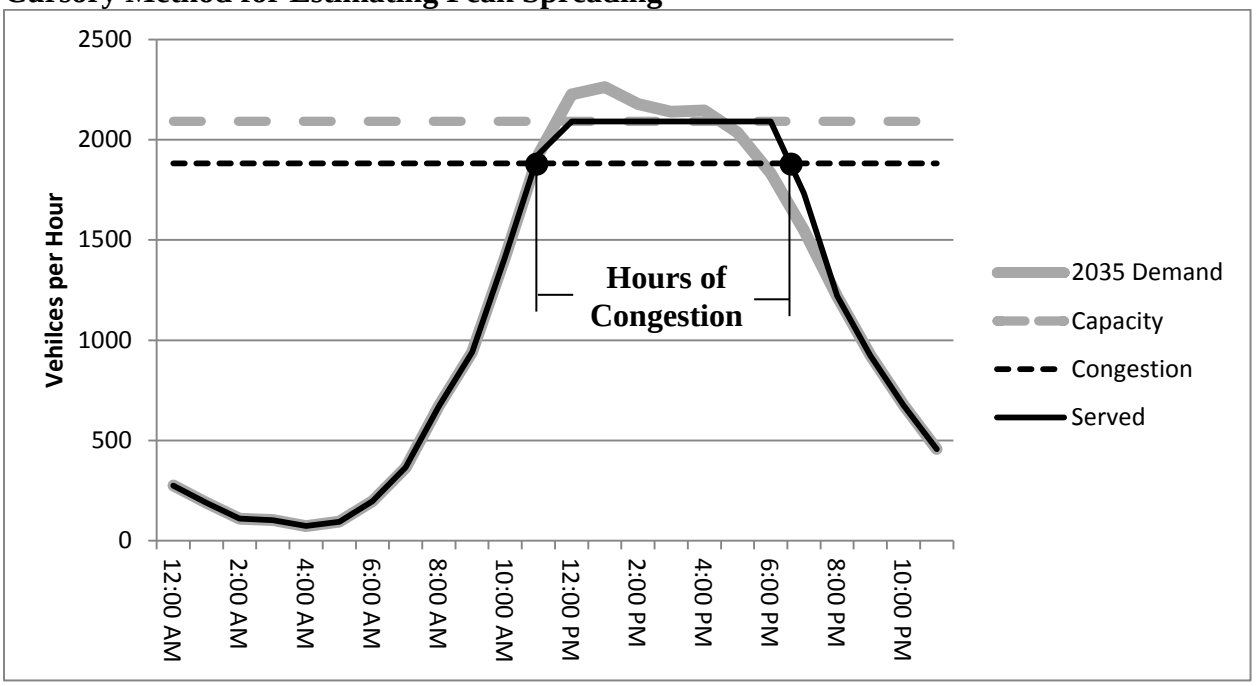
- **Step 4: Apply Peak Spreading by Shifting Demand to Determine the Volume Served.** First, for this analysis, it was assumed that due to the high amount of recreational traffic during the seasonal peak that no trips would shift before the peak. Therefore, all peak spreading would occur by shifting to a later period. This exercise included comparing each projected (unconstrained) hourly demand to the capacity. When an hourly volume exceeds capacity, the difference is added to the demand of the next hour. After shifting demand, demand is capped at capacity (2,091 vehicles/hour in this example). The following table shows the original demand projected for each hour as well as the resulting shifted capacity. Time periods where the ultimate volume is different than the original demand are shaded.

Shifted Volume Constrained by Capacity

Time	Demand	Capacity	Volume
12:00 AM	275	2091	275
1:00 AM	189	2091	189
2:00 AM	110	2091	110
3:00 AM	103	2091	103
4:00 AM	73	2091	73
5:00 AM	95	2091	95
6:00 AM	197	2091	197
7:00 AM	365	2091	365
8:00 AM	671	2091	671
9:00 AM	940	2091	940
10:00 AM	1416	2091	1416
11:00 AM	1927	2091	1927
12:00 PM	2226	2091	2091
1:00 PM	2263	2091	2091
2:00 PM	2178	2091	2091
3:00 PM	2140	2091	2091
4:00 PM	2145	2091	2091
5:00 PM	2036	2091	2091
6:00 PM	1831	2091	2091
7:00 PM	1549	2091	1731
8:00 PM	1219	2091	1219
9:00 PM	925	2091	925
10:00 PM	676	2091	676
11:00 PM	457	2091	457

- **Step 5: Determine "congestion."** Congestion can be defined many ways, but in this example, congestion is assumed as volume/capacity (v/c) of 0.90 or higher. To determine the equivalent volume at which the approach becomes congested, the v/c ratio is multiplied by capacity: 0.90*2,091 = 1,882 vehicles/hour.
- **Step 6: Determine hours of congestion.** For 8 hours of the day (11 a.m. to 7 p.m.) the volume of the southbound approach exceeds 1,882 vehicles/hour. This information is summarized in the figure below.

Cursory Method for Estimating Peak Spreading



Areas with Travel Demand Models (excluding the Portland Metropolitan Area)

Travel demand models have been developed for a number of areas around the state.[38] These models generally fit into one of two categories, each with distinctions that may provide ability to estimate peak spreading.

- Oregon Small Urban Models (OSUM) - Population under 50,000
- Joint Estimated Model in R (JEMnR) Population over 50,000 (MPOs)[39]

The following sections provide an overview of peak spreading available with each type of model. These methods could be applied systematically over the entire model area. Additional post-processing and refinements that incorporate more real-world data (such as spot location use of actual traffic profile data) and/or use of subarea modeling methods could provide information for peak spreading and traffic profiles on other network locations.

In addition, there is the potential that Metro's methods for pre-processing the trip table (shifting the demand of O-D pairs to other adjacent time periods based on a TTI ratio), described later in this section, could be applied to these other models with additional effort and coordination. In these urban areas, the modeler would need to identify whether there is systematic peak spreading, or if spreading is limited to a specific corridor through investigation of the variability of the TTI. This endeavor (and travel time data collection) would require further discussion and scoping with TPAU and Region traffic to determine the extent of the analysis based on the unique characteristics of the urban area. Application of this method would require development of a TTI ratio based on a perceived accepted maximum level of congestion (and travel delay) that currently occurs.

The following sections provide a general overview of the model tools and abilities. Coordination with TPAU modeling staff is critical to ensure appropriate use of the individual modeling tools based on issues related to model age, data sources, and calibration.

OSUM

The OSUM models can produce hourly trip matrices based on static input factors that can be assigned for each hour of the day. These trip matrices provide the ability to determine raw, model level demand profiles for links in the transportation model network. Additional post processing of these demands using real-world traffic data (depending on analysis need) has the potential to readily provide information about peak spreading. A key limitation for this method is that reliability would be a question for time periods that haven't been validated (e.g., 10 p.m. to 11 p.m.). Metro's method of pre-processing the trip table (shifting individual demand of OD pairs to adjacent time periods) may be an option, as noted in the previous section.

[38] For more information: http://www.oregon.gov/ODOT/TD/TP/Pages/Tools.aspx

[39] The Eugene-Springfield travel demand model is not a JEMnR model, but it shares many of the same features as it relates to modeling time-of-day and (the lack of) sensitivity to peak spreading.

JEMnR (MPO)

The JEMnR model by default does not produce hourly matrices. Instead, the model is typically set up for the daily, a.m., and p.m. peak periods. It may however be set up for different time periods if desired. To develop matrices for other time periods, static input factors would be needed to split the daily person trip matrices by time-of-day and direction. Separate factors are used for each trip purpose. Once individual matrices were developed, the tool could be applied in a similar method as the OSUM models – with assignment of individual time periods and additional post-processing (using real-world traffic data), as needed, based on specific application needs. Metro's method of pre-processing the trip table (shifting individual demand of O-D pairs to adjacent time periods) may be an option, as noted in the previous section.

Portland Metropolitan Region

There are two recent tools that have been developed to analyze peak spreading in the Portland metropolitan region. A summary of each of these tools is presented in the following section, but additional documentation for each tool may be available[40].

Hours of Congestion (HOC) Tool [Interim Method]

ODOT Region 1 developed this tool as an interim method to assess the duration of congestion in the Portland region. The following excerpts summarize the purpose and methods used to develop the tool. Additional documentation is available from ODOT.

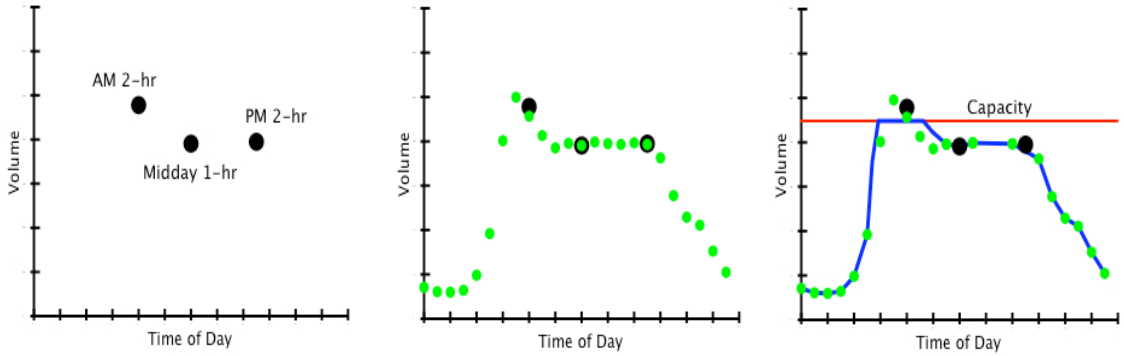
The tool is in the form of a spreadsheet that imports and processes data from the travel demand model to calculate hourly demand for every link in the model. The following excerpts from the documentation provide an overview of the procedures used by the tool:

> "The purpose of this study was to develop a method to address peak hour spreading given the limitations of a traditional four-step travel demand model. This was accomplished by using a link-based approach that post-processes travel demand model outputs to generate peak-spreading measures at the link level. The link based approach is viewed as an interim method for addressing hours of congestion where a more robust method would adjust the travel demand model trip tables. However, the link based approach is viewed as a reasonable estimate that will allow the congested hours on freeways and arterial roadways in the Portland metropolitan area to be approximated for purposes of policy discussions and project prioritization.
>
> Hours of Congestion Application
> To capture peak spreading on a corridor with a link based approach, traffic volumes produced from a travel demand model need to be post-processed to reveal an hourly volume profile. For this study, an application was developed that accomplishes this process in three basic steps, as shown in Figure 1 [Exhibit 8-26]. The first step involves gathering Metro's model data for the AM, midday,

[40] For additional information, contact ODOT Region 1 Traffic Unit for the Hours of Congestion study or Metro's Transportation Research and Modeling Services for information related to regional model peak spreading.

and PM peak periods. Next, the model data is used to estimate Average Daily Traffic (ADT) and hourly traffic volumes for the entire 24-hour period. Finally, the hourly volumes are compared to the link capacity and, where volumes exceed capacity, peak spreading is applied to spread the volume into shoulder hours.

Exhibit 8-26 HOC Figure 1: Tool Development Process Summary



Step 1: Metro Model Data | Step 2: Hourly Estimation | Step 3: Apply Peak Spreading

Methods

To determine the congested hours on roadways in the Portland metropolitan area using the link based approach described above, a data mining effort was undertaken to build the Hours of Congestion application based on observed traffic characteristics in the Portland area. The following sections describe the four major components of the data mining.

Data Collection

Data for ODOT facilities in the Portland area were collected for the most recent four years from PORTAL, ODOT Automated Traffic Recorders (ATRs), available 24-hour tube counts, and TriMet GPS bus travel time records. Reality checks and data quality screenings were performed on the PORTAL, ATR and tube-count data to remove data from outside the area of interest, incomplete or suspect data, and/or data that did not meet data quality diagnostics. For an example, of the original 665 PORTAL detector locations, 455 remained in the database after the data screening and quality checks were performed.

Volume Profile Analysis

Metro's regional travel demand model provides forecasts for a 2-hour AM period, a 1-hour midday period, and a 2-hour PM period. Daily traffic volumes are not directly forecasted. To estimate a 24-hour vehicle volume profile, regression analysis was conducted to first develop estimation factors for the total daily volume (ADT). With the predicted daily volumes and the peak period volume forecasts, a 24-hour volume curve was estimated to represent an "unconstrained"[41] forecast for each link.

[41] It should be noted that while Metro's model does not provide temporal spreading of the traffic volumes

Peak Spreading Analysis
To develop an application that can spread excess volumes in peak periods, existing peak spreading in the Portland area was investigated in the PORTAL traffic volume database. Traffic volume data was examined to essentially identify congested vs. uncongested traffic flow days at locations where peak spreading was found to occur. At these locations, AM and PM peak periods were examined to determine how spreading occurs (i.e., which direction traffic shifts relative to the peak hour). These volume shifting factors were then used in the Hours of Congestion application to adjust 24-hour profiles when demand was forecasted to be above capacity. This shifting of traffic volume is an important distinction, as total daily traffic volume is conserved whereas some methods used by other agencies for similar efforts "trim" peak period volumes and do not maintain ADT.

Congestion Threshold Analysis
Review of Hours of Congestion analysis compared to speed data in the PORTAL system found that the congestion threshold (where vehicle speeds are significantly reduced from free-flow speed) may be well below the ODOT mobility standard, which is essentially where volume reaches capacity. An evaluation of speed congestion information compared to link v/c estimates was conducted, which found that a v/c ratio of 0.80 (instead of 1.00) would be a reasonable threshold for congestion. Therefore, the Hours of Congestion application was built to track both how many hours exceed a v/c ratio of 0.80 and how many hours reach a v/c ratio of 1.0."

The output of the Hours of Congestion tool is link-level traffic volumes for each hour of the day as shown in Exhibit 8-27. This example demonstrates a case where the link demand during the evening peak approaches the link capacity (4,000 vph) shown by the red line but does not reach the capacity. If the demand had exceeded the capacity, the tool would process the demand to the shoulder periods.

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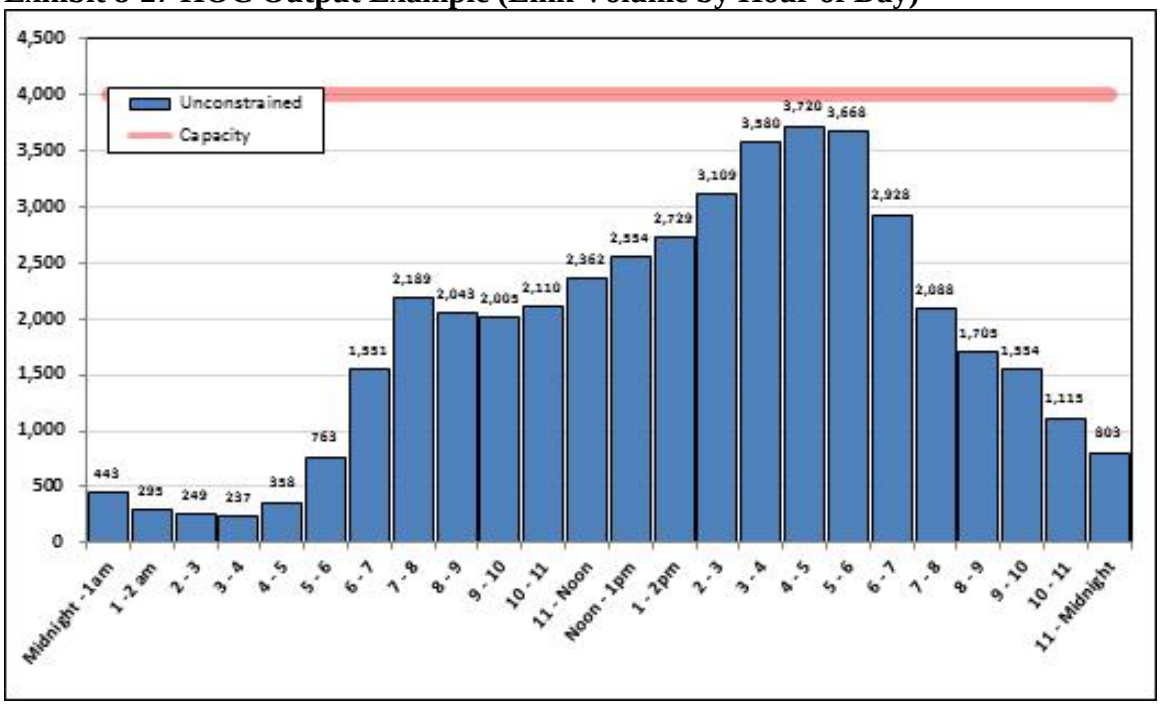
in the peak periods when congestion occurs, it does spatially spread volumes to parallel corridors when possible to balance travel times in the system.

Exhibit 8-27 HOC Output Example (Link Volume by Hour of Day)



Metro Travel Demand Model with Peak Spreading

Metro has developed a methodology for pre-processing raw demand volumes from the static travel demand model to feed into dynamic traffic assignment (DTA). The output of the tool is an adjusted origin-destination matrix for each hour between 2:00 p.m. to 7:00 p.m. The following text is an excerpt for Metro's tool documentation, which is distributed with other travel demand model assignment tools[42]:

> "Metro's peak spreading algorithm is a method for measuring congestion through a travel time index (TTI), which is simply *travel time / free flow travel time*. For example, if the free flow travel time between an O-D pair is 10 minutes and the peak period travel time is 15 minutes, then the O-D pair has a TTI of 1.5 (15 minutes / 10 minutes).
>
> A proxy 'threshold' for congestion is based on the highest TTI corridor in our region within Existing Year (2010) regional model--I-5 NB from 5pm to 6pm. It's a corridor that currently experiences a good deal of peak spreading, which is represented in the relatively long congested peak (3pm – 6:30pm or later on most work nights). The TTI for this corridor is 1.6, and establishes a threshold for comparing all other congestion against. It is assumed that travelers are willing to accept congestion up to a TTI of 1.6 before they begin peak spreading.[43]
>
> The TTI threshold is used to adjust future year demand for each hour in the PM peak period. Since congestion is widely prevalent in the future, the peak period is

[42] Contact Metro's Transportation Research and Modeling Services for additional information.
[43] Application of this methodology to areas outside of the Portland metropolitan region would require assumptions about an appropriate TTI to use.

measured from 3pm-6pm. Hour-long shoulder periods are also produced, resulting in a full 5 hours of PM peak period trip tables (2pm-7pm).

To begin the peak spreading algorithm, a 5pm-6pm (peak of the peak) hourly static assignment is run, and the TTI for each O-D pair is then calculated. For each O-D pair in which the TTI exceeds the TTI threshold (1.6), trips are removed based on how much the TTI exceeds the threshold. For example, if an O-D pair has a 2.0 TTI, and the TTI threshold is 1.6, the difference is 0.4. This number is 25% above the TTI threshold (0.4 / 1.6), therefore 25% of the trips from this O-D pair are removed from the 5pm-6pm trip tables (SOV and HOV only) [Note that latent demand for other O-D pairs may potentially be reassigned to links belonging to paths and O-D pairs that were adjusted][44].

The trips that are removed from the 5pm-6pm hour are added to the 4pm-5pm and 6pm-7pm trip tables. For each of these hours, the above process is repeated: Produce hourly static assignments with the new trip tables, calculate the O-D TTIs, and remove excess trips based on the TTI-to-threshold ratio. The excess trips get added to the next shoulder hour (e.g., 3pm-4pm for the 4pm-5pm hour). The process is continued on through every hour of the 5-hour PM peak period.

There are a few additional rules that are observed during the process, such as never removing more than 50% of the trips in an O-D pair for the 5pm-6pm hour and never reducing the O-D trips in subsequent shoulder hours to values less than the final 5pm-6pm peak spread tables.

The final result is a set of hourly trip tables encompassing the 2pm-7pm time period, with O-D pairs reflecting different degrees of peak spreading depending on the initial amount of 'congestion' (i.e., comparison against the TTI threshold) measured during each hour."

Additional frequently asked questions for Metro's peak spreading methodology are available in Appendix 8A.

8.6.4 Key Considerations for Peak Spreading Application

Policy and Performance Measures

While accounting for peak spreading generally improves the reasonableness of traffic volumes, it may not be compatible with some performance measures and policies that are based on those performance measures. For example, mobility targets in the Portland region are based on V/C ratios, which for some locations (such as a Town Center) exceed 1.0. These policies are based on traditional tools that do not fully account for limitations

[44] The spreading is applied to the O-D matrix itself and not the assigned link volume. Therefore, after the O-D matrix has been adjusted it will need to be reassigned. The reassignment may result in different paths than the original assignment and (while the demand for the original O-D pairs using a link will be reduced) other latent demand from other O-D pairs may shift to the link that was originally over capacity. Therefore, reducing all O-D pairs assigned to a link by 25% may not ultimately result in a 25% demand reduction.

related to peak spreading and capacity constraints within congested systems. Peak spreading methods have the potential to greatly improve the reasonableness of reported measures; however, it is important to understand the limitations and differences between policy measures and the tools that are used to analyze them.

Existing and Future Year Methods

Projecting peak spreading for future year conditions adds another aspect of uncertainty. Given limited resources and data, one approach may be to scale an existing demand profile to a forecasted future magnitude. However, assuming that existing year demand profiles (shape, not magnitude) are similar in the future may be affected by the following:

- Location of future growth areas and travel patterns on the facility
- Traveler decision making based on future changes to society and technology
- Future conditions on other areas of the travel network, including upstream/downstream bottlenecks and adjacent routes

Appendix 8A – Peak Spreading Procedure

Appendix 8B – PTV Vision Software Network Setup Guide

9 NOT YET WRITTEN – SEE APM VERSION 1

10 NOT YET WRITTEN – SEE APM VERSION 1

11 NOT YET WRITTEN – SEE APM VERSION 1

Appendix 11A – Procedure for Analysis and Design of Weaving Sections, A User's Guide

Addendum 11B – Two-Lane Highways

12 NOT YET WRITTEN – SEE APM VERSION 1

Appendix 12A – Preliminary Traffic Signal Warrant Analysis Form

Addendum 12B – Two-Way Stop Control Intersection Queuing

13 NOT YET WRITTEN – SEE APM VERSION 1

Addendum 13A – Progression Analysis

14 MULTIMODAL ANALYSIS

14.1 Purpose

In order to truly quantify the operation of a roadway segment, all of the modes that use it need to be analyzed. This includes pedestrians, bicycles, transit in addition to automobiles and trucks. This chapter will eventually cover a reasonable range of different multimodal analysis types and modal considerations that will apply to plans and projects of all detail levels.

14.2 Multimodal Analysis Methodologies

The current generation of multimodal analysis methodologies are generally a perception-based rating system of the safety, comfort, and convenience of transportation facilities from the perspective of the user, whether a motorist, bicyclist, pedestrian or transit rider. The range of methodologies presented in this chapter is meant to be complimentary, not competitive, and have been tested for compatibility. There are many types of multimodal analysis methodologies available; however, not all are suitable for all applications. The overall context of the plan or project and the resulting scope of work will control the ultimate methodological choice. Some methods require very specific data which may not typically be collected in a high level study such as a transportation system plan. Some methods are too simple and will not be able to answer the questions posed in the design of a modernization project.

Applicability of multimodal analysis methods by project type is illustrated in Exhibit 14-1. Methods increase in detail from left to right, while plan/project types increase in complexity from top to bottom. As the application increases in level of detail, more specific questions can be addressed, but the analysis will require more data and resources. Regardless of method applied, it is important to include some sort of multimodal analysis on all analysis efforts.

Exhibit 14-1 Multimodal Analysis Tool Applications[1]

	Qualitative Multimodal Assessment	Level of Traffic Stress[2]	Multimodal Level of Service
Regional Transportation Plan (RTP)	○	●	
Transportation System Plan (TSP)	●	●	
Facility Plan/Interchange Area Management Plan (IAMP)	○	○	●
Project Development		○	●
Development Review		○	●

[1]Solid circles represent the preferred methodology. Outlined circles represent where methodology can also be used.
[2]Use of LTS for project development and development review should be limited to a screening-based analysis to quickly identify existing and future needs

Any project or plan could use any single level or multiple levels of multimodal analysis, but many levels of analysis are more suited to a particular application. For example, Level of Traffic Stress (LTS) could be used at a system level to identify key locations, which then can be analyzed further using Multimodal Level of Service (MMLOS).

The primary tool for Regional Transportation Plans (RTP) is LTS as this methodology can be easily adapted to use travel demand model inputs or can be generalized enough to apply to a whole region without too much data and effort. The Qualitative Multimodal Assessment (QMA) can be used to fill in other modes that are not covered by LTS. These methods require limited data, most of which can be obtained from existing inventories, aerial photography, or from “windshield” field surveys. These methods will be able to identify areas of concern whether in system connectivity (LTS) or in operations (Qualitative Multimodal Assessment).

Transportation System Plans (TSP) have enough detail in the inventory and analysis to provide for adequate QMA and/or LTS analyses. Do not duplicate modes between the two methodologies if both are used in a single effort.

More detailed planning efforts such as facility plans and Interchange Area Management Plans (IAMP) typically will use MMLOS-based methods as there is a need for more objective results especially in comparisons of alternatives. This level usually will have a higher amount of detailed data available which is consistent with the smaller analysis

segments and more specific detail required. Most elements could be obtained without doing a detailed field inventory, provided that unobstructed, high-quality aerials that can be used for the basis of measurements are available. This data level will make comparison easier across concepts and time periods with less subjectivity than with QMA.LTS and/or QMA can still be used if a plan will be relatively standalone. Plans that need to be consistent with future potential project development efforts especially with environmental assessments or environmental impact statements should use MMLOS-based methods for alternatives and limit LTS/QMA to screening analysis.

Project development requires the highest amount of data as objective design-level decisions need to be supported. The MMLOS methods are the most rigorous and commensurate with the typical available data. LTS can also be used as an initial screening measure to identify areas with existing or future needs. Analysis with the MMLOS segment and intersection methodologies even with appropriate ODOT defaults will take more effort and have a greater chance of needing additional specific field inventory data.

Assessing multimodal impacts in development review will typically involve use of LTS to quickly identify existing/future needs or development impacts and then using MMLOS techniques to identify mitigation scenarios. The urban context will need to be taken into account as the more urban an area is, even a standard zone change (i.e. residential to commercial) may require more detail. Transportation Planning Rule (TPR) -0060 analysis for a plan amendment can likely rely on more use of LTS (however, transit is only available at the MMLOS level) Transportation Impact Analyses (TIA) would likely need to primarily use MMLOS techniques in order to capture the specific scenario details.

While the designation of Multimodal Mixed Use (MMA) areas are based solely on safety concerns, once the designation is in place, non-automobile multimodal impacts can still be analyzed. Depending on the level of effort desired for a plan/project/TIA that involves a MMA, the multimodal analysis could use any of the methodologies.

14.3 Qualitative Multimodal Assessment

The Qualitative Multimodal Assessment (QMA) methodology is based on work done by David Evans and Associates and generally uses the principles of the full version 2010 Highway Capacity Manual (HCM) MMLOS but was modified to stay consistent as much as possible with the more objective methods presented later in this chapter. This methodology uses the roadway characteristics and applies a context-based subjective "Excellent/Good/Fair/Poor" rating. This method is best applied when comparing different alternatives side-by-side to each other but can also be used with a single scenario to compare the proposed improvement to existing conditions and to applicable standards. For example, a six foot sidewalk is standard in a residential area and would be rated Good (or Excellent if it had a buffer). Ratings can be "averaged" to obtain one for every mode, or they can be shown for every element if more detail is desired like in a technical appendix. This method is most appropriate when one or more of the following conditions apply:

- The subject roadway does not easily divide into segments with uniform characteristics between intersections.
- The subject roadway has rural/suburban characteristics with infrequent or no signal control, where the MMLOS methodology is not applicable.
- Insufficient data is available to complete a MMLOS analysis
- Future alternatives may not have enough detail to properly quantify roadway characteristics required by other methodologies.

If a roadway has limited facilities because they are provided on parallel roadways (i.e. bike boulevards), consideration should be given to also applying the methodology to that parallel facility. This way the complete picture of the multimodal facilities offered along a corridor can be shown.

The full HCM MMLOS is most applicable to urban roadways with uniform segments broken up by signalized intersections. The MMLOS only evaluates segments bracketed by signalized intersections but the qualitative assessment can be done at all types of traffic control (e.g. roundabouts). Many communities do not have any signals or have too few signals to make the full HCM MMLOS method usable. In addition, this methodology allows for a multimodal look at a reasonable cost without requiring intensive data gathering. For most planning efforts, design details are not generally available until later, within phases such as refinement plans or project development, so it can be difficult to properly create the MMLOS inputs. All of the elements below should be considered for each mode. However, not all of the elements below will be contextually applicable in every community (i.e. volumes not sufficient for traffic signals or all-way stop control) so deviations can occur but should be documented.

14.3.1 Pedestrian

On segments, the following factors are considered:

- **Outside travel lane width:** Wider travel lanes are rated better than narrower travel lanes because of the larger buffer space between vehicles and pedestrians.
- **Bicycle lane/shoulder width:** The addition of bicycle lanes or shoulders creates greater separation between vehicles and pedestrian traffic and acts as a buffer. Wider facilities are rated better than narrow or non-existent facilities.
- **Presence of buffers (landscaped or other):** Buffer presence that separates pedestrians from traffic results in an improved rating. Wider buffers are rated better than narrower or non-existent ones.
- **Sidewalk/path presence:** The presence of sidewalks or paths will rate higher versus shoulders or no facilities at all. Wider sidewalks/paths rate better than narrower or non-existent ones.
- **Lighting:** The presence of lighting, whether roadway or pedestrian-scale, is rated

better than roadways without lighting.

- **Travel lanes and speed of motorized traffic:** Less travel lanes and lower vehicle speeds will rate higher than more lanes and higher speeds.

At intersections, the following factors are considered:

- **Traffic control:** Intersections with a traffic signal or all-way stop control with crosswalks are rated better than locations with only two-way stop control or locations without crosswalks.
- **Crossing width:** Fewer turn or through travel lanes to be crossed is rated better than more turn/though lanes because the exposure to traffic and potential conflicts are less.
- **Median islands:** The presence of a median island is rated better than no islands as two-stage crossings are possible at unsignalized crossings.

14.3.2 Bicycle

On segments, the following factors are considered:

- **Preferred Bicycle facility type:** Bicycle facilities with greater separation from vehicles rate higher than shared or lesser separated facilities. Wider bicycle facilities will rate better than narrower or non-existent ones. Ideally, arterials (7000+ AADT) have separated facilities (i.e. buffered bike lanes, cycle tracks, bike paths); collectors (1500-7000 AADT) have bike lanes; and local streets have shared facilities. This will vary by location, context, and size of the community. For more information, please refer to the Separation Matrix of the ODOT Bicycle and Pedestrian Design Guide (Chapter 1, Page 3).
- **Shoulder presence/width:** Shoulders serve bicyclists in the absence of bike lanes, and wider shoulders rate higher than narrower or non-existent ones.
- **Outside travel lane width:** Wider travel lanes are rated better than narrower travel lanes on higher volume/speed roadways (i.e. arterials) because of the larger buffer space between vehicles and bicyclists. On lower volume and speed urban roadways, narrower lanes are better than wider lanes for better shared lane utilization (i.e. sharrow marked roadways).
- **Grade:** Level roadways/shallow grades are rated better than roadways with steep grades.
- **Pavement condition:** Poor pavement condition or obstacles (such as sewer grates, skewed railroad crossings, or in-street trackage) affect bicycling so better pavement condition and lack of obstacles will rate better than poor condition and many obstacles.
- **Obstructions:** Shoulders/bike lanes free of debris and other temporary obstacles such as construction barricades are rated higher than ones that are usually littered with gravel, glass, or frequently blocked.
- **On-street parking:** No parking or low parking utilization is rated better than high utilization and turnover rates because of potential conflicts with bicycles. Back-in parking is rated better than front-in parking. Parallel parking is rated better if it

includes a buffer from the bike lane.

- **Travel lanes and speed of motorized traffic:** Less travel lanes and lower vehicle speeds will rate higher than more lanes and higher speeds.

At intersections, the following factors are considered:

- **Traffic control:** Intersections with a traffic signal or all-way stop control with crosswalks are rated better than locations with only two-way stop control or locations without crosswalks. Intersections with bike signals are rated the highest.
- **Crossing width:** Fewer turn or through travel lanes to be crossed is rated better than more turn/though lanes because the exposure to traffic and potential conflicts are less.

14.3.3 Transit

The following factors are considered for transit:

- **Frequency and on-time reliability:** More frequent service and higher on-time schedule reliability are better than less frequent service and less reliable schedules.
- **Schedule speed/travel times:** Faster average peak hour schedule speeds and travel times are rated better than slower speeds and longer travel times.
- **Transit stop amenities:** The presence of shelters, benches, and lighting is rated better than stops with limited or no amenities. High-rated stops should have adequate boarding/maneuvering areas.
- **Connecting pedestrian/bike network:** Stops connected to a network of paths or sidewalk-equipped streets with improved crossings are better than those with no pedestrian facilities.

14.3.4 Auto

The following factors are considered for the auto mode:

- **Volumes/queues:** Lower observed volumes and queues are rated higher than higher volumes/queues on mainline and side-street intersection approaches. The number of lanes and functional class can be used as a surrogate to actual volumes if they are not readily available at this stage.
- **Safety:** Roadway conditions that provide for a decreased chance of crashes such as having illumination, longer intersection/driveway spacing, lower speeds, turn lanes and greater separation between fixed objects are better than conditions that may promote more crashes. The values of the seven criteria below can be "averaged" to obtain a single value for safety if desired.
    - Lighting: Roadways with lighting are rated better than ones without.
    - Driveway density: Lower driveway density is rated better than higher driveway density
    - Intersection spacing: Longer intersection spacing distances are rated

higher than shorter intersection spacing.

- Speed: Lower speeds are rated higher than higher speeds
- Fixed objects: Roadways with fewer fixed objects (trees, signs, barriers, etc.) close to the roadway (less than 25 feet) are rated higher than ones with more.
- Median/traffic separators: Presence of a median and/or traffic separators are rated higher than segments without.
- Turn Lanes: Intersection/driveway approaches with turn lanes are rated higher than approaches without turn lanes.

Example 14-1 Qualitative Multimodal Application

This example is based on work by David Evans and Associates on the OR99 Corridor Plan, but has been simplified and modified from the original analysis to illustrate the methodology.

The study area on OR99 in Talent, Oregon south of Medford is approximately one mile in length with a single traffic signal at Rapp Road. South of Rapp Road the area becomes increasingly less dense and suburban/rural to the southern city limits. There are limited bicycle, pedestrian, and transit facilities. OR99 is currently a four-lane undivided section, so a five-lane and a three-lane scenario was developed for analyzing potential future project alternatives. Conditions along the OR 99 corridor (limited signalization, limited data, and difficult to subdivide into homogenous segments) support the use of a qualitative MMLOS analysis to assess the multimodal aspects of existing and future scenarios. The table at the end of the example summarizes the analysis results.

Pedestrian & Bicycle Facilities - Existing Conditions
No existing separate pedestrian or bicycle facilities are in the corridor except the Bear Creek Greenway Trail located to the east of OR99 but not adjacent to the highway in this location. Pedestrians must walk on the shoulder and bicycles must share the right lane with vehicles, so the pedestrian and bicycle facilities are rated poor throughout.

Pedestrian & Bicycle Facilities - Future Scenarios
Both future scenarios would add a sidewalk or path to each side of the highway and would include a buffer on at least one side of the highway and bike lanes on both sides. The segments were rated as good for these conditions. The less travel lanes in the three-lane scenario rated higher than the five lane scenario as it creates a better environment for bicycles and pedestrians. At intersections, the three-lane scenario was rated better than the five-lane scenario because there would be fewer travel lanes for a pedestrian or a bicyclist to cross.

Transit Facilities – Existing and Future
Conditions are not expected to change in any substantial way from existing conditions. While connectivity to stops would increase, frequency, reliability, speed and travel time will be unchanged, therefore positive change will not be enough to change the grade overall.

Auto Facilities – Existing and Future
The assessment reflects the volumes and the safety evaluation. Analysis of existing conditions and both future scenarios resulted in relatively lower volumes with shorter queues on side street approaches. The low volumes minimize conflicts between through and turning vehicles so the safety conditions are relatively close for all scenarios.

Segment/ *Intersection*	**Mode**			
	Pedestrian	**Bicycle**	**Transit**	**Auto**
Existing Conditions – (Four Lanes)				
Rapp Rd to Arnos Rd	Poor	Poor	Fair	Good
OR99 at Arnos Rd	Poor	Poor	Fair	Good
Arnos Rd to Creel Rd	Poor	Poor	Fair	Good
OR 99 at Creel Rd	Poor	Poor	Fair	Good
Scenario 1 - Five lanes				
Rapp Rd to Arnos Rd	Good	Fair	Fair	Good
OR99 at Arnos Rd	Fair	Fair	Fair	Good
Arnos Rd to Creel Rd	Good	Fair	Fair	Good
OR 99 at Creel Rd	Fair	Fair	Fair	Good
Scenario 2 – Three lanes				
Rapp Rd to Arnos Rd	Good	Good	Fair	Good
OR99 at Arnos Rd	Good	Good	Fair	Good
Arnos Rd to Creel Rd	Good	Good	Fair	Good
OR 99 at Creel Rd	Good	Good	Fair	Good

14.4 Bicycle Level of Traffic Stress

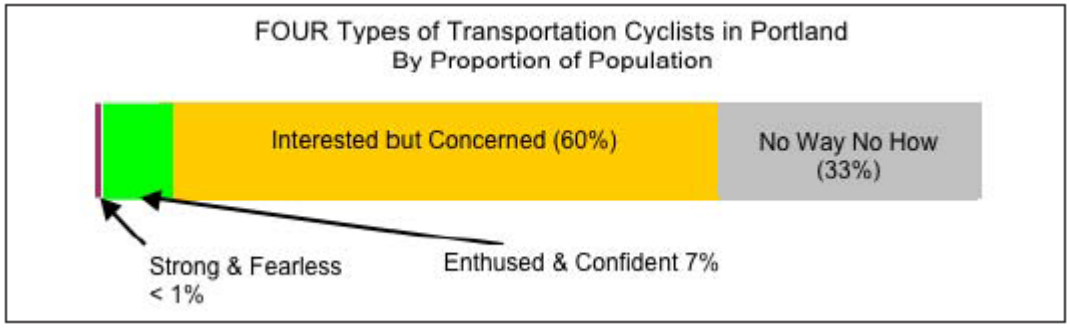
The Bicycle Level of Traffic Stress methodology breaks road segments into four classifications for measuring the effects of traffic-based stress on bicycle riders. The original methodology can be obtained from the paper, "*Low Stress Bicycling and Network Connectivity*", Mineta Transportation Institute, Report 11-19, May 2012. The version of the methodology described in this section has been modified from the original to correct inconsistencies in the tables, allow for additional intersection and bicycle features, and allow for more flexibility and engineering judgment in practice. Support for left turn lanes, one-way streets, roundabouts, buffered bike lanes, and shared lane markings have been added. A methodology for high-speed rural applications has been added since the original was for primarily urban areas. More detailed information on changes is provided in the specific topic areas.

This measure of traffic stress quantifies the perceived safety issue of being in close proximity to vehicles whether on a spacing distance or speed basis. The methodology does not include explicit consideration of traffic volumes as the proximity stress is present regardless of how much traffic happens to be occurring at that time. For example, a bicyclist travelling on a higher-speed arterial in the early morning hours without any bike lanes will still be having traffic (even though volumes are low) passing by closely and at high speeds. This bicyclist will experience higher stress than one riding in a buffered bike lane under the same conditions because the proximity to traffic is greater. An analogy to this would be as a pedestrian, having sidewalks with landscaped buffers is much more pleasant to walk on than curb-tight sidewalks right next to moving traffic. There are places in the methodology where there is implicit consideration of volumes, such as in the ability to cross intersections and interactions with turn lanes. Full consideration of traffic volumes require the use of more detailed methodologies, however the level of detail required is not necessarily consistent with the typical planning application but more project-like.

This methodology allows a quick assessment of system connectivity without going into the data requirements (i.e. traffic volumes) and calculations of the HCM Bicycle Multimodal Level-of-Service (MMLOS) method and is well suited for high-level plans such as corridor and transportation system plans (TSP). This method can also be used in detailed refinement-level plans and projects as a screening or flagging tool. Most of the data should be available as part of TSP inventories and/or supplemented with aerial photos. Depending on the community, TSP inventories may be limited to collector and arterial streets. Field inventory may still be needed to verify elements or supplement when vegetation or other obstructions make it difficult to see. Traffic counts/daily volumes are not required except for higher-speed rural applications. The methodology is designed for urban application, but can also be used for rural locations. The methodology is visual-based so the results can be easily communicated from the engineer to other agency and local government staff and the general public.

The tendencies of the general population to choose the bicycle as a mode and make route choices can be broken into four overall groupings based on City of Portland, [Oregon] surveys (Exhibit 14-2). While the percentages may change in different cities and rural/suburban areas, the groupings are still applicable.

Exhibit 14-2 Bicycle Rider Groupings as Percentage of Population



Source: "*Four Types of Transportation Cyclists in Portland*" by Roger Geller (2006)

The smallest group, "Strong and Fearless" represents people who will travel by bike under any condition and on any roadway. A second group, the "Enthused and Confident" represents advanced cyclists who travel on most roadways but avoid high volume and speed conditions. Over half of the population falls into the largest group, "Interested but Concerned" who would ride if roadway conditions were perceived to be safe enough. The last group, representing around a third of potential riders, is "No Way No How", who will not ride under any circumstances. More information on this methodology can be obtained from "*Four Types of Transportation Cyclists in Portland*" by Roger Geller (2006) and "*Four Types of Cyclists? Examining a Typology to Better Understand Bicycling Behavior and Potential*" (2012) Jennifer Dill and Nathan Winslow McNeil.

The Bicycle Level of Traffic Stress methodology adopted the above groupings, as the perception of user comfort being impacted by the proximity of vehicular traffic is one of the major decisions on whether one chooses this mode of travel. Further separation generally means less stress for users. The smallest group "Strong and Fearless" (avid cyclists and/or commuters) will travel most routes under any conditions, weather, light level, etc. and will tolerate the highest stress levels. On the other end, the "Interested but Concerned" group (casual or inexperienced riders) has little stress tolerance and will only accept the routes with the greatest perceived safety (separation). The research further breaks the largest "Interested but Concerned" group into adult and children riders where children require more safety awareness than adults along roadways and at intersections. Lastly, the "No Way No How" group was not included since the methodology concentrates on the current or potential bicycle-riding population.

Different trip purposes could have multiple ranges of acceptable stress levels for the same person. Someone making a work-based trip will likely have a greater stress tolerance than if they were riding merely for recreation. Going for a bike ride might mean a low stress tolerance for some riders, but they might accept a much higher stress level if they are on their way to work. Familiarity with the route, costs associated with driving and parking a car daily near a worksite, available bicycle infrastructure, vehicle availability/ownership, and other factors can influence someone's maximum acceptable level of traffic stress.

The overall rider groupings are translated into four levels of traffic stress (LTS) classifications.

- LTS 1 – Represents little traffic stress and requires less attention, so is suitable for all cyclists. This includes children that are trained to safely cross intersections (around 10 yrs. old/5th grade) alone and supervising riding parents of younger children. Generally, the age of 10 is the earliest age that children can adequately understand traffic and make safe decisions which is also the reason that many youth bike safety programs target this age level. Traffic speeds are low and there is no more than one lane in each direction. Intersections are easy to cross by children and adults. Typical locations include residential local streets and separated bike paths/cycle tracks.

- LTS 2 – Represents little traffic stress but requires more attention than young children can handle, so is suitable for teen and adult cyclists with adequate bike handling skills. Traffic speeds are slightly higher but speed differentials are still low and roadways can be up to three lanes wide in total for both directions. Intersections are not difficult to cross for most teenagers and adults. Typical locations include collector-level streets with bike lanes or a central business district.

- LTS 3 – Represents moderate stress and suitable for most observant adult cyclists. Traffic speeds are moderate but can be on roadways up to five lanes wide in both directions. Intersections are still perceived to be safe by most adults. Typical locations include low-speed arterials with bike lanes or moderate speed non-multilane roadways.

- LTS 4 – Represents high stress and suitable for experienced and skilled cyclists. Traffic speeds are moderate to high and can be on roadways from two to over five lanes wide in both directions. Intersections can be complex, wide, and or high volume/speed that can be perceived as unsafe by adults and are difficult to cross. Typical locations include high-speed or multilane roadways with narrow or no bike lanes.

14.4.1 Additional Rider Factors

The Bicycle Level of Stress does not include other factors that may be important to bicycle riders that should be taken into consideration when applying this methodology. These can include presence of steep or long climbs, poor pavement condition, heavy vehicle use, narrow travel lanes, neighborhood crime, noise, absence of lighting, high driveway density, skewed railroad crossings, in-pavement streetcar/railroad tracks, and curbside conditions (snow removal or litter/gravel in the roadway). Congested conditions can also be considered if they add difficulty to getting gaps in traffic to get into a right or left turn lane for instance. Roadway locations with either a documented (reported total bike crashes including any injury or fatal ones) or a perceived (near misses, known unreported crashes) crash history should be flagged for reference.

Some of these can be significant determinants to the comfort of potential cyclists and

may, at times, degrade a segment by one or even two levels rendering a route unacceptable. If a number of these considerations exist, the stress levels can be optionally adjusted to account for them or they can be placed on a stress map or in a separate graphic to flag them as concerns. These can also come into play when determining alternate paths to high-stress routes. As some of these can be subjective, adequate documentation should be provided outlining the reasons for the deviations. Roadways where biking is prohibited, such as certain urban freeways, should also be noted.

14.4.2 LTS Targets

A target level of traffic stress for the bikeway system may be identified in an attempt to maximize the bicycle mode share with the available resources. A LTS 2 is often used as the target as it will typically appeal to the majority of the potential bike-riding population and maximize the available bicycle mode share. Other LTS levels may also be used as targets depending on a jurisdiction's needs and maturity of the available bike network.

When evaluating networks near schools (within ¼ mile), the desirable level of traffic stress is LTS 1 since LTS 1 is targeted at 10-yr olds (5th grade) or parents of younger children. Elementary school-age children should be able to travel between homes and schools without having to cross arterial streets (LTS 3 and 4). Ideally, elementary schools and their related attendance boundaries should be placed to allow at least a few LTS 1 routes. Middle and high school placement may not allow only LTS 1 routes but routes should be no more than LTS 2 since older children can use these without difficulty.

14.4.3 LTS Criteria

The traffic stress criteria in the LTS methodology is broken into three categories. Table-based criteria are applied separately for segments, intersection approaches, and intersection crossings. Depending on the community context and the detail level desired, segments can be block-by block or be between higher functionally-classified roadways (arterials or collectors). The overall methodology can usually be simplified based on the general consistency of facility types, as certain elements (i.e. no turn lanes, no bike lanes, limited speeds, etc.) may not exist in a particular community. Segments are typically considered to be two-way but there are areas where conditions are not the same on each side of the street (i.e. parking only on one side). Both directions can be reported separately, or the worst direction reported. The methodology uses the worst overall LTS value for each overall segment. For example, if a segment has a LTS 2 but there is an intersection approach at the end of the segment at LTS 4, then the whole segment is coded LTS 4. The same applies for entire routes which are typically reported in a single direction between two points of interest and can contain many segments and intersections. It is likely that the LTS will be different (i.e. right turn lane vs. left turn lane) in the two directions, so both directions should be reported. One poor crossing at LTS 4 will render a route unacceptable to most people even though the rest of the route is at LTS 2.

14.4.4 LTS Segment Criteria

The LTS segment criteria are broken into three classes: physically separated paths and lanes, standard bike lanes, and without bike lanes (mixed traffic). The physically separated paths include bike paths and cycle tracks which may be separated from motor vehicles by landscaped buffers, curbs, or on-street parking (for cycle tracks). Physically-separated bike paths and lanes (assuming full bike standards) are generally classified as LTS 1.

Marked bike lanes have different criteria depending on whether they are adjacent to a parking lane or not, as shown in Exhibit 14-3 and Exhibit 14-4. These exhibits are formatted differently from the original methodology to fix inconsistencies with roadways with bike lanes having higher stress levels than roadways without bike lanes. In addition, slight changes were made so bike lane width makes a difference in the lower stress levels. Buffered bike lanes have been added to Exhibit 14-4 to account for their increased positive separation effects.

The criteria are based on through lanes per direction, the sum of the width of the bike and parking lanes, speed limit or prevailing speed, and any bike lane blockage (in commercial areas from driveways, loading zones, stopped buses, or parking maneuvers). For these and following tables, the criteria aggregate following the weakest link principle: the dimension with the worst level of stress governs. For example, a roadway with one lane per direction, 25 mph, but has frequent bike lane blockages will be at LTS 3 which overrides the LTS 1 values of the other components.

Exhibit 14-3 Bike Lane with Adjacent Parking Lane Criteria

1 Lane per direction				**≥2 lanes per direction**	
Prevailing or Posted Speed	**≥ 15' bike lane + parking**	**14' – 14.5' bike lane + parking**	**≤ 13' bike lane + parking or Frequent blockage[1]**	**≥ 15' bike lane + parking**	**≤ 14.5' bike lane + parking or Frequent blockage[1]**
≤25 mph	LTS 1	LTS 2	LTS 3	LTS 2	LTS 3
30 mph	LTS 1	LTS 2	LTS 3	LTS 2	LTS 3
35 mph	LTS 2	LTS 3	LTS 3	LTS 3	LTS 3
≥40 mph	LTS 2	LTS 4	LTS 4	LTS 3	LTS 4

[1]Typically occurs in urban areas (i.e. delivery trucks, parking maneuvers, stopped buses).

Exhibit 14-4 Bike Lane without Adjacent Parking Lane Criteria

1 Lane per direction					**≥2 lanes per direction**	
Prevailing or Posted Speed	≥ 7' (Buffered bike lane)	5.5' – 7' Bike lane	≤ 5.5' Bike lane	Frequent bike lane blockage[1]	≥ 7' (Buffered bike lane)	<7' bike lane or frequent blockage[1]
≤30 mph	LTS 1	LTS 1	LTS 2	LTS 3	LTS 1	LTS 3
35 mph	LTS 2	LTS 3	LTS 3	LTS 3	LTS 2	LTS 3
≥40 mph	LTS 3	LTS 4	LTS 4	LTS 4	LTS 3	LTS 4

[1]Typically occurs in urban areas (i.e. delivery trucks, parking maneuvers, stopped buses).

Mixed traffic conditions are roadways without any bike markings (including widened shoulders not marked as bike lanes). Mixed traffic segment criteria for urban/suburban sections are based on the speed limit or the prevailing speed if different, and the number of lanes by direction, as shown in Exhibit 14-5. This exhibit was reformatted into "lanes per direction" from the original methodology, for consistency with the other segment criteria exhibits and to fix the with/without bike lane issue previously mentioned.

Designated bike boulevards or marked shared low-speed "sharrow" routes also are considered as mixed traffic conditions, but depending on judgment and area context, may have LTS levels reduced by one. Markings and signs give bicyclists more perceived safety and warn drivers about potential bicycles being in the roadway which tends to lower overall speeds.

Exhibit 14-5 Urban/Suburban Mixed Traffic Criteria

Prevailing Speed or Speed Limit (mph)	**Unmarked Centerline**	**1 lane per direction**	**2 lanes per direction**	**3+ lanes per direction**
≤ 25[1]	LTS 1	LTS 2	LTS 3	LTS 4
30	LTS 2	LTS 3	LTS 4	LTS 4
≥ 35	LTS 3	LTS 4	LTS 4	LTS 4

[1]Presesence of "sharrow" markings may reduce the LTS by a level for 25 mph or less sections depending on overall area context.

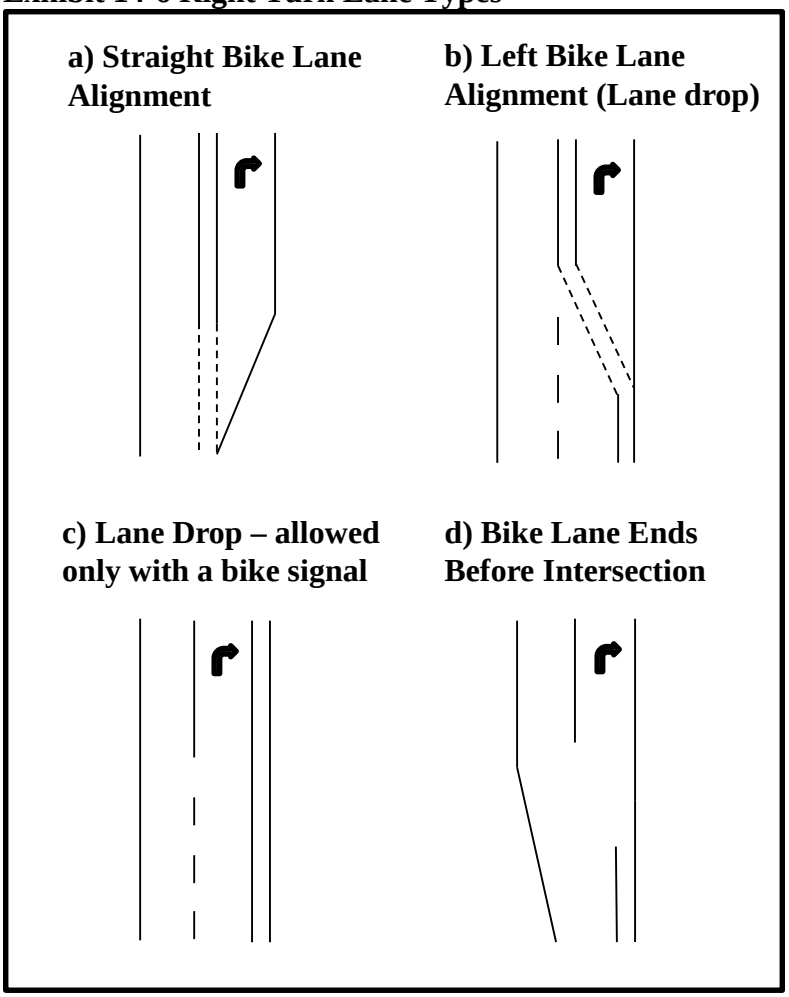
14.4.5 LTS Intersection Approach Criteria

Intersection approach criteria are based on the presence and type of right or left turn (vehicular) lanes. If there are no turn lanes on an approach, then this portion of the methodology is skipped.

ODOT Bicycle Design Guide standards have the right turn lane to the right of the bike lane so the bike lane continues straight and requires vehicles to turn and yield to bicyclists across a marked dashed bike lane (see Exhibit 14-6a). Locations where the through travel lane becomes a right turn lane (lane drop) may have a more stressful design where the bike lane shifts to the left while the travel lane continues straight (Exhibit 14-6b). In this case, the bike lane cannot be to the right of a right-turn lane unless controlled by a separate bicycle signal (see Exhibit 14-6c), as the through bicycle lane would directly conflict with the right turn lane with the potential for

many “right-hook” type crashes. Other intersection designs may have the bike lane end where the right turn lane begins (i.e. T-intersections, roundabouts) and re-appear on the other side of the intersection (Exhibit 14-6d).

Exhibit 14-6 Right Turn Lane Types



The right turn criteria are based on whether the bike lane stays straight or shifts to the left, turn lane length and turning speed. The longer the turn lane, the longer a bicyclist will have traffic on both sides in close proximity if continuing straight, or mixing with traffic if turning right. When the bike lane stays straight, turn lanes of 150’ or less (100’ is typical for most urban applications) and low turning speed (15 mph is a common for most residential and commercial areas) will have a LTS 2 as seen in Exhibit 14-7. Longer turn lanes, higher turning speeds or at skewed intersections will result in a LTS 3 rating. Dual shared or exclusive right turn lanes are typically in very high volume locations which add additional stress and are LTS 4.

A roadway with no marked bike lanes and a right turn lane will be a high stress location unless the right turn lane is short and rarely used. This condition will also occur if a bike lane is dropped ahead of an intersection. If the turn lane is short (less than 75’) then there is no impact on the LTS.

Exhibit 14-7 Right Turn Lane Criteria

Right-turn lane configuration	Right-turn lane length (ft)	Bike Lane Approach Alignment	Vehicle Turning Speed (mph)[2]	LTS
Single	≤ 150	Straight	≤ 15	2
Single	>150	Straight	≤ 20	3
Single	Any	Left	≤ 15	3
Single[1] or Dual Exclusive/ Shared	Any	Any	Any	4

[1]Any other single right turn lane configuration not shown above.
[2]This is vehicle speed at the corner, not the speed crossing the bike lane. Corner radius can also be used as a proxy for turning speeds.

The original methodology did not consider the impact of left turn lanes. The left turn lane criteria were based on logical breaks in stress levels with the following considerations. Left turn lanes are more stressful than right turn lanes. Left turns require the cyclist to yield and merge into traffic like a vehicle and occupy the through and/or the left turn lane. The more through lanes a cyclist must cross to reach the left turn lane increases the stress level especially in higher speed locations, as both longitudinal and lateral mixing with traffic is increased, as shown in Exhibit 14-8.

Shared through-left lanes where a bike lane is present can act similar to mixed traffic conditions as the rider only has to move into the adjacent lane from the bike lane. Similarly, roadways with no bicycle lanes also act like mixed traffic conditions as the rider may already be in the shared left-through lane or just needs to move laterally into a left turn lane. Low-speed intersections that are set up for bicyclists to make two-stage left turns like with a bike box can be LTS 1. Please note that the only currently allowable bike box application is a two-stage left turn box at a "T"-intersection. All other intersection types and other bike box applications are considered experimental and require FHWA approval. See FHWA's Bicycle Facilities Design Guidance web page for up to date information. Separate left turn lanes require the rider to occupy a through lane for some distance (to allow for signaling intentions to following vehicles). Dual left turn lanes (either shared or exclusive) indicate high-volume locations which add additional stress above and beyond the speed and necessary lateral movements and are typically LTS 4.

For rating routes, only include the effect of the left turn lane if the route requires a left turn. For through and right turn movements, include the effect of the right turn criteria.

Exhibit 14-8 Left Turn Lane Criteria

Prevailing Speed or Speed Limit (mph)	No lane crossed[1]	1 lane crossed	2+ lanes crossed	Dual shared or exclusive left turn lane[2]
≤25	LTS 2	LTS 2	LTS 3	LTS 4
30	LTS 2	LTS 3	LTS 4	LTS 4
≥ 35	LTS 3	LTS 4	LTS 4	LTS 4

[1]For shared through left lanes or where mixed traffic conditions occur (no bike lanes)
[2]Any other single left turn lane configuration not shown above.

14.4.6 LTS Unsignalized Intersection Crossing Criteria

Unsignalized intersection crossings can act as a barrier to bicyclists especially with a high number of lanes or higher speeds. The crossing can be an impediment to travel if the bicyclist has to cross six or more lanes at any speed or has to cross a 35 mph (or greater) four-lane street. The criteria for unsignalized intersection crossings depend on the presence of a median of sufficient width to provide for a two-stage crossing. Pedestrian/bicycle over/underpasses would be considered as separate facilities and are LTS 1.

Signalized crossings usually do not create a barrier as the signal provides a protected way across and are not considered in the methodology. Signalized intersections do pose risks for right-turn "hook" crashes, however, especially where right turn lanes are not present. Bicyclists may have also difficulty triggering the signal detection (vs. walking the bike across the street as a pedestrian). There may be areas where engineering judgment is required in assigning stress levels higher than LTS 1 at signalized intersections for these reasons. The presence of bike signals may be a mitigating factor in higher-risk areas thus keeping the LTS at 1.

Roundabouts were not included in the original research, but a single-lane roundabout assuming mixed traffic conditions (Exhibit 14-5) where the bicyclist takes the lane with the typical sub-25 mph speeds should be LTS 2. Dual-lane roundabouts should also use the mixed traffic conditions for two lanes (LTS 3). Dual-lane roundabouts may require bicyclists to cross a through lane to turn left which would have a similar application to Exhibit 14-8, however the mixed traffic conditions will likely still control. Right-turn bypass lanes within the roundabout would be considered as right turn lanes as shown in Exhibit 14-7.

Where there is no median refuge, with two-way crossings of up to three lanes, the LTS ranges from 1 to 3 depending on speed, as seen in Exhibit 14-9. For crossings of four to five lanes, the LTS ranges from 2 to 4.

Exhibit 14-9 Unsignalized Intersection Crossing Without a Median Refuge Criteria[1]

Prevailing Speed or Speed Limit (mph)	**Total Lanes Crossed (Both Directions)[2]**		
	≤ 3 Lanes	**4 -5 Lanes**	**≥ 6 Lanes**
≤ 25	LTS 1	LTS 2	LTS 4
30	LTS 1	LTS 2	LTS 4
35	LTS 2	LTS 3	LTS 4
≥ 40	LTS 3	LTS 4	LTS 4

[1]For street being crossed.
[2]For one-way streets use Exhibit 14-10.

In a change from the original methodology, to better accommodate one-way streets, the intersection crossing with a median refuge criteria was changed to lanes per direction versus total lanes crossed. One-way streets carry higher volumes than two-way streets of the same number of lanes and thus can have greater stress levels applied to them. Use Exhibit 14-10 for one-way street applications.

Exhibit 14-10 has the maximum number of lanes a bicyclist encounters on each side of a median refuge. Adding a median refuge of at least six feet in width (10 feet for LTS 1 eligibility) will decrease the LTS versus when a refuge is not present. The presence of turn lanes are also accounted for as they add conflict points and vehicle paths to the awareness needs.

Exhibit 14-10 Unsignalized Intersection Crossing With a Median Refuge Criteria[1]

Prevailing Speed or Speed Limit (mph)	**Maximum Through/Turn Lanes Crossed per Direction**		
	1-2 Lanes	**2-3 Lanes**	4+ **Lanes**
≤ 25	LTS 1[2]	LTS 1[2]	LTS 2
30	LTS 1[2]	LTS 2	LTS 3
35	LTS 2	LTS 3	LTS 4
≥ 40	LTS 3	LTS 4	LTS 4

[1]For street being crossed.
[2]Refuge should be at least 10 feet to accommodate a wide range of bicyclists (i.e. bicycle with a trailer) for LTS 1, otherwise LTS=2 for refuges 6 to <10 feet.

Since crossings are not part of a link, the LTS to cross the major street is applied to the minor street. If the crossing LTS is greater than the minor street link LTS, the crossing LTS applies (controls) to that link.

14.4.7 Rural Applications

While the original methodology was designed only for urban applications, it can be used for rural roadways that have posted or operating speeds less than 45 mph. Rural roadways with speeds less than 45 mph tend to be one or two-lane local, undeveloped roadways that 1) connect rural communities, 2) exist in parks or other recreational areas or 3) provide a connection to a tourist destination. These are typically low volume and have no or little paved shoulder width. Sight

distances are likely to be lower (sharper vertical and horizontal curves) because of the lower road design standards used. LTS will be primarily based on speed in these cases. Use the regular LTS mixed traffic criteria shown in Exhibit 14-5 for these roadways and Exhibit 14-9 or Exhibit 14-10 for intersections. Approach criteria will probably not be applicable because low volume roadways generally do not have turning lanes.

Application of the LTS methodology to the typical higher-speed rural environment requires considering shoulder widths and volumes. Traffic counts/volumes are necessary for this method. The normal LTS methodology tops out at 40 mph, while most typical state and county rural roadways are posted at 45 - 55 mph.

A large portion of the bicycle-vehicle crashes occur when a vehicle attempts to overtake a bicyclist on a roadway with no or little available paved shoulder width. The wider the shoulder the less likely a bicyclist will be in the same path as vehicles. The occurrence of bike crashes is highest on higher volume rural facilities with little or no paved shoulders, poorly placed rumble strips, or deteriorated shoulder pavement conditions.

Narrow or no shoulders and higher volumes (increased overtaking conflicts) will increase the stress level. Unless an adjacent separated multi-use path/bike lane is provided (LTS 1), most rural roadways do not have bike lanes and bicyclists will depend on paved shoulders. Exhibit 14-11 shows the LTS for typical rural conditions for higher speed rural roadways.

Rural intersection crossing stress levels will be typically based on approach volumes and number of lanes (Exhibit 14-12). Since the rural environment is more unpredictable (higher speeds and motorists are less likely to be aware of or anticipate bicyclists) than the urban environment, the minimum LTS is 2.

Exhibit 14-11 Rural Segment Criteria with posted speeds 45 mph or greater[1,2,3]

Daily Volume (vpd)	**Paved Shoulder Width**			
	0 – <2 ft	**2 - <4 ft**	**4 – <6 ft**	**≥ 6 ft**
<400	LTS 2	LTS 2	LTS 2	LTS 2
400 - 1500	LTS 3	LTS 2	LTS 2	LTS 2
1500 - 7000[4]	LTS 4	LTS 3	LTS 2	LTS 2
> 7000	LTS 4	LTS 4	LTS 3	LTS 3

[1] Based on p1-3 & Table 1-2 from the Oregon Bicycle and Pedestrian Design Guide, 2011.
[2]Adequate stopping sight distances on curves and grades assumed. A high frequency of sharper curves and short vertical transitions can increase the stress level especially on roadways with less than 6' shoulders. Engineering judgment will be needed to determine what impact this will have on the LTS level on a particular segment.
[3]Segments with flashing warning beacons announcing presence of bicyclists (typically done on narrower long bridges or tunnels) may, depending on judgment, reduce the LTS by one, but no less than LTS 2.
[4]Over 1500 AADT, the Oregon Bicycle and Pedestrian Design Guide indicates the need for shoulders.

Exhibit 14-12 Unsignalized Rural Intersection Crossing with posted speeds 45 mph or greater[1]

Daily Volume (vpd)	≤ 3 Lanes	4 -5 Lanes	≥ 6 Lanes
<400	LTS 2	n/a	n/a
400 - 1500	LTS 2	n/a	n/a
1500 - 7000	LTS 2	LTS 3	n/a
> 7000	LTS 3	LTS 4	LTS 4

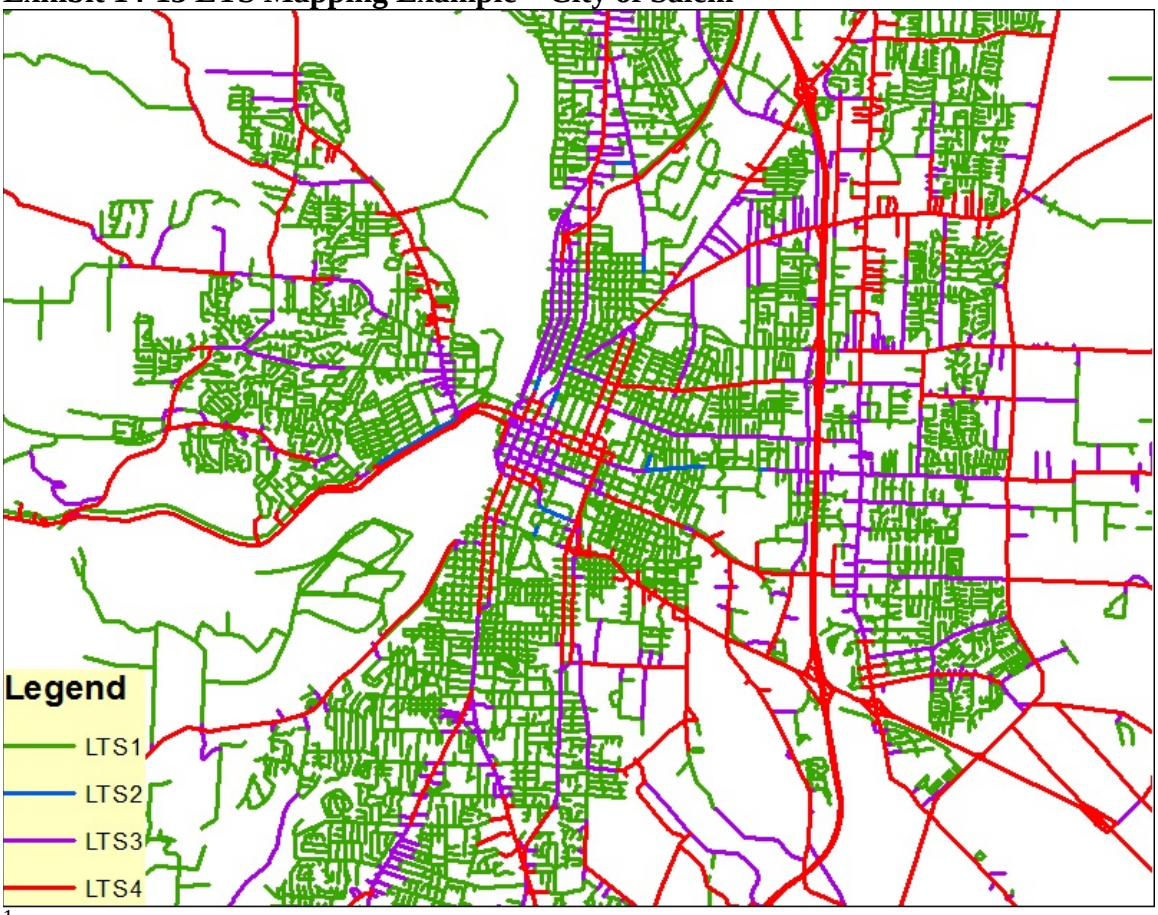
[1]For roadway being crossed.

For intersection approaches, the presence of left or right lanes will increase the LTS at least by one level as they greatly increase the chance that vehicles will cut across the bicyclist's path or that the bicyclists will need to utilize these lanes to turn. Low volume roadways (less than 1500 ADT) are not likely to have turn lanes.

14.4.8 Route Connectivity using LTS

The LTS designations should be mapped on the system network. This can be facilitated with GIS or with a travel demand model if available. The objective of mapping is to identify locations with LTS values exceeding a desired level that may then be targeted for improvements. Exhibit 14-13 shows an example of using LTS showing the different stress levels. The high stress routes can easily be contrasted against the lower stress ones.

Exhibit 14-13 LTS Mapping Example – City of Salem[1]

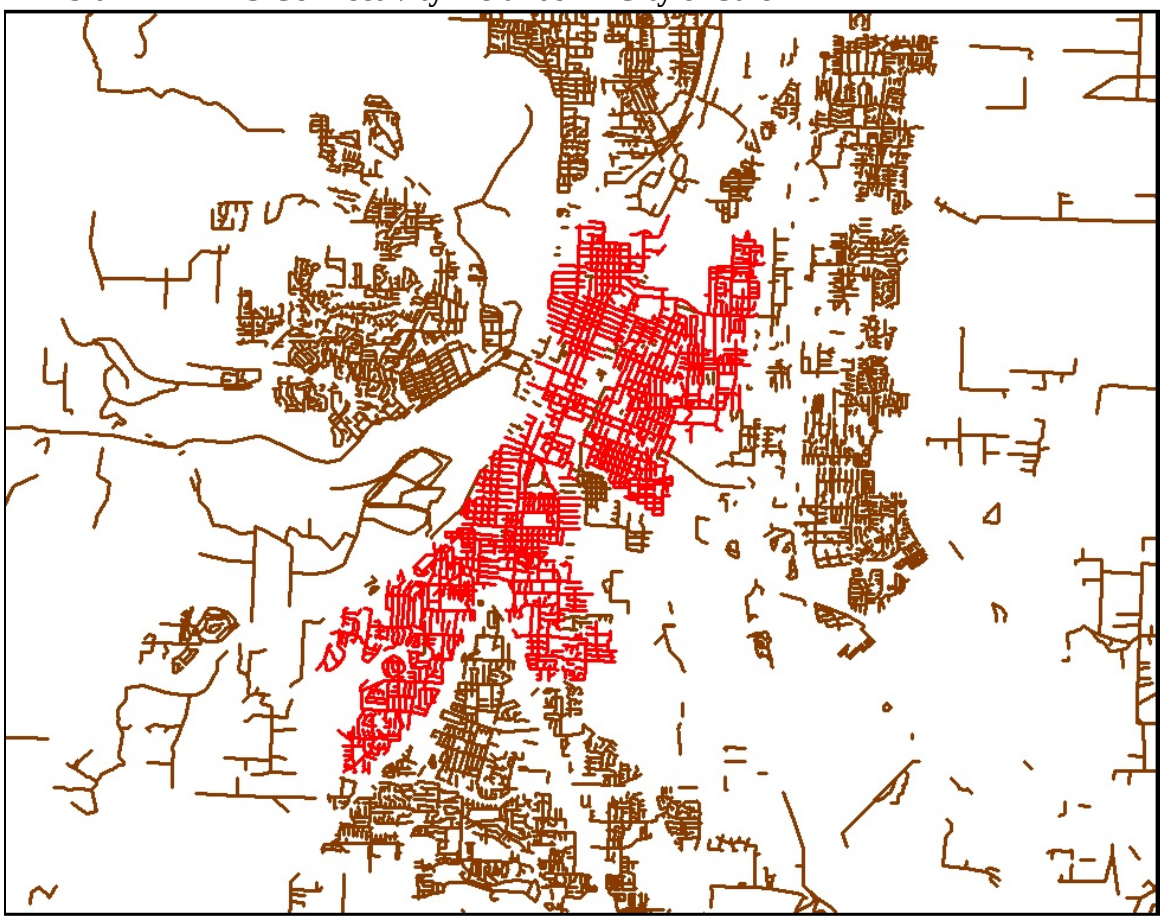


[1]Source: Haizhong Wong, Matthew Palm, Jonathan Mueller, Salem BLOS Application, OSU, 2012.

Another significant advantage of the LTS methodology is that it allows the identification of connectivity "islands", surrounded by higher LTS streets/intersections and other natural and physical barriers (i.e. rivers and railroads). This allows for a true connectivity look versus just considering system gaps, as one high stress location may prevent many routes or connections between adjacent neighborhoods. Improvements can be prioritized by the amount of additional low stress routes or points connected, thereby enhancing the system in addition to just gap filling.

Exhibit 14-14 shows an example of mapping just the LTS 1 and 2 routes. Barriers and high stress routes break the network into "islands" shown in brown and red. For emphasis in the original application, the downtown and surrounding system that can be reached via low stress routes is shown in red.

Exhibit 14-14 LTS Connectivity "Islands" – City of Salem[1]



[1]Source: Haizhong Wong, Matthew Palm, Jonathan Mueller, Salem BLOS Application OSU, 2012.

14.4.9 Specific Routes and Out-of-Direction Travel

Instead of tracking an entire jurisdiction/area of individual segments and crossings, the LTS mapping effort can also be applied based on routes between significant origins and destinations (i.e. neighborhoods to schools). Alternatively, this method may be used to help identify alternate (parallel) lower stress routes to help address a particular high stress location. It may be possible to attract potential cyclists by reducing the LTS of key links. For example, if an LTS 4 crossing is located along a route where all segments are at LTS 2 or less, it may be a good candidate for adding a median crossing refuge because it would complete the route and make it more attractive to more riders.

For each identified alternative route (for example to bypass a steep hill or a high stress intersection) a check for the out-of-direction travel should be made. For connectivity purposes, a route between two points should be low stress and without too much out-of-direction or extra travel distance. Too much extra travel time results in some riders choosing to travel the shorter, higher stress route, while other less stress-tolerant riders choose to not travel by bicycle at all, especially if they have a choice of modes.

According to the original research report[1], riders can typically tolerate up to 25% extra distance since the vast majority of trips are within 25% of the shortest-path available. However, most bicyclists choose trip paths that are only 10% longer than the shorter higher-stress routes, so 10% is a good target value. A 10% target represents a half-mile of extra travel on a five mile trip. Short trips should not have detours of longer than 1/3 mile which represents two minutes of travel time at 10 mph. In addition, the 25% maximum threshold for connectivity can also be used to predict route selection, to plan way-finding routes, or even analyze detour routes around a construction zone.

Routes can be assessed for acceptable out-of-direction travel if the either of the following relationships is true:

$L_k/L_4 \leq 1.25$; OR
$L_k - L_4 \leq 1{,}760$ feet (0.33 mile)

Where L_k = route distance at any given stress level, k.
L_4 = route distance using any links with stress levels up to and including LTS 4 (but not including links where riding is prohibited).

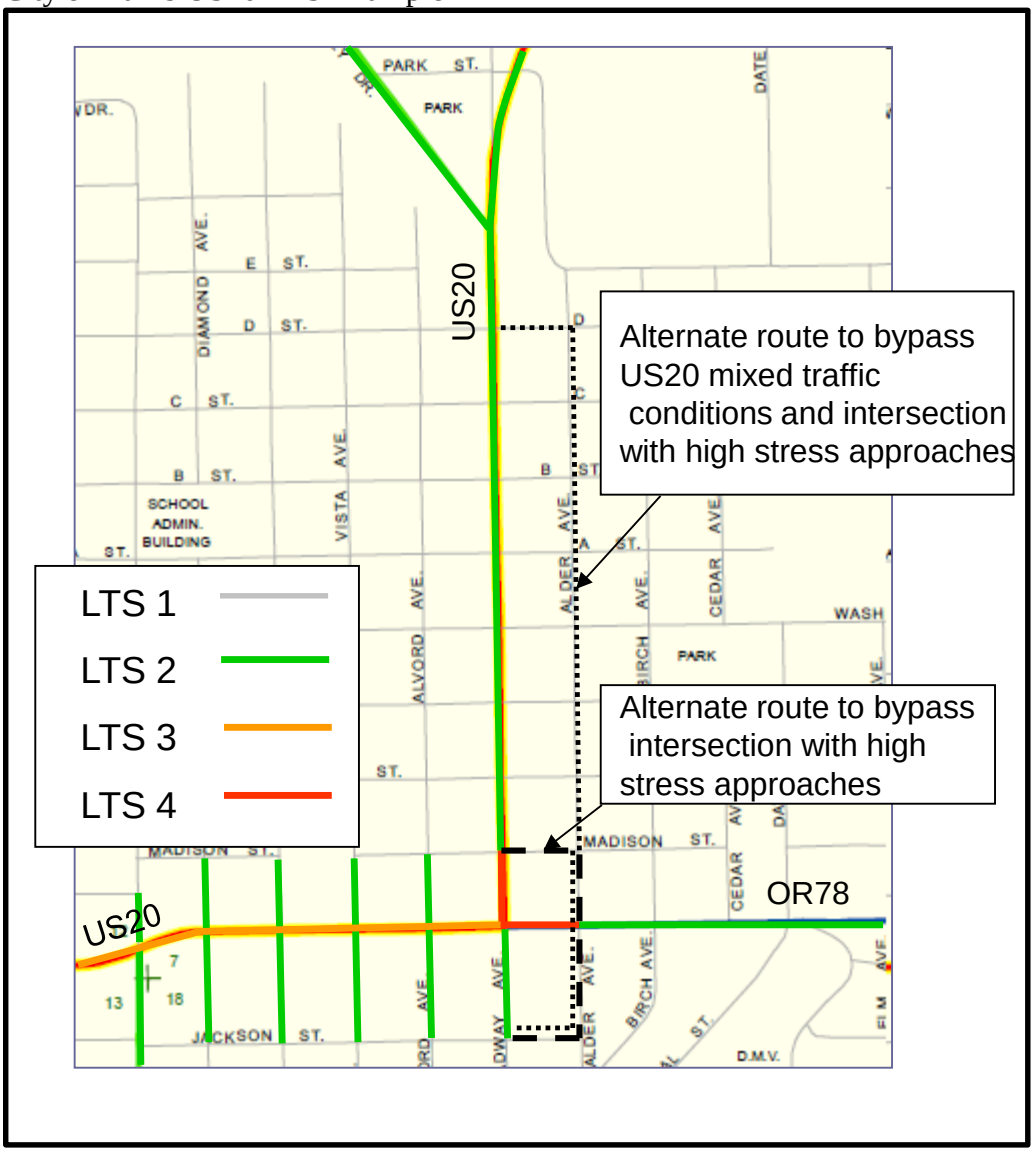
Note: Some routes with hills or many stops (or any of the previously mentioned additional considerations) may decrease desirability even though the criteria above are met.

[1]Low-Stress Bicycling and Network Connectivity, Mekuria, Furth, & Nixon, Mineta Transportation Institute, May 2012, pp14-15.

Example 14-2 Alternate Route Out-of-Direction Travel

This example illustrates the impact of out-of-direction travel on alternate routing. Two routes, one short and one long, are shown bypassing a signalized intersection with high-stress approaches in the figure below. These are only two routes of the many that are available to use.

City of Burns US20 LTS Example



For the (exaggerated) short route, the normal high-stress route through the intersection is 700 feet. Adding in the two extra blocks of travel (600' total) to cross on a lower-stress path creates a 1300 foot route. While the total length of extra travel distance is acceptable as 600 feet is less than 1,760 feet, the overall extra trip distance as a proportion of the total is not, as 1300 feet/700 feet = 1.86 or 86% extra distance. For this route, bicyclists are unlikely to take the alternate path. Higher stress-tolerant users will just deal with the LTS 4 section while less tolerant users will likely take another mode such as walking or driving.

For the longer route, the normal higher-stress route is 2,650 feet through the downtown section and across the intersection. Like with the short route, the extra distance is 600 feet for a total route distance of 3,250 feet. In this case, the extra distance has less of a proportional impact on the trip as 3,250 feet/2,650 feet is 1.23 or 23%. This is less than the 25% threshold so bicyclists may choose this route instead, especially if they are less-stress tolerant. This distance is still greater than the desirable 10% level so not all (especially higher-stress tolerant riders) will use this particular route. This path would need to be over twice as long to meet the 10% level with even just a couple extra blocks out of direction.

14.4.10 Solutions to Decrease LTS Level

There are a number of ways to lower stress levels and to achieve a desired LTS level on a segment, approach, or crossing. For more detail on these solutions, please refer to the Oregon Bicycle and Pedestrian Design Guide, the ODOT Traffic Manual, and the ODOT Highway Design Manual. A few examples (not exhaustive):

- Creating conventional bike lanes, buffered bike lanes, raised bike lanes, and bike boulevards.
- Creating segregated bike facilities such as cycle tracks or bike paths.
- Safety measures in design, such as couplets, medians, or pedestrian refuges. If four lanes of vehicular capacity is still needed then investigating a couplet may also achieve stress reductions.
- Increase width of outside lanes on roadways too narrow for striped bike lanes to create more buffer space and room for bicyclists.
- Paving/widening shoulders or removing parking.
- Reducing the number of lanes through a road diet.
- Install road markings (such as sharrows) and way-finding signs.
- Addition of flashing pedestrian beacons (i.e. RRFB's) or mid-block pedestrian hybrid beacons (i.e. HAWK) can improve higher-volume crossing locations.
- Removing or improving barriers, such as providing a safe grade-separated crossing over highways or railroads.
- Improving the pavement conditions on the shoulders of roadways.
- Adding left-turn bike boxes (see Section **Error! Reference source not found.** for limitations).
- Adding bike signals to clarify bike movements.
- Reducing speeds, enforcement of speeds limit or education about speed.

14.4.11 LTS Application Example

Example 14-3 Level of Traffic Stress

This example illustrates the use of LTS for the central section of the City of Burns in eastern Oregon in Harney County. This covers the signalized junction of US20 and OR78 in downtown Burns as well as including surrounding residential areas. Data was quickly obtained by using

available state highway inventory data and views from commercial aerial photos.

Segment LTS:
Most roadway sections are two lanes and 25 mph except for US20 west of the OR78 junction which has four lanes. No bike lanes are in the example area so all roadways are considered mixed traffic, which will be LTS 2 for the two-lane major roadways (US20 and OR78), LTS 3 for the four-lane section of US20, and LTS 1 for the local streets (no marked centerlines).

Approach LTS:
On the southbound and westbound approaches to the US20/OR78 junction, the right turn lanes are both a full block long with an adjacent shared-through left lane. These right turn lanes will create a high stress level for a bicyclist as it forces them to mix directly with right turning traffic if they wish to turn right or mix with through traffic in the southbound shared through-left lane if they wish to continue southbound. Because these are greater than 150 feet and do not have an adjacent bike lane, these are both coded LTS 4. The adjacent shared left-through lanes on both approaches would have an LTS 2, but the LTS 4 right turn lane arrangement supersedes it.

On the northbound approach, there is a short 50' right turn lane with an adjacent shared –left lane. The right turn lane is short, so there is no additional impact on the LTS. The adjacent shared though-left lane would be an LTS 2, as no lane would need to be crossed since an approaching bicyclist will end up in this lane if they are not turning right. Here, the approach LTS 2 will override the segment LTS 1 value.

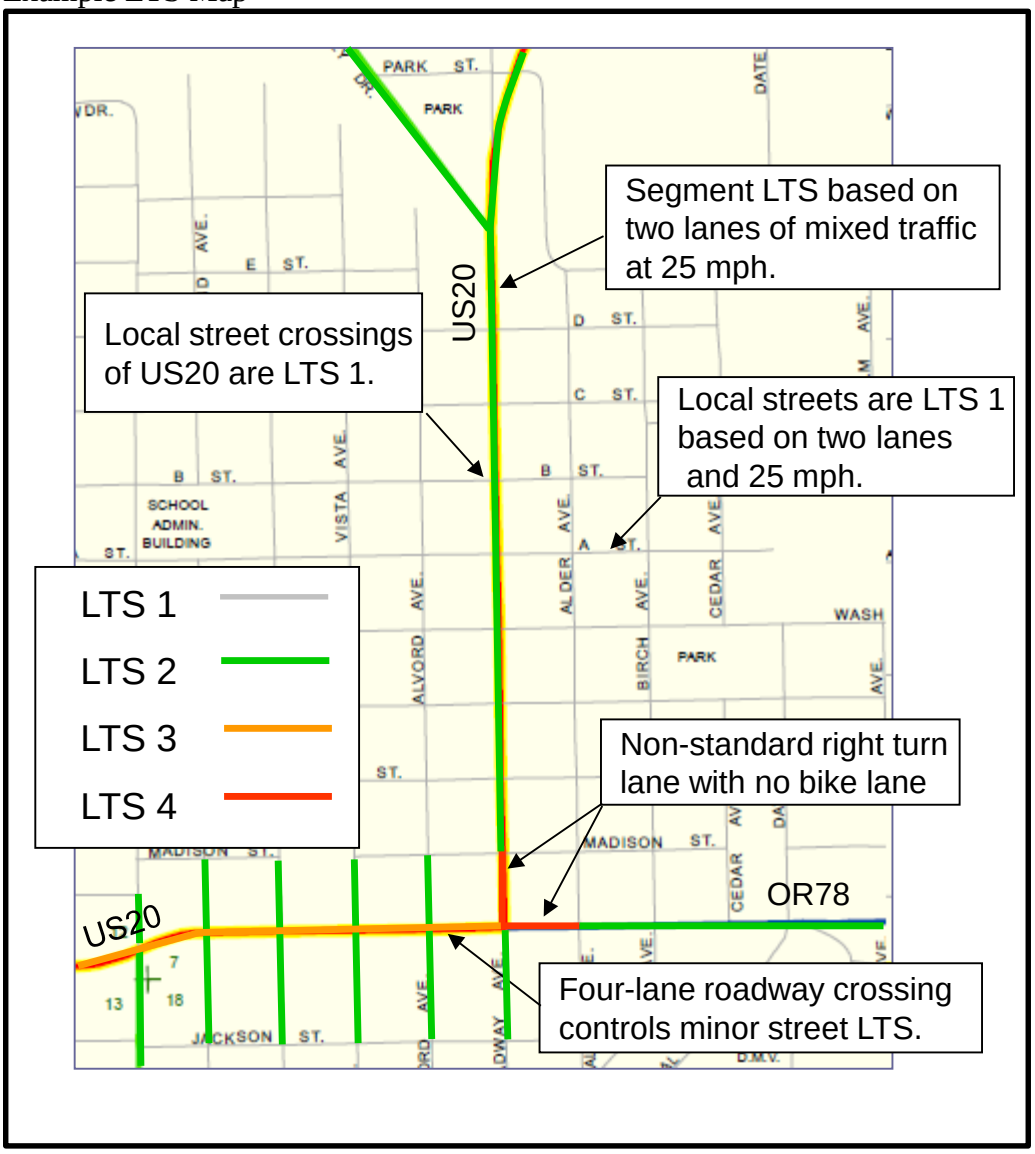
The eastbound approach has a left-lane drop lane where the left turn lane is a full block long with an adjacent through-right lane. Since mixed traffic conditions exist, the bicyclist would just move into the left turn lane. This would be at a LTS 2 level, but the segment LTS 3 level would still control.

Crossing LTS:
The signalized intersection of US20 & OR78 is LTS 1. However, this is overridden on the southbound and westbound approaches by the LTS 4 for the approaches; on the eastbound side by the LTS 3 four lane sections; and on the northbound side for the LTS 2 approach. On the four-lane portion of US20, the local street crossings are increased to LTS 2 which affects the coding of local street segments that are adjacent to US20.

Summary:
Since the highest LTS controls, and using the US20/OR78 intersection as an example, the approach criteria is greater than the segment or crossing criteria, except for the eastbound approach where it matches the LTS 3 value. The resulting LTS at the intersection can be seen in the figure below.

Most of the roadway system in the example is LTS 1 or 2. The long right turn lanes coupled with the absence of bike lanes on US20 and OR78 approaching the highway junction convert a potential route using these roadways into LTS 4, which most bicyclists will avoid. While the various parts of the city are generally well connected with LTS 1 or LTS 2 networks, it is easy to see the disconnect created along the primary arterials by the intersection of US 20 and OR 78.

Example LTS Map



14.5 Pedestrian Level of Traffic Stress

14.5.1 Purpose

The purpose of the Pedestrian Level of Traffic Stress (PLTS) is to create a high-level inventory and a walkability/connectivity performance rating of pedestrian facilities in a community without needing a significant amount of data. The Pedestrian Level of Traffic Stress methodology classifies roadway segments according to the level of pressure or strain experienced by pedestrians and other sidewalk users. Other users include non-motorized forms of transportation as well as motorized power chairs, scooters, and other wheeled mobility devices which are

permitted and assumed to use pedestrian facilities[45]. The PLTS method would typically be used during the creation of a Regional Transportation Plan (RTP), or Transportation System Plan (TSP). It can also be used for screening in a facility plan or project (See Section 14.2 for more information on applications). This methodology is intended for use in urban areas. It can be used in rural conditions where pedestrian facilities exist, however the method will yield a high PLTS where there is higher speed traffic.

14.5.2 Methodology

PLTS was created to be a companion with the Bicycle Level of Traffic Stress (BLTS)[46]. Both methods group facilities into four different stress levels for segments, intersection approaches and intersection crossings. It is recommended that BLTS and PLTS be performed at the same time to completely understand the multimodal and intermodal deficiencies of an area. New techniques were developed to support the pedestrian segment method while the intersection crossings are adapted from the BLTS method, as these were based on a pedestrian's view of comfort and perceived safety. Like BLTS, the PLTS methodology does not require extensive data collection; much of the data is collected routinely and some of the data collected for PLTS overlaps with BLTS.

Segment data:

- Sidewalk condition and width
- Buffer type and width
- Bike lane width
- Parking width
- Number of lanes and posted speed
- Illumination presence
- General land use

Crossing data:

- Functional class
- Number of lanes and posted speeds
- Roadway average daily traffic (ADT) [optional]
- Sidewalk ramps
- Median refuge & illumination presence
- Signalized general intersection features

For state highways, a good portion of the data needed is available in ODOT's databases

[45] A non-motorized form of transportation refers to vehicles that would not use the roadway to travel on a roadway. Motorized power chairs, scooters, and other wheeled mobility devices are permitted and assumed to use pedestrian facilities.

[46] The BLTS methodology is based on the paper, *Low Stress Bicycling and Network Connectivity*, Mineta Transportation Institute, Report 11-19, May 2012 that was adapted by the Oregon Department of Transportation in 2014. This version can be found in the "Analysis Procedures Manual," Oregon Department of Transportation, Version 2, June 2015.

including the on-line TransGIS application. Sidewalk condition and width, buffer presence, bike lane width, numbers of lanes, posted speeds, functional class, traffic volumes, and sidewalk ramps are available. Other jurisdictions may have existing TSP or public works inventories of some of these items. Use of Internet-based aerial imagery and street-level tools will capture any remaining widths or presence variables such as parking and buffer widths or intersection/mid-block crossing features. Sidewalk condition will likely require some sort of field inventory if it not available from other sources. Volumes, if used, should be from existing sources, or already counted as part of the same study. Streets with similar characteristics with known volumes can be used as proxy for other streets in the study area. PLTS uses four levels of traffic stress with PLTS 1 being the lowest stress level:

- **PLTS 1**- Represents little to no traffic stress and requires little attention to the traffic situation. This is suitable for all users including children 10 years or younger, groups of people and people using a wheeled mobility device (WhMD[47]). The facility is a sidewalk or shared-use path with a buffer between the pedestrian and motor vehicle facility. Pedestrians feel safe and comfortable on the pedestrian facility. Motor vehicles are either far from the pedestrian facility and/or traveling at a low speed and volume. All users are willing to use this facility.
- **PLTS 2**- Represents little traffic stress but requires more attention to the traffic situation than of which young children may be capable. This would be suitable for children over 10, teens and adults. All users should be able to use the facility but, some factors may limit people using WhMDs. Sidewalk condition should be good with limited areas of fair condition. Roadways may have higher speeds and/or higher volumes. Most users are willing to use this facility.
- **PLTS 3**- Represents moderate stress and is suitable for adults. An able-bodied adult would feel uncomfortable but safe using this facility. This includes higher speed roadways with smaller buffers. Small areas in the facility may be impassable for a person using a WhMD and/or requires the user to travel on the shoulder/bike lane/street. Some users are willing to use this facility.
- **PLTS 4**- Represents high traffic stress. Only able-bodied adults with limited route choices would use this facility. Traffic speeds are moderate to high with narrow or no pedestrian facilities provided. Typical locations include high speed, multilane roadways with narrow sidewalks and buffers. This also includes facilities with no sidewalk. This could include evident trails next to roads or 'cut through' trails. Only the most confident or trip-purpose driven users will use this facility.

It should be noted that the trip purpose and route options affect the level of stress a person is willing to experience. A person making a work-based trip is typically willing to experience a greater stress level than a person using the facility for recreation or exercise. Other elements including time of day, cost associated with other modes, ownership of vehicles, etc., influence the level of stress a person is willing to experience.

[47] A wheeled mobility device (WhMD) includes walkers, manual wheelchairs, power base chairs, and light weight scooters. Each of these devices requires the operator to maneuver and set the direction of travel. All of these devices can be operated independently and do not require additional people to maneuver the device. The American with Disability Act (ADA) (1990) sets limits on the vertical change in a surface to 0.5 inches.

Additional Pedestrian Considerations

PLTS does not include some additional factors that may influence the overall level of traffic stress. These considerations may be somewhat subjective and may not be easily measured. These factors include, but are not limited to, steep grades, neighborhood crime/personal security, access density, crash history, and heavy bicycle use (on sidewalk or path). If desired, the methodology could be modified to include these factors. If one or more negative conditions apply to a roadway, the final score can be further downgraded with proper documentation. Additional notation should be included if the downgrade was based on subjective observations.

14.5.3 PLTS Targets

PLTS 2 is generally a reasonable minimum target for pedestrian routes. This level of accommodation will generally be acceptable to the majority of users. Higher stress levels may be acceptable in limited areas depending on the land use, population types, and roadway classifications, but they will generally not be comfortable for most users. Each land use has specific needs for the pedestrian network and study areas should have multiple targets for the different areas.

Facilities within a quarter mile of schools, and routes heavily used by children should use a target of PLTS 1. This is because of the large number of children that may use the system with little or no adult supervision. The area around elementary schools should contain no PLTS 3 or 4 because of the associated safety concerns and the discouraging effect that such facilities have on walking rates. Pedestrian facilities near middle and high schools may include PLTS 2, since the students are in the older age group, but PLTS 1 routes are ideal.

Other land uses should also have a target of PLTS 1; these include downtown cores, medical facilities, areas near assisted living/retirement centers, and transit stops. Downtown cores, for example, should have wide sidewalks with street furniture. Roadways near medical facilities and residential retirement complexes should have sidewalks in good condition with adequate width.

Transit stops should have facilities that connect the passengers from the origin of their trip to the destination of their trip. The PLTS should be overlaid with the typical ¼ mile walking distance to transit for transit routes (or a roadway for a proposed route) to fully show where PLTS 1 is desired.

When setting targets, looking at the end user is vital. The land use that surrounds a corridor, pedestrian walking behavior, and local demographics will all influence the target PLTS for a corridor.

14.5.4 PLTS Criteria

PLTS measures are derived from the physical characteristics of the roadway segment and intersection crossing. Pedestrians will go either direction on a sidewalk. If there is not a sidewalk, pedestrians typically walk in the opposite direction of traffic and both sides of the roadway should be classified.

The PLTS is broken into a number of different segment and crossing tables based on several physical characteristics of the corridor.

Variable Definitions: To complete the segment PLTS analysis, information on six different variables is used. The variable definitions are listed below:

Sidewalk[48] Width: The physical width of the solid smooth surface (typically poured concrete, but could be asphalt, brick, or concrete paver blocks) that pedestrians use. This does not include solid surfaces that contain vegetation, additional lighting, street furniture, parking meters, etc. If a sidewalk has frequent obstructions (posts, poles, mailboxes, and encroaching vegetation) that limit the usable width, use the narrower or effective width instead of the physical width.

Sidewalk Condition: The sidewalk condition is a visual high-level classification process (see Exhibit 14-15). Sidewalk condition can vary within a block segment. Use the worst sidewalk condition, as a section of poor sidewalk can block some users from using the facility.

The criteria and pictures for each category are based off the Good-Fair-Poor (GFP) Pavement Condition Rating Manual for Bicycle and Pedestrian Facilities and the Pavement Distress Survey Manual developed by ODOT's Pavement Services Unit. These values are also generally compatible with the sidewalk condition ranking in ODOT's TransGIS tool. For each corridor segment the general pavement condition should be considered. A sidewalk segment that contains a mix of different conditions should be rated using the worst condition. For example, a sidewalk is smooth with only minor cracking but has a very large fault caused by a tree root. The sidewalk would be considered in "Very Poor" condition. For a sidewalk to be considered in "Fair" condition, none of the properties can be "Poor" or "Very Poor" and at least one is in the "Fair" category. For a sidewalk to be considered "Good"' all of the criteria must be met and it must be of relatively new construction. Additional examples are located in Appendix B.

STOP

If obtaining data from ODOT's online FACS_STIP or TransGIS tools for use in a PLTS analysis, please be aware that there is no "Very Poor" equivalent at this time. Analysts will need to field verify sidewalk sections marked as "Poor" to ensure that there are no "Very Poor" sections within them.

[48] Sidewalk refers to sidewalks, shared-use paths, and pedestrian paths. The methodology was designed to be used for sidewalks but, can apply to other pedestrian facilities.

Exhibit 14-15 Sidewalk Condition Rating

Rating	Facility Properties	Example
Good	• No minor cracking • No patching or raveling and has a very smooth surface • No faulting • New construction	
Fair	• Minor cracking (generally hairline) • Minor patching and possibly some minor raveling evident. Surface is generally smooth • Minor faulting (less than ¼”)	
Poor	• Minor cracking in several locations • Rough areas present but not extensive • Faulting may be present but less than ½” (No major faulting)	
Very Poor	• Major cracking patterns • Rough conditions (major deterioration, raveling, loose aggregate, missing pavement, etc.) • Faulting greater than ½”	

Rating	Facility Properties	Example
No sidewalk	• No solid and smooth surface is present on the side of the roadway. Pedestrians use the travel lane, paved shoulder, or soil shoulder to travel along the roadway.	

<u>Physical Buffer Type</u>: The physical buffer is the distance from the outside edge of sidewalk to the edge of pavement or curb. The buffer type is categorized into six major groups. This area is also referred to as the furniture or planter zone.

No Buffer: The narrower sidewalk (<10 ft in width) is adjacent to the curb (curb tight). The facility may still include a bike lane and/or on street parking (see total buffering width distance).

Solid Surface: The buffer is a hard surface that can contain buffering elements such as lighting, street furniture, parking meters, and bicycle racks. If the buffer is wide enough, street trees can also be present which help improve the walking experience. The buffer still allows people to maneuver to the roadway edge without leaving the solid surface. The surface material can also change to indicate a buffer (i.e., stamped concrete, pavers). Purely decorative buffers usually do not have any "furniture elements" in them. A wide sidewalk (10+ feet) can also be itself a buffer even if there is no extra delineation.

Landscaped: the area between the edge of the sidewalk and the curb includes a soil area with low shrubs or vegetation. The vegetation does not create a wall or reduce pedestrian sight distance. These can also have a ditch, slope, or other topographical feature.

Landscaped with trees: The area between the edge of the sidewalk and the curb includes trees. Once the trees are mature, a canopy effect is created over the pedestrian facility and the edge of roadway. Trees are spaced for heathy growing and sight distance is not limited. This buffer type tends to be wider than a regular landscaped buffer and also can have a ditch, slope, or other topographical feature included.

Vertical: A vertical buffer (i.e. retaining wall) elevates the pedestrian facility higher than the roadway surface. This typically contains an additional fence or pedestrian buffer facility.
Prevailing or Posted Speed: The prevailing (or average) speed is the recommended speed to be used in the methodology. If prevailing speed data is not available posted speed should be used.
Total Buffering Width: The total buffering width is the distance from the edge of the sidewalk to the edge of the travel lane. This includes but is not limited to:

- the physical buffer (above),
- on-street parking, if parking is not striped then assume the standard parking distances (six to eight feet) for the facility type
- Bicycle facility, and
- Shoulder

Total Number of Travel Lanes: The total number of travel lanes includes the total number of lanes on the segment. This includes the number of thru lanes for both directions, two-way left turn lanes (TWLTL), and continuous right turn lanes. For example, a five-lane roadway could have two thru lanes in each direction and one two-way left turn lane. Note: This category is different than used in the BLTS method because pedestrians can use either side of the roadway to go either direction and are not limited by one-way streets.

General Land Use
The general land use of an area with the corresponding building placement, amenities, and attractions/destinations affects the overall desired walkability of a segment. Areas that are more pedestrian-friendly typically have more destinations for walking trips, a higher pedestrian presence, and the corresponding expectation from a vehicle driver's perspective. Land use types are grouped by the likelihood for a high number of origins and/or destinations, likely pedestrian presence, perceived attractiveness and exposure, noise, heavy vehicle use, and directness.
Intersection variable definitions:

Functional Class – This is the local or state functional class assigned to a roadway. These are typically included in a Transportation System or Regional Transportation Plan document.

Average Daily Traffic – This is the total daily traffic in both directions. These can be obtained from ODOT's Transportation Volume Tables, local counting programs, calculated from traffic counts or estimated from shorter duration counts. See APM Chapters 3 and 5. If ADTs are not readily available, the methodology allows a mid-range value to substitute.

14.5.5 PLTS Classifications

The PLTS criteria are broken into two primary sections. Table-based criteria are applied separately for segments and intersection crossings. The follow sections outline the nine tables used to classify the PLTS for a roadway. The first four tables are the roadway segment criteria and the last five are for roadway intersections. The methodology uses the worst overall PLTS value for each segment and intersection crossing. The worst (highest) PLTS value of a series of segments and crossings will control a route.

Sidewalk Criteria

The condition and geometry of the sidewalk is the first criterion in the PLTS methodology. The criterion splits sidewalks into greater than five feet and less than five feet in width. The five foot condition is based on federal and state design codes and recommendations. The federal standard for a sidewalk is five feet. In Oregon, the Oregon Bicycle and Pedestrian Design Guide (OBPDG) states that the standard pedestrian zone is six feet and those five feet may be acceptable in some areas (local and residential streets). Short (<200') sections can have widths as narrow as four feet. While sidewalks along a state highway may need to be wider, sidewalks in central business districts of heavy used pedestrian areas may also need to be wider. Guides such as the OBPDG and the Highway Design Manual (HDM) should be referenced for more information.

Exhibit 14-16 uses the overall condition and the effective (useable) width of the sidewalk. The purpose is to rate which groups of users can safely and comfortably utilize a facility. A narrow (from obstructions or actual width) or low quality sidewalk will not be passable for all user groups. The actual sidewalk width, especially if it is less than five feet, will impact the use by disabled people while effective width rates the comfort and flow of pedestrians along a sidewalk. The effective width is the simple average clear width of a sidewalk segment rather than following the more-detailed Highway Capacity Manual procedure.

Use the actual sidewalk width first in Exhibit 14-16 to see if the minimum actual width is present, then check the effective width if the sidewalk is at least six feet wide to determine the appropriate PLTS. If the effective width is less than five feet use the corresponding actual width rows as obstructions will still cause impediments to disabled users. A PLTS 1 sidewalk must be accessible to all users, have six effective feet or wider path, and in good or fair condition. If a segment does not have illumination, consider increasing the PLTS up one level. The impact of darkness requires increased awareness for safety/security and especially if the sidewalk is in poor condition or is not present.

Exhibit 14-16 Sidewalk Condition [1,3]

Actual/Effective Sidewalk Width (ft)[2]		Sidewalk Condition				
		Good	Fair	Poor	Very Poor	No Sidewalk
Actual	<4	PLTS 4	PLTS 4	PLTS 4	PLTS 4	PLTS 4
	≥4 to <5	PLTS 3	PLTS 3	PLTS 3	PLTS 4	PLTS 4
	≥5	PLTS 2	PLTS 2	PLTS 3	PLTS 4	PLTS 4
Effective	≥6 [4]	PLTS 1	PLTS 1	PLTS 2	PLTS 3	PLTS 4

[1]Can include other facilities such as walkways and shared-use paths
[2]Effective width is the available/useable area for the pedestrian. Does not include areas occupied by store fronts or curb side features.
[3]Consider increasing the PLTS one level (Max PLTS 4) for segments that do not have illumination. Darkness requires more awareness especially if sidewalk is in fair or worse condition.
[4]Effective width should be proportional to volume as higher volume sidewalks should be wider than the base six feet. Use a minimum PLTS 2 for higher volume sidewalks that are not proportional (include documentation).

14.5.6 Physical Buffer Type Criteria

The treatment of buffers is split into two parts: the physical buffer type and the total buffering width, which includes the physical buffer and any on-street areas outside the travel lanes (parking, bike lanes, and shoulders). The HDM and the OBPDG have standards and guidance pertaining to buffers. There are several advantages of having a buffer or furniture zone on a facility. The advantages include an increase in a pedestrian's sense of security, sidewalks that stay level over driveways, and improved drainage. Exhibit 14-17 shows stress levels associated with varying buffer types.

Exhibit 14-17 Physical Buffer Type

Physical Buffer Type				
Buffer Type[1]	Prevailing or Posted Speed			
	≤25 MPH	30 MPH	35 MPH	≥40 MPH
No Buffer (curb tight)	PLTS 2	PLTS 3	PLTS 3	PLTS 4
Solid surface	PLTS 2[2]	PLTS 2	PLTS 2	PLTS 2
Landscaped	PLTS 1	PLTS 2	PLTS 2	PLTS 2
Landscaped with trees	PLTS 1	PLTS 1	PLTS 1	PLTS 2
Vertical				

[1]Combined buffers: If two or more of the buffer conditions apply, use the most appropriate, typically the lower stress level.
[2]If street furniture, street trees, lighting, planters, surface change, etc. are present then the PLTS can be lowered to PLTS 1.

14.5.7 Total Buffering Width Criteria

Exhibit 14-18 considers the stress associated with the total distance from the pedestrian to the vehicular traffic on one side of the roadway. The number of lanes is used to imply the level of the traffic volumes and functional classification of the roadway.

Exhibit 14-18 Total Buffering Width

Total Number of Travel Lanes (both directions)	Total Buffering Width (ft)[1]				
	<5	≥5 to <10	≥10 to <15	≥15 to <25	≥25
2	PLTS 2	PLTS 2	PLTS 1	PLTS 1	PLTS 1
3	PLTS 3	PLTS 2	PLTS 2	PLTS 1	PLTS 1
4 - 5	PLTS 4[2]	PLTS 3	PLTS 2	PLTS 1	PLTS 1
6	PLTS 4[2]	PLTS 4[2]	PLTS 3	PLTS 2	PLTS 2

[1]Total Buffering Width is the summation of the width of buffer, width of parking, width of shoulder and width of the bike lane on the side same side of the roadway as the pedestrian facility being evaluated.
[2]Sections with a substantial physical barrier/tall railing between the travel lanes and the walkway (like might be found on a bridge) can be lowered to PLTS 3.

14.5.8 General Land Use Criteria

The general land use can create an overall positive effect on walkability and use of certain facilities if destinations are frequent and convenient. Higher pedestrian use leads to a greater driver expectation and driving behaviors typically reflect such (i.e. more likely to yield). Conversely, land use can create a dampening effect to the point that it will not matter how well the facilities are laid out or constructed, the desire to walk on a segment is diminished if the facility goes through a perceived unattractive/unsecure/noisy/too-busy area. Areas that are more auto-oriented have lower driver expectations for pedestrians so yielding behaviors are much less likely. Exhibit 14-19 groups typical land use types by PLTS level with more pedestrian-friendly walkable areas getting lower PLTS levels.

Exhibit 14-19 General Land Use

PLTS	Overall Land Use
1	Residential, central business districts (CBD), neighborhood commercial, parks and other public facilities, governmental buildings/plazas, offices/office parks
2	Low density development, rural subdivisions, un-incorporated communities, strip commercial, mixed employment
3	Light industrial, big-box/auto-oriented commercial
4	Heavy industrial, intermodal facilities, freeway interchanges

14.5.9 Crossing Criteria

Unsignalized crossings at intersections or at mid-block can act as barriers to pedestrians, especially where there are a high number of lanes or higher speeds. The crossing can be an impediment to travel if the pedestrian has to cross four or more lanes at any speed or has to cross a 35 mph (or greater) street. The criteria for unsignalized intersection crossings depend on the functional class of the roadway, average daily traffic, speed limit, number of lanes, and presence of a median of sufficient width to provide for a two-stage crossing. Average daily traffic (ADT) of the roadway being crossed can be optional if data is not available by using the footnoted

columns in the following exhibits. Over or underpasses are considered as separate facilities and are PLTS 1.

For functionally classified local and collector streets use Exhibit 14-20 for crossing with and without a pedestrian median refuge. The vast majority of these roadways should be under the 5,000 ADT limit for the table, but if it is known that a facility has an abnormally high amount of traffic for its functional class (there also should be a count performed on this section; See APM Chapter 3), it should be compared with Exhibit 14-23 or 14-24. Also, if a collector-level roadway has more than two lanes or is one-way, then Exhibit 14-23 or 14-24 should be used.

Unsignalized crossings on functionally classified minor/major/principal arterial roadway sections should use Exhibit 14-21 for crossings without pedestrian median refuges. Sections with pedestrian refuge islands or are one-way should use Exhibit 14-23 and 14-24. If ADT is not available for a section (or not possible to be estimated), use the midrange columns (as per table footnote) in these exhibits to find an appropriate PLTS. Enhanced arterial crossings (with or without refuge islands) can use Exhibit 14-22 to lower the PLTS to a maximum two level reduction or minimum PLTS 2.

When a crossing lacks “standard” modern ramps, the facility is limited to able-bodied users. A standard modern ramp will have a flatter grade, may have a level landing surface, and some sort of detectable surface for visually impaired pedestrians (usually an etched-in cross hatching). Current ADA-standard ramps have a thermoplastic “truncated dome” insert attached to the ramp surface, so these are relatively easy to spot. Older ramps with short and or steep grades (these almost never have any detectable surfaces) are considered equivalent to no ramp at all. Impaired users will either not use the facility or will be forced into an uncomfortable position by using the street via a nearby driveway. In these cases, the minimum PLTS is 3.

Pedestrian median refuges need to be at least six feet in width (10 feet for PLTS 1 eligibility) and have some sort of a raised concrete or vegetated island for protection. Crossings at roundabouts should use PLTS 1 for a single lane crossing of an entry or exit assuming that the splitter island is at least 10 feet wide, otherwise use PLTS 2. Two-lane exits and entries are PLTS 2.

Increase the PLTS by one level (to a maximum PLTS 4) if the intersection or mid-block crossing is not illuminated in Exhibits 14-20, 21, 23, and 24. Unlit crossings require more awareness by the pedestrian as they are harder for drivers to see and/or expect in darkness.

Exhibit 14-20 Collector & Local Unsignalized Intersection Crossing [1, 2, 3, 4]

Prevailing Speed or Speed Limit (mph)	No Median Refuge		Median Refuge Present
	Total Lanes Crossed		Maximum One Through/Turn Lane Crossed per Direction
	1 Lane	2 Lanes	
≤ 25	PLTS 1	PLTS 1	PLTS 1[5]
30	PLTS 1	PLTS 2	PLTS 1
35	PLTS 2	PLTS 2	PLTS 2
≥ 40	PLTS 3	PLTS 3	PLTS 3

[1]For street being crossed.
[2]Minimum PLTS 3 when crossing lacks standard ramps.
[3]Use Exhibit 14-23 or 14-24 for one-way streets, when ADT exceeds 5,000, or total number of lanes exceeds two.
[4]Street may be considered a one-lane road when no centerline is striped and when oncoming vehicles commonly yield to each other.
[5]Refuge should be at least 10 feet for PLTS 1, otherwise use PLTS 2 for refuges 6 to <10 feet.

Exhibit 14-21 Arterial Unsignalized Intersection Crossing Without a Median Refuge [1, 2]

Prevailing Speed or Speed Limit (mph)	Total Lanes Crossed (Both Directions)[3]					
	2 Lanes			3 Lanes		
	<5,000 vpd	5,000-9,000 vpd[4]	>9,000 vpd	<8,000 vpd	8,000-12,000 vpd[4]	>12,000 vpd
≤ 25	PLTS 2	PLTS 2	PLTS 3	PLTS 3	PLTS 3	PLTS 4
30	PLTS 2	PLTS 3	PLTS 3	PLTS 3	PLTS 3	PLTS 4
35	PLTS 3	PLTS 3	PLTS 4	PLTS 3	PLTS 4	PLTS 4
≥ 40	PLTS 3	PLTS 4	PLTS 4	PLTS 4	PLTS 4	PLTS 4

[1]For street being crossed.
[2]Minimum PLTS 3 when crossing lacks standard ramps.
[3]For one-way streets, use Exhibit 14-10 and 14-24.
[4]Use these columns when ADT volumes are not available

Exhibit 14-22 Adjustments for Crosswalk Enhancements

Treatment	Deduction	Treatment	Deduction
Markings[1]	0.5	In-street signs	1.0
Roadside signage[1]	0.5	Curb extensions	0.5
Lighting	0.5	Raised crosswalk	1.0
RRFB	1.0		

[1]Not applicable for roadways with pedestrian median refuges as crosswalk markings and roadside signage assumed as part of the basic installation.

Exhibit 14-23 Arterial Unsignalized Intersection Crossing (1 to 2 lanes) with a Median Refuge [1, 2]

Prevailing Speed or Speed Limit (mph)	Maximum Through/Turn Lanes Crossed per Direction			
	1 Lane	2 Lanes		
	Any	<5,000 vpd	5,000-9,000 vpd[4]	>9,000 vpd
≤ 25	PLTS 1[3]	PLTS 1[3]	PLTS 2	PLTS 2
30	PLTS 2	PLTS 2	PLTS 2	PLTS 2
35	PLTS 2	PLTS 2	PLTS 2	PLTS 3
≥ 40	PLTS 3	PLTS 3	PLTS 3	PLTS 4

[1]For street being crossed.
[2]Minimum PLTS 3 when crossing lacks standard ramps.
[3]Refuge should be at least 10 feet for PLTS 1, otherwise use PLTS 2 for refuges 6 to <10 feet.
[4]Use these columns when ADT volumes are not available.

Exhibit 14-24 Arterial Unsignalized Intersection Crossing (3 or more lanes) with a Median Refuge [1, 2]

Prevailing Speed or Speed Limit (mph)	Maximum Through/Turn Lanes Crossed per Direction			
	3 Lanes			4+ Lanes
	<8,000 vpd	8,000-12,000 vpd[4]	>12,000 vpd	Any
≤ 25	PLTS 1[3]	PLTS 2	PLTS 3	PLTS 4
30	PLTS 2	PLTS 2	PLTS 3	PLTS 4
35	PLTS 3	PLTS 3	PLTS 4	PLTS 4
≥ 40	PLTS 4	PLTS 4	PLTS 4	PLTS 4

[1]For street being crossed.
[2]Minimum PLTS 3 when crossing lacks standard ramps.
[3]Refuge should be at least 10 feet for PLTS 1, otherwise use PLTS 2 for refuges 6 to <10 feet.
[4]Use these columns when ADT volumes are not available.

The PLTS to cross the major street is applied to the minor street in the direction of travel along the route. If the crossing PLTS has a higher stress level than the minor street segment PLTS, the crossing PLTS applies (controls) to that minor street segment.

Signalized crossings usually provide a protected way across the roadway and are typically rated at PLTS 1 (i.e. midblock crossings with regular or HAWK-type signals). The PLTS will be higher in areas if the following are evident:

- Permissive left or right turns. Pedestrians will need to be more wary about the potential for increased conflicts, so PLTS 2 is typically given in these cases.
- Missing basic features such as lighting or countdown pedestrian signal heads will increase the PLTS to PLTS 2.
- Presence of complex elements will increase the PLTS to PLTS 3:

- Multiple or narrow (less than six feet) refuge islands,
- No standard ramps,
- More than six total lanes crossed at once,
- Non-standard geometry (more than four legs, or highly skewed approaches),
- Closed or limited crosswalks available; Free-flow or yield-controlled channelized right turns

If the distance between crossing opportunities (i.e. signalized or a low-stress unsignalized) is greater than approximately 0.10 mile, then the resulting out-of-direction travel incurred by a pedestrian may be too great. This may deter or impede travel along a segment if the desired route includes a major street crossing.

14.5.10 Results

Mapping the PLTS for a community is a typical result from the analysis and can be easily done using GIS. The map shows the gaps and barriers in the system which can be used to inform stakeholders when creating a list of prioritized projects. The maps can also be included in planning documents and used to help inventory the pedestrian facilities.

14.5.11 Solutions to Decrease PLTS Level

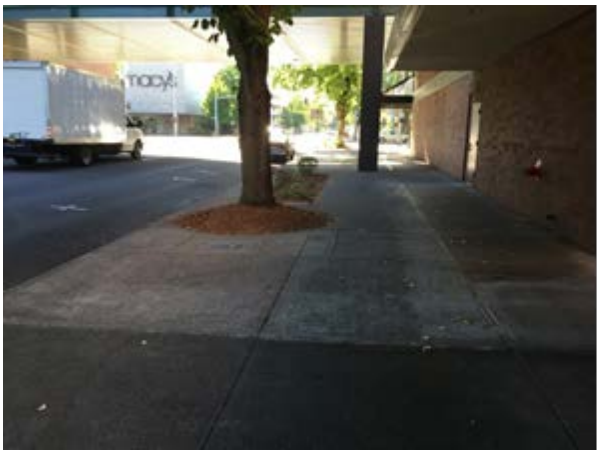
There are several ways reduce PLTS and reach the chosen target for a roadway. Several publications including the Oregon Bicycle and Pedestrian Design Guide, the ODOT Traffic Manual, and the ODOT Highway Design Manual, includes design considerations for pedestrian facilities. A few examples of actions that can reduce PLTS:

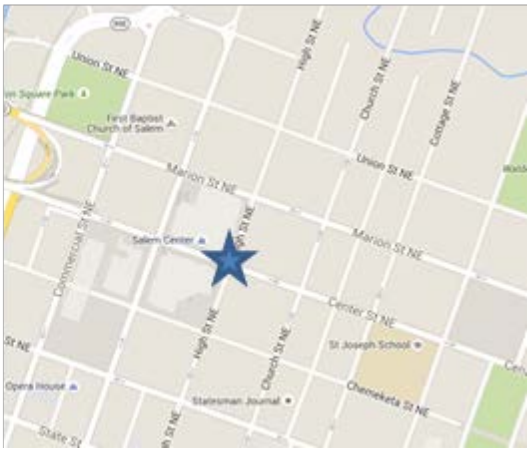
- Installing pedestrian facilities, or expanding facilities where pedestrian routes exist
- Create paved surfaces where there are trails or worn paths are evident
- Improving the condition of the sidewalk, including limiting vertical change and smoothing the surface
- Infilling gaps in sidewalk to create connectivity
- Redesigning roadway to include wider or buffered sidewalks
- Creating a multi-use path on high speed roadway
- Significantly changing the roadway character and reducing speed limit
- Installing additional crossing enhancements at unsignalized crossings (beacons, lighting, curb extensions, etc.), r
- removing barriers to connectivity
- Redesigning buffer to include trees, large vegetation, and/or street furniture
- Land use changes over time to encourage more pedestrian-scale developments

Example 14-4 Pedestrian Level of Traffic Stress

The following section shows examples of corridor sections for each PLTS. All of the examples are pedestrian facilities within the Salem city limits. The purpose of the example is to illustrate different PLTSs.

Center Street at High Street





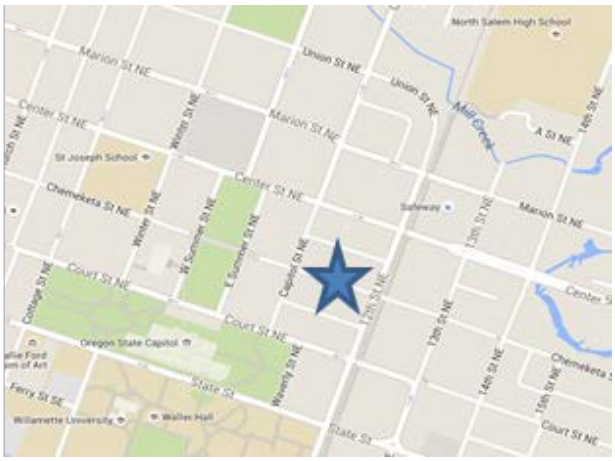
Street Name		Center St at High St
Sidewalk	Condition	Fair
	Width (ft)	12
Buffer	Width (ft)	0
	Buffer Type	Solid Surface; street trees present
Bike Lane	Width (ft)	0
Parking	Width (ft)	8
Roadway	Number of Lanes	4
	Posted Speed (mph)	30
Land Use	Type	Central business district
Total Buffering Width (ft)		16

Center Street at High Street is located on a major roadway in downtown Salem. This segment is within the Salem Center Mall District with storefronts along the street. The segment contains a large 12 foot sidewalk with an effective width at least six feet and a solid surface buffer with street trees which leads to PLTS 1 ratings in the sidewalk and buffer type criteria. The total buffering width is just large enough to counteract the effect of the four-lane roadway so the PLTS is 1. This location is within a central business district so the general land use PLTS is 1. All of the categories are PLTS 1 so the overall PLTS is 1.

Street Name	Center St at High St
Sidewalk Condition	PLTS 1
Physical Buffer Type	PLTS 1
Total Buffering Width	PLTS 1
General Land Use	PLTS 1
Final PLTS	**PLTS 1**

If a mid-block crossing of Center Street was to be analyzed, then the functional class of the roadway would need to be obtained. In this case, Center Street is an arterial. This is a one-way four-lane section so ADT is not needed in the methodology. One-way sections need to use the tables for arterial streets with median refuges as the total lanes crossed are all in a single direction. The resulting PLTS would be 4 for a midblock crossing. This compares to the PLTS of 2 for the adjacent signalized intersections with permissive turns.

Chemeketa Street between Capitol Street and 12th Street



Street Name		Chemeketa St. between Capitol St & 12th St
Sidewalk	Condition	Good
	Width (ft)	5
Buffer	Width (ft)	10
	Buffer Type	Landscaped with trees
Bike Lane	Width (ft)	0
Parking	Width (ft)	15
Roadway	Number of Lanes	2
	Posted Speed (mph)	25
Land Use	Type	Office/Residential
Total Buffering Width (ft)		25

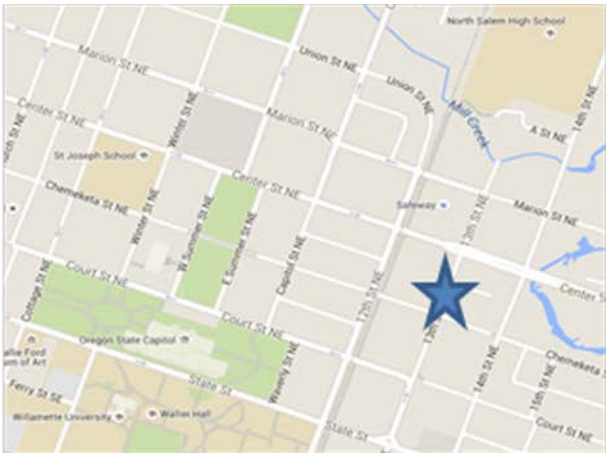
Chemeketa Street serves as a low volume street connecting 12th Street to parking areas around the Capitol mall area. The sidewalk condition is rated as good as it is of newer construction and

has an actual width of five feet. This makes the facility a PLTS 2 under the sidewalk condition. The physical buffer type is landscaped with trees and the roadway has a 25 mph posted speed which makes the buffer PLTS 1. The total buffering width on this side of the roadway is 25 feet and there are two lanes on the roadway. This leads to the PLTS 1 for the total buffering width category. The general land use on this segment is offices and high density residential so the PLTS is 1. The sidewalk condition controls so the overall PLTS for this segment is 2.

Street Name	**Chemeketa St. between Capitol & 12th St**
Sidewalk Condition	PLTS 2
Physical Buffer Type	PLTS 1
Total Buffering Width	PLTS 1
General Land Use	PLTS 1
Final PLTS	**PLTS 2**

If the adjacent intersection at 12th and Chemeketa were added to the segment, as would be done if a route was being investigated, the intersection's PLTS would not control over the segment's PLTS 2. This signalized intersection has permissive left turns, but is free of complex elements, so the PLTS is 2, which is equal to the final segment PLTS.

13th Street at Chemeketa Street



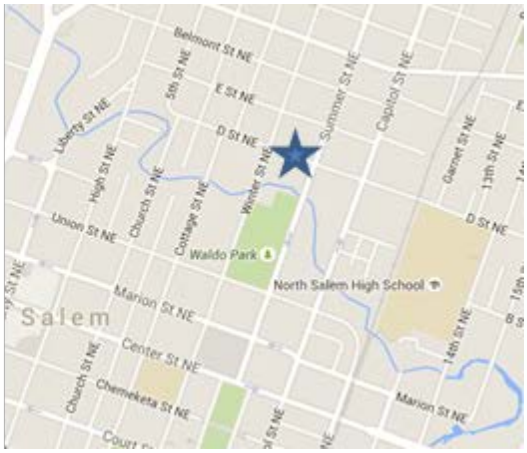
Street Name		**13th St at Chemeketa St**
Sidewalk	Condition	Good
	Width (ft)	5
Buffer	Width (ft)	4
	Buffer Type	Landscaped with trees
Bike Lane	Width (ft)	0
Parking	Width (ft)	0
Roadway	Number of Lanes	2
	Posted Speed (mph)	25

Land Use	Type	Office/Residential
Total Buffering Width (ft)		4

13th Street at Chemeketa Street is located in the transition between downtown Salem and residential areas. With a sidewalk condition of good as it is of newer construction and a width of five feet the sidewalk condition PLTS is rated at 2. The buffer type is trees with a posted speed of 25 MPH which categories the facility at a PLTS 1. The total buffering width category is a PLTS 2. This is because the total buffering width is less than five feet and there are two travel lanes. This is in a mainly residential/office location so the general land use PLTS is 1. The final PLTS for this facility is PLTS 2.

Street Name	**13th St at Chemeketa St**
Sidewalk Condition	PLTS 2
Physical Buffer Type	PLTS 1
Total Buffering Width	PLTS 2
General Land Use	PLTS 1
Final PLTS	**PLTS 2**

D Street between Summer Street and Capitol Street (near Parrish Middle School)



Street Name		**D St between Summer St & Capitol St**
Sidewalk	Condition	Fair
	Width (ft)	5
Buffer	Width (ft)	0
	Buffer Type	n/a
Bike Lane	Width (ft)	0
Parking	Width (ft)	0
Roadway	Number of Lanes	2
	Posted Speed (mph)	30
Land Use	Type	Residential

Total Buffering Width (ft)	0

D Street between Summer Street and Capitol Street is located on the edge of downtown Salem and Parrish Middle School in a residential area. The sidewalk is in fair condition. There is no buffer between the sidewalk and the roadway. This, combined with the posted speed of 30 mph, categorizes this facility at a PLTS 3 and is the controlling PLTS.

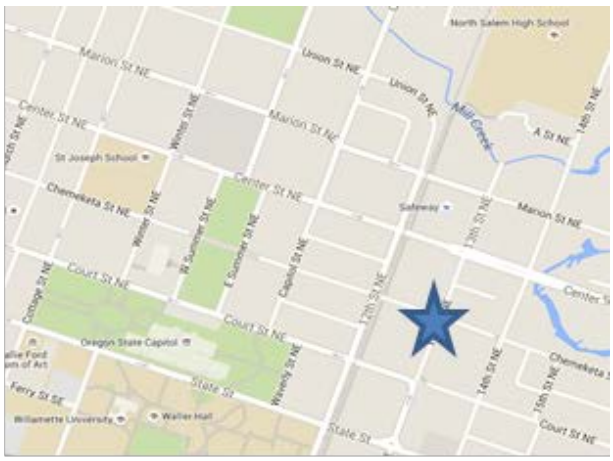
Street Name	**D St between Summer & Capitol St**
Sidewalk Condition	PLTS 2
Physical Buffer Type	PLTS 3
Total Buffering Width	PLTS 2
General Land Use	PLTS 1
Final PLTS	**PLTS 3**

If a crossing of D Street was to be analyzed, then the following additional information would be gathered:

- Functional Class = Collector
- ADT = 1600 vehicles per day
- Median refuge = Not present

Since D Street is a collector, ADT is not needed other than as a check to see that it is under the 5000 veh/day limit (typically it can be assumed that collectors and lower are under the limit without needing an ADT count to verify). Since there is no pedestrian median refuge, both lanes are crossed at once on this 30 mph roadway which is a PLTS 1.

Chemeketa Street at 14th Street

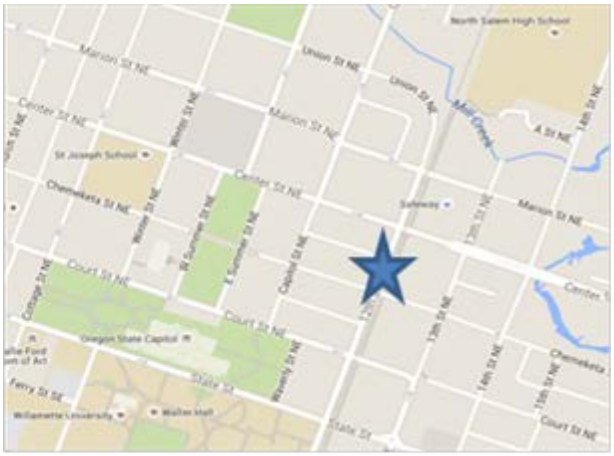


Street Name		Chemeketa St at 14th St
Sidewalk	Condition	Very Poor
	Width (ft)	5
Buffer	Width (ft)	8
	Buffer Type	Landscaped with trees
Bike Lane	Width (ft)	0
Parking	Width (ft)	7
Roadway	Number of Lanes	2
	Posted Speed (mph)	25
Land Use	Type	Residential
Total Buffering Width (ft)		15

Chemeketa Street at 14th Street is an old residential street with poor sidewalk condition. The sidewalk condition is very poor with several areas of substantial uplift and large cracks. This leads to the PLTS rating of 4 for sidewalk condition as it will make it impassable for disabled pedestrians and even difficult in spots for non-impaired individuals. The posted speed is 25 mph and the buffer is a treed planter zone, so the buffer type is rated as PLTS 1. The general land use is residential so this is a PLTS 1. The total buffer width is 15 feet and the number of travel lanes is 2 for the roadway and because of these attributes the total buffer distance PLTS is 2. The overall PLTS for this segment is PLTS 4.

Street Name	Chemeketa St at 14th St
Sidewalk Condition	PLTS 4
Physical Buffer Type	PLTS 1
Total Buffering Width	PLTS 2
General Land Use	PLTS 1
Final PLTS	**PLTS 4**

12th Street between Marion Street and Center Street



Street Name		12th St at Center St
Sidewalk	Condition	Poor
	Width (ft)	3
Buffer	Width (ft)	0
	Buffer Type	N/A
Bike Lane	Width (ft)	0
Parking	Width (ft)	0
Roadway	Number of Lanes	4
	Posted Speed (mph)	30
Land Use	Type	Mixed employment
Total Buffering Width (ft)		0

The 12th Street corridor is a moderate speed and volume facility in a mixed commercial/office area. The sidewalks along the west side of the roadway are narrow at three feet and in poor condition. This leads to a PLTS of 4 for sidewalk condition. There is no buffer and speed of 30 mph on the roadway which leads to a PLTS 3 for the buffer type. The total buffer distance is zero feet and the total number of travel lanes is four, which is a PLTS 4 in the total buffer distance category. The general land use is a mix between commercial uses, offices and large employee parking lots, so this would be generally PLTS 2. With one or more categories at PLTS 4, the segment of roadway is a PLTS 4.

Street Name	12th St at Center St
Sidewalk Condition	PLTS 4
Physical Buffer Type	PLTS 3
Total Buffering Width	PLTS 4
General Land Use	PLTS 2
Final PLTS	**PLTS 4**

If the adjacent intersections at 12th/Center and 12th/Marion were added to the segment as would be done if a route was being investigated, neither intersection's PLTS would control the overall segment. Both signalized intersections have permissive turns, but are free of complex elements and would have a PLTS of 2, but these are still lower than the PLTS 4 for the segment.

14.6 Multimodal Level of Service

The Level of Service (LOS)–based methods presented in this section and Section 14.6 are intended for use when a detailed analysis is desired such as in facility plans or projects when a no-build alternative is compared to one or more build alternatives. These methods are not meant for defining overall needs or making prioritization decisions, so those sorts of applications should use the Qualitative Multimodal Assessment or Level of Traffic Stress methodologies

instead (see sections 14.2 to 14.4).

The Auto mode is not included as analysis at this level of detail would typically be done at intersections with applications such as Synchro, Highway Capacity Software, or Vistro. Application of the methodologies is via Excel-based calculators available on the Transportation Development – Planning Technical Tools webpage.

14.6.1 Re-estimated Pedestrian & Bicycle Methodology Application

The pedestrian and bicycle procedures in this section are re-estimated versions of the link-level full *Highway Capacity Manual* (*HCM*) *2010* Multimodal Level of Service (MMLOS) methodologies. The use of probabilistic methodologies with the original research data allowed the number of variables to be significantly reduced while maintaining or improving accuracy of the results. These simplified procedures will still produce a Level of Service (LOS) letter grade, will indicate the current "state of the system, and can be done in a fraction of the time that the full MMLOS methodology requires".

These methodologies only include link-level detail. There are a number of issues with the intersection-level LOS in the full HCM MMLOS method that create non-intuitive results when combined with the link-level LOS by obscuring or limiting changes (the full method is rather insensitive to change compared to the links-only portion). Non-HCM but consistent analysis procedures for capturing the LOS for unsignalized and signalized street crossings for the bicycle and pedestrian modes will be added at a later date.

These procedures are intended for application on urban arterial (excluding freeways)/collector-classed roadways. Roadways are segmented to ensure demand, control, and geometry are relatively uniform within each segment. Caution should be exercised if applying these on functionally classified local streets as results may not be intuitive. The Qualitative Multimodal Assessment (QMA, see Section 14.3) should be used for applications in other areas such as unincorporated communities and rural areas.

14.6.2 Pedestrian & Bicycle LOS Criteria

LOS scoring threshold criteria for pedestrian and bicycle modes are shown in Exhibit 14-25 which is based on the updated HCM values.

Exhibit 14-25 Pedestrian and Bicycle LOS Criteria

LOS	Pedestrian & Bicycle LOS Score
A	≤1.5
B	>1.5 – 2.5
C	>2.5 – 3.5
D	>3.5 – 4.5
E	>4.5 – 5.5
F	>5.5

Multimodal LOS scores are based on user perceptions (traveler satisfaction) and are graded from best (LOS A) to worst (LOS F). This kind of perception-based rating varied from the many test respondents (there is no one single definition of a multimodal LOS grade) and was eventually grouped into LOS ranges. The methodology results represent the probability that a user (or the population of users) will pick a given LOS (or a range of LOS). Better conditions will result in better LOS scores. For example, narrower slower streets will rate better than wider faster ones for pedestrian and bicycle modes. Presence of sufficient-width sidewalks and bike lanes will score better than streets without them. Since these methodologies are a prediction of the user perception of quality of service, the LOS results need to be evaluated in context with other planning considerations (e.g. available funding for improvements, land use context, etc.).

14.6.3 Pedestrian LOS

Methodology Summary

This methodology is based on a re-estimation of the original video clip data used to create the HCM Pedestrian LOS (*National Cooperative Highway Research Program* (*NCHRP*) *Project 3-70* and *Report 616 Multimodal Level of Service Analysis for Urban Streets*). Details on the research and methodology approach can be found in the paper *Cumulative Logistic Regression Model for Pedestrian Level of Service Rating* by Ali, Cristei, and Flannery, George Mason University (undated). By re-estimating the model using the individual response surveys instead of averages of *NCHRP Project 3-70*'s data, the researchers were able to isolate the variables that most significantly impact the pedestrian LOS. This allowed a significant reduction in the number of independent variables needed while creating a better LOS estimate using probability-based ranges.

Of the seven sidewalk-related independent variables in the full HCM method (i.e. sidewalk width, buffer width, presence of barriers, etc.), the strongest variable influencing pedestrian comfort was sidewalk width. The major traffic-related independent variables (same direction traffic volumes, number of traffic lanes, and speed limit) were all found to have strong negative impacts on pedestrian comfort. All of the variables used in the model have categorized ranges of data input, so it is only necessary to know on what side of a threshold a data item lands, rather than the actual absolute amount.

Data Needs and Definitions

The simplified methodology uses four variables to estimate Pedestrian LOS. The analysis is intended to be applied on road segments on a per direction basis like most HCM-based methods. The variables and their category values are shown below:

- Sidewalk (Actual) Width (0-5 ft or >5 ft)
- Directional Traffic Volume (0-500 vph, 500-1500 vph, or >1500 vph)
- Number of (Through) Traffic Lanes per direction (1, 2, 3, or 4)
- (Posted) Speed Limit (20-40 mph or >40 mph)

Segments are at least defined between major (signalized) intersections or where the threshold values change between categories. For example, a change from 30 to 35 mph would not be significant in this method, but a change from 40 to 45 mph would be as the value changes categories and a new segment would also need to be created. Similarly, if a street had no sidewalks (zero feet in width) but had a section of six foot sidewalk in the middle, then the street section would be broken into three segments (two 0-5 ft width sections and one >5 ft width section). However, if the sidewalk section was a substandard three foot width, then one overall segment would suffice.

Sidewalk width is the actual width, not the effective or clear width. The methodology implicitly assumes the larger sidewalk widths may also include increased buffer space with physical barriers (bike racks, meters, trees, etc.). These buffers and barriers generally increase the overall comfort (assuming that any elements do not intrude into the walking space) for a pedestrian resulting in better LOS levels.

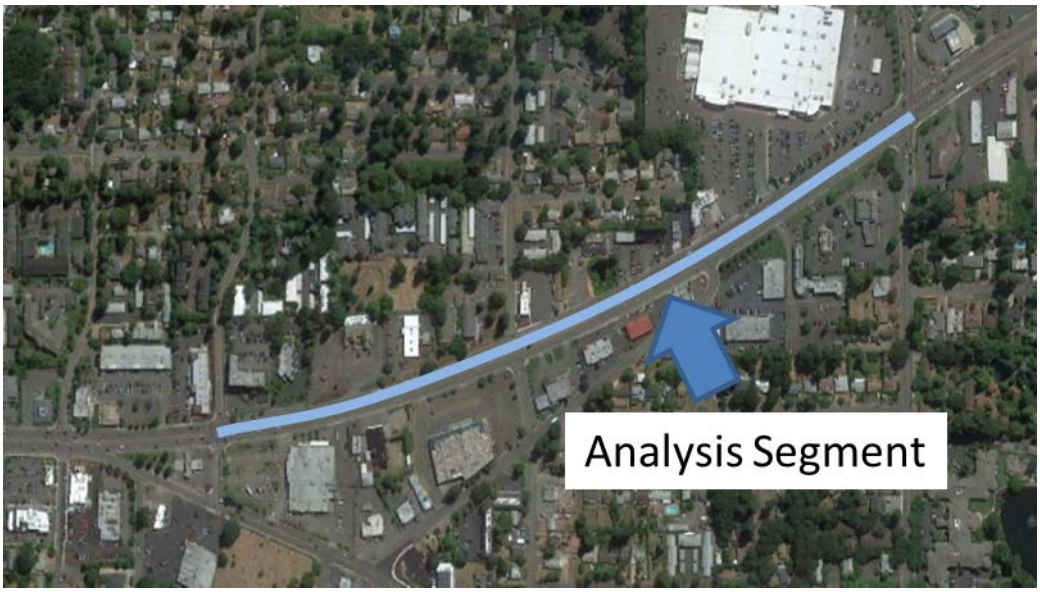
The Directional Traffic Volume is intended to be consistent with the analysis peak hour used for other analysis tasks, such as vehicle v/c ratio or LOS. It is possible that the final pedestrian LOS may be different between different peak hours such as AM and PM. Creation of the existing or future volumes should follow Chapter 5 or 6 using hourly counts or appropriate reductions from daily counts.

The number of lanes per direction considers the impact of through and shared through/turn lanes only. Ignore any center two-way left-turn lanes or exclusive turn lanes as this methodology is only for segments and not for crossings. There is no difference in the methodology between one-way and two-way segments except that all through lanes would be considered on a one-way segment for each side of the roadway this is where the three and four lanes per direction will be mostly applied to), instead of just half. The speed limit used to select the category should be the posted or statutory limit (i.e. 20 mph for downtown or 25 mph for residential areas, etc.).

The data values should be easily obtainable from inventories or aerial photographs. Results can be shown in tables or in a GIS-created map figure. A network-wide LOS could be estimated using a travel demand model with custom variables or expressions. The directional volumes, speeds, and lanes are common base variables. The sidewalk variable could be assumed, based on field data, or obtained from the model if it considered pedestrian trips in greater detail.

The values are entered into the calculator to obtain the cumulative probabilities which are subtracted from one another to obtain the LOS probabilities. The highest probability is chosen as the most-likely LOS. Check to see if any probabilities fall within a (0.90 x the highest probability) range. If the next highest probability is within this range, assume that this is a LOS range (i.e. LOS E-F) with a total probability that is the sum of the individual probabilities.

Example 14-5 Pedestrian LOS



A segment of a five-lane suburban arterial is analyzed for the afternoon peak hour as part of a local transportation system plan. The roadway has a peak month ADT of 31,000 and has a 35 mph speed limit. Six-foot sidewalks and bike lanes exist on both sides of the street. The roadway traverses a commercial district so there are a substantial number of driveways on both sides. From count data at nearby intersections, there is 50/50 directional split (D-factor) and the percent of the daily traffic as part of the peak hour (K-factor) is 9%.

The ADT is converted into an approximate peak hour volume by multiplying the ADT by the segment K-factor. The peak hour volume is then converted into a directional volume by multiplying it by the directional split. (See Chapter 5 for more information on determining peak hour volumes).

Directional volume (vph) = ADT * K-Factor * D-factor = 31,000 * 0.09 * 0.50
= 1395 vph which falls into the 500-1500 vph category

From the existing conditions data given, sidewalks are greater than five feet, there are two lanes per direction, and the speed is between 20 and 40 mph.

These four pieces of data are entered into the calculator and the highest probable result is LOS C at 25.51%. Other close LOS possibilities indicated are LOS B at 21.48%, LOS D at 21.29% and LOS E at 20.12%. The 10% significance check value (90% of the LOS C value) is 22.96% which

is greater than any of the other LOS probabilities, so the LOS C value is reported as the final result for the first direction. The calculator will always provide multiple segment probabilities for the purpose of helping the user decide which LOS to report, rather than reporting just the highest probability.

Final LOS Probabilities						Max	Probability	Final
F	E	D	C	B	A	Probability	90% Check	LOS
0.0832	0.2012	0.2129	0.2551	0.2148	0.0329	0.2551	0.2296	C

LOS C has the greatest chance of selected as the user-perceived value. This also can be thought over the percentage of the population that would view this as LOS C. Adding in other ranges; about 50% would view this section as acceptable as LOS A-C while 50% would view this section poorly as LOS D-F. LOS C is the approximate middle ground. A 50% poor probability is significant so some improvement is likely necessary for this segment. The analysis is repeated for the second direction which will have the same answer in this case as the conditions are symmetrical.

14.6.4 Bicycle LOS

Methodology Summary

This methodology is based on a re-estimation of the original video clip data used to create the HCM Bicycle LOS in *NCHRP Project 3-70* and *Report 616*. Details on the research and methodology approach can be found in the paper *Using Cumulative Logistic Regression Model for Evaluating Bicycle Facilities on Urban Arterials"* by Ali, Cristei, and Flannery, George Mason University (undated).

By re-estimating the model using the individual response surveys instead of averages of *NCHRP Project 3-70*'s data, the researchers were able to isolate the variables that most significantly impact the Bicycle LOS. This allowed a significant reduction in the number of independent variables needed while creating a better LOS estimate using probability-based ranges. In addition, the issue with the coefficients in the full MMLOS method, which generally prevent obtaining LOS A or B, has been eliminated.

Of the 13 independent variables in the full HCM method (e.g., volume, pavement condition, etc.) in *Project 3-70*, only four were found to be significant in the re-estimation. In addition, based on the validation in the research, it appears utilizing the other nine variables does not warrant the level of effort needed to obtain them. In other words, the time spent calculating pavement condition, heavy vehicles, percentage of on-street occupied parking, etc. does not enhance the ability to obtain an accurate LOS. This means, for many applications, there is no need to conduct further more-detailed Bicycle LOS analysis.

The method in this section is only meant for analysis applications on roadway sections with shared-use vehicle lanes or regular bike lanes because of limitations in the original research data set. Higher speed/volume roadways will most likely score poorly and indicate the need for some

sort of separation of bicyclists from vehicular traffic. Following future sections will be applicable to other facility types. The LOS of this section would need to be compared with the generated LOS for other facility types to either establish operational ranges or a single LOS for an alternative (LOS with shared lane, LOS with bike lane, LOS with shared path, etc.). The Qualitative Assessment (see Section 14.3) may be the best choice if more factors are desired to be included in a facility plan analysis (See Section 14.2) without the limitations of the full MMLOS method. The simplified re-estimated methodology is also consistent with the Bicycle Level of Traffic Stress (see Section 14.4) if that method is used as a screening tool in a detailed refinement plan or project effort as poor LOS levels will result in poor segment stress levels and vice versa.

The major bicycle-related variables are presence or absence of a bike lane/usable paved shoulder and the number of unsignalized conflicts per mile, both of which are responsible for most of the variation in the LOS ratings from the response surveys and thus will have the biggest impact on the LOS results. For example, a section of roadway without any unsignalized driveway approaches could have a LOS D while the presence of driveways drops the section to a LOS F. The most significant vehicle-traffic related variables are the number of through traffic lanes and the posted speed limit, both of which have a negative impact on bicyclist comfort. All of the variables used in the model have categorized ranges of data input, so it is only necessary to know on which side of a threshold is the particular data item, rather than the absolute value.

Data Needs and Definitions

The methodology uses four variables to estimate Bicycle LOS. The analysis is intended to be applied on road segments on a per direction basis like most HCM-based methods. Segments can be defined between major intersections or as desired. The variables and their category values are shown below:

- Number of Through Traffic Lanes per direction (1 or >1)
- Bike Lane or Paved Shoulder Present (Yes or No)
- (Posted) Speed Limit (<= 30 mph or >30 mph)
- Unsignalized Conflicts (Yes or No)

Like with the Pedestrian LOS, segments should be created at least between major intersections or when the variables change categories. For example, if the bike lane disappears along a roadway then reappears later; a new segment is needed every time this happens. Short sections should be highlighted and documented especially if they are due to narrow bridges or other physical obstructions.

The number of lanes per direction is for through and shared through/turn lanes only. An exclusive turn lane could be considered if it extends the length of the segment. Ignore any center two-way left-turn lanes or exclusive turn lanes as this methodology is only for segments and not for crossings. A bike lane is assumed where there is a striped lane or where a useable paved shoulder that allows the bicyclist to be direct conflict with traffic exists. Mixed traffic conditions where there is no striped bike lane or shoulder stripe should be assumed to fall into the “No” category. The speed limit used to select the category should be the posted or statutory limit (i.e.

20 mph for downtown or 25 mph for residential areas, etc.).

The unsignalized conflicts account for the impact of any unsignalized intersections or driveways in the segment. All driveways (residential/commercial/industrial) should be accounted for as each creates potential conflict locations regardless of driveway volume.

The data values should be easily obtainable from inventories or aerial photographs. Results can be shown in tables or in a GIS-created map figure. A network-wide LOS could be estimated using a travel demand model with some use of custom variables or expressions. The directional speeds and lanes are common base variables. The unsignalized conflict variable would likely need to be defaulted to "yes" unless the facility segments were access–controlled and still legally allowed bikes. The bike lane variable could be assumed, based on field data, or obtained from the model if it considered bicycle trips in greater detail.

The values are entered into the calculator to obtain the cumulative probabilities which are subtracted from one another to obtain the LOS probabilities. The highest probability is chosen as the most-likely LOS. Check to see if any probabilities fall within a (0.90 x the highest probability) range. The calculator will highlight any probability that falls within 90% of the highest value. If the next highest probability is within this range, assume that this is a LOS range (i.e. LOS E-F) with a total probability that is the sum of the individual probabilities.

This modal methodology has the highest occurrence of LOS ranges. Probabilities that are greater than 10% apart can also be reported as a range. For example, LOS A is not possible as a reported final LOS with the most favorable parameters, but it does have a good likelihood of occurring. In this case, the final result could be reported as LOS B or LOS A-B depending on the engineer's judgment of the overall context of that particular segment.

Example 14-6 Bicycle LOS

This example uses the same segment of roadway as described in the Pedestrian LOS section. A segment of a five-lane suburban arterial is analyzed for the afternoon peak hour as part of a local transportation system plan. The roadway has a 35 mph speed limit. Six-foot sidewalks and bike lanes exist on both sides of the street. The roadway traverses a commercial district so there are a substantial number of driveways on both sides.

From the given data, the number of traffic lanes per direction exceeds one, there is a bike lane present, the speed limit exceeds 30 mph and there are unsignalized intersection and driveway conflicts.

The four data elements are added into the calculator and the highest probable result is LOS F at 27.11% for the first direction. The 10% significance check (90% of LOS F) is 24.40%, which is about equal to the LOS E value at 24.41%. The calculator highlighted the highest probability and any that fall within 90% of that value. The overall reported result is a range and the probabilities added together which results in a 51% chance of a LOS E-F.

Final LOS Probabilities						Max	Probability	Final
F	E	D	C	B	A	Probability	90% Check	LOS
0.2711	0.2441	0.2081	0.1724	0.0832	0.0210	0.2711	0.2440	F

The calculator will always provide multiple probabilities for every segment for the purpose of helping the user decide which LOS to report rather than just reporting the highest probability. In this case, the "Final LOS" column would need to be manually overridden (as per the spreadsheet directions) to reflect a LOS E-F so it can be shown correctly on the summary output sheet. The same LOS E-F result is computed for the second direction as conditions are the same.

14.6.5 Separated Bikeways

The separated bikeway methodology augments the re-estimated HCM bicycle methodology of the previous section by adding new facility types. Low-stress tolerant users desire a greater degree of separation between them and the adjacent traffic stream. The standard bike lane or even a buffered bike lane does not offer the amount of separation needed especially for roadways with higher volume and/or speeds. Separated bikeways (also known as cycle tracks or protected bike lanes) offer additional comfort (lower stress) to the bicyclist by creating a vertical delineation between the bicycle lane and the vehicle lanes and are a step up from a buffered bicycle lane. Vertical delineation can be simple as a line of posts (candlesticks), to large planters, to physically separating the bikeway with the vehicle parking strip. Exhibit 14-26 illustrates the differences in separation for the typical bicycle facilities from least to most.

The LOS is relatively poor for sections of standard bike lanes on higher speed and/or volume urban roadways, so adding a separated bikeway will allow for a better LOS. If a previously conducted Bicycle Level of Traffic Stress analysis indicated system needs, adding a separated bikeway on major routes can further enhance or help establish a low-stress network. For separated bikeways to have the greatest benefit, they need to intersect other lower-stress bicycle facilities such as bike boulevards, streets with standard bike or buffered lanes, or even low-speed routes with sharrows rather than being an isolated facility. Routes with established substantial bicycle volumes or more direct routes that have limited use because of high-stress elements may be good candidates for separated bikeways. Separated bikeways appeal to the largest segment of current and potential bicyclists, so having them in certain high-connectivity corridors should help to increase the overall mode share along a route and increase the total amount of users.

The context of the corridor should be considered on whether separated bikeway is the appropriate treatment. Not all roadways are suitable for separated bikeways. Separated bikeways have the greatest benefit on roadways with no or limited driveways and wider spaced intersections to maximize bicycle flow and minimize potential conflicts. Every intersection and driveway is a point of conflict and can introduce safety and operational issues especially when paired with adjacent parking. Parking between the travel lane and the separated bikeway can create sight distance issues. If sight distance is not maintained sufficiently (by prohibiting parking close to the intersection/driveway) then this may encourage vehicles to creep out and block the bikeway while waiting to turn. Higher volume and/or many driveways can substantially impede operations of bikes and increase the risk of collisions. The parking can also

create visibility issues for drivers to see oncoming bicyclists (could be in both directions for a two-way bikeway) as they turn into a driveway and across the bikeway. If access management solutions to consolidate/minimize driveways are not possible, then a buffered bike lane may be more appropriate in a parking and /or driveway dense location.

A constrained right-of-way, and/or existing features (e.g. number of driveways or parking needs) may pose design challenges. This analysis should not be done in isolation as safety shall be evaluated whether the features associated with the separated bikeway treatment may affect bike users or another transportation mode's safety. For example, more substantial separators such as bollards or large planters could create a fixed-object hazard for vehicles as they are close to the lane edge especially with higher speeds. The analyst needs to discuss the applicability of separated bikeways with Region, Traffic-Roadway Section, or local jurisdiction roadway/bicycle-pedestrian staff (as appropriate) before pursuing a separated bikeway treatment.

Methodology Summary

This methodology is based on the paper, *A Level-of-Service Model for Protected Bike Lanes* by Foster, Monsere, Dill and Clifton, Portland State University, 2014. The research was based on recent video-clip data obtained in a similar manner as previous HCM research efforts. The methodology uses the same cumulative logistic model form as the re-estimated bike lane method (Section 14.5) so results will be consistent between the two. The methodology is limited to segments only. Intersection crossings will be covered in future sections.
The methodology does not cover roadways that have a substantial amount of driveways and/or higher volume driveways as most of the research was based in central business districts or residential areas where high numbers of driveways or high-volume driveways or were uncommon. The most significant variables for estimating the performance of separated bikeways are buffer type, direction of travel, and adjacent vehicle speed and daily volume. The resulting LOS scores are based on user perceptions of each video clip and are graded from best (LOS A) to worst (LOS F). The methodology results represent the probability that a user (or the population of users) will pick a given LOS (or a range of LOS). Better conditions will result in better LOS scores. An Excel-based calculator is available on ODOT's Planning Section webpage.

Data Needs and Definitions

The methodology uses the following four variables to estimate the separated bikeway LOS. The analysis is intended to be applied on road segments on a per direction basis like most HCM-based methods. Segments with two-way separated bikeways only need to be evaluated in one direction. The variables and their category values are shown below:

- Buffer type (posts, planters, parking strip, raised/parking)
- Direction of (bikeway) travel (one-way or two-way)
- Adjacent vehicle speed (25 – 35 mph)
- Average daily volume in both directions (9,000 – 30,000) vehicles per day

Segments are at least defined between major (signalized) intersections or where the threshold values change between categories. For example, a change from 25 to 30 mph or a change in

vertical delineation type would be significant and a new segment would be needed.

Exhibit 14-26 Bicycle Facility Separation[49]

Exhibit 14-27 illustrates the different kinds of buffer types used in this methodology. Post-type

[49] Separated Bike Lane Planning and Design Guide, FHWA, May 2015, p.14.

(candlestick) buffers are the easiest to implement however they do not have the same sort of separation benefits as more physical barriers such as planters. The planter type buffer in the methodology is for substantially sized planters such as shown in Exhibit 14-27. Smaller planters are typically paired with posts so these should use the post-type buffers instead. The parked cars buffer type occurs when the parking is placed between the motor vehicle lanes and the bikeway. There should be enough buffered space so open vehicle doors do not interfere with the bicyclist's path. Some designs have the separated bikeway raised slightly higher than the adjacent travel lanes but less than the adjacent sidewalk. If parking is provided along this type then the parking is raised to the same level as the bikeway. This configuration is also known as a raised bike lane. Raised bike lanes were included in the study but not called out as their own buffer type as there were not enough separate sites. These should use the "raised/parking" buffer type as an equivalent.

Exhibit 14-27 Separated Bikeway Buffer Types[50]

Posts

Parked cars

Planters

Raised

Most separated bikeways are one-way in the direction of roadway travel but there are situations such as on a one-way street where a contra-flow bikeway is desired to limit out-of-direction travel. Separated bikeways in these cases are typically two-way facilities. Two-way separated bikeways require more considerations regarding intersections and driveways, so coordination with ODOT Region and/or Traffic-Roadway Section staff is necessary.

The methodology is limited to speeds between 25 and 35 mph and ADT values between 9,000 and 30,000 vehicles per day and thus will be limited in most cases to arterials in denser urban

[50] Images from Separated Bike Lane Planning and Design Guide, FHWA, May 2015, pp. 83-87.

locations. Use caution if values extend outside of these limits. Higher volumes and speeds than the methodology limits will tend to make the LOS better than expected while lower volumes and speeds will make the LOS worse than expected. Lower speed and lower volume roadways will be more applicable to shared markings, a standard bike lane, or buffered bike lanes. Roadway applications with higher volumes or speeds should gravitate toward total separation with a shared-use path (Section 14.7).

The values are entered into the calculator to obtain the cumulative probabilities which are subtracted from one another to obtain the LOS probabilities. The highest LOS probability is chosen as the most-likely LOS. The calculator will also flag any values within 10% of the highest probability. Check the LOS probabilities in the calculator for any highlighting. The highlighting will indicate the potential for a LOS range (i.e. LOS A-B) with a total probability that is the sum of the individual probabilities. Judgement based on the overall project context is required to decide to leave the LOS as calculated or override it to a lower/higher LOS or create a LOS range.

Example 14-7 Separated Bikeway LOS

This example uses the same segment of roadway as described in the previous sections on Pedestrian and Bicycle LOS. The roadway has five lanes, a 35 mph speed limit and a peak month ADT of 31,000. The roadway currently has six foot bike lanes on both sides. The previous Bicycle LOS analysis indicated a LOS E-F for the no-build conditions with just standard bike lanes. It was desired to improve the bicycle network in this area with the addition of a separated bikeway using a post-type buffer.

From the given data, the buffer type is posts, the direction is one-way, the speed is 35 mph and the ADT is 31,000. It was noted that the ADT was slightly outside of the top range (30,000) but judged close enough not to have too much LOS overestimation (at 30,000 ADT the highest probability is LOS B at 38.44%) or any non-intuitive results.

The four data elements are added into the calculator and the highest probable result is LOS B at 38.27%. The 10% significance check (90% of LOS B) also captures LOS A at 37.40% so a LOS range is possible. The calculator will always provide multiple probabilities for every segment for the purpose of helping the user decide which LOS to report rather than just reporting the highest probability. However, because of the chance of some LOS A overestimation with the high ADT, the LOS was left at LOS B instead of going to LOS A-B as seen below.

Final LOS Probabilities						Max	Probability	Final
A	B	C	D	E	F	Probability	90% Check	LOS
0.3740	0.3827	0.1757	0.0428	0.0160	0.0087	0.3827	0.3445	B

14.6.6 Buffered Bike Lanes

Buffered bike lanes offer additional comfort to the bicyclist by providing separation from the vehicle lanes using a striped and/or hatched buffer. Buffered bike lanes can be used when speeds

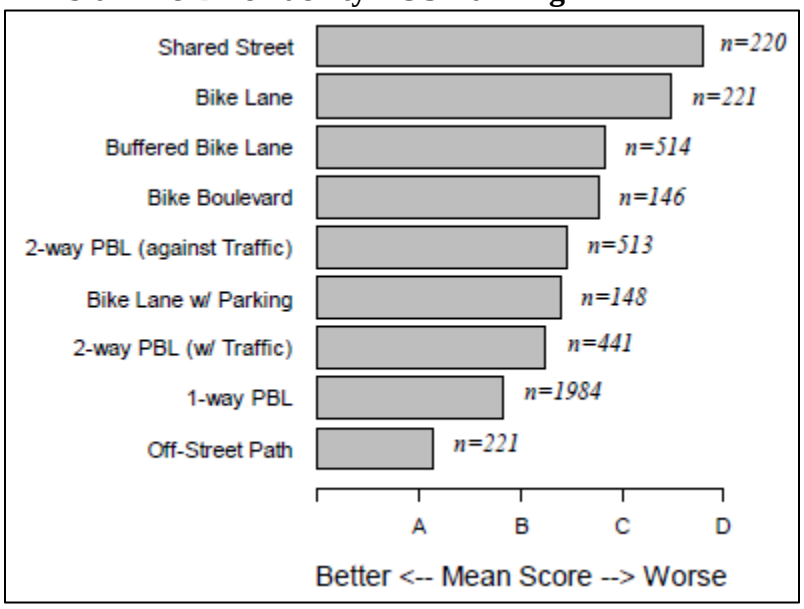
exceed 20 mph or when volumes are in excess of 1,500 ADT and should be used when speeds reach 40 mph and/or 7,500 ADT[51]. This type of bike lane will allow a more acceptable LOS grade than a standard bike lane for higher volume and speed facilities, such as most urban state highways. Buffered bike lanes may also be a good compromise in areas with a substantial amount of driveways that would make operations of a separated bikeway difficult or create a number of safety issue locations because of visibility/sight distance.

Methodology Summary

The methodology for the estimation of a buffered bike lane LOS is based on an extension of Exhibit 14-28. The LOS of a buffered bike lane falls in the LOS B-C range which is approximately halfway between the LOS of a standard bike lane at LOS C-D and a separated (one-way) bikeway at LOS A-B. The estimated buffered bike lane LOS is obtained from averaging the LOS scores of both the bike lane and separated bikeway since both methods use the same cumulative logistic regression model form. This procedure is considered an interim method until better facility-specific methodologies are available. An Excel-based calculator is available on ODOT's Planning Section webpage which combines both methodologies for a quick but separate (i.e. the presence of unsignalized conflicts only applies to the standard bike lane methodology) comparison.

This estimated method is best applicable within the ranges of the separated bikeway methodology (speeds 25-35 mph & 9,000-30,000 AADT). Higher volumes and speeds (vice versa for low speeds/volumes) will tend to make the separated bikeway LOS better while the bike lane LOS becomes worse which will generally make the differences balance out between them.

Exhibit 14-28 Bike Facility LOS Ranking[52]



[51] Urban-Suburban Separation Matrix, Oregon Bicycle and Pedestrian Design Guide, 2011, p 1-3.
[52] Foster, N., C. Monsere, J. Dill, K. Clifton, A Level-of-Service Model for Protected Bike Lanes, Figure 2, p. 7-8.

The standard bike lane and separated bikeway variables are entered into the calculator to obtain the cumulative probabilities which are subtracted from one another to obtain the LOS probabilities. The highest LOS probability is chosen as the most-likely LOS. The calculator will also flag any values within 10% of the highest probability. Check the LOS probabilities in the calculator for any highlighting. The highlighting will indicate the potential for a LOS range (i.e. LOS A-B) with a total probability that is the sum of the individual probabilities. Judgement based on the overall project context is required to decide to leave the LOS as calculated or override it to a lower/higher LOS or create a LOS range.

Once the base LOSs for the standard bike lane and separated bikeway are calculated and optionally adjusted, the LOS grades are converted into scores which are averaged together and then reconverted into an estimated buffered bike lane LOS. Application is best for future scenarios as the LOS for a standard bike lane, buffered bike lane, and separated bikeway will all be shown for comparison, but can also be used for an existing buffered bike lane (use posts buffer and a one-way bikeway).

Example 14-8 Buffered Bike Lane LOS

This example uses the same segment of roadway as described in the previous sections. The roadway has five lanes, a 35 mph speed limit and a peak month ADT of 31,000. The roadway currently has six foot bike lanes on both sides and goes through a commercial area with a substantial amount of driveways. The previous Bicycle LOS analysis (Example 14-6) indicated a LOS E-F for the no-build conditions with just standard bike lanes. Example 14-7 calculated a LOS B for a separated bikeway. An additional alternative for a buffered bike lane was also needed to be analyzed as the higher amount of driveways was thought by project staff to potentially create too much interference for good operation of the separated bikeway. .

The additional bike lane data of greater than one travel lane in each direction and the presence of unsignalized conflicts are added into the calculator input tab supplementing the separated bikeway data.

The additional data elements are added into the calculator and by checking the bike lane results show a LOS F at 27.11%. The 10% significance check also captures the LOS E level at 24.41%. The final LOS is overridden in the bike lane LOS columns, so it will be reported correctly on the output sheet and in the overall buffered bike lane calculations.

The calculator averages the bike lane and separated bikeway results and provides an estimated buffered bike lane value at LOS C-D which would also be an improvement over a standard bike lane as seen below.

APM Example 14-8 — **Protected Bikeway /Buffered Bike Lane MMLOS** — 06/23/16

E.N. Gineer — **Segment LOS Output Summary**

Roadway	Dir	From-To	Prot. Bikeway LOS	Buffered Bike Lane Estimated LOS	Bike Lane LOS
Example Ave	S	1st St - 10th St	B	C-D	E-F

14.6.7 Shared-use Paths

Methodology Summary

This methodology is a full application of the Highway Capacity Manual (HCM) 2010 Chapter 23 method on paved shared-use (multi-use) paths. Use this methodology with caution on unpaved paths as the research only contained data from paved paths. A shared-use path is completely separated from roadway traffic for the use of non-motorized modes. Typically these paths have at least 35 feet of separation from an adjacent roadway, but they may be closer if the barrier between the path and roadway is substantial (i.e. soundwall, retaining wall, etc.) so that the effect of vehicular traffic is limited. Paths may also be on their own separate right-of-way, such as along a creek in a greenway. Paths with lesser buffers should be considered a protected bikeway or sidewalk and analyzed with the other methods in this chapter. This methodology is intended to work in concert with the other HCM-based "streamlined" and other segment and intersection methodologies in this chapter. More information on shared-use paths is available in Chapter 7 of the Oregon Bicycle and Pedestrian Design Guide.

The methodology considers the impacts on pedestrians and bicyclists by other path users mainly through the accounting of passing (overtaking) and meeting events considering volumes, speeds and densities. The path segment is divided into very small 0.01 mile pieces and impact of the approaching other users (pedestrians, adult and child bicyclists, runners and inline skaters) on a bicyclist is measured for each piece and then summed across the entire path segment. Impact on pedestrian users is handled more simply by considering flow rates of all path users and the relative difference between the average pedestrian and bicycle speeds. Both bicycle and pedestrian methods measure crowding on a path segment and how much interference there will be from passing, meeting, or being forced to wait to pass. The methodology is segment-based so segments should start and end at path junctions, intersections with roadways or where path width changes substantially.

Application of the shared-use path method needs to be done via an Excel-based calculator provided on the Transportation Development – Planning Technical Tools webpage as the math and statistical work required is too much for simple hand calculations. This methodology works equally well for analysis of existing or future paths. For planning applications (proposed paths or changes to existing ones) most of the inputs can be estimated. For actual project and detailed refinement planning efforts it is recommended that most of the inputs come from actual design/field values. For analysis of intersections of shared-use paths at unsignalized or signalized roadway crossings, please refer to (future) Sections 14.5 through 14.7.

LOS Criteria

The applicable LOS criteria and descriptions for shared-use paths come from HCM Exhibits 23-4 and 23-5 which are combined into Exhibit 14-29 and 14-30 below. The LOS criteria is mainly based on recreational users which considers the influence of child bicyclists, runners, skaters and walkers in addition to the bicyclist mode. More user

conflicts (passings and meetings) will result in lower LOS grades. A poor LOS indicates less user satisfaction versus a chance of a potential route shift. Since a shared path will generally offer the lowest stress route, route shifting is unlikely unless there are nearby adjacent routes without out-of-direction travel and the path carries high amount of high-stress tolerant (commuter) bicyclists that could travel comfortably on an on-street bike facility. Poor LOS grades generally indicate that the path is too narrow for the amount of existing or projected users.

This method and LOS criteria assume that users stay on the path surface, especially while being passed. Frequent observations of side-stepping or use of the "shoulder" area may indicate a path that is too narrow and/or is reaching capacity regardless of the LOS results obtained. Also, the LOS criteria are based on user comfort and do not give any specific indication that the facility is compliant with the Americans with Disabilities Act (ADA) or other design standards.

Exhibit 14-29 Pedestrian and Bicycle LOS Criteria

LOS	Pedestrian Weighted Event Rate per hour	Bicycle LOS Score
A	<=38	>4.0
B	>38 - 60	>3.5 – 4.0
C	>60 - 103	>3.0 – 3.5
D	>103 - 144	>2.5 – 3.0
E	>144 - 180	>2.0 – 2.5
F	>180	<=2.0

Exhibit 14-30 Pedestrian and Bicycle LOS User Description

LOS	Pedestrian LOS Description	Bicycle LOS Description
A	Optimum conditions, bicycle conflicts rare	Optimum conditions, ample ability to absorb more riders
B	Good conditions, few bicycle conflicts	Good conditions, some ability to absorb more riders
C	Difficult to walk two abreast	Meets current demand, marginal ability to absorb more riders
D	Frequent bicycle conflicts	Many conflicts, some reduction in bicycle travel speed
E	Frequent and disruptive bicycle conflicts	Very crowded, significant reduction in bicycle travel speed
F	Significant conflicts, diminished experience	

Data Needs and Definitions

These are the inputs and definitions as used in the methodology and the available calculator.

Shared-use Path Volume (users per hour) – This is the total of the non-motorized mode users on the specific shared-use path segment in both directions. User modes

include adult and child bicyclists, pedestrians, runners and (inline) skaters. This value may be estimated through demographics/available planning documents or from an actual count (required for design purposes) for existing conditions. Future conditions could be obtained from using historical bicycle/pedestrian count data or post-processed assignments/mode splits in a metropolitan area travel demand model. Volume changes of more than 10% should be broken into a new path segment.

Highest Directional Split – Expressed as a decimal, this is the highest total directional flow percentage (i.e. 0.57) within the hour of analysis on the segment. Path use may be dominated by commuter, recreational, or multi-purpose flows. If directional counts and resulting flows are not available, then reasonable defaults can be assumed (0.55) for commuter and (0.50) for recreational and multi-purpose (mixed) uses.

Peak Hour Factor – See APM Section 5.8 for the definition and example calculations. For this to be obtained explicitly in this method, counts with 15-minute breakdowns are required which may not be a common specification for bike/pedestrian counts. A default PHF can be assumed where detailed counts are not available (0.90 to 1.00) depending on whether this particular path segment is subject to peaking characteristics. Highly urban areas, biking/walking friendly areas, commuter corridors, or nearby employers with high non-motorized modal users may cause noticeable peaking on certain segments.

Segment Length (miles) – This is the length of a segment between path junctions, street crossings, any location where the volume changes by more than 10%, or path surface width changes.

Path Width (feet) – This is the width of the path surface. The minimum width is eight feet and the maximum width is 20 feet as defined in this methodology. Paths less than eight feet wide become too-narrow to function as a true multi-use path as passing becomes challenging (typically a user has to step to the side) and are really closer to a pedestrian foot-path. The desirable width is 12 feet but can go as low as eight feet for pinch points with low volume and as much as 20 feet for high volume paths according to the Oregon Bicycle and Pedestrian Design Guide. A change of one foot or more should be broken into a new segment. For a given volume, changing of width on narrower paths will have more impact than on wider ones.

Centerline Presence – This indicates whether a path has a marked centerline. This is a Yes/No choice in the Input tab in the calculator tool. A marked centerline can constrain the maneuverability freedom of users and results in lower LOS scores.

User Mode Default Parameters – The calculator assumes defaults for mode split, average mode speed, mode speed standard deviation, and mode passing distance from the HCM. These can be completely updated if detailed information is available or at the very least, the mode split can be proportionally changed to reflect the typical path users or area demographics.

It is recommended that at least one count on an existing or for a future multiuse path be full featured (15-min breakdowns, directional, and by user class) so that the calculator can be customized for the specific application. Paths with significant commuter flows should be counted in the typical AM/PM peak periods. Paths that are recreational or are mixed use should have counts that cover the midday peak and/or weekend periods. It may be necessary to obtain a week-long count with daily and hourly volumes to determine when peak periods occur if this information is not available from sites with similar characteristics.

Example 14-9 Pedestrian & Bicycle LOS

A section of paved shared-use path links two arterials along a creek-side greenway. The unbroken path segment is 1.2 miles long and is 12 feet wide with no marked centerlines. A recent volume count showed 100 users of all types in the peak hour of the facility.

The count had hourly breakdowns only and it was determined in the peak hour that the highest directional flow was 60%. A PHF was estimated at 0.95 as there was not much influence from uses that would cause higher spikes in the user volume. The default modal splits and other parameters were used.

The input data was entered into the calculator tool in the yellow-shaded boxes as shown below. Mode splits, speeds, and passing distances were left as defaults in the orange-shaded boxes.

Total shared-use path users per hour =	100
Highest directional split (decimal)=	0.60
Peak Hour Factor (PHF) =	0.95
Segment Length (L) (mi) =	1.20
Path Width (min 8 - max 20 ft) =	12.0
Does path have a marked centerline? (Yes/No)	No

	Mode Split (decimal)	Ave. Mode speed, ui (mph)	Mode Std. Dev. (mph)	Mode Passing Distance (ft)	Flow rate , qi users/h	Density users/mi
Bike	0.55	12.8	3.4	100	35	2.71
Ped	0.20	3.4	0.6	60	13	3.72
Runner	0.10	6.5	1.2	70	6	0.97
Skater	0.10	10.1	2.7	100	6	0.63
Child bike	0.05	7.9	1.9	70	3	0.40

Yellow-shaded cells are user supplied data (Directional split and PHF can be defaulted)
Orange-shaded cells are user-changeable defaults if better information is available
Gray-shaded cells are calculations used as inputs to other tabs

The calculator macro tool was run and the results obtained are shown below. Both the bicycle and pedestrian modes have a LOS B which is indicative of favorable conditions

on this analysis segment.

Bike LOS Calculation			
Total Meetings per Min=		2.79	
Total Active Passings per Min=		0.81	
Total Weighted Events per Min		10.87	
Delayed Passings per Min =		0.08	
Bike LOS Score =	4.00	LOS =	B
Final LOS adjustment for low volume=			B
Pedestrian LOS Calculation			
Pedestrian Events/hr =		52	
Pedestrian LOS =		B	

14.6.8 Unsignalized Intersections (TBD)

14.6.9 Crossing Enhancements (TBD)

14.6.10 Signalized Intersections (TBD)

14.7 Transit LOS

Methodology Summary

Unlike the simplified Pedestrian and Bicycle LOS methods, there is no re-estimated Transit LOS. Instead, this is a streamlined version of the regular HCM Transit LOS methodology using simplifying assumptions and specific defaults. The full transit methodology involves calculating transit vehicle running time, delay, and speeds, then determining impacts caused by waiting times, stop amenities, and pedestrian access. Like with other MMLOS methods, the methodology is done separately for each direction of travel. This simplified method should only be applied to segments within the study area that have applicable fixed-route transit.

It also would be possible to estimate the Transit LOS within a travel demand model if transit routes were considered explicitly so the frequency could be captured. The travel times for the various route segment would need to be summed across each major segment and the other inputs likely defaulted with use of some custom variables or expressions.

The pedestrian LOS portion of the calculation could be computed from volumes, speeds and number of directional lanes which are common variables in a travel demand model and the sidewalk variable either assumed or based on field data.

The simplified methodology uses transit schedule speed, instead of calculating a transit travel speed, to consolidate the first three steps of the full MMLOS process. Schedule speed ultimately controls as transit vehicles will dwell at time points if they are ahead of schedule. Schedule speeds are also periodically reviewed and adjusted to account for ridership, dwell times, and traffic conditions.

For segments with heavy congestion, where travel speeds are substantially lower, the transit speed should be considered instead if the schedule does not reflect extra time for the regular peak hour congested conditions. Alternatively, the actual transit vehicle speed can be used if available from recent surveys or preferably from active GPS installations on the transit vehicles from the transit district. Note that other private data source travel times will only reflect the running speed of the average vehicle on the segment and will be too high for use as they will not reflect the transit stop delay and dwell times.

The re-estimated Pedestrian LOS (Section 14.5.3) is used in the Transit LOS calculation and is equated to an LOS score to avoid needing to calculate a full-detailed Pedestrian LOS score. The rest of the methodology uses reasonable defaults and assumptions using the HCM equations.

This method is applicable for urban street-running transit vehicles operating in an exclusive or a mixed-use lane. While the typical transit vehicle is a bus, it should not be assumed that this is always the case as this methodology also applies for bus rapid transit (BRT), streetcars, or light rail operating in mixed mode street-running conditions. Analysis of transit operating in a separated right-of-way such as adjacent to a street, in a median, or grade-separated is not covered under this methodology but in the companion *Transit Capacity and Quality of Service Manual*.

14.7.1 Transit LOS Criteria

LOS scoring threshold criteria for the transit mode is shown below in Exhibit 14-31. These are based on updated values of HCM Exhibit 17-3 and 17-4. The pedestrian LOS input has been converted from a range into an averaged single value for input into the final transit LOS equation.

Exhibit 14-31 Transit LOS Criteria

LOS	Pedestrian LOS Score, I_p	Transit LOS Score, I_t
A	0.75[1]	≤ 2.00
B	2.00	>2.00 – 2.75
C	3.00	>2.75 – 3.50
D	4.00	>3.50 – 4.25
E	5.00	>4.25 – 5.00
F	5.75[2]	>5.00

[1]The average score for LOS A is based on the minimum value of 0.00 and the highest score of 1.5.
[2]The average score for LOS F is based on the maximum value of 6.0 in HCM Equation 17-61 and the minimum value of 5.50.

Like with the other modes, these LOS scores are based on user perceptions (traveler satisfaction) and are graded from best (LOS A) to worst (LOS F). This kind of perception-based rating varied from the many test respondents (there is no one single definition of a multimodal LOS grade) and was eventually grouped into LOS ranges. Better conditions will result in better LOS scores. For example, more frequent transit service will rate better than less frequent service.

Transit LOS is heavily influenced by frequency, and frequency is influenced by land use density and availability of capital (vehicles) and operating (employees) funds. Therefore, a low LOS score may simply reflect the maximum feasible capability of a transit district on a particular route and should not be immediately equated with "poor" service. Better service (and LOS) may not be possible because of restricted funding and/or the land use is not dense enough to support it. The funding context of a particular transit district needs to be taken into account when reporting Transit LOS values.

Data Needs and Definitions

Transit Schedule Speed (S_t) – This is the speed (mph) calculated by dividing a known segment length by the difference of two adjacent time points published in the route timetable. If a segment covers parts of two sets of time points, then the resulting schedule speeds should be weight averaged. If there is more than one route on a given segment, then the schedule speeds should be averaged or weight averaged if frequencies are different.

Transit Frequency (v_s) – This is the number of transit vehicles per hour on the directional segment. Sum up the frequency of all routes that may travel this segment. Start with the route that has the highest frequency during the analysis hour(s). For additional routes, note which times are offset versus ones that seem to duplicate.

For instance, a 60-minute route that runs on the same schedule as another 60-minute route will result in one vehicle following another and should only be coded as one vehicle per hour. If the two routes were offset (say one on the hour and the other on the half-hour), then code this as two vehicles per hour. The route duplication does not have the same frequency benefit for the rider compared to a more even time spacing.

For corridors with very frequent service, like with in-road bus rapid transit or light -rail transit, consider these routes to likely control the segment as the short headways (typically less than 10 minutes) makes it unlikely that additional routes will have times that do not duplicate, so there will not be any additional frequency benefit. Only consider "tripper" service (additional frequency and/or minor route changes to serve schools) if it is active during the chosen analysis period.

From the transit frequency, the headway factor (F_h) is computed from HCM Equation 17-54:

$$F_h = 4.00e^{-1.434/(v_s+0.001)}$$

All of the following inputs are defaults with the exception of needing the Pedestrian LOS data in Section 14.5.3.

Passenger Load Factor (a_1) – For this simplified methodology, this factor is assumed to be 1.0, which represents that, on the average of all transit vehicles using that segment in the desired time period, they are 80% or less full (0.8 passengers per seat). On congested segments where passenger per seat ratios are higher than 80% and up to 100%, use passenger load factors in Exhibit 14-32 or the 2nd case of HCM Equation 17-57. If overcrowding exists on the average where the numbers of passengers exceed the number of seats (presence of standees), please refer to the 3rd case of HCM Equation 17-57 for computing the appropriate passenger loading factor.

Exhibit 14-32 Passenger Load Factors[1]

Passenger to Seat Ratio	Passenger Load Factor(a_1)
<0.81	1.00
0.85	1.05
0.90	1.10
0.95	1.14
1.00	1.19
>1.00	Use HCM Equation 17-57

[1]Derived from *2010 Highway Capacity Manual* Equation 17-57

Other general defaults are the threshold late time, which is the time that transit agencies typically consider a vehicle late, set at 5.0 minutes, and the proportion of transit vehicles arriving within the late time threshold, set at 0.75 (75% considered to be on-time). The late time threshold proportion value could be adjusted if it is desired to estimate reliability impacts. Both of these can be changed if more specific information is available from a transit district.

A large part of the full methodology involves calculating perceived travel time rates and factors which involves the transit speed, on-time ability, and stop amenities such as benches and shelters. Passengers generally view excess waiting time worse than slower

travel speeds, but may wait longer if there are amenities.

With the above default threshold late time and the on-time arrival percentage in HCM Equation 17-59, a fixed excess wait time of 1.6 minutes is calculated. The excess wait time is converted into the excess wait time rate of 0.41 min/mi by dividing the excess wait time by the average trip length of 3.8 miles based on reported Oregon transit system data in the National Transit Database. The proportion of shelters and benches in the full methodology has been found not to be very sensitive[53] to the final results and is ignored in this simplified method. The perceived travel time rate (HCM Equation 17-56) equation can be simplified with the above defaults and simplifications to:

T_{ptt} (min/mi) = $60/S_t$ +0.86, where S_t is the transit schedule speed

Use the equation form T_{ptt} (min/mi) = $a_1[60/S_t]$ +0.86, where a_1 is the passenger loading factor, if the default 1.0 value was not used.

The perceived travel time factor (F_{tt}) is a combination of the perceived travel time rate and the base travel time rate, which is assumed to be defaulted at 4.0 min/mi for areas below five million in population. There also is a default ridership elasticity factor of -0.40 which considers changes in the travel time rate. Using the above defaults in HCM Equation 17-55, the equation reduces to:

$$F_{tt} = (5.6 + 0.6T_{ptt}) / (1.4T_{ptt} + 2.4)$$

The final Transit LOS score (I_t) is the combination of the wait-ride score and the Pedestrian LOS score (I_p) based on HCM Equation 17-61. The wait-ride score portion of the equation is the product of the perceived travel time factor F_{tt} and the headway factor F_h.

$$I_t = 6.0 – 1.5 (F_h * F_{tt}) + 0.15I_p$$

The Pedestrian LOS (I_p) is calculated for the directional segment using the methodology in Section 14.5.3. Since the Pedestrian LOS from Section 14.5.3 is based on a probability of the entire range, the average LOS score is used for I_p in Exhibit 14-31, which is based on HCM Exhibit 17-4. If the Pedestrian LOS results in a range of levels, then the appropriate Pedestrian LOS scores in the second column in Exhibit 14-31 should be averaged together. The Transit LOS score (I_t) is then compared to the transit score range in the third column in Exhibit 14-31 to determine the final LOS for the directional segment.

[53] Carter, P., Martin, F., Nunez, M., Peters, S., Raykin, L., Salinas, J., et al. (2013). Complete Enough for Complete Streets? Senstivity Testing of Multimodal Level of Service in the Highway Capacity Manual. *Transportation Research Record: Journal of the Transportation Research Board, No,2395*, 36-37.

Example 14-10 Transit LOS

The same suburban arterial segment from the previous examples is used to continue the multimodal analysis. There are two transit routes on this roadway segment, one on 15-minute and one on 30-minute headways. The schedules are offset enough so the 30-minute route does not directly overlap the 15-minute route. For the analysis period, both routes are operating less than 80% full.

The first step is to calculate the schedule speed of the directional segment. For the 15-minute headway route, the available transit schedule shows seven minutes to travel from time point A to B. Measurement of the distance via aerial photos between A and B results in 5405 feet. The 30-minute route shows four minutes (apparently assuming less stops) between its time points C and D that bracket the analysis segment. The distance from C to D is measured as 6150 feet.

The schedule speed (S_{t15}) for the 15-minute route is calculated as:

S_{t15} = (segment length in feet / 5280 feet per mile) / (travel time in minutes / 60 minutes per hour)
= (5405 ft / 5280 ft/mi) / (7 min / 60 min/hr)
= 1.024 mi / 0.117 hr
= 8.75 mph

The schedule speed (S_{t30}) for the 30-minute route is calculated as:

S_{t30} = (segment length in feet / 5280 feet per mile) / (travel time in minutes / 60 minutes per hour)
= (6150 ft / 5280 ft/mi) / (4 min / 60 min/hr)
= 1.165 mi / 0.067 hr
= 17.48 mph

The average schedule speed (S_t) is weight averaged between the two routes as the 15-minute route has four vehicles per hour (67% of total) and the 30-minute route has two vehicles per hour (33% of total) for a total of six.

S_t = 8.75(0.67) + 17.48(0.33)
= 11.63 mph

Next, the headway factor (F_h) is computed from the overall transit frequency (6 veh/hr):

$F_h = 4.00e^{-1.434/(v_s+0.001)}$
$= 4.00e^{-1.434/(6+0.001)}$
= 3.15

The perceived travel time rate (T_{ptt}) is computed from the overall schedule speed:

T_{ptt} $= 60/S_t + 0.86$
$=60/11.63 + 0.86$
$= 6.02$ min/mi

The perceived travel time rate (T_{ptt}) is inserted into the simplified travel time factor (F_{tt}) equation:

F_{tt} $= (5.6 + 0.6T_{ptt}) / (1.4T_{ptt} + 2.4)$
$= (5.6 + (0.6 * 6.02)) / ((1.4 * 6.02) + 2.4)$
$= 9.21 / 10.83$
$= 0.85$

The final Transit LOS score (I_t) is calculated using the headway factor and the travel time factor from previous steps in addition to the Pedestrian LOS score (I_p) for the segment. The Pedestrian LOS was LOS C from the first example. This equates to an average LOS score in Exhibit 14-15 of 3.00.

I_t $= 6.0 – 1.5 (F_h * F_{tt}) + 0.15I_p$
$= 6.0 – 1.5 (3.15 * 0.85) + 0.15(3.00)$
$= 6.0 – 4.02 + 0.47$
$= 2.43$

Comparing the final LOS score with Exhibit 14-15 shows this segment to have a Transit LOS B (both directions the same).

Some of the calculator inputs and intermediate calculations done above are shown below as an example. Note that some columns are hidden.

Schedule Speed mph	Headway Factor	Perceived Travel Time Rate min/mi	Perceived Travel Time Factor	Pedestrian LOS Score	Transit LOS Score	Transit LOS
11.63	3.15	6.02	0.85	3.00	2.43	B

15 NOT YET WRITTEN – SEE APM VERSION 1

Addendum 15A – Protocol for Vissim Simulation

Note: The Protocol for VISSIM Simulation provides practitioners with ODOT expectations, guidelines, and requirements when considering and performing traffic simulation analysis with VISSIM. The protocol shall be followed on all ODOT plans and projects.

16 NOT YET WRITTEN – SEE APM VERSION 1

Appendix 16A – Noise, Air and Energy Traffic Requirements Checklist

17 NOT YET WRITTEN – SEE APM VERSION 1

18 TRANSPORTATION SYSTEMS MANAGEMENT & OPERATIONS

18.1 Purpose

The purpose of this chapter is to provide an overview of transportation system management and operations (TSMO) program elements, methods, strategies and analysis tools. The chapter guides users on integrating established TSMO procedures, analytical tools and data into existing planning processes and project development.

FHWA defines TSMO as "an integrated program to optimize the performance of existing multimodal infrastructure through implementation of systems, services, and projects to preserve capacity and improve the security, safety, and reliability of our transportation system". This section includes an overview of the content of the chapter and background information on the policy basis and rationale for TSMO.

Technology related to TSMO is changing rapidly and will continue to evolve in the coming decades. With accelerated change as the norm, this chapter represents a snapshot of current conditions and trends that will need to be updated frequently. For more details on many of the methods in this chapter also refer to FHWA's Planning for Operations website.

18.1.1 Overview of Chapter Sections

This chapter covers a range of TSMO topics:

- Policy Basis and Rationale for TSMO – State and federal policy foundation for TSMO
- TSMO and Data – Considerations and procedures for obtaining and processing TSMO-related data for performance measurement
- Planning and Programming for TSMO – Considerations for objectives-driven, performance-based operations planning, TSMO strategies, programming, multi-modal system performance measures, ITS architecture, systems engineering, and analysis tools
- Corridor Management – Considerations and analytical procedures for incorporating TSMO into corridor management
- System Management – Planning-level sensitivities and considerations for operations strategies related to incident and emergency management, road weather operations, special events management, traveler information, transportation demand management, and connected/automated vehicles

18.1.2 Policy Basis for TSMO

ODOT has established transportation goals that are both supportive of and supported by TSMO. The overarching goal of the 2006 Oregon Transportation Plan (OTP) is "a safe,

efficient and sustainable transportation system that enhances Oregon's quality of life and economic vitality." OTP Goal 2, Management of the System, is specific to TSMO and states "improve efficiency of the transportation system by optimizing the existing infrastructure with improved operations and management." OTP Key Initiatives A and B reflect the desired direction of the OTP to maximize existing system assets and to optimize capacity using TSMO strategies.

Other state transportation policies that are supportive of TSMO include the Oregon Highway Plan (OHP) Policy 1G, Major Improvements, which states "maintain highway performance and improve safety by improving system efficiency and management before adding capacity"; OHP Action 1G.1, which establishes an investment hierarchy that prioritizes strategies that "protect the existing system" above all others; and Policy 2E, Intelligent Transportation Systems, which states "consider a broad range of TSMO services to improve safety and efficiency in a cost-effective manner." Operational Notice PB-03 issued to ODOT personnel provides direction for developing financially feasible ODOT facility plans and local Transportation System Plans consistent with OTP and OHP policies for managing and maintaining ODOT's existing transportation system.

Beyond the ability to advance many key transportation goals in the state, TSMO also provides a platform for implementing a performance-based approach to planning, designing, operating, and maintaining a transportation system. The federal surface transportation legislation, Moving Ahead for Progress in the 21st Century Act (MAP-21), laid the groundwork for a paradigm shift in planning and programming transportation improvements with the establishment of a performance-based program. The need for on-going data to support a performance-based program is acute and TSMO technologies provide a way to automate the collection and archiving of large amounts of operational performance data. The TSMO program also offers an objectives-driven, performance-based approach for planning and programming that effectively applies data in the decision-making process.

18.1.3 Rationale for TSMO

This section is intended as a high level overview of TSMO. For a more in depth understanding of TSMO refer to FHWA Planning for Operations web page.

TSMO offers a performance-based approach to managing the multimodal transportation system in support of the OTP and OHP goals and policies. The many strategies that fall under the TSMO umbrella address one or more of ODOT's key policy goals of safety, efficiency and sustainability.

Safety

Safe travel is ODOT's highest priority for the transportation system. TSMO can help address system safety for all users through technology and operational strategies that focus on minimizing conflicts. This can take the form of traffic signals with dedicated phasing for different movements and modes; traffic incident management programs that

quickly clear incidents to increase safety for responders and reduce the risk of secondary crashes; road weather information systems to notify travelers of adverse weather conditions; or variable speed signs that adjust advisory travel speed based on traffic conditions ahead.

Efficiency

The economic health and prosperity of Oregon and its communities depend on a well-functioning transportation system. TSMO's contribution is considered in two ways: the efficient use of the existing transportation system and efficient use of resources.

With regard to efficient use of the existing transportation system, many TSMO strategies address non-recurring events that cause travel delay in both urban and rural settings such as ineffective traffic control operations, traffic incidents and inclement weather. These strategies support reliable travel for people and goods by actively managing the existing transportation system. The intent is to maximize the function and performance of current transportation networks to reduce delay and improve reliability for all modes. The TSMO strategies applied vary based on the modes, facility types, and land use context. For example, strategies like transit signal priority or pedestrian signal phasing can help keep travelers moving in busy urban environments while in rural locales strategies like smart work zones or incident or event based traveler information can address those unique needs.

The expected growth in population, freight tonnage, and total vehicle miles traveled will place an enormous burden on the existing transportation infrastructure into the future. As fewer funds are available for adding capacity, optimizing the existing transportation system has become a critical and practical approach. TSMO strategies generate resource efficiency by enhancing system capacity for less money, time, and disruption than traditional approaches. It optimizes resource use by allocating financial and personnel resources to cost-effective programs, such as reducing incident response times or maintaining traffic signal timings that have proven effective in increasing performance of the transportation system.

Another dimension to TSMO's resource efficiency is the opportunity to share resources across agencies. TSMO is most effective when multiple partners coordinate or collaborate to deliver a service like traveler information; or share infrastructure like fiber optic cable network; or establish interagency agreements like joint traffic signal operations and maintenance.

Sustainability

Transportation has an integral role in protecting and preserving livable and sustainable communities. Livability is described by ODOT as "the attributes of a community that affect its suitability for human living". The ODOT Sustainability Act of 2001(ORS 184.421) defines sustainability as "using resources in a manner that enables people to meet their current needs while allowing future generations to meet their needs." Managing how the transportation system operates is a vital aspect of livability and sustainability.

The broad suite of TSMO strategies actively contribute to both goals of meeting community needs today and managing resources for the future. In addition to the livability benefits to transportation safety and efficiency, TSMO can also facilitate multimodal travel choices, optimize on and off-street parking, or provide route options to avoid delay-inducing events. It helps to preserve mobility by implementing operational solutions like bike signals, transit signal priority, and personalized trip planning that support safer and more sustainable travel choices.

A significant environmental benefit of TSMO centers on optimizing the efficiency of vehicles to save fuel and reduce vehicle emissions. Several categories of TSMO strategies such as congestion management (ramp meters) or speed management (variable speed signs) can smooth traffic flow and bring down vehicle speeds. Multiple studies have documented the reductions in fuel use and harmful emissions as a result of reducing vehicle acceleration and deceleration events. With the growing efforts to address climate change in Oregon, TSMO strategies offer near-term, lower cost, efficiency-focused approaches to transportation-related greenhouse gas reduction and for adaption to a changing climate.
The overall benefits attributed to TSMO strategies typically include:

- Reduced travel delay
- Reduced travel times
- Improved travel time reliability
- Reduced number of crashes
- Reduced instance of secondary crashes
- Reduced fuel consumption
- Improved air quality
- Improved agency operational efficiency

18.2 TSMO and Data

This section provides an overview of the relationship between TSMO and data. While the use of data has long been a key element in the practice of planning, designing and operating the transportation system, the use of technology to actively manage the transportation system has given rise to new data sources and new applications of that data in operating the transportation system.

Data is an integral element of TSMO. The rapid and dynamic changes in transportation technology are delivering a wealth of new data sources that are being generated by both roadside and mobile sensors that register changes in motion, temperature, light, air quality, and the list goes on. This data can be collected and transferred in real-time to end users and it can be captured and stored for later use in evaluation or research. Sensor-based technologies are delivering the data necessary to support active operation of the system and objectives-driven, performance-based decision-making for investments, as described in Section 18.3, Planning and Programming for Operations.

While there is overlap with Chapter 3, Transportation System Inventory, the focus of this section is on sensor-based data and its relationship to managing and operating of the transportation system. The section discusses the following topics:

- Data Management lists considerations for collecting, processing and interpreting sensor-based data.
- Agency TSMO Data describes sources of sensor-based transportation-related data available through ODOT and partner agencies.
- Third-Party TSMO Data describes sources of sensor-based transportation-related data available from private sources.
- Portal Transportation Data Archive provides an overview of the publicly accessible transportation data archive housed at Portland State University.
- TSMO Performance Evaluation and Monitoring discusses the use of before and after analysis and system monitoring in deploying TSMO.

ODOT is in the process of preparing a TSM&O Performance Measures Plan. The outcomes of the planning effort will be incorporated in this section.

18.2.1 Data Management

Data management encompasses the organization and use of data. The first step to good data management is a clear understanding of how data will be used. Clarity in the application of data helps to inform decisions about collecting, processing, and

interpreting data. The following list includes common components and considerations for managing data.

- Collection is the systematic process of gathering and measuring data. Traffic data can be collected using either automated or manual methods. Automated data collection methods are designed to continuously record data in discrete time periods. Some examples of automated collection methods are traffic counters, portable traffic recorders, Bluetooth or Wi-Fi recorders, and weigh-in-motion devices. Manual collection refers to visually observing and recording data using tally sheets, counting boards, or manually reported data such as crash data.[54]

- Data Quality refers to the strength, trustworthiness, and validity of data. A specification can be used to ensure data quality is preserved. There are five key factors to consider when assessing data quality:

    - The *Validity* of the data is the relevance of collected data to the performance measure or goal being studied.
    - The *Completeness* of the data indicates whether there is enough information to draw a reasonable conclusion about the data.
    - *Data Consistency* considers whether data is collected using the same processes and procedures in every instance and by every individual or agency collecting the data.
    - The *Accuracy* of the data refers to whether the data makes sense and is free from significant errors.
    - The *Verifiability* of the data considers whether there are ways to verify the data was reported and collected according to accepted procedures.[55]

- Data Monitoring is the practice of routine checking of data against quality control factors. Monitoring data can assist with design, maintenance, operations, safety, environmental analysis, finance, engineering economics, and performance management.[56] As an example, sensor failures can be detected through data monitoring practices. Data monitoring can also provide feedback to inform planning, such as whether planning goals for implementation and effectiveness of TSMO program investments are being met. For more information see section 18.2.5.

- Calibration is the process of performing a variety of tests on equipment to ensure that it functions as intended and correctly collects, processes, and reports data. The calibration process can identify errors such as failed or improperly set up sensors or incorrect algorithms that can result in collecting, processing, storing, and disseminating inaccurate statistics.[57]

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[54] https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_fhwa_pl_13_015.pdf
[55] http://www.nationalservice.gov/sites/default/files/resource/Data_Quality_Elements_Performance_Measures_LearningAidFinal7.23.pdf
[56] https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_fhwa_pl_13_015.pdf
[57] https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_fhwa_pl_13_015.pdf

- Storage – Data storage can be a major challenge as the volume of data being collected is increasing drastically. However, the per gigabyte storage cost of data continues to decline as technology advances. There are also many alternate data storage methods available through the private sector, including cloud storage and data warehouses.[58] With the volumes of collected sensor data, established retention policies provide guidelines for how long data is kept and for what purposes.

- Data Fusion is the process of synthesizing data from several different sources to obtain more meaningful information than gained from a single source. The data is gathered, cleaned to remove inconsistencies, and exported to a centralized database. A detailed analysis of the characteristics of the data is necessary to mitigate issues with merging different sources of data. Fusing highly incompatible data sources can be extremely painstaking work, but some of this work can be minimized with software tools.[59]

- Interoperability is an approach in which a number of databases are linked through a communications network so that they appear to be from a single source. Interoperable databases allow users from multiple agencies to make a query without concern for where the data resides or how it is organized. An interoperable database provides easier access to resources, improved availability, and greater ability to share data than a fused database. However, the interface for an interoperable database is much more difficult to configure and the maintenance needs are much more complex.[60]

- Sharing – Data collected by agencies may be useful to other agencies or the general public through traveler information systems. Considerations for data sharing include establishing procedures for access and dissemination. The Federal Highway Administration has developed a Data Exchange Format Specification (DXFS) to facilitate the development of interoperable traveler information systems between agencies and with private entities. [61]

- Granularity refers to the level of depth or detail in a set of data. The finest level of granularity is the smallest pieces of information a data set can be subdivided into. Courser levels of granularity may include more summarized or aggregated representations of data.

- Communication – Traffic systems use communication systems to transmit data between field equipment and traffic management centers. These systems consist of agency-owned cable, leased privately-owned cable, or wireless systems. Communication between field devices is standardized based on National

[58] https://www.fhwa.dot.gov/asset/dataintegration/if10019/dip06.cfm
[59] https://www.fhwa.dot.gov/asset/dataintegration/if10019/dip06.cfm
[60] https://www.fhwa.dot.gov/asset/dataintegration/if10019/dip05.cfm
[61] http://www.ops.fhwa.dot.gov/publications/fhwahop13047/seces.htm

Transportation Communications for Intelligent Transportation System Protocol (NTCIP) specifications. Data sharing and storage are important considerations for data communication.

- Security – In the past, transportation agencies relied on security through obscurity for protection of their communication system. Now that more conventional technologies such as Wi-Fi and Ethernet are commonly used in field devices, communications systems are more vulnerable to attack. It is important for agencies to use current best practices and industry standards to improve security. [62] The FHWA has developed a National Institute of Standards and Technology Framework for Improving Critical Infrastructure Cyber Security: https://www.fhwa.dot.gov/asset/dataintegration/if10019/dip05.cfm.

- Privacy – Agencies must take into account any privacy issues that may arise as a result of disclosure of traffic data. Both federal and state laws recognize a certain degree of privacy with respect to driver information. For this reason, traffic data that a public agency collects or purchases should be anonymous in nature.

- Metadata is data that provides information about other data, often how the data was collected. An example of metadata is the location and timestamp data associated with a photograph. Metadata can also include elements such as the person who collected the data, the title of the data set, file size, date created, date modified, timeframe, accuracy, collection method, and information about the collection device.

18.2.2 Agency TSMO Data

Agency data services are critical for successfully managing Oregon's transportation system. ODOT manages data sets on both freeways and arterials, including vehicle, pedestrian, bicycle, and transit data. More information about many of these data sources can be found in Chapter 3, Transportation System Inventory.

Freeway Data
ODOT shares live video feeds from the State's traffic cameras as well as weather, incident, closures, delays, and construction data on the Trip Check website – http://www.tripcheck.com/.

On Oregon's freeways, ODOT collects speed, volume, classification, and occupancy data with both loops and radar through Automatic Traffic Recorder (ATR) stations, ramp meters, and temporary counting stations. ODOT also collects travel time data using Bluetooth stations. This data is gathered and managed by the Transportation Data Section (TDS). Volume data is shared through the TDS web site through the Transportation Volume Tables.[63] Volume and classification data is also publicly available through

[62] https://www.fhwa.dot.gov/publications/publicroads/16sepoct/01.cfm
[63] http://www.oregon.gov/ODOT/TD/TDATA/pages/tsm/tvt.aspx

ODOT's TransGIS web site.[64]

ODOT records and logs every message displayed by a Variable Message Sign (VMS) or Variable Advisory Speed (VAS) sign through its data acquisition system, managed by the ITS Unit.

Weigh in Motion (WIM) devices capture and record axle weights and gross vehicle weights as drivers drive over a measurement site. ODOT currently operates 22 WIM stations that pre-clear an average of 4,400 trucks a day.[65] WIM data is managed by TDS.

Multimodal Arterial Data

Many of the same methodologies for data collection on ODOT's freeways can also be applied to arterial corridors. Count stations gather volume, speed, and lane occupancy data. Some traffic signals are also equipped with detectors that can gather vehicle counts by lane and time period. Bluetooth sensors gather travel time and origin-destination data to help measure and optimize arterial performance. Additionally, pedestrian and bike data can be collected on arterial corridors. Pedestrian volumes can be estimated using pushbutton actuations at signals and enhanced pedestrian crossings such as Rectangular Rapid Flashing Beacons (RRFBs). Bicycle volumes and travel times can be determined using many of the same methods used to count motor vehicles.

Arterial traffic data is also used to operate adaptive traffic signal control systems. Adaptive signal control systems continuously monitor and evaluate data and adjust signal timings every few minutes to improve travel time and reduce delay.

Transit Data

TriMet, C-TRAN, and many other transit agencies provide real time data for buses and trains in General Transit Feed Specification (GTFS) format. TriMet also publishes monthly ridership and performance statistics.[66,67] ODOT is starting a project to standardize ridership data and formats from transit agencies around the state. The project will seek to develop an ecosystem of open source software tools around the new data standard.

Incidents

Automated incident detection and management data is available through the Highway Traffic Operations Center System (TOCS). The system collects, analyzes, disseminates and archives data in the transportation areas of operations, traffic, incident, and emergency management. The TOCS will include traffic surveillance, road/weather condition monitoring, incident detection and reporting, signal control, and emergency call taking.

The Highway Travel Conditions Information System (HTCIS) includes the status updates

[64] https://gis.odot.state.or.us/transgis/
[65] http://www.oregon.gov/ODOT/MCT/Pages/GREEN.aspx
[66] https://developer.trimet.org/
[67] https://trimet.org/about/performance.htm

that are shared with the public on the ODOT TripCheck website, through 511, and ODOT's TripCheck Traveler Information Portal (TTIP), which allows external sources to access ODOT's data for redistribution. It includes which lanes are affected and what the expected impact is to travelers (i.e., delay experienced). Each incident usually has multiple status updates throughout the duration of the incident. This database also includes weather related information (atmospheric and the resulting road conditions) at the various weather stations throughout the State. The ITS Unit manages these data sources.

ODOT also collects crash data from individual driver and police crash reports through its Crash Data System (CDS) managed by the Crash Analysis & Reporting Unit.

Weather Data
ODOT has weather stations installed across the state that continuously record temperature, dew point, humidity, wind direction, wind speed, visibility, and precipitation. Weather data can be accessed by the public via TripCheck.[68] ODOT also has several roadway weather surface state sensors that monitor grip factor (or relative friction) of the roadway. ODOT's ATM systems currently use this data in adjusting advisory speeds in variable speed corridors and activing advanced curve warning systems. The data is captured in the data acquisition system (DAC), managed by ODOT's ITS Unit.

Additional weather data is available from the Oregon Department of Environmental Quality, which monitors air quality and reports an air quality index based on the concentration of pollutants in the air.

ODOT also has a pilot program that collects data from a subset of agency-owned snow plows. Data collected by the pilot program includes road temperature, air temperature, location, speed, vehicle diagnostics, plow position, and details about the surface treatments applied to the road.

18.2.3 Third-Party TSMO Data Sources

Third-party data comprise an increasingly important source of transportation data for ODOT, providing the agency data types, resolution, locations, and date ranges not otherwise available from agency-owned data collection systems. This subsection provides a general overview of the types of data that can be acquired from third-party sources, with a focus on the third-party data providers with whom ODOT has developed agreements for use of real-time data that has been archived and made available for secondary use.

Travel Time, Speed, and Congestion Data
In the absence of strategically installed Bluetooth readers, Wi-Fi sensors, or similar infrastructure elements, travel time data is most commonly obtained from GPS probe vehicles runs. The prevalence and low-cost of GPS-enabled mobile devices makes private

[68] http://www.tripcheck.com/textpages/RWISreport.asp?curRegion=0

crowdsourced travel time, speed, and congestion data collection an attractive offering to third-party developers.

Location referencing for the third party transportation data is enabled by the Traffic Message Channel (TMC), the commercial industry standard used by HERE and TeleAtlas mapping firms. Use of third party data by public agencies requires the integration of the TMC referenced road network with the agency road network. The basic data elements provided with third party data are date, timestamp, roadway link identifier, roadway link length, and roadway link travel time or speed.[69]

Major third-party travel time, speed, and congestion data providers include HERE, TomTom, INRIX, and Google-owned Waze. Each data provider utilizes a driver network, comprising vehicles, smartphones, or other GPS-enabled devices, to monitor basic location and speed attributes of the vehicle. The provider often utilizes a data analytics capability to derive useful information from these attributes, including travel time and congestion levels. Incorporating a large probe user base with sufficient distribution across a given geographic region, a third-party data provider can generate detailed segment-based speeds and travel times for all the primary roadways in the region.

ODOT Partnership Highlight – INRIX Travel Time Data

ODOT partnered with INRIX to acquire raw segment speed information for major Oregon roadways for the years 2008 to 2013. As part of this agreement, ODOT received access to RITIS, the INRIX online analytical tool used to perform data visualization, reporting, and analytics on the raw data sets. Note - As of 2016 ODOT does not have a current contract with INRIX and therefore cannot access the RITIS analytics capabilities for the archived raw data.

INRIX data collection does not differentiate between passenger vehicles and freight vehicles, so any freight traffic analysis using this data set requires making assumptions about the vehicle mixes. The Transportation Planning Analysis Unit (TPAU) oversees access to this data set.

ODOT Partnership Highlight – National Performance Management Research Data Set (NPMRDS) Travel Time Data

Made available by the FHWA Office of Freight Management and Operations to all state DOTs and MPOs, the NPMRDS contains raw HERE travel time data for all National Highway System routes. This data set is provided in 5-minute periods and differentiates between auto, truck, and combined travel times. Although freely available, NPMRDS does not include an analytical component. ODOT utilizes the data analysis and visualization tools, JMP and Tableau, to analyze, filter, and visualize the data. TPAU oversees access to this data set.

ODOT Partnership Highlight – HERE

Beginning in 2016, ODOT has access to raw HERE travel time data that expands upon

[69] http://www.ops.fhwa.dot.gov/publications/fhwahop11029/ch2.htm

the NPMRDS-provided coverage to include a large number of non-NHS routes. The data set includes historical data (as far back as 2012) in five-minute increments and current data available in one-minute increments. The contract with HERE includes the Iteris analytics tool, iPeMS, to be used to analyze, filter and visualize the data. Like with the NPMRDS, the HERE travel time data set can be differentiated between passenger and freight vehicles. TPAU oversees access to this data set.

Incident Data

Most roadway incident data are generated by public agencies, typically by highway patrol or transportation management center systems. However, some crowd-sourced mobile traffic and mapping applications support an active user interaction component in addition to using GPS to report the location of the vehicle. A well-known and well-used example is Waze, which provides users the ability to submit en route reports on roadway conditions, including incidents, road hazards, traffic jams, and police presence.

Some public agencies are beginning to partner with traffic data companies to acquire their user-generated reports on incidents and other conditions to supplement their own detection and reporting systems. Examples include Florida DOT, which in 2014 entered into a data-sharing agreement with Waze to share its traffic detection data in exchange for Waze's user road conditions reports. In 2015, the city of Los Angeles entered into a partnership with Waze to provide the company information about construction, film shoots, planned closures, and events occurring on L.A. streets. In return, the city receives Waze user-generated incident reports. Additionally, the city can use the Waze application as a broadcast platform to send out hit-and-run and child abduction alerts to Waze users. Public agencies may also purchase data from Waze or other crowd-sourced mobile traffic mapping applications.

Currently, Waze consumes data through the TripCheck Traveler Information Portal (TTIP) on road closures, incidents and construction supplied by ODOT and local agencies using the TripCheck Local Entry (TLE) Tool).

Bicycling and Pedestrian Data

Similar to third-party vehicular travel time data providers, third-party bicycling data providers utilize a GPS device-enabled crowdsourced approach to generate bike trip data that can be purchased by public agencies. Available data types include bicycle volumes, locations (including cut-through pathways), speeds, time of day, direction of travel, route choice for given origins and destinations, and user-generated conditions observations.

Some platforms, like Strava, are geared toward fitness users who use the application to track training rides and compare their results against others in the Strava community. Other app platforms, like Ride Report (https://ride.report/) and Portland State University and ODOT sponsored ORcycle (http://www.pdx.edu/transportation-lab/orcycle), encourage users to report on their perceived stress level of routes and to provide feedback on crash, safety, or infrastructure issues observed on a ride.

Third-party pedestrian data is a relatively unexplored area of third-party data sources to

date. Potential sources include GPS device-enabled fitness tracking apps, similar in function to Strava, in which users run the application in order to track their workouts or monitor their overall movement and activity level. Examples include Human (http://human.co/ & http://cities.human.co/details/United_States/Portland) and Nike+ Running (http://www.nike.com/us/en_us/c/running/nikeplus/gps-app). Most household travel surveys also incorporate GPS tracking as part of monitoring the daily travel by all modes on a select survey day.

Another emerging approach to obtaining pedestrian movement data is through installed detectors that infer pedestrian activity within the system's field of detection. These systems are most commonly deployed in retail environments to help businesses monitor foot traffic for operational improvements.

For example, Navizon (https://www.navizon.com/product-navizon-analytics) utilizes a small hardware device to detect and count Wi-Fi enabled devices within a defined target area. Placemeter (http://www.placemeter.com/) analyzes camera footage to detect pedestrians and obtain pedestrian traffic volumes and walking direction.

ODOT Partnership Highlight – Strava Bicycle Data

In 2014, ODOT became the first public agency in the nation to license bicycling trip data from Strava, a leading app developer and social platform for users to track their bike rides via GPS. Strava data relates to TSMO because it provides a representation of bicycle volumes that can be used to inform both operational and planning decisions. Strava data can also be used to compare one route to another. TPAU oversees access to this data set.

The motivation for the partnership was to supplement the limited bicycle travel information collected by the agency through travel surveys and strategically located fixed counters. The lack of information on bicycle travel information makes it more difficult to track the success of statewide biking efforts and to target future investments appropriately.

The Strava data set provides statewide minute-by-minute bike traces (i.e., the presence and direction of travel of a Strava user) mapped to link segments on the Open Streets Map base map. Aggregating these traces reveals not just how many Strava users are using the system, but how, when, and where they are riding.

For the 2014 year, the Strava data set included travel data for 20,400 Oregon users, who logged 540,000 bike trips (averaging 26 trips per year each), for a total of 5.6 million bike miles traveled.

Comparing Strava data records for a given time period and location against fixed location bicycle counter readings (for example, at Hawthorne Bridge in Portland and various locations in Eugene), ODOT has determined that Strava users represent roughly 1 - 10% of the total bicycle volume. While the share of Strava trips varies by location, the percentage has remained consistent over time at each location. Further analysis by ODOT has indicated that Strava data are representative of which routes are popular with users

overall and identify non-auto pathways used by cyclists.

Key use cases proposed by ODOT that make use of Strava data include:

- Identify and validate high-demand areas in which to locate bicycle counters, especially in non-urban areas
- Inform the deployment and placement of highway rumble strips to identify locations where high bicycle volumes may warrant different installation approaches
- Justify and target seasonal maintenance efforts
- Supporting county and other non-ODOT jurisdictions with cycling data to inform bike path plans and designs

Transit Data
Third-party sources of transit data are uncommon since transit providers are typically public agencies. However, there are third-party data analytics companies, like Urban Engines (https://www.urbanengines.com/), that specialize in ingesting raw data generated by the transit agency (like fare card data and GPS traces) and performing various analytics functions to visualize travel patterns, identify delays and congestion, platform crowding, and wait times.

NextBus (http://nextbus.cubic.com) is another example of a third-party data analytics company that provides added value to the data generated by transit agency. NextBus uses GPS location information from the transit vehicle and a proprietary algorithm that incorporates historical travel data to track transit vehicles and predict their arrival time.

Weather Data
In addition to the publicly available National Weather Service weather data, several third-party providers offer weather data services. An example is Weather Underground (https://www.wunderground.com/), which provides forecasts generated by a proprietary forecasting system that draws from a network of tens of thousands of neighborhood and personal weather stations across the country. Weather Underground offers an API that provide layers such as radar and satellite and a variety of weather data features, including alerts, conditions, forecasts, and astronomy.

18.2.4 Portal Transportation Data Archive

Portal Transportation Data Archive, formally known as PORTAL the Portland Oregon Regional Transportation Archive Listing (http://portal.its.pdx.edu/home), is a publically funded data archive hosted and maintained by Portland State University. Started in 2004, Portal is the region's archive for many different types of transportation related data for the Portland and southwest Washington metropolitan areas.

Currently, Portal archives freeway detector data from ODOT and WSDOT, travel time data from ODOT and PBOT, VMS/VAS messages from ODOT, Weigh-in-Motion data from ODOT, arterial detector data from Clark County and PBOT, traffic signal data from

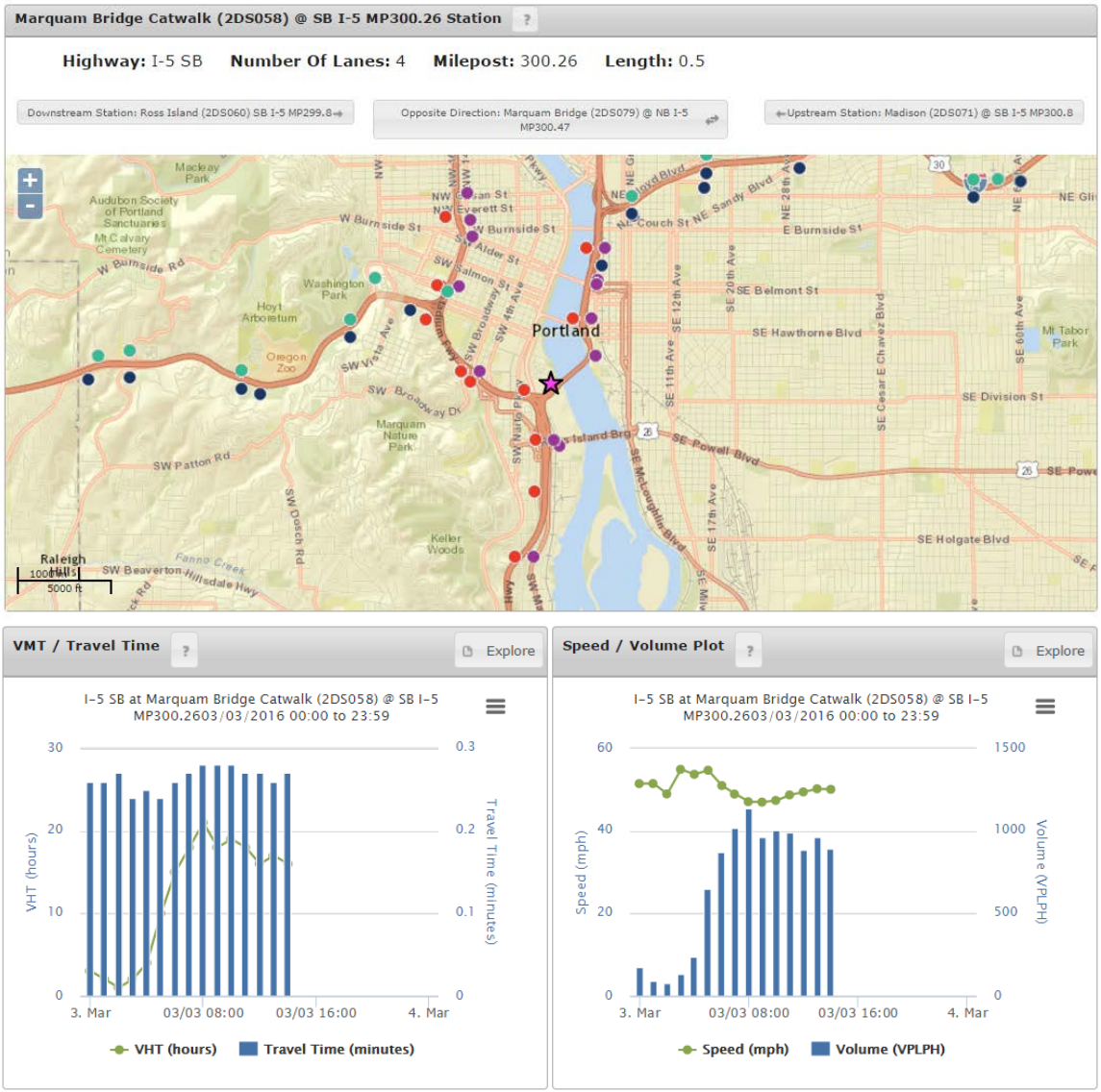
PBOT, bike and pedestrian counts from PBOT, automatic vehicle location (AVL) and automated passenger counter (APC) data from TriMet, air quality data from DEQ, and weather data from NOAA.

While Portal archives all of the above mentioned data, a graphical user interface is also available for viewing and downloading some of the data described. The Portal website offers maps, graphs, and data downloads related to the following:

- Detector data on OR and WA highways in the Portland and Vancouver areas
- Detector data on Portland and Vancouver Arterials
- Travel time data in Portland
- Transit performance metrics in Portland and Clark County

Examples of some of the Portal visualizations are shown below in Exhibit 18-1.

Exhibit 18-1: Portal Stations Map and Subsequent VMT/Travel Time and Speed/Volume Graphs[70]



In addition, the information available through the Portal website, additional data available upon request. A complete list of data archived is listed below in Exhibit 18-2.

[70] http://portal.its.pdx.edu/stations/view/id/3186/

Exhibit 18-2: Data Archived at Portal including Resolution and Date Ranges

Type of Data	Agency	Detection	Resolution	Date Range(s)	Location	Collection Frequency
Speed Volume Occupancy	ODOT	Loops Radar	20-sec 5-min 15-min Hour	2004- (loops) ~2014- (radar)	Portland freeways, Beltline in Lane Co.	Every 2 minutes
Speed Volume Occupancy	WSDOT	Loops Radar	20-sec 5-min 15-min Hour	~2012	Vancouver freeways	Every 20 seconds
Travel Times	ODOT	Bluetooth	Individual Traversals	~2014-	Portland freeways & selected arterials	Every 2 minutes
VMS/VAS Messages	ODOT	N/A	On sign change	~2014	Where installed	Every 2 minutes
WIM	ODOT	In-road sensors	Hour	~2011-2013	WIM stations in Oregon	Monthly
Travel Time	PBOT	Bluetooth	Individual detections	~2012-	Various locations in Portland	Hourly
Arterial Speed, Volume	Clark County	High Definition Radar	5-min	~2014-	Various locations in Clark County	Daily
Traffic Signal Data	PBOT	TransSuite, MOE & SCATS	5-min	~2014-	City of Portland	Hourly
Passenger Counts, On-time Performance	TriMet	AVL/APC	Quarter	~2012	TriMet service area	Quarterly
Weather	NOAA	NOAA detection	Hour	~2004-	Airports (PDX, Hillsboro, Aurora)	Hourly
DEQ Air Quality	DEQ	Weather and Air Quality data	Hour	~2014	DEQ site near Powell Blvd.	Hourly
Bike counts	PBOT/ LCOG	Loops	Unknown	~2014	Various locations in Portland	Hourly

Type of Data	Agency	Detection	Resolution	Date Range(s)	Location	Collection Frequency
Bike counts	LCOG	Loops, pneumatic tubes, infrared, manual	Short duration	~2012	Various locations in Eugene, Springfield, and elsewhere in Lane County	
Pedestrian Pushbutton Actuations	PBOT/LCOG	Pushbutton	Individual actuations			

18.2.5 TSMO Performance Evaluation and Monitoring

Most TSMO deployment projects involve evaluating, adjusting, and improving the performance of the system. Performance evaluation informs the effectiveness of specific TSMO strategies and can aid decision makers in project selection for future capital investments. Performance evaluation can also identify problems or failures, identify fixes to implement, or determine parameters to adjust to optimize performance. Often, the performance evaluation component of a project takes the form of a before and after study, where baseline "before" transportation data are compared to "after" data collected post-deployment.

Before and after study designs can be used to assess the impacts from TSMO deployments on efficiency, reliability, safety, and travel behavior. Data needs are dictated by intent of the evaluation. For example, a before and after evaluation of impacts to travel time reliability from a TSMO project require collecting travel time data during the periods before and after deployment. It is important to collect sufficient data ahead of a project implementation and after completion to statistically measure factors like reliability. The cost of performing before and after studies, which has been a barrier, is greatly reduced with technology-based methods.

Evaluation should define in the project planning phase. Depending on the study design, performance evaluation can be set up as a one-time before period vs. after period analysis, or as a comparison of before data to after data collected over time. A study design with multiple after periods allows for observations of trends over time. After periods typically occur at specified intervals (e.g. annually). The initial after period typically does not occur until a duration of time passes beyond project construction (e.g. six months). This is so data are not skewed by abnormal behavior that may occur upon installation of new transportation devices in the system. It is important that the before period and after period occur during the same time of year so seasonal differences in traffic and travel conditions do not skew the results.

Analysis methods can vary depending on the goals of the evaluation, data structure, and

data availability. In the ideal case, a simple matched pairs comparison[71] can highlight whether significant changes occurred in the data between before and after periods due to a TSMO project. **Examples of some before and after studies completed in Oregon** are shown below in Exhibit 18-3.

Exhibit 18-3: Example Before and After Evaluations

Project Name	Description	Performance Measures	Data Used	Findings
OR 217: Active Traffic Management	Evaluated effectiveness of Active Traffic Management System	Crashes Travel Time Travel Time Reliability	Transportation Data Services Crash Reports Washington County Consolidated Communications Agency Data HERE Data PORTAL	Reduction in travel time, improvement in travel time reliability
Beltline Highway Ramp Metering	Evaluated system performance of Beltline Highway in Eugene, Oregon before and after implementation of ramp meters	Incidents Volumes Speeds Travel Times Reliability	ODOT Incident logs ODOT ATR Data ODOT INRIX™ Analytics Suite	Reduction in incidents, negligible change in speeds, travel times, and travel time reliability
Cornell Road InSync Evaluation	Comparison on operations between TOD signal timing plans and InSync adaptive signal system operation	Travel Time Delay	Bluetooth MAC address data Percent Arrival on Green Traffic Counts	Reduction in travel time during high volume periods, small increase in overall delay
911 CAD Integrated Dispatch Project	Evaluation of 911 dispatch interconnect system between Deschutes County 911 call center, OSP call center, and ODOT incident response system	Notification Time Dispatch Response Time Incident Duration Responder Arrival Time Percentage of Highway-Related Notifications Received by ODOT	ODOT Incident Logs OSP Call Center Logs Deschutes County 911 Call Center Logs	Reduction in dispatch response time, incident response time, and incident duration
District 8	Evaluation of	Clearance Time	ODOT Highway	Reduction in

[71] See Dalgaard, P. (2008). *Introductory Statistics with R*. Springer Science & Business Media, or another introductory statistics text.

Project Name	Description	Performance Measures	Data Used	Findings
Incident Response Evaluation	pilot program for a dedicated incident response service patrol	Average Incident Response Time Maintenance Calls	Traffic Operation Center System (HTOCS) Highway Travel Conditions Information System (HTICS)	response time, incident duration, clearance time, and maintenance calls

Key considerations for evaluations include collecting quality baseline (before) data, accounting for external factors that may affect data collected in the future, and developing analysis tools for reproducibility.

Collecting quality baseline (before) data

Issues with baseline before period data are frequent in before and after studies, and often include incomplete or missing data, structures and formats that don't correspond to after data, and inadequate sample sizes for comparisons. These issues are difficult to overcome because once project deployment occurs, one cannot simply go back and collect more data for the before period. Before data should match the after data in structure, and therefore should be collected by the same or similar methods. Before period data should be examined and verified for quality and accuracy prior to project deployment. This can be done through testing and creating a baseline report. Statistical tools like power analysis can help analysts determine minimum sample sizes needed to make appropriate comparisons.

Accounting for external factors

After period data are subject to influence by external factors beyond the TSMO deployment. Examples include a reduction in vehicle miles traveled due to a spike in fuel costs, a downturn in the economy, or weather conditions that change travel patterns. Therefore, performance evaluations should anticipate normalizing or scaling after period data by also collecting traffic volumes on nearby facilities or other variables. In the case of controlling for traffic volumes, annual ATR data could be used as a potential data source. The nature of the particular study can inform the types of external variables that may be of interest.

Developing analysis tools for reproducibility

Before and after performance evaluations can benefit greatly by employing reproducible analysis tools. Reproducible tools allow analysts to reach the same results given a set of data and include clear documentation. Reproducible tools can expedite the analysis task in cases when after data are collected at specified intervals. Employing traditional analysis tools may lead to more opportunity for problems in the future. For example, complex spreadsheets in Microsoft Excel may be hard to reproduce when an extended period of time has passed between reporting periods or when employee turnover occurs. Many open-source scripting languages like R and Python are well suited for creating reproducible analysis tools.

Performance monitoring differs from performance before and after evaluation in that it is the periodic measurement of progress in meeting operational objectives. Monitoring includes a set of agreed upon measures that are reported out at regular intervals. For TSMO application, performance monitoring can be used to support day to day operational decision making, such as winter road operations or incident management. It also applies to the planning for operations process as described in Section 18.3.

18.3 Planning and Programming for TSMO

The section introduces the concept of planning and programming for TSMO. It begins with an overview of the objectives-driven, performance-based approach that supports integration of TSMO into ODOT's planning and programming processes. Key elements of the objectives-driven, performance-based approach are described in this section including stakeholder collaboration, operational objectives and performance measures, TSMO strategies, programming, intelligent transportation system (ITS) architecture and system engineering requirements, and analysis tools.

The intent of this section is to provide guidance for developing and incorporating TSMO into ODOT planning processes including transportation system plans, corridor plans, and modal plans. As noted in Section 18.1, the OTP and the OHP have established the policy basis for TSMO in planning, designing, and operating Oregon's transportation system. Additionally, ODOT has completed a statewide ITS plan and numerous regional ITS plans that serve as resources for planning processes.

18.3.1 Objectives-Driven, Performance-Based TSMO Planning

The basic tenet of the objectives-driven, performance-based approach is to maximize the performance of the existing transportation system. To accomplish this, the approach relies on a collaborative process to establish measurable operational objectives that are supported by system and demand management strategies focused on improving near-term travel conditions for all modes. For comparison, the traditional approach to transportation planning focuses on addressing issues and problems with a set of infrastructure projects that extend into the distant future. The difference between approaches is the focus on near-term measurable outcomes and solutions. While the objectives derive from issues and problems, the solutions are matched to future-focused objectives and monitored for performance over time. The objectives-driven, performance-based approach is a cyclical process of objectives setting, strategy development, implementation, and performance measurement to manage the transportation system.

Exhibit 18-4 demonstrates the process flow for the objectives-driven, performance-based approach. It is important to note that this approach has points of integration with the broader community planning processes to ensure TSMO is incorporated. Integral to the process is the coordination and collaboration with a broad range of stakeholders that occurs at every step. The implementation and operation of TSMO strategies often requires partnership among multiple business units within an agency and across modes and jurisdictions in a region. Applying an objectives-driven, performance-based approach

to operations planning further broadens the circle of collaboration to include transportation planners and non-transportation entities such as public safety officials, special interest groups, key attractions, and major employers. Coordination and collaboration among planners and operators is necessary across all steps in the approach, and is particularly important in defining operations objectives that feed into long-range transportation plans.

Exhibit 18-4: Objectives-driven, Performance-based Approach

Source: *Advancing Metropolitan Planning for Operations: An Objectives-Driven, Performance-Based Approach – A Guidebook*, FHWA

Establishing TSMO goal(s) focused on the safe, efficient and reliable management and operation of the transportation system is where the process begins. This is a point of integration with broader corridor, regional or statewide planning processes. A transportation plan may identify a single overarching TSMO goal or a set of goals that are broad but address different aspects of TSMO, such as reliability, efficiency, quality of service, and travel options.[72] As noted in Section 18.1.2, ODOT has established TSMO goals and objectives in the OTP and the OHP. It is important to note that TSMO and ITS plans will often include a vision for TSMO. However, when TSMO is integrated into broader planning processes including RTPs and TSPs, TSMO should be reflected in the vision created for these plans.

Operations objectives are the bridge between goals and actions and help determine the selection of and investment in TSMO strategies. These objectives focus on the desired

[72] Regional Goals, http://www.ops.fhwa.dot.gov/plan4ops/focus_areas/integrating/regional_goals.htm, FHWA

operational performance of the transportation system and address issues related to system reliability, congestion, safety, incidents, weather, work zones, and major events. The process for setting operations objectives relies heavily on stakeholder participation and an understanding of the needs and interests of the traveling public. Section 18.3.2 provides further detail on developing operations objectives and associated performance measures.

The process for identifying and selecting TSMO strategies begins with an analysis of needs in a study area. Here, operations objectives and baseline performance measurement provide the criteria for determining operations needs. Stakeholder input is also critical to ascertaining and verifying needs. Potential TSMO strategies are matched to operations objectives they help to achieve. Strategy evaluation assesses the benefits and costs for each strategy and identifies any co-benefits to other goals and operations objectives. Analysis tools, such as sketch planning tools, travel demand forecasting model post-processors, and simulation modeling may be used to help forecast system needs and analyze the potential benefits of operations strategies.[73] Section 18.3.3 describes common TSMO strategies and considerations for their application. Section 18.3.6 provides an overview of analysis tools commonly used in assessment of operational needs and benefit-cost analysis.

With the selection of operations objectives, associated performance measures, and supportive TSMO strategies, the process shifts to integrating these elements into long-range transportation plans and funding programs, such as the OTP or ODOT's Statewide Transportation Improvement Program (STIP). It is important to note that TSMO strategies can be implemented as standalone projects or programs or they can be incorporated into the implementation of other projects types like preservation, modernization, and safety. The benefit of on-going collaboration across a diverse set of stakeholders is the opportunity to partner on implementation of TSMO strategies. Section 18.3.4 delves into more detail on programming for TSMO.

Given the diversity of geography that ODOT serves, it is important to note that the objectives-driven, performance-based process is highly scalable to the planning context and can evolve over-time. Large urban regions may develop a robust plan with several TSMO-related goals and supporting operations objectives that address a variety of issues. In contrast, smaller rural regions can apply the same process that results in a single TSMO goal with a few operations objectives that address critical system performance issues. The cyclical nature of the process means that initial TSMO planning can be refined and expanded upon over time.

[73] Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations – A Desk Reference, FHWA 2010

18.3.2 Multimodal System Performance Measures

To learn more about establishing operations objectives and performance measures including examples refer to Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operation - A Desk Reference.

Operations objectives are the bridge between goals and actions and help determine the selection of and investment in TSMO strategies. These objectives focus on the desired operational performance of the transportation system and address issues related to system reliability, congestion, safety, incidents, weather, work zones, and special events. The process for setting operations objectives relies heavily on stakeholder participation and an understanding of the needs and interests of the traveling public.

Operations objectives should exhibit S-M-A-R-T characteristics:

- **Specific** — The objective provides enough detail (e.g., decrease travel time delay) to identify actions that will achieve the objective.
  Criteria: What is the target issue? What will be accomplished?

- **Measurable** — The objective is quantifiable (e.g., by 10 percent) defining how many or how much should be accomplished. Tracking progress against the objective enables an assessment of the effectiveness of an action or set of actions.
  Criteria: Is the objective quantifiable? Can it be measured? How much change is expected?

- **Agreed Upon** — Stakeholders come to a consensus on a common objective. This is most effective when the planning process involves a wide range of stakeholders to facilitate regional collaboration and coordination.
  Criteria: Does the objective address an issue of importance to stakeholders? Does it have broad support from stakeholders?

- **Realistic** — The objective can reasonably be accomplished within the limitations of resources and other considerations. The objective may require substantial coordination, collaboration, and investment to achieve. To be achievable, it may need to be re-evaluated and adjusted once strategies and costs are defined.
  Can the objective be accomplished with available resources and support?

- **Time-bound** — The objective identifies an achievable timeframe (e.g., within five years). As with the Realistic characteristic, the timeframe

may need to be adjusted once strategies and costs are defined. *Can the objective be accomplished within the proposed timeframe?*

A basic sentence structure for operations objectives looks like this:

(Action verb) + (the target subject) + (descriptor) by X (unit of measure) by (year).

- Common Action verbs show directionality and include words like *increase, achieve, reduce,* and *decrease*.
- The Target Subject is the activity being measured such as *mode share* or *delay.*
- Descriptors provide detail about the subject such as time period of interest (e.g. peak hour, average weekday), geographic focus (e.g. region, neighborhood), mode (e.g. transit, trucks) facility type (e.g. bus route, corridor), and user type (e.g. freight carriers, single-occupancy vehicle drivers).
- Unit of measure defines the standard for a quantity such as *percent* or *miles.*
- Year is the target timeframe such as by *2040*.

Below are some examples of S-M-A-R-T operations objectives:

- *Reduce the number of freeway miles at level of service F in the PM peak by 5% by 2040.*
- *Increase the percent of major employers actively participating in transportation demand management programs by 20% within 10 years.*

There are two general categories of operations objectives: *outcome-based* and *output-based*. Outcome-based operations objectives address whether strategies resulted in overall improvement. These objectives are high-level, crosscutting and user-focused. These characteristics mean that plans will include fewer outcome-based measures. Examples of outcome-based objectives are delay reduction, travel time reliability, and increases in non-single occupancy vehicle mode share.

Output-based operations objectives are focused on the quantity or magnitude of output. They are focused on the operational activities of organizations and support desired system performance outcomes. Output-based objectives tend to be more abundant in plans because organizations more readily monitor outputs and have data to support measurement of the objective. Examples of output-based operations objectives include the frequency of signal re-timing, average incident response time, and share of transit stops with real-time traveler information.

Performance measures quantify operations objectives. They are indicators of the extent to which the transportation system is achieving desired operations objectives. Performance measures also help identify transportation system issues and needs; assess potential

impacts of TSMO strategies; communicate progress in achieving goals and objectives; and provide accountability.

Exhibit 18-5 provides a table of common operations objectives, associated performance measures, and relationship to modes.

Exhibit 18-5: Example Operations Objectives and Performance Measures Reference Table[74]

Operations Objectives	Performance Measures	Modes Potentially Affected by Objectives and Performance Measures Auto = A; Transit = T; Freight = F; Bike = B; Pedestrian = P				
		A	T	F	B	P
System Efficiency						
Extent of Congestion	• Percent of intersections operating at LOS F or V/C > 1.0 • Rate of increase in facility miles operating at LOS F or V/C > 1.0	●	●	●		
Duration of Congestion	• Hours per day at LOS F or V/C > 1.0 (or other threshold)	●	●	●		
Vehicle Miles Traveled	• Average VMT per capita per day, per week, or per year	●	●	●	●	●
Safety	• Traffic fatalities and injuries per 100 million vehicle miles traveled • Traffic incident clearance time	●	●	●	●	●
Delay	• Hours of delay per capita or per driver	●	●	●	●	●
Energy Consumption	• Total fuel consumed per capita for transportation	●	●	●	●	●
System Reliability						

[74] Source: Adapted from Table 3.2.1: *Cross-Reference Table in* *Advancing Metropolitan Planning for Operations: The Building Blocks of A Model Transportation Plan Incorporating Operation - A Desk Reference*, FHWA

Operations Objectives	Performance Measures	Modes Potentially Affected by Objectives and Performance Measures Auto = A; Transit = T; Freight = F; Bike = B; Pedestrian = P				
		A	T	F	B	P
Non-recurring Delay	• Travel time delay per capita during scheduled and/or unscheduled disruptions to travel	●	●	●	●	●
Travel Time	• Average travel time during peak periods (minutes)	●	●	●	●	●
Transit On-time Performance	• Arrival and departure times (if different) from a select number of stops on transit facilities of interest		●			
System Options						
Mode Share	• Share of trips by each mode of travel	●	●	●	●	●
Modal Options for Individuals with Disabilities	• The percent of intersections with ADA provisions • The percent of individuals with disabilities that can access transit		●			●
Bicycle and Pedestrian Mobility	• Average delay for pedestrians and bicyclists on primary routes • Average pedestrian or bicyclist comfort level measured by survey				●	●

There are limitations that must be considered when developing operations objectives and performance measures. The availability of data needed for performance measures and the difficulty in agreeing upon an appropriate target or timeframe for achievement are obstacles for agency use of this approach. Developing operations objectives requires data on baseline conditions and often requires information on historical conditions and forecasts of future conditions in order to determine a reasonable target and timeframe. These limitations should be factored into consideration and selection of operations objectives and performance measures. It is advisable to begin with a select number of agreed upon objectives and performance measures and develop a process for data management, evaluation, reporting, and decision-making. The cyclical nature of the planning process provides ample opportunity for the refinement over time.

Chapter 9 (not yet written) includes more information about performance measures.

18.3.3 TSMO Strategies

Numerous TSMO strategies can be applied to support operations objectives and should be considered and evaluated as part of any planning effort. Appendix 18A provides an extensive list of strategies with a description, key benefits, order of magnitude cost, geographic application, influencing factors, data needs, and level of staffing associated with each one. The strategies are grouped by category:

- Regional Traffic Control
- Traveler Information
- Maintenance and Construction
- Road Weather Operations
- Incident Management
- Emergency Management
- Public Transportation
- Freight
- Archived Data Management
- Transportation Demand Management
- Complementary Strategies
- Strategies that Require Political and Policy Changes
- Emerging Strategies

Exhibit 18-6 provides a list of TSMO strategies to consider based on operations objectives.

Exhibit 18-6: TSMO Strategies to Consider Based on Operations Objectives

High-Level Operations Objectives*	TSMO Strategies to Consider	
System Efficiency		
Extent and Duration of Congestion • Reduce recurring congestion (extent and duration) • Improve intersection LOS	*(see right)*	Applicable to all system efficiency objectives: • Traffic network surveillance • Transportation operations centers • Enhanced traffic signal operations • Transit signal priority • Incident management • Travel demand strategies that encourage shifts in travel mode, time, or route • Congestion pricing strategies that encourage shifts to off-peak periods • Roadside truck electronic screening/clearance • Traveler information • Archived data management • Connected/autonomous vehicles • Ramp metering • Freeway/arterial integrated corridor management (ICM)
Intensity of Congestion (Travel Time Index) • Reduce travel time index	*(see right)*	
Travel Time • Improve travel time	*(see right)*	
Delay • Reduce hours of delay • Reduce control delay at traffic signals • Improve roadway LOS	• Access management • Managed lanes • Bottleneck removal • Ramp closures	
Energy Consumption • Reduce energy consumption • Reduce fuel consumption	*(see right)*	
Cost of Congestion • Reduce cost of congestion	*(see right)*	
Vehicle Miles Travel • Reduce vehicle miles traveled	• Transportation demand management: trip elimination, trip chaining, mode shifts, increasing vehicle occupancy, land use strategies • Improve transit travel times and reliability	
Trip Connectivity • Reduce door-to-door trip time • Reduce cost of transfer fees	• Transportation demand management for end users: minimize trip transfers, fare integration	
System Reliability		
Non-Recurring Delay • Reduce person hours of delay caused by scheduled events, work zones, system maintenance, unscheduled disruptions, and traffic incidents	*(see right)*	Applicable to all system reliability objectives: • Traffic network surveillance • Transportation operations centers • Active traffic management • Freeway/arterial integrated corridor management • Safety applications • Incident management • Emergency management • Special event management • Work zone management • Maintenance and construction activity coordination • Road weather operations • Traveler information • Archived data management • Connected/autonomous vehicles
Travel Time Buffer Index • Reduce travel time buffer index	• Managed lanes • Freight only lanes	
Planning Time Index • Reduce average planning time index	• Ramp metering • Managed lanes • Public transportation improvements	
Travel Time 95th/90th Percentile • Reduce the 90th (or 95th) percentile travel time	*(see right)*	
Variability • Reduce travel time variability	*(see right)*	

High-Level Operations Objectives*	TSMO Strategies to Consider	
On-Time Performance • Improve average on-time performance for transit and freight	• Advanced transit operations management • Transit signal priority • Truck traffic signal priority • Managed lanes (including transit and freight options) • Electronic fare collection • Roadside truck electronic screening/clearance	
System Options		
Mode Share • Reduce per capita single occupancy vehicle commute trip rate • Increase alternative (non-SOV) mode share • Increase active (bicycle/pedestrian) mode share	• Travel demand management • Parking management • Traveler information • Congestion pricing (with electronic toll collection and automated enforcement)	
Transit Use • Increase transit mode share • Increase average transit load factor • Increase passenger miles traveled	• Advanced transit operations management • Electronic fare collection • Transit surveillance and security • Traveler information • Travel demand management: marketing, rider incentive programs, transit ease of use	
Travel Time – Transit Compared to Auto • Reduce the travel time differential between transit and auto	• High performance transit • Queue jump lanes at signalized intersections • Transit lanes/managed lanes • Transit signal priority	
Bicycle and Pedestrian Accessibility and Efficiency • Decrease average delay for pedestrians and bicyclists • Increase the number of intersections with pedestrian features	• Bicycle and pedestrian operations and safety (e.g. pedestrian countdown signals, bicycle detection, timing)	

* For numerous SMART objectives, see *Advancing Metropolitan Planning for Operations: The Building Blocks of A Model Transportation Plan Incorporating Operation - A Desk Reference*, FHWA.

18.3.4 TSMO Programming

Programming is the process of selecting projects for funding (based on long-range planning efforts and a prioritization process), identifying funding resources, and scheduling project implementation. This section provides an overview of long-range planning, project selection, TSMO funding sources, and additional TSMO programming resources.

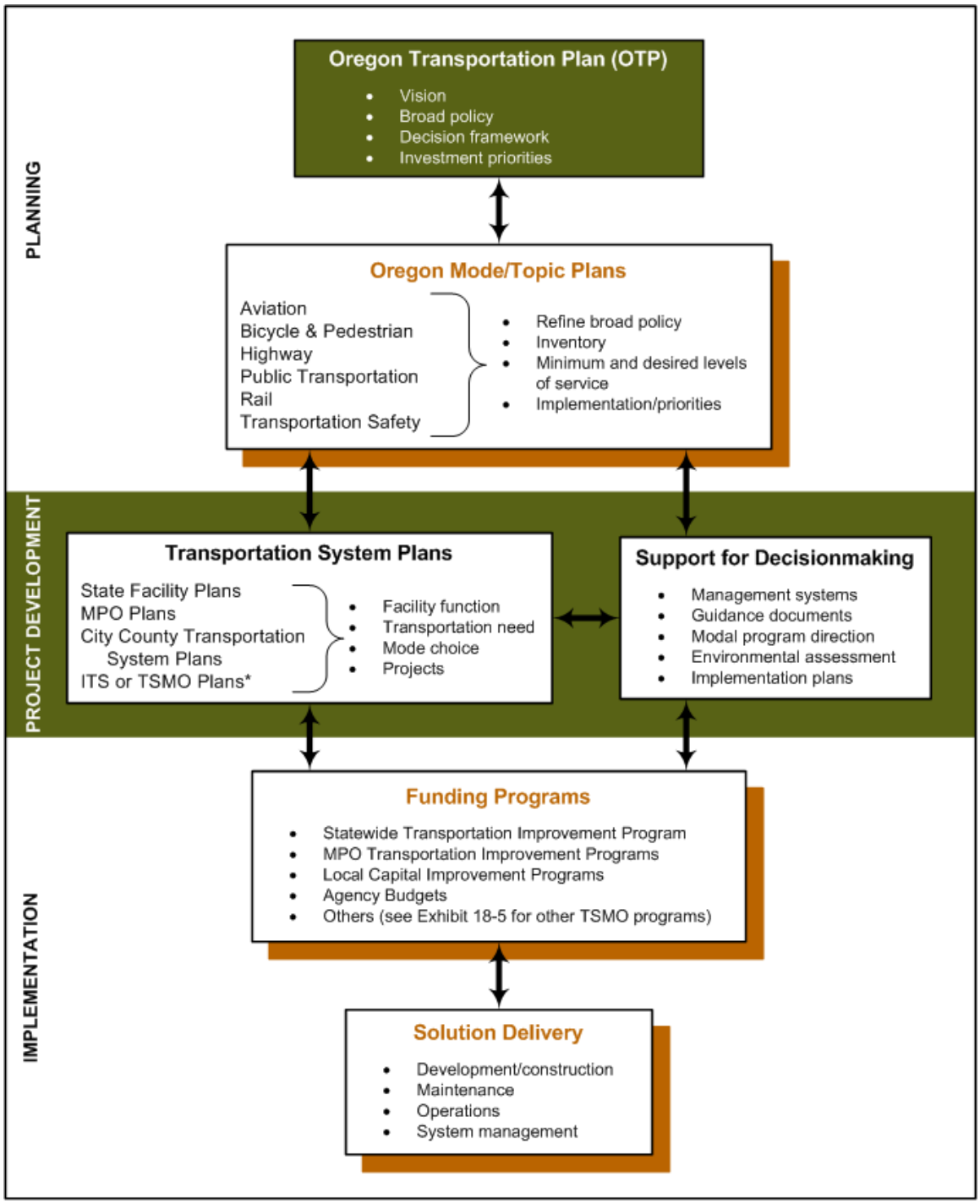
Long-Range Planning
The Oregon Transportation Plan (OTP) and the six associated mode/topic plans (e.g. Oregon Highway Plan) provide the foundation for long-range planning for regional and local transportation system plans in Oregon. The OTP is a 25-year plan that sets statewide goals for mobility and accessibility, management of the system, economic vitality, sustainability, safety and security, funding the transportation system, and coordination/communication/cooperation. The Transportation Planning Rule (OAR 660-012) requires regional and local transportation system plans to be consistent with the OTP.

Exhibit 18-7 illustrates the relationship between the OTP, statewide mode/topic plans, and regional and local transportation system plans. The project development and funding programs shown in the exhibit are discussed in the following sections.

TSMO Project Selection for Programming
Projects are typically identified as part of the development of regional or local transportation system plans. These plans use the OTP and state mode/topic plans as policy guidance and develop a list of long-range projects to meet the objectives and goals of the transportation system plan. In the context of the objectives-driven, performance-based approach to planning for operations, measurable operations objectives should be used to support funding decisions as well as to monitor and evaluate projects so that prioritizations can be modified as necessary. Other measures are also used in the project selection process such as benefit/cost analysis or ODOT's least cost planning method.

To date many ITS or TSMO plans have been developed separately from regional or local transportation system plans. [Note: TSMO is broader than ITS as previously defined at the beginning of this chapter. Until recently most agencies focused on ITS plans instead of TSMO plans.] However, the ITS or TSMO plans are often referenced in the applicable transportation system plan or adopted as an appendix. ITS or TSMO plans typically include a phased implementation plan of projects that often compete for funding with projects from the transportation system plans. More work is needed to bridge the gap between traditional planning and operations planning.

Exhibit 18-7: Integrated Transportation Planning and Programming



Source: *Oregon Transportation Plan*, 2006, Figure 7

* Regional or local ITS or TSMO plans are often referenced in or adopted as an appendix to MPO, city, or county transportation plans.

TSMO Funding Sources

Successfully funding TSMO projects or a TSMO program depends on a combination of capital, operations, and maintenance investments to support active management and operations of the transportation system. The funding sources identified in Exhibit 18-8 primarily identify funds that could be used for capital investments; however, funding is also critical for ongoing operations and maintenance. Often operations and maintenance budgets are funded through each agency's own budget.

Exhibit 18-8: Potential TSMO Funding Sources and Application Cycles

Potential Funding Program	Applicable Project Types	Application Cycle
Oregon Statewide Transportation Improvement Program (STIP) *(Note: Prior to the current programs, most TSMO projects received funding through the STIP Operations Program)*	Enhance: Activities that enhance, expand, or improve the transportation system Fix-It: Activities that fix or preserve the transportation system; currently each region receives an allocation of funds specifically for ITS as a subcategory under Operations.	Process begins in odd-numbered years and results in a 4-year funding program
ConnectOregon	Non-highway freight, transit projects, and active transportation projects	Roughly every 2 years
U.S. DOT Transportation Investment Generating Economic Recovery (TIGER) Discretionary Grants	Projects that generate economic development and improve transportation safety, reliability, and affordability	Yearly (typically May)
FTA State of Good Repair (SGR) Grant Program	Transit projects	Varies; part of a 4-year program
U.S. DOE Energy Efficiency and Conservation Block (EECBG) Program	Projects that improve energy efficiency (e.g. signal timing)	Yearly
Homeland Security Funding	Traffic surveillance, CAD integration with 911 centers	Varies
Metropolitan Transportation Improvement Program (MTIP)	Any regional or local TSMO project within an MPO	Varies by MPO and results in a 4-year program
Local Funding (e.g. gas tax, property tax, system development charges)	Any TSMO project; Local match for other funding programs	Varies

Agencies have developed creative solutions for obtaining TSMO funding or reducing costs through practices such as these:

- System sharing (e.g. central signal system shared by multiple agencies)
- Communications infrastructure sharing with other departments within an agency, other transportation agencies, emergency management agencies, or the private sector (e.g. PGE)
- Installing conduit underground as part of capital improvement projects that have been identified as future fiber optic communications corridors
- Staff sharing between agencies for TSMO activities
- Local flexible fund for TSMO that can be used as the local match for STIP, MTIP, or other funding sources
- Purchase of spare parts or back-ups as part of capital construction projects

TSMO Programming Resources
Additional information about programming for TSMO projects is available at:

- FHWA Integrating Operations into Planning and Programming
- FHWA Performance-Based Planning and Programming Guidebook
- FHWA Programming for Operations: MPO Examples of Prioritizing and Funding Transportation System Management & Operations Strategies (includes a Portland case study)
- NCHRP 20-07/345 Program Planning and Development for TSM&O in State Departments of Transportation
- SRHP2/TRB Guide to Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes
- Oregon Statewide Transportation Improvement Program
- Metro Regional TSMO Plan 2010 – 2020, Appendix F: Finance Report

18.3.5 ITS Architecture and Systems Engineering

This section describes how the ITS architecture and a systems engineering approach can be used in the planning process.

ITS Architecture
An ITS architecture provides a common framework for planning, defining, and integrating ITS within a region. The U.S. Department of Transportation developed the National ITS Architecture so that intelligent transportation systems deployed around the country, and within a region, can communicate with one another and share information to maximize the return on investment for ITS. For example, if a transportation agency wants to clear incidents faster, the architecture defines a function to monitor roadways and identifies the interconnection and information flows between roadway devices, the traffic operations center, and the emergency management center needed to provide responders with incident information. The architecture provides the framework for the process, but does not define the technology or management techniques used to provide the information flows. More details on the National ITS Architecture are available at

http://www.iteris.com/itsarch/.

The FHWA published a Final Rule policy (FHWA Docket No. FHWA-99-5899) that requires all agencies using federal highway trust funds for ITS projects develop a regional or statewide architecture that is compliant with the National ITS Architecture. The FTA published a similar policy (FTA Docket No. FTA-99-6147) that applies to federal funding from the mass transit account of the highway trust fund. For more details on the Final Rule refer to http://ops.fhwa.dot.gov/its_arch_imp/archrule_final_1.htm.

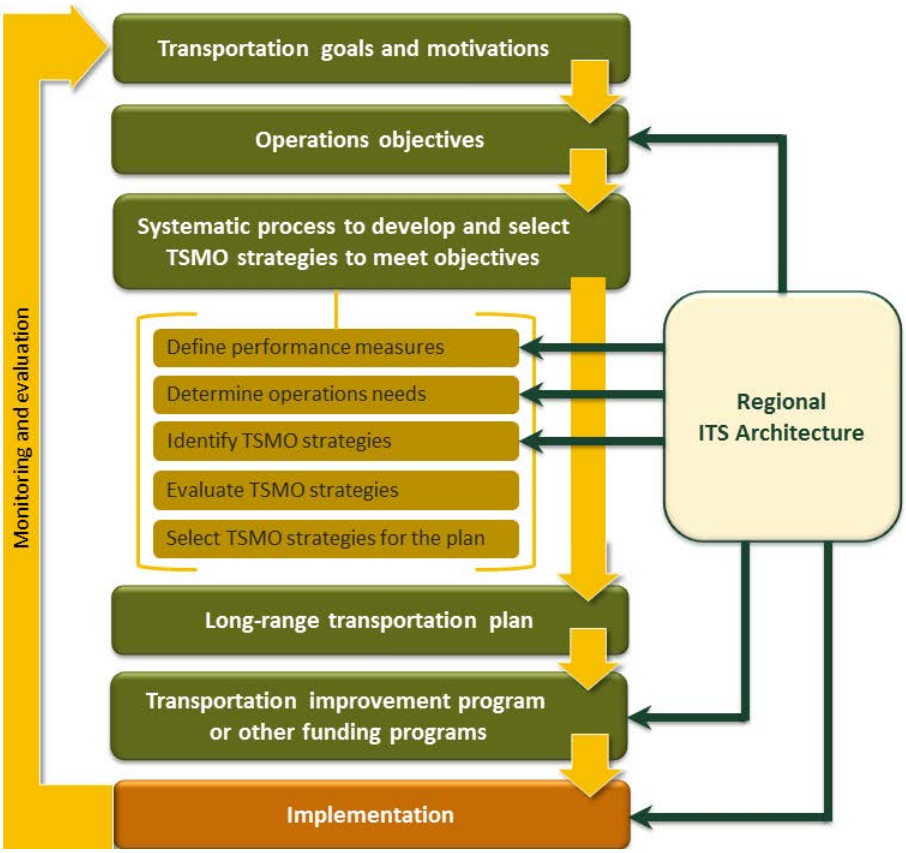
In Oregon, ITS architectures have been developed for the following regions (documentation at http://www.oregon.gov/ODOT/HWY/ITS/Pages/its_documents.aspx):

- Oregon Statewide
- TransPort (Portland area)
- Salem-Keizer
- Central Willamette Valley
- Eugene-Springfield
- Rogue Valley
- Deschutes County

Exhibit 18-9 shows how a regional ITS architecture can provide support for an objectives-driven, performance-based approach to planning for operations. The regional ITS architecture helps answer important questions such as:

- What existing or planned TSMO strategies may be available to help achieve operations objectives?
- What stakeholders and collaborative relationships can be leveraged as part of the planning process?
- What data is available to monitor transportation system performance and track progress toward operations objectives?
- What parts of the architecture's operational concepts, functional requirements, or other contents can be used to support project development?

Exhibit 18-9: Regional ITS Architecture Use in Planning for Operations



Source: *Applying a Regional ITS Architecture to Support Planning for Operations: A Primer*, FHWA

Systems Engineering

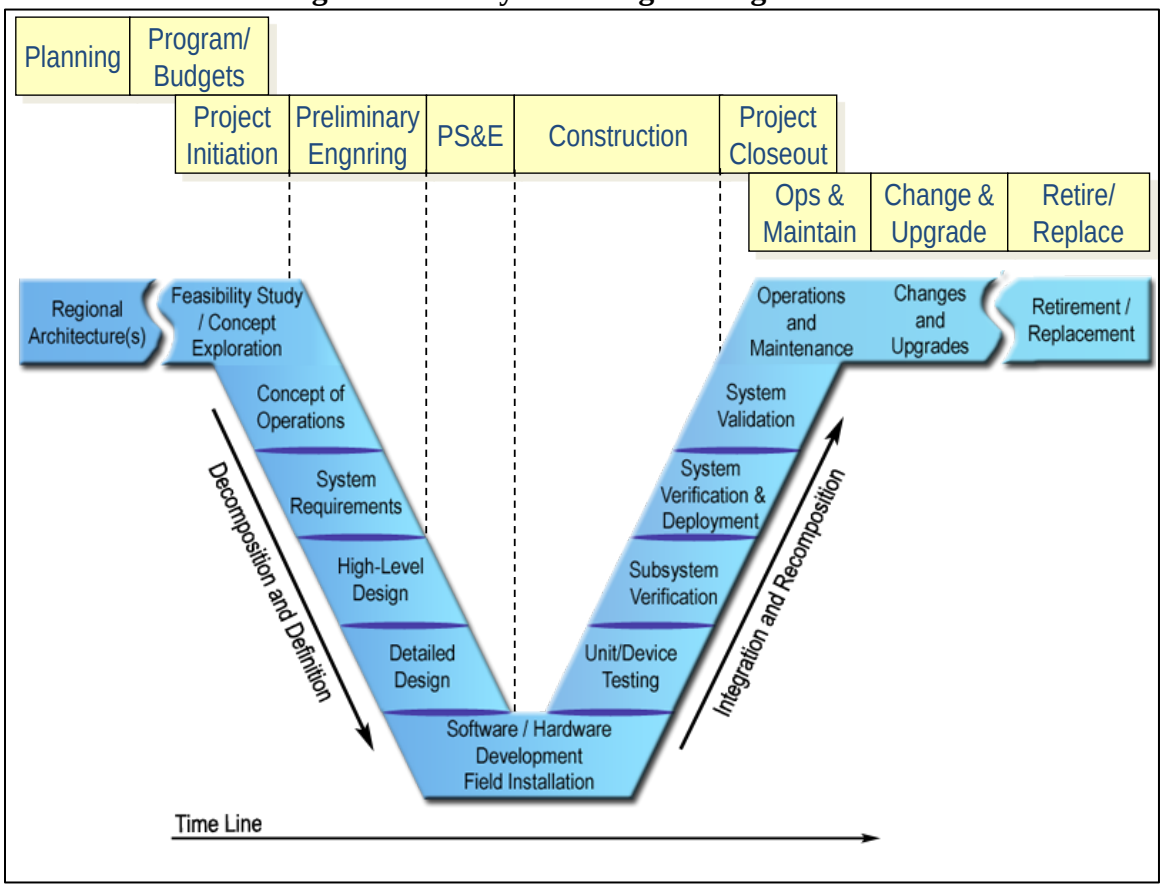
Systems engineering is an organized approach intended to improve the success rate of systems projects by clearly communicating user needs and providing a logical organization that ties all aspects of the implementation cycle to those user needs and requirements. The approach can be applied to any of the TSMO strategies related to systems that are described in this manual. Systems engineering analysis is required for all ITS projects using federal funds per the Final Rule described in the ITS Architecture section above. The Final Rule requires a systems engineering analysis that includes, at a minimum:

- Identification of portions of the regional ITS architecture being implemented (or if a regional ITS architecture does not exist, the applicable portions of the National ITS Architecture)
- Identification of participating agencies' roles and responsibilities
- Requirements definitions
- Analysis of alternative system configurations and technology options to meet requirements
- Procurement options

- Identification of applicable ITS standards and testing procedures
- Procedures and resources necessary for operations and management of the system

Although there are many ways to represent the systems engineering process, the winged "V" (or "Vee") model diagram shown in Exhibit 18-10 has been broadly adopted in the transportation industry. The left wing of the "V process shows the regional ITS architecture, feasibility studies, and concept exploration that support initial identification and planning for a project. Transportation planning fits within the left wing. The operations objectives and performance measures identified during the planning phases should be applied throughout the systems engineering process and actually validated once the project reaches the deployment phase in the right wing of the "V" diagram. This approach provides a systematic method to plan and design systems to achieve the desired operations objectives.

Exhibit 18-10: Planning within the Systems Engineering "V" Model



Source: *Systems Engineering Guidebook for ITS*, ver. 3.0, FHWA CA Division

ITS Systems Engineering and Architecture Compliance Checklist

The ODOT ITS Unit developed a systems engineering and architecture compliance checklist, which essentially forms a Systems Engineering Plan for an ITS project or a project with ITS/TSMO elements. The checklist can be used to define how a project will comply with federal requirements and identify which systems engineering tasks need to

be completed as part of the project scope of work. This checklist is required for all federally funded ITS projects in Oregon but is also useful for ITS projects funded through other sources. The checklist is available at http://www.oregon.gov/ODOT/HWY/ITS/Pages/its_documents.aspx.

18.3.6 Analysis Tools

This section describes the scoping and selection of TSMO planning-level analysis tools and methods, which include a full range of analytical level of detail from sketch models through simulation. See Chapter 2, Section 2.4 for additional information on planning tools.

There is a wide selection of tools and methods that can be used during the various stages of the TSMO planning process. The analysis tools are generally broken out into these categories:

- Sketch-planning tools
- Deterministic tools
- Traffic signal optimization tools
- Simulation tools

Sometimes classified as tools and methods, these items are also used as inputs to many of the before mentioned tools:

- Travel demand models
- Crash modification factors
- Archived operations data

These tools, methods, and inputs range from easy to use to very complex. Exhibit 18-11 lists basic advantages and challenges of each tool or method.

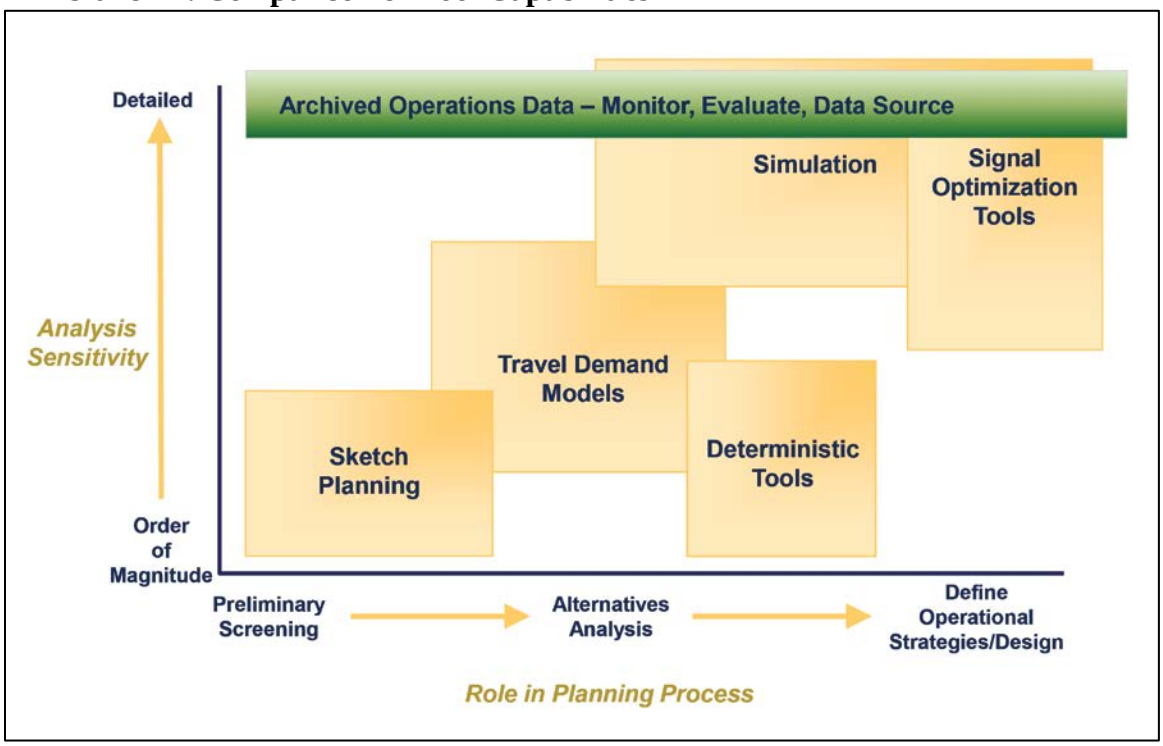
Exhibit 18-11: Advantages and Challenges of TSMO Analysis Tools/Methods

Tool/Method	Advantages	Challenges
Primary Tools and Methods		
Sketch-planning tools *Used to produce general order of magnitude estimates of impacts*	• Low cost • Fast analysis times • Limited data requirements • View of the "big picture" • Efficient initial screening	• Limited in scope, robustness, and presentation capabilities
Deterministic tools *Used to predict impacts based on inputs*	• Quickly predict impacts for an isolated area • Widely accepted	• Limited ability to analyze broader network impacts • Limited performance measures
Traffic signal optimization tools *Used to develop optimal signal phasing and timing plans*	• Effective tool for testing plans prior to field implementation • Proven operational benefits	• Calibration process can be time consuming
Simulation tools *Used to observe the effects of inputs in a modeled environment*	• Detailed results, particularly microsimulation • Dynamic analysis of incidents and real-time diversion patterns • Visual presentation opportunities	• Demanding data and computing requirements, particularly microsimulation • Research requirements may limit network size and number of analysis scenarios • Requires substantial experience working with models
Supplementary Tools and Methods		
Travel demand models	• Validated models available for most metro areas • Evaluation of the regional impacts • Consistent with current planning practices	• Limited ability to analyze operational strategies • Typically does not capture nonrecurring delay
Crash modification factors	• Low cost • Fast analysis times • Limited data requirements	• Quality of factors can be low • Factors not present for many countermeasures
Archived operations data	• Quick data collection • Current/up-to-date data • Provides detailed response to public officials based on real-world data	• Limited availability of quality data • Requires access to data/privacy concerns

Adapted from Table 2 in *Applying Analysis Tools in Planning for Operations*, FHWA

The detail and complexity of a tool can vary between quick and easy (sketch-planning) to time intensive and complex (simulation). Tools also have different uses depending on the stage of the planning process. Preliminary screening would typically involve sketch-planning tools while simulation would start during the alternatives analysis process and potentially continue through design. Exhibit 18-12 shows the comparison of tool capabilities as they relate to the TSMO planning process and their respective analysis sensitivity.

Exhibit 18-12: Comparison of Tool Capabilities



Source: *Applying Analysis Tools in Planning for Operations Participant Workbook*, FHWA Workshop Series

Throughout the planning process, archived operations data and crash modification factors/countermeasures may be used as inputs for a variety of tools. For example, historical vehicle volumes may be used to calibrate travel demand models or simulations while a crash modification factor might be used in a benefit/cost analysis.

There are many tools and methods that can be used to evaluate TSMO strategies throughout the planning process. This section describes some of these tools in more detail and Exhibit 18-13 provides an overview of what category applies to each tool or method and the level of effort to apply it regarding data needs, staffing, and time. See Section 2.4.2 for detailed descriptions of the High (H), Medium (M), and Low (L) rankings.

Some of the tools previously developed by FHWA for operational analysis have been phased out for newer models. Screening Analysis for ITS (SCRITS), Surface Transportation Efficiency Analysis Model (STEAM), and IMPACTS are no longer available online.

Exhibit 18-13: TSMO Analysis Tools/Methods

Tools/Methods	Sketch-Planning	Deterministic	Traffic Signal Optimization	Simulation	Input to Other Tools	Data Needs	Staffing	Time
	Category					Applications		
Tool for Operations Benefit Cost Analysis (TOPS-BC)	X					L	M	L
SHRP2 Analysis Tools	X					L	M	L
ITS Benefits/Cost Database and Before-After Studies	X				X	L	L	L
Mesoscopic/Dynamic Traffic Assignment				X		M	M	M
Travel Demand Model		X			X	M	M	M
Crash Modification Factors (CMFs)/Countermeasures					X	L	L	L
Regional Strategic Planning Model (RSPM)					X	H	H	H
Traffic Signal Optimization			X			M	M	M
Microscopic Simulation				X		H	H	H

Tool for Operations Benefit Cost Analysis (TOPS-BC)
(http://www.ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm)
TOPS-BC is a sketch-planning tool that was developed in parallel with the FHWA Operations Benefit/Cost Analysis Desk Reference. This spreadsheet-based tool has four key capabilities:

1. Allows users to look up the expected range of TSMO strategy impacts based on a database of observed impacts in other areas
2. Provides guidance and a selection tool for users to identify appropriate benefit/cost methods and tools based on the input needs of their analysis
3. Provides the ability to estimate life-cycle costs of a wide range of TSMO strategies
4. Allows for the estimation of benefits using a spreadsheet-based sketch-planning approach and the comparison with estimated strategy costs.

In addition to the four key capabilities, local weather station data can be used in evaluation of non-recurring events and to calibrate to local conditions. TOPS-BC can also be used to evaluate emissions for Congestion Mitigation and Air Quality (CMAQ) funds assuming that there is a local emissions model/tool that can also be used. The most common tool used for emissions modeling is MOVES, which was developed by the US

EPA.

SHRP2 Analysis Tools
(http://www.fhwa.dot.gov/goshrp2/Solutions/Operations/List)
The SHRP2 analysis tools are a repository of different solutions designed to meet various challenges. These tools are the result of over 100 research projects that address various transportation challenges. The SHRP2 solutions are broken out into the following disciplines:

- Planning and Environment
- Safety
- Design
- Risk Management
- System Management and Operations
- Bridges
- Utilities and Railroads
- Pavement and Materials
- Construction

Under the discipline of system management and operations, the focus areas include capacity, reliability, and renewal. Some examples of solutions include advanced travel analysis tools for integrated travel demand modeling, freight demand modeling and data improvement, validation of urban freeway models, and incorporating travel-time reliability into the highway capacity manual.

Incorporating travel-time reliability into the highway capacity manual is one tool that is part of a suite of tools to help transportation planners and engineers improve monitoring and analysis of data to achieve more consistent, predictable highway travel. In order to implement the methodology of the freeway reliability analysis, a Java-based tool with a graphical user interface was created call FREEVAL-RL (FREeway EVALuation ReLiability).

The FREEVAL-RL tool analyzes freeway segments for both undersaturated and oversaturated conditions. For oversaturated conditions, demand, volume, and vehicle queuing are tracked over time and space. Using outputs from the FREEVAL-RL tool, reliability can be estimated over various scenarios.

Other Sketch-Planning Tools
Additional sketch-planning tools include:

- ITS Benefits/Cost Database (http://www.itskrs.its.dot.gov/)
    - This website-based tool developed by the US DOT provides a database of previous studies for numerous TSMO strategies. The user must sort through data to find similar benefits or costs to apply, which can be time consuming.
- Results from other before and after studies

- Results from other studies with similar TSMO strategies or project elements can be useful in a quick evaluation of potential benefits and costs.

These methods are limited to available data and studies and may be more time intensive to sort through. However, these methods may be more cost-effective for smaller projects or for projects evaluating emerging TSMO strategies or TSMO strategies not available for analysis in other tools.

Mesoscopic/Dynamic Traffic Assignment

Mesoscopic/dynamic traffic assignment falls under the category of a simulation tool. This tool is one of the more complex tools and requires a higher cost and more staff training to use; however, it provides a higher level of resolution than the other tools discussed. Per Chapter 8 (Mesoscopic Analysis), a mesoscopic model is defined as:

> *A hybrid model that includes combinations or approximations of elements from both macroscopic and microscopic models. Mesoscopic models may include a routable network similar to a macroscopic model (with a supplementary origin-destination matrix), while also incorporating more detailed operational elements of the transportation network to better estimate travel time based on traffic operations similar to a microscopic model. Elements from either the macroscopic or microscopic models may be generalized or simplified.*

One piece of mesoscopic modeling is Dynamic Traffic Assignment (DTA). DTA considers traffic routes and travel times that can vary by time of day whereas the more traditional travel demand models use a static assignment of routes during a time interval. The advantage of DTA models is they come close to achieving the same detail that microsimulation models achieve while maintaining elements of macro-simulation models. DTA is a further level of effort and refinement of model assignment between the typical travel demand model and micro-simulation. Common DTA software tools used are DynusT and Dynameq.

More details on DTA including general concepts, scoping, and tool selection can be found in Chapter 8, Section 8.5.

Travel Demand Model

The Travel Demand Model is typically a system-level tool that is generally limited to the facility level. Details include basic characteristics such as number of lanes and speed limits. Travel demand models are used to compare scenarios or help screen alternatives by using origin and destination patterns, demand to capacity ratios, differences in percent volumes, and rough estimates of travel times. They are also used as input to other tools when design hour volumes are needed.

While travel demand models typically do not include the level of detail (e.g., intersection performance) or specific components/modules (e.g., intelligent transportation systems) to directly assess TSMO strategies, there may be methods for manipulating the travel demand model tool in an indirect manner that serves as a proxy for TSMO strategies. For

example, the analyst could consider increasing the capacity of a corridor in order to emulate the potential corridor benefits related to improved access management or signal control system enhancements.

Additional information regarding TDM can be found in Chapter 17 (not yet written).

Crash Modification Factors (CMFs)/Countermeasures

Crash Modification Factors and countermeasures can be used as a simple tool on its own but more often than not, is used as an input to other more detailed tools. A CMF is a multiplicative factor, that when used in conjunction with a countermeasure, provides the long-term expected number of crashes. In a benefit/cost analysis that incorporates safety, there are two sources that can be used to estimate the impact of a particular countermeasure: the CMF Clearinghouse and the All Roads Transportation Safety (ARTS) program. If available, the list through the ARTS program should be used prior to other sources because ARTS was developed for Oregon through collaboration with ODOT, the League of Oregon Cities (LOC), and the Association of Oregon Counties (AOC). Funding for crash countermeasures is also available through the ARTS program.

Chapter 4 (Safety) provides additional information regarding crash analysis. In particular, Section 4.4 provides detail on predictive crash analysis with a thorough explanation of crash modification factors in Section 4.4.2.

Regional Strategic Planning Model (RSPM)

(http://www.oregon.gov/ODOT/TD/OSTI/Pages/scenario_planning.aspx#reg)

The Regional Strategic Planning Model (RSPM, formally known as GreenSTEP) is used for strategic planning preceding an RTP or TSP goal-setting process. As such, it can be helpful in setting a vision, as it quantifies the regional benefit of several TSMO strategies, against competing non-TSMO policy actions/investments. RSPM was initially developed for state and regional greenhouse gas emissions reduction planning and helped establish MPO emissions targets. It has one of the most detailed understandings of future vehicle types and fuels, per collaboration with sister state agencies Department of Environmental Quality (DEQ) and Department of Energy (DOE). RSPM has no network to shorten run-times, but uses demand to capacity relationships and congestion approach by functional class to evaluate the impact of various freeway and arterial ITS (ramp metering, incident response, signalization, and access management) and other speed smoothing policies. Other policies addressed include Transportation Options programs (e.g., workplace TDM and individualized marketing programs). Recent applications have used a broader set of transportation and land use outcomes such as household travel costs, walk and bike travel, and delays. Estimations are done at the household level for a metropolitan planning area or larger. RSPM is being implemented in Oregon MPOs, and typically reports at a region or jurisdiction level.

Chapter 7 includes more information about scenario planning assessment and RSPM.

Traffic Signal Optimization Tools

Traffic signal optimization tools are primarily used to develop optimal signal timings for

corridors, networks, and individual intersections. These tools can incorporate items such as intersection capacity, cycle lengths, splits, and signal coordination and offset. The most common traffic signal optimization tool used in Oregon is Synchro.

Microscopic Simulation

Microscopic Simulation tools can simulate the individual movement of vehicles and pedestrians. These tools are typically complex and require the highest cost and staff training; however, they provide a high level of confidence. Two examples of microscopic simulation tools are VISSIM and Paramics.

VISSIM is a tool that involves microscopic traffic simulation for multimodal traffic and can handle congested conditions under different traffic scenarios. It is capable of handling dynamic route choice and realistic differences in driver behavior. VISSIM can analyze capacity, traffic control, signal systems and re-timing, and public transit. VISSIM can handle adaptive traffic control (such as SCATS). It has the capabilities to handle multimodal networks, including pedestrians, bicyclists, and transit. It can be linked to various emissions models as well.

Paramics is a tool that involves microscopic traffic simulation and can handle congested conditions under various traffic scenarios. Paramics can be applied on freeways, intersections, roundabouts, for ITS applications, public transportation, pedestrian modeling and environmental/emissions. Paramics can evaluate various ITS strategies, such as variable speed limits, high occupancy tolling, vehicle actuated signals, and incident management.

18.3.7 Incorporating TSMO in Planning Statements of Work

ODOT conducts many different types of planning activities: regional and local transportation system plans, corridor/facility plans, and topical or area specific refinement plans. Exhibit 18-14 lists the typical tasks performed under a planning work scope and identifies considerations for incorporating TSMO.

Exhibit 18-14: TSMO Considerations in Planning Work Scopes

Planning Tasks	TSMO Considerations
Stakeholder/Public Involvement	Broaden stakeholders to include internal and external operations staff on the project advisory committee. If a standing operations committee exists in the area, notify them of the planning process and seek their input at key points in the planning process.
Vision, Goals, and Objectives	TSMO is an element supporting the broader planning vision. Include a TSMO-related goal and supporting SMART objectives and performance measures.
Evaluation Criteria	Operational performance measures provide useful information on how well the existing transportation system is functioning. Carry forward performance measures for system efficiency, system reliability, and system options into the evaluation criteria.
Existing Plans, Policies, Regulations, and Standards	A number of regions along with the state of Oregon have completed ITS and/or TSMO plans and architectures. The OTP and OHP include TSMO policies. Incorporate these references when documenting supporting plans and policies.
Current Conditions, Deficiencies, and Transportation Needs	Capture ITS infrastructure and TSMO program activities such as TIM and TDM as part of the transportation system inventory. If available, existing ITS/TSMO plans are a resource for this information.
Solution Alternatives	The OHP 1G1 Policy requires ODOT to maintain highway performance and improve system efficiency and management before adding capacity. Include TSMO strategies as part of the solution alternatives. See Appendix18A for list of TSMO strategies.

18.4 Corridor Management

This section provides considerations and analytical procedures for incorporating TSMO into planning for corridor management. A corridor is typically considered a linear system of multimodal facilities where an existing roadway or transit facility serves as the spine. Some corridors may also include a broader travel shed with parallel facilities or connections to major activity centers or logical destinations. Corridor limits can range

from a few miles long in urban areas to tens or hundreds of miles long for state or multi-state corridors. Corridor planning typically includes a combination of modes and the modal focus can vary by corridor (e.g. freight route, high capacity transit route, limited access highway).

TSMO strategies used for corridor management are grouped into four categories in this document:

- **Arterial Management** is the use of strategies on arterial-type facilities to improve the efficiency, safety, and capacity of the facility, without increasing its size.[75]Arterial management generally applies to roadways that have signalized intersections and carry a combination of vehicles (autos, transit, and freight), pedestrians, and bicyclists.
- **Freeway Management** is the management of freeway-type facilities for safety and mobility improvement. Mobility improvement addresses congestion (recurrent and non-recurrent) in response to prevailing and predicted traffic conditions. Freeway management generally applies to roadways that have uninterrupted flow and only carry vehicles (autos, transit, and freight).
- **Demand Management** is the dynamic management of travel demand to influence traveler behavior in real-time to achieve operational objectives.
- **Integrated Corridor Management (ICM)** is an approach to managing the transportation network that encourages multi-agency coordination and combines arterial and freeway strategies to balance and manage travel demand across networks (freeway, arterial, transit, and parking). ICM plays an important role during events such as incidents, planned special events, inclement weather, and through work zones.

The first three groups are all elements of Active Transportation and Demand Management (ATDM). FHWA defines ATDM as "the dynamic management, control, and influence of travel demand, traffic demand, and traffic flow on transportation facilities."[76] FHWA's definition of ATDM includes three components: 1) Active Traffic Management, 2) Active Demand Management, and 3) Active Parking Management. In this document the active traffic management element is divided into arterial and freeway management categories, and the demand management category encompasses both the active demand management and active parking management components.

Appendix 18A includes a more detailed list of TSMO strategies, benefits, cost magnitude, and implementation factors.

Exhibit 18-15 provides a list of corridor TSMO strategies to consider based on facility type and surrounding area. In some cases, there is a clear distinction between the strategies applied to an arterial versus a freeway. However, there are many strategies that may apply to both types of facilities, such as dynamic warning signs and variable speeds. The following subsections provide an overview of each of the four categories of corridor

[75] Oregon Transportation Planning Rule, Oregon Administrative Rule (OAR) 660-012-0005
[76] Definition according to FHWA Office of Operations http://www.its.dot.gov/atdm/index.htm

TSMO management as well as analysis considerations and procedures for evaluation as appropriate.

Exhibit 18-15: TSMO Strategies to consider based on Facility Type and Area

Corridor TSMO Strategies	Facility Type*					Area*		
	Interstate	Freeways & Expressways	Ramps	Principal Arterial	Minor Arterial & Major Collector	Urbanized	Small Urban	Rural
Arterial Management (Section 18.4.1)								
Traffic signal enhancements (updates, phasing, advanced)				●	●	●	●	●
Dynamic lane use			●	●	●	●	●	●
Queue jumps (ramp meter or signal)			●	●	●	●		
Transit signal priority			●	●	●	●	❍	
Truck signal priority			●	●	●	●	❍	●
Bicycle signals				●	●	●	●	●
Automated enforcement			●	●	●	●	●	●
Added capacity for critical movements (Section 10.3.2)			●	●	●	●	●	●
Improved traffic control schemes (Section 10.3.2)			●	●	●	●	●	●
Freeway Management (Section 18.4.2)								
Variable speed control	●	●		●		●	●	●
Automated speed enforcement	●	●	●	●	●	●	●	●
Dynamic lane use control	●	●		●		●	❍	
Dynamic lane reversal	●	●		●		●	❍	❍
Managed lanes (HOT/HOV)	●	●	❍	❍		❍	❍	
Adaptive ramp metering			●			❍		
Dynamic merge control	●	●				●	●	●
Dynamic warning	●	●	●	●	●	●	●	●
Hard shoulder running	●	●				●	●	❍
Dynamic re-routing	●	●	●	●	●	●	❍	●
Dynamic truck restrictions	●	●	●	●	●	●	●	●
Demand Management Strategies (Section 18.4.3)								
Corridor monitoring	●	●	●	●	●	●	●	●
Corridor specific traveler information	●	●	●	●	●	●	●	●
Active transit management	●	●	●	●	●	●	❍	❍
Active parking management						●	❍	
Congestion pricing	●	●		●		●		
Gamification	●	●	●	●	●	●	●	●
Shared-use mobility	●	●	●	●	●	●	❍	❍
Employer based transportation demand management	●	●	●	●	●	●	❍	❍
Neighborhood based transportation demand management	●	●	●	●	●	●	❍	❍
Integrated Corridor Management (Section 18.4.4)								

Corridor TSMO Strategies	Facility Type*					Area*		
	Interstate	Freeways & Expressways	Ramps	Principal Arterial	Minor Arterial & Major Collector	Urbanized	Small Urban	Rural
Corridor management strategies above	●	●	●	●	●	●	●	●
System Management (Section 18.5)	●	●	●	●	●	●	●	●
● Strategy applies to facility ❍ Strategy MAY apply to facility								

* For facility type and area by highway and milepost, see:
http://www.oregon.gov/ODOT/TD/TDATA/rics/docs/ORStateHwysFCandNHS.pdf

18.4.1 Arterial Management

The arterial management strategies are part of a broader category of Active Traffic Management (ATM) strategies. Active Traffic Management (ATM) is "the ability to dynamically manage recurrent and non-recurrent congestion based on prevailing and predicted traffic conditions."[77] Additional information is available on FHWA's Active Traffic Management website.[78]

This document divides active traffic management into two categories: arterial management and freeway management. Arterial management focuses on facilities that have traffic signals, interrupted flow, and carry a combination of vehicles, pedestrians and bicyclists. On the other hand, freeway management focuses on facilities that mainly carry vehicles (a combination of autos, transit, and freight) and have limited access points. As shown in Exhibit 18-15, some of the freeway strategies can also apply to arterials, yet arterial strategies generally do not apply to freeways.

The arterial management strategies discussed in this section aim to improve the efficiency, safety, capacity of an arterial-type transportation facility without increasing its size.

This section focuses on seven types of arterial strategies:

- Traffic signal enhancements
- Dynamic lane use
- Queue jumps
- Transit signal priority
- Truck priority
- Bicycle signals
- Automated enforcement

[77] FHWA Office of Operations, http://ops.fhwa.dot.gov/atdm/approaches/atm.htm
[78] FHWA website: http://ops.fhwa.dot.gov/atdm/approaches/atm.htm

Traffic Signal Enhancements

These strategies can be implemented by making improvements to traffic signal timing. This may include updating the base signal timings to accommodate multi-modal users, modifying the phasing to improve efficiency, or implementing advanced signal control strategies such as adaptive signal control. The strategies also include upgrading the existing signal system infrastructure to facilitate implementation of the operational improvements.

- Base Signal Timing – Reviewing and updating the basic signal timings, such as minimum and maximum green, walk, flashing don't walk, yellow and red clearance intervals and vehicle detector settings can improve the safety and efficiency of the intersection operation. It is not uncommon for the basic signal timings to remain unchanged from the first day a signal is turned on. It is good practice to review and update the base timings on a routine basis as standards for clearance intervals and detector settings may change.

- Traffic Signal Phasing – Modifying the traffic signal phasing, such as adding a protected left turn phase, converting a protected left turn phase to protected/permissive left turn phase or installing a right turn overlap can improve the safety and efficiency of the intersection operation. Depending on the traffic volumes, changes to the phase sequence (lagging a left turn phase) may improve the efficiency of an intersection. Changes to the traffic signal phasing may require minor equipment changes to the traffic signal indications.

- Advanced Features – Implementing advanced features of the traffic signal software, including phase re-service, dynamic phase length, or ped-friendly flashing yellow arrow (FYA) can improve the safety and efficiency of an intersection. Some of the signal timing parameters may work better in free (not coordinated) operation and others may work better in coordinated operation. The advanced features should be explored if there is a unique operating condition, and not implemented everywhere, since some of the features may work against others.

- Coordinated Timings – Coordinated signal timings require a group of signals to operate on a common cycle length. Coordinated signal timings are best used on corridors where the intersections are regularly, closely spaced (within one half mile), or where platoons of vehicles do not disperse too much from one signal to the next and where there is a predominate movement that needs to be progressed between multiple intersections. A well timed corridor (or group of signals) can serve traffic efficiently using Time-of-Day coordination without the need for advanced signal timing. To get the most effective operation, the timings must meet the operational goals of the corridor (favor main street flow, balance delays on all approaches, promote transit, etc.). Typically, signals operate coordinated timing plans based on the time of day for set time periods (am peak, midday and pm peak), without much attention paid to the weekend timing plans. A simple way to improve the operation of a corridor is to evaluate the weekend operations

of the signals and implement weekend timings if needed. A common rule of thumb is for agencies to update the coordinated timings every three to five years, however using performance measurement data as a trigger allows agencies to use their resources more efficiently. Doing this will require the agency to monitor operations on a more on-going basis in order to see trends in the performance measures that need to be addressed.

- Event/Incident Timings – Event and incident timings are special timing plans that are developed to serve traffic associated with an event (sporting event/concert or adverse weather) or an incident (crash, either on the arterial being controlled or on parallel facility). The timings are developed based on assumptions from previous events and can include operating special coordinated timing plans or operating one or more intersections in free mode. Typically, the event/incident timings are manually turned on and off using a command from the central signal system, but they can also be enabled using a trigger, like volumes from a system detector or weather sensor.

- Traffic Responsive Signal Timing – Traffic Responsive (TR) signal timing operates similar to traditional coordinated timings, but instead of using the time of day, it uses volume and occupancy as the trigger to change the previously developed timing plans. For example, under traditional time-of-day operation, the p.m. peak plan starts at 4:00 p.m., but under traffic responsive, it may start at 3:30 p.m. (ex. school or work shift ends) or not at all (ex. holiday). It is best used on corridors with predictable and distinct traffic patterns (ex. heavy inbound in the a.m. and heavy outbound in the p.m.) where adjusting the start times of the existing plans is needed. Traffic responsive plan selection normally occurs in a field master or a central signal system. It uses the detection data to calculate the most appropriate timing plan and then sends a command to the local signal controllers to tell them which plan to operate. TR requires additional system detectors to be installed along the corridor and can be time consuming and complex to set up and monitor.

- Traffic Adaptive Signal Control – Traffic Adaptive signal control uses special algorithms to optimize the signal timings along a corridor. Typical adaptive systems adjust the cycle, split, and offsets every cycle to match the fluctuation in traffic. Adaptive systems show benefit at locations where the traffic conditions are unpredictable and/or volumes are high, as adaptive systems can delay the onset of oversaturation and can recover more quickly from a saturated condition. The adaptive algorithms are typically calculated in a central system and the cycle, splits and offsets for each intersection are commanded from the central system. However, some systems provide the processing power at a field “master” location along the corridor. Adaptive systems require robust vehicle detection and reliable communications between the field controllers and the master/central system. Each corridor/group of signals should be evaluated before deploying an adaptive signal system to ensure it is the best operational/management choice.

- Traffic Signal Controllers – In the state of Oregon, agencies operate two types of traffic signal controllers (with various firmware), including the Model 170 and the Model 2070. In recent years, agencies have been replacing the Model 170 controllers with Model 2070 controllers, as they provide additional operational features, extra computing power and more data storage. ODOT has recently decided to install ATC controllers at some intersections and is expected to make the ATC controller a standard in the near future. These new controllers provide even more computing power, collect more performance data, and are compatible with future connected vehicle technology. Upgrading the traffic signal controllers to the current standard 2070 or to the ATC will improve the intersection operation because of the additional operating features and computing power available.

- Central Signal System – The central signal system manages the local traffic signal timing databases, provides remote access to the local controllers, and collects/disseminates performance measurement data. A central system allows an agency to monitor the operations of their traffic signals and make adjustments if necessary, such as during an incident. Multiple agencies within a region can benefit by sharing a single central system.

- Communications – Communications between traffic signals provides the ability for the signals to talk to each other and is most beneficial for keeping the time clocks synchronized. Communications between the traffic signals and a central system allows an agency to remotely manage and monitor traffic signal operations. Reliable communications is very important when operating traffic responsive or adaptive operations, as the computing is done by the central system or by a field master with the commands being sent in real-time from the central or master location to the local controller.

- Detection – A traffic signal system needs robust detection in order to operate in the most efficient manner. Detection is necessary for all signal operations, except fixed-time control, yet it is the one thing that is often not maintained as well as it should be. Traditional vehicle detection uses inductive loops cut into the pavement. They are a very reliable form of detection, but they are susceptible to damage by poor pavement conditions or accidentally being cut. Once they are installed, there is no flexibility to move them to a different location and it is sometimes challenging to detect motorcycles and bicycles with them. Video detection is a non-intrusive form of detection as it uses cameras mounted above the pavement. Video detection can detect vehicles and bicycles and allow agencies to adjust the zones if needed. This form of detection is susceptible to false calls due to fog and shadows and can sometimes miss vehicles because of occlusion. It also has a limited range of how far it can see in advance of the intersection. Video detection requires more frequent maintenance than loop detection. Radar detection is a non-intrusive form of detection as it uses a radar detector mounted above the pavement. Radar detection can detect vehicles and bicycles and allow agencies to adjust the zones if needed. This form of detection is not susceptible to false calls due to fog and shadows, but requires different units

for advance and stop bar detection. The choice of type of detection at an intersection should be evaluated considering the physical condition of the site and the operational objectives, with the most appropriate type installed.

- Closed Circuit Television (CCTV) Cameras – CCTV cameras, in conjunction with a central traffic signal system, help an agency assess operational issues quickly from a remote location. The central signal system tells the agency what the traffic signals are doing and a CCTV camera allows the agency to see what may be causing a problem (crash, power outage, etc.). CCTV cameras help the agency to monitor signal operations if timings are changed. For example, if additional green time is added to a left turn phase, the agency can watch how the other phases operate with less green time. CCTV cameras should be installed at most major intersections to allow the agency to view traffic operations along the major corridors. CCTV cameras are also used for identifying incidents and dispatching responders.

Dynamic Lane Use

Modifying intersection approach lane uses may be done with dynamic lane use signing. For example, an intersection may have two approach lanes (left/through and through/right), but during the p.m. peak, the left turn movement is restricted. The restriction can be conveyed to the driver by using a blank-out sign that uses the time of day or a volume threshold to turn on/off. The appropriate lane assignments should be based on a traffic analysis to ensure that the intersection works well throughout the various peak periods. This type of operation requires additional signing to be installed on the signal mast arm and in advance of the intersection along with special logic programmed in the controller.

Queue Jumps

A queue jump is a special phase for an intersection approach that is only used under certain conditions. One common application of a queue jump is for transit, where, if a bus is detected at a certain location, the traffic signal will provide a special indication for the bus so it can proceed through the intersection ahead of the adjacent through traffic. A queue jump can also be used for bicycle traffic. It is an effective solution if there is an existing source of delay at the intersection. A queue jump requires that the bus has a dedicated lane and specific detection. It can work during Free and Coordinated operation, however queue jumps may not be beneficial where there are high volumes of right turning vehicles. A queue jump may also be employed at a ramp meter where transit or other high occupancy vehicles are provided a special lane to avoid the queue on the ramp. This may require additional right-of-way to implement.

Transit Signal Priority

Transit signal priority (TSP) provides additional green time to the approaches at an intersection that serve buses. TSP can be implemented on any corridor that has transit service, with more benefit going to corridors with higher number of buses and corridors that are not over capacity. Most TSP systems require that the bus be equipped with an emitter and the controller cabinet be equipped with a detector unit. This can be done

using infrared, wireless communication (such as Wi-Fi) and GPS, or connected vehicle technology. Once a bus is detected, the traffic signal will determine if and how much extra time the bus approach can be given. The time can either be a green extension (hold bus phase green longer) or an early green (bring up bus phase earlier) depending on which phase of the cycle the traffic signal is when the priority request is detected. Typically, TSP provides an additional 2-10 seconds for a bus approach, which is taken from other approaches at the intersection.

Truck Priority

Truck priority is similar to transit signal priority in that it provides additional green time to an approach where a heavy vehicle is detected. The additional green time is only provided as green extension, since the goal of truck priority is to minimize the stops (and subsequent start-ups) for heavy vehicles. Truck priority works well on corridors with a high percentage of heavy vehicles, speeds above 35 mph, on roads with no major curves, and where the traffic signals operate in free mode. The traffic signal needs to receive an input that indicates the presence and speed of a heavy vehicle. This can be accomplished via inductive loop detectors in the pavement or connected vehicle technology on the truck. Based on the data, the traffic signal will provide additional green time when a heavy vehicle is detected and it does not have enough time to enter the intersection before it turns yellow. Typically, truck priority provides an additional 5-10 seconds to the truck approach.

Bicycle Signals

Most traffic signals are capable of providing priority to multi-modal traffic including bicycles, buses, and heavy vehicles. For example, bicycles can be detected using specific detectors and the bicycle rider can be shown a special bicycle phase, separate from cars.

Automated Enforcement

Automated red light enforcement and automated speed enforcement are two somewhat controversial techniques to improve safety. Both have been shown to be effective in improving compliance with red lights or speed limits. In the correct location, where there is a history of crashes related to red-light running or speed, the technologies can be effective at reducing the crashes related to poor driver behavior. The use of these devices should be carefully weighed and used only where the results would yield a reduction in crashes. These technologies require statutory authority to implement and participation from law enforcement.

18.4.2 Freeway Management

With a focus on trip reliability, freeway management works to maximize the efficiency and effectiveness of facilities by using automation to quickly respond to conditions to influence travel behavior with respect to lane and facility choices. This section describes freeway management strategies and how they may be applied to facilities in Oregon.

Variable Speed Control
Variable speed control (aka variable speed limits, variable advisory speeds, speed harmonization, or dynamic speed limits) is a management strategy to actively manage the posted or advisory speeds at a location or throughout a corridor. On multilane facilities, speeds can also be managed for individual lanes. The speeds are adjusted in real-time to respond to roadway traffic and weather conditions and can be regulatory speed limits or advisory speeds. Variable speed control can be used virtually anywhere including rural or urban settings and can be applied to different modes of travel (autos, bikes, buses, trucks).

The common goals and objectives of agencies considering the development and deployment of variable speed control is improved safety, increased mobility, and reduced environmental impacts. Speed harmonization is a term that is used synonymously with variable speeds in urban areas with recurring congestion. Speed harmonization refers to bringing everyone's speed into "harmony" or reducing the variability between the high and low speeds. Reducing this variability improves safety by reducing starting and stopping of congested traffic and the potential number of rear end collisions. By improving safety and harmonizing speed, mobility in a corridor can be increased through higher average speeds and increased capacity. With less congestion and less starting and stopping, environmental impacts can also be reduced.

Variable speed control is typically applied to interstates, freeways, expressways, or principal arterial highways and is most commonly used to address congestion, inclement weather, or construction. Congestion applications should be considered for corridors where there is frequent queuing at bottleneck locations or a history of rear-end crashes. While congestion applications are more commonly applied to urban corridors, they can also be applied to rural corridors to address seasonal congestion. Inclement weather applications should be considered for corridors with a history of crash issues related to inclement weather (e.g. ice, snow, rain, high winds). Work zone applications can be considered for any work zone, particularly for larger projects with a longer duration where work is being done in close proximity of travel lanes. For ODOT facilities, coordinate with the ITS Unit, who developed an *Oregon Statewide Variable Speed System Concept of Operations* and can help with planning.

Input from the State Traffic Engineer, law enforcement, local jurisdictions, and elected officials should be considered in the planning process.

Automated Speed Enforcement
This strategy requires statutory authority to use and participation of law enforcement. The strategy may involve fixed mounted cameras or cameras that can be stationed at different places along the roadway. The cameras are often installed at locations where there have been a history of speeding violations and/or crashes associated with speeding. The camera records violators and issues citations that are reviewed by law enforcement officials. While this strategy can be applied on any facility, it has been found particularly effective to support variable speed control and in work zones.

Dynamic Lane Use Control
Lane use control is the dynamic control of lanes typically through opening or closing them as conditions warrant. Lanes will typically be closed due to incidents or work zones with the goal of safely merging traffic into adjoining lanes. By closing lanes due to an incident or work zone, the goal is to reduce rear end and secondary crashes. Dynamic lane control is typically applied to urban interstates, freeways, expressways, or principal arterials.

Dynamic Lane Reversal
This strategy dynamically reverses the travel direction for one or more lanes to better allocate capacity based on traffic demand. This strategy should only be considered where lane reversal can be done safely, such as a lane separated by barrier on a high-speed facility or a clearly marked lane on a low-speed facility. Dynamic lane reversal may also be considered for facilities adjacent to or near event centers where there is a large imbalance in travel directions, such as a large ingress pre-event and a large egress post-event and minimal traffic in the opposing direction.

Managed Lanes (HOT/HOV)
Managed lanes refer to travel lanes dedicated to a particular use, most commonly to high occupancy vehicle (HOV), high occupancy toll (HOT), and electronic toll lanes. HOV lanes require passenger vehicles to have a minimum number of occupants in order to use a specific lane, while HOT lanes allow single occupant vehicles to pay a toll in order to drive in a specific lane, while HOVs travel free or at a discount. Electronic toll lanes may require all vehicles using the lane to pay a toll. The pricing of HOT lanes and electronic toll lanes may vary depending on the demand (higher price when demand is higher).

HOV and HOT lanes both improve the air quality by reducing the congestion on a facility. HOT lanes have actually proven to be more efficient than traditional HOV lanes because more vehicles are able to use the reserved lane, while continuing to encourage drivers to use transit or carpool. HOT lanes produce revenue that can be used to supplement the cost of construction, maintenance and enforcement.

Adaptive Ramp Metering
Adaptive ramp metering is the dynamic turn on, turn off, and adjustment of ramp metering rates that respond to real-time traffic conditions. Ramp metering uses signals at ramps to control the rate at which vehicles are allowed to enter the facility (typically an urban interstate, freeway, or expressway). Adaptive ramp metering takes into account current roadway conditions and varies the metering rate depending on those conditions. Other features of adaptive ramp metering may include bottleneck identification, incident detection, and integration into neighboring traffic signals.

The objective of adaptive ramp metering is to prevent a high-speed, low-access network or corridor from being inundated with vehicles and causing a heavily congested network. An adaptive ramp metering system can assist in keeping all vehicles moving, by regulating the number and frequency of vehicles entering a facility.

Considerations for adaptive ramp metering include:

- Corridor wide implementation
- Density of detection
- Length of ramps

In order for adaptive ramp metering to be successful, all entrances to a corridor should be regulated by a ramp meter signal. If some entrances are not controlled by ramp meters, users may try to use those entrances instead and the system would have a harder time regulating the density of vehicles on the facility.

Having reliable detection throughout the corridor is necessary for the successful deployment of adaptive ramp metering. At a minimum, detection should be present near each on-ramp with additional detection desired near off-ramps and in sections between ramps. Detection is also needed at the ramp meters themselves and further up the ramp.

The length of a ramp can also dictate how fast or slow a ramp metering rate might be. If a ramp is not sufficiently long and a queue builds up, there is a potential for the queue to spill onto nearby local streets. If a ramp is long and the ramp metering rate is very slow, it can take a vehicle a significant amount of time to enter the facility. Balancing these two items can be a challenge.

Although dynamic ramp metering has been implemented in several corridors in Oregon, it has been controversial with the public. Implementation of this strategy needs to include a public education component to facilitate understanding of its benefits and acceptance.

Dynamic Merge Control

Dynamic merge control is also known as dynamic lane merge or dynamic early merge. Using a dynamic message sign, information on an upcoming merge and expected behavior can be displayed during congestion conditions. Dynamic merge typically closes an upstream lane that neighbors a downstream merge point. This can improve the speed in which the downstream traffic is able to merge while maintaining a higher vehicle throughout.

Typical installations are in places where there is recurrent congestion and significant merging vehicles, particularly for urban interstates, freeways, or expressways. The mainline should have sufficient capacity upstream of the merge point and may be better suited for locations where peak periods of the mainline and merging roadway are at different times.

Dynamic Warning

Dynamic warning signs notify drivers of a specific condition ahead based on real-time traffic conditions. Dynamic queue warning automatically notifies drivers of a queue of stopped or slowed vehicles ahead. Additional information such as distance to the queue and queuing lane(s) is desirable.

The objectives of dynamic queue warning are to reduce rear-end crashes and smooth

traffic flow. By notifying drivers of slowed or stopped vehicles ahead, drivers will be less likely to be surprised by the end of a queue. In addition, if a queue is caused by a crash, secondary crashes can also be reduced. Queues are determined by comparing the speed, volume, and occupancy from one detection location to another.

Dynamic queue warnings can be used in spot locations or throughout a corridor. A spot location installation may be applicable where there is recurrent queuing or throughout a corridor where recurrent congestion occurs at multiple locations.

Dynamic warning signs may also warn drivers of adverse pavement conditions based on weather sensors or about wildlife close to the roadway based on animals in the detection zone. The signs would advise drivers of the condition and recommend an action, such as a slower speed. Dynamic warning signs may be applicable on both freeways and arterials.

Hard Shoulder Running

Hard shoulder running, also known as dynamic shoulder lanes, is the use of shoulders as a travel lane or lanes. To be considered an "active" traffic management option, this strategy needs to be implemented, when conditions warrant, with the use of real-time information. Hard shoulder running can be set up for all travelers or be for special purpose only (e.g. transit only). The goal and objective of hard shoulder running is to increase capacity, improve speeds, and improve volume of a segment when conditions warrant.

If the hard shoulder is on the right side, corridors with a higher number of ingresses and egresses may not be a good candidate for hard shoulder running unless ramp tapers can provide smooth merging operations. Hard shoulder running also requires a sufficiently wide shoulder to adequately function as a lane of traffic.

Dynamic hard shoulder running is often implemented with the use of variable speed and lane use control. The lane use control signs over the shoulder provide frequent real-time reminders of the status of the hard shoulder (open or closed). The variable speed displays can reinforce any reduced speeds needed in the corridor, particularly if the shoulder lane requires a lower speed. Like with lane use control, a typical distance between over lane signs is generally in the half-mile range in the U.S.

Currently, an interpretation of Oregon statutes has determined that hard shoulder running is not legal and would require enabling legislation to apply it. For more information on use of freeway shoulders see Use of Freeway Shoulders for Travel — Guide for Planning, Evaluating, and Designing Part-Time Shoulder Use as a Traffic Management Strategy, FHWA, February, 2016.

Dynamic Re-Routing

This strategy provides alternate route information to travelers in response to increasing congestion on a corridor at bottlenecks or due to events such as incidents (on the corridor or a parallel facility). This is an emerging strategy that will likely advance further as connected vehicles advance with broadcast traveler information and dynamic mapping

features. In the meantime, traveler information systems can be used to provide dynamic re-routing information that travelers can check pre-trip or passengers can check en-route.

Dynamic Truck Restrictions
This strategy limits trucks to certain ramps, lanes, or routes based on traffic demand so that at least one lane of traffic is available exclusively for passenger traffic. The goal of this strategy is to allow passenger traffic to flow more freely without having to brake or slow down for less agile truck traffic. In turn this helps improve safety, support uniform speed, and improve traffic flow. Dynamic truck restrictions should be considered for highways with high truck volumes and major arterials and collectors that serve both freight and passenger traffic. This strategy requires enabling legislation as well as political support and support from the freight community.

18.4.3 Demand Management

Demand Management strategies dynamically manage travel demand to influence traveler behavior in real-time to achieve operational objectives such as preventing or delaying bottleneck conditions, improving safety, promoting sustainable travel modes, reducing emissions, and maximizing system efficiency. Specific demand management strategies and how they may be applied to facilities within Oregon are discussed herein. Additional information on Demand Management strategies can be found on FHWA's websites for Active Demand Management and Active Parking Management.

Corridor Monitoring
Continuous multimodal monitoring of corridors is a fundamental requirement for deploying other multimodal strategies because it provides a current snapshot of transportation conditions and can be used with archived data and predictive methods to maintain or achieve system performance. While monitoring is often done at Traffic Operations Centers for larger agencies like ODOT, it can also be done from single workstations at smaller agencies or at ODOT district or maintenance offices. The most common forms of monitoring include:

- Camera monitoring systems provide a visual means for observing traffic operations and identifying unplanned events. For interstates, freeways, and expressways, cameras are often installed at major interchanges, at regularly spaced intervals in urbanized areas, or at known trouble spots (e.g. winter conditions, geometric curvature). For arterials and collectors, cameras are often installed at traffic signals due to the availability of power, communications, and available mounting locations. When additional coverage is needed in urbanized areas, street light poles or separate camera poles are also used.
- Detection systems (e.g. radar, video, inductive loops, Bluetooth) collect a variety of data such as volume, speed, occupancy (vehicle density), and travel times. Data collected by the detection system(s) is used to produce performance measurement reports. Detection systems should be considered for all facilities. Extensive

coverage is typically needed in urbanized areas. Pedestrian and bicycle specific detection should be considered in urbanized and small urban areas.

- Transit Operations Data can be used to inform system operators about transit ridership, service routes, service frequency, current transit vehicle availability, and other data to improve the efficiency of the system. This type of data may be especially important to coordinate integrated corridor management when transit is brought into the equation.
- Third party data (e.g. INRIX, Waze) is also a good source of information for monitoring corridors. This type of data is often captured by tracking mobile phones or from crowd-sourced information.
- Automated system performance or alerts should be used and considered when acquiring new transportation management systems. For example, central signal systems can provide alerts when traffic signals go into flash or a transit management system can provide alerts when a bus route is running behind schedule.
- Predictive algorithms can be developed using archived data to generate corridor travel forecasts based on real-time data.

Corridor Specific Traveler Information

Although providing traveler information is often a system wide effort (see Section 18.5), traveler information can also be tailored to specific corridors. This is done by providing travelers with existing or predictive travel times for parallel corridors through roadside dissemination (e.g. dynamic message signs) or broadcast through other systems (e.g. mobile apps, multimodal trip planners, websites). This can help travelers decide which travel route and mode to take. For example, if both a parallel freeway and arterial are congested, the parallel bus rapid transit or light rail line may be a much faster option.

Active Transit Management

Several strategies are available for actively managing demand for transit services:

- Dynamic fare reduction can be used to reduce the fare for the transit system in a particular corridor as congestion or delay increases to encourage travelers to select transit.
- Dynamic transit capacity assignment involves reorganizing schedules or reassigning assets (e.g. buses) based on real-time and anticipated demand patterns on a particular corridor.
- On-demand transit allows travelers to make real-time requests for transit services with flexible routes and schedules.
- Transfer connection protection works to improve the reliability of transfers between a high frequency transit service (e.g. light rail) to a low frequency transit service (e.g. bus). For example, a bus departure at a transfer point may be delayed to allow passengers to make the connection from a light rail train that is running late.

Active Parking Management
Active parking management involves actively optimizing performance and utilizing parking facilities to affect travel by influencing trip timing choices, mode choice, and parking facility choice at trip ends. Active parking management strategies include:

- Dynamic overflow transit parking uses overflow parking facilities (e.g. large retail parking lots) near transit stations or park-and-ride facilities when existing parking facilities are at or near capacity. Agreements are often needed with other entities for this strategy. This strategy helps encourage transit use on corridors over automobiles.
- Dynamic parking reservation allows travelers to reserve a parking space at their destination facility on demand to ensure availability. In a corridor context, the availability of parking at a traveler's final destination may influence them to travel by automobile (alone or with other occupants) or the availability of parking at a popular transit park-and-ride near the beginning or mid-point of their trip may encourage them to take transit along the corridor instead.
- Dynamic wayfinding provides real-time parking information about space availability and location to optimize the use of parking facilities and minimize the time spent searching for parking. This strategy helps travelers choose which corridor to use.
- Dynamically priced parking uses variable parking fees based on demand and availability to influence trip timing choice and parking facility choice in an effort to balance parking supply and demand. This strategy has an impact on mode choice, which corridors travelers select, and when they travel.

These strategies are typically applied in urbanized or small urban areas but can also be used in rural areas where there is high parking demand at special event facilities such as fairgrounds or amphitheaters.

Congestion Pricing
Although not currently used in Oregon, congestion pricing is a strategy that can be used to manage demand on congested facilities by time of day or day of week. For corridors, congestion pricing is typically applied to the entire corridor, a segment of the corridor, or by certain lane(s) within the corridor. The use of variable pricing by lane, segment, time of day, or day of week influences travel demand by encouraging travelers to consider alternate corridors or travel modes during peak demand periods. Pricing can be pre-set by time of day or can be updated dynamically based on current travel conditions. In the US, congestion pricing is typically used on interstates, freeways, or expressways in urbanized areas. Internationally, many cities have designated a "cordon" around the central business district that charge for the entry of private vehicles on a time-of-day basis. Often, variable pricing is used for specific lanes during peak periods so that traffic in those lanes continues to flow for high occupancy vehicles, transit, emergency services, and those willing to pay the higher prices. In other parts of the world, such as downtown London, congestion pricing is also extended to arterials and collectors in urbanized areas. For more information on congestion pricing, see http://www.ops.fhwa.dot.gov/congestionpricing/.

Caveat: The use of congestion pricing in Oregon requires legal authority and integration with ODOT's road user charging initiatives. Also, it typically requires political and public support.

Gamification
There are numerous applications (apps) that travelers can use to earn points or even monetary rewards for delaying travel or using a route that avoids peak congested areas. This gamification process manages demand by rewarding travelers to use routes and travel times to make the transportation system as a whole more efficient.

Shared-Use Mobility
Shared-use mobility includes any transportation services that are shared among users such as traditional public transit, ridesharing, carsharing, ridesourcing, or bikesharing. Shared-use mobility services can be provided by public agencies, private entities, or through public-private partnerships. Although typically a broader system wide transportation demand management effort (see Section 18.5), shared-use mobility can also be applied to corridors. Ridesharing services can be targeted to provide carpool or vanpool options along particular corridors (typically interstates, freeways, or expressways but also for principal arterials) to provide high occupancy travel between outlying areas of a city to employment centers or between urban areas (e.g. service on I-5 between Wilsonville and Salem). In urbanized areas, shared-use mobility can be achieved on arterial and collector corridors by providing travel options such as bikesharing or parking spaces for carsharing. Visit Drive Less Connect to find links to many ride matching services currently available in Oregon.

Employer Based Transportation Demand Management
Although typically a broader system wide transportation demand management effort (see Section 18.5), employers can help influence travel demand on corridors by:

- Adjusting shift times to start and end during non-peak periods of the adjacent corridor
- Providing incentives to use modes such as transit, bike, or walking
- Providing shuttle services to provide employee transportation between the nearest transit center and the employment center

These strategies are often used in urbanized areas but can also be applied in rural areas. For example, when a large employment center is located at an interstate interchange, adjustments to shift time may reduce delay for employees and travelers at the nearby interchange.

Neighborhood Based Transportation Demand Management
Another TDM strategy may target specific neighborhoods with incentives to travel via carpools, car-shares, walking, biking, or other non-single occupancy vehicle modes.

18.4.4 Integrated Corridor Management

The vision of Integrated Corridor Management (ICM) is to optimize the movement of people and goods within the corridor, balancing travel demand across all networks. ICM requires proactive management and collaboration between partner agencies, allowing for real-time operational decisions that benefit the corridor as a whole. ICM strategies focus on balancing travel demand across networks (freeway, arterial, transit, and parking) and providing multi-agency management of events such as incidents, special events, inclement weather, and work zones[79].

The ICM approach is based on three key concepts:

1. Corridor-level focus on operations
2. Agency integration
3. Active management of corridor assets and facilities

The first concept is a corridor-level focus on operations. As described earlier in Section 18.4, a corridor is a system of multimodal facilities that link travelers to a variety of destinations and services. A corridor also includes cross-network connections that allow travelers to connect to other corridors. ICM focuses on optimizing operations within the corridor to balance travel demand as much as possible.

Integration is the second key concept of ICM and includes three levels: institutional, operational, and technical. The overarching theme of integration is sharing information and infrastructure between agencies. The path to full integration can progress in steps. Initial steps may be sharing data and information with other agencies, and eventually pave the way to sharing full communication infrastructure and central system critical to managing the transportation system.

- Institutional integration involves collaboration between agencies within and across corridor boundaries and is necessary for successful implementation of ICM. The collaboration efforts might include sharing responsibilities and traffic operation functions, dissemination of traveler information, or sharing analysis information.

- Operational integration involves implementing multi-agency management strategies across the corridor. The multi-agency management strategies often require real-time information sharing to maximize corridor capacity. For operational integration to work smoothly, there are three key factors that need to be considered:

    - Assets – all of the transportation facilities and capabilities along the corridor

[79] Note that ODOT's Mobility Procedures Manual (April 2015) provides detailed information about coordinating with the freight industry for a variety of corridor work zone conditions.

- Availability – whether or not the assets are available
- Scale of Response – whether the response needs to be conservative, medium, or aggressive

- Technical integration provides the means, such as communication links and system interfaces for agencies to collaborate and see the impact of operational decisions in real-time.

Active management of the corridor assets and facilities is the third concept of ICM. With active management, an action is implemented, the results are monitored and assessed, then additional actions are evaluated and recommended, and (if necessary) another action is implemented. This active management cycle is continuous. This process can be fully automated or developed to include human input at key decision points.

Once all of these concepts are adopted and in place, corridor management can be optimized during planned and unplanned events. To understand how all these pieces might come together, take an example of a major freeway blocking event. With this scenario ICM could be used to inform drivers via variable message signs or personal devices to shift to a different route. Active traffic management strategies can be implemented or modified and ramp metering rates can be adjusted to facilitate traffic movement to avoid the incident. ICM could be used to help inform emergency responders how best to reach the scene, as well as adjusting signal timing on arterials handling an unexpected spike in traffic. If the event is severe enough, drivers can even be advised to use transit, and transit partners can increase transit service temporarily.

18.4.5 Analysis Procedures

This section provides analysis procedures for evaluating TSMO strategies at the corridor level using:

- Tool for Operations Benefit Cost Analysis (TOPS-BC)
- Crash Modification Factors (CMFs) – also see Chapter 4 in APM Version 2
- Dynamic Traffic Assignment (DTA)

Each tool includes discussion on steps, input parameters and settings, output, results interpretation and reporting, sensitivities, and caveats and cautions.

In addition to the tools discussed in depth in this chapter, there are several additional analysis tools that can be used to evaluate TSMO strategies. Synchro and SimTraffic are most appropriate for optimizing traffic signals. VISSIM and Paramics are more powerful microsimulation tools that can be used to evaluate many types of TSMO strategies including but not limited to adaptive signal systems, ramp meters, transit signal priority, variable speed limits, and hard shoulder running. Chapter 8 of the APM Version 1 provides information on how to use these tools.

Tool for Operations Benefit Cost Analysis

The Tool for Operations Benefit Cost Analysis (TOPS-BC) was created by the FHWA Office of Operations as a sketch-planning analysis tool for TSMO related strategies. It is meant to provide a preliminary screening and initial prioritization of TSMO strategies and replaces the ITS Deployment Analysis System (IDAS). As described in Section 18.3 the TOPS-BC tool provides four key functions:

1. Allows users to look up the expected range of TSMO strategy impacts based on a database of observed impacts in other areas nationally and internationally
2. Provides guidance and a selection tool for users to identify appropriate benefit/cost methods and tools based on the input needs of their analysis
3. Provides the ability to estimate life-cycle costs of a wide range of TSMO strategies
4. Allows for the estimation of benefits using a spreadsheet-based sketch-planning approach and the comparison with estimated strategy costs.

As a sketch planning level tool, TOPS-BC allows users to quickly understand typical benefits for a range of TSMO strategies and then estimate the benefit-cost ratio of those TSMO strategies. The tool also provides a suggested list of analysis tools for TSMO strategies depending on user-selected criteria such as: the level of confidence required, which TSMO strategies are being investigated, key measures of effectiveness, and a few other filters.

The tool exists as a Microsoft Excel spreadsheet with several tabs and color coded cells that clearly identify where the user needs to provide information. Before getting into a detailed description of TOPS-BC, it is worthy to note that since the tool is an Excel spreadsheet, the user does have the ability to modify it as needed. The Excel file for TOPS-BC can be found here:
http://www.ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm

Exhibit 18-16 provides a list of the TSMO strategies included in the TOPS-BC tool, and whether typical impacts/benefits are provided for the strategy, as well as more detailed tabs to calculate costs and benefits.

Exhibit 18-16: TSMO Strategies Included in TOPS-BC

TSMO Category	TSMO Strategy	Typical Impacts	Cost	Benefit
Traveler Information	Dynamic Message Signs (DMS)	Yes	Yes	Yes
	Highway Advisory Radio (HAR)	Yes	Yes	Yes
	Pre-Trip Traveler Information	Yes	Yes	Yes
	Web/Internet Multi-Modal Traveler Info	Yes	No	No
	In Vehicle – traveler info or route guidance	Yes	No	No
Traffic Signal Coordination Systems	Preset Timing	Yes	Yes	Yes
	Traffic Actuated	Yes	Yes	Yes
	Central Control	Yes	Yes	Yes
	Transit Signal Priority	Yes	Yes	No
	Emergency Signal Priority	Yes	No	No
Ramp Metering Systems	Central Control	Yes	Yes	Yes
	Traffic Actuated	Yes	Yes	Yes
	Preset Timing	Yes	Yes	Yes
Incident Management	Traffic Incident Management (general)	Yes	Yes	Yes
	Incident Detection/Verification	Yes	Yes	No
	Incident Response/Management	Yes	Yes	No
	Incident Detection and Response	Yes	Yes	No
	Freeway Service Patrols	Yes	Yes	No
Advanced Traffic Demand Management (ATDM)	Speed Harmonization	No	Yes	Yes
	Employer Based Traveler Demand Management	No	Yes	No
	Hard Shoulder Running	Yes	Yes	Yes
	High Occupancy Toll (HOT) Lanes	Yes	Yes	Yes
	Road Weather Management	Yes	Yes	Yes
	Work Zone	Yes	Yes	Yes
	Advanced Public Transit Systems	Yes	No	No
	Congestion Pricing (HOT lanes and variable tolls)	Yes	No	No
Public Transit	Fixed Route Transit (various features)	Yes	No	No
	Paratransit (various features)	Yes	No	No
Supporting Strategies	Traffic Management Center	No	Yes	No
	Loop Detection	No	Yes	No
	CCTV Cameras	No	Yes	No

The cost and benefit components of TOPS-BC each calculate costs and benefits on an annual basis, and provide an overall benefit/cost ratio for the strategy.

TOPS-BC calculates an annualized cost for each strategy by incorporating the useful life of the equipment, the replacement cost, and the annual operations and maintenance cost. The net present value of implementing the strategy is also provided, and while default values for the discount rate and time horizon are provided, the user can change those values.

The cost components for each strategy are broken down into two categories: the one-time costs to create the backbone structure for the strategy such as software and system integration; and the incremental cost of each additional installation such as additional loops, weather stations, and dynamic message signs. Default costs are included in the

spreadsheet for all of the cost components. The user simply needs to enter the number of infrastructure deployments (typically one), and the number of incremental deployments.

If better cost data is available, the user can easily modify the spreadsheet with project specific costs or add components to the spreadsheet. One cost component that is not captured in the cost estimating tool is right-of-way acquisition, which should not be ignored.

Exhibit 18-17 provides an example of how TOPS-BC calculates the cost of dynamic message signs. Again, the tool provides default unit costs for capital equipment and operations and maintenance annual costs, as well as the useful life of the equipment. These values can all be changed if the user has more precise information relevant to the specific project. However, for a quick planning level cost analysis, the user simply needs to provide information in the green cells:

- The number of infrastructure deployments (typically one as is the case in this example)
- The number of incremental deployments, shown as five in this example
- The year of deployment.

Based on this example, the average annual cost to implement and maintain this strategy over a 25 year lifespan is $88,400.

Exhibit 18-17: Example Cost Calculation of Dynamic Message Signs

FHWA Tool for Operations Benefit/Cost (TOPS-BC): Version 1.1

PURPOSE: Estimate Lifecycle Costs of TSM&O Strategies

WORK AREA 1 - ESTIMATE AVERAGE ANNUAL COST

Traveler Information: DMS

Equipment	Useful Life	Capital / Replacement Costs (Total)	O&M Costs (Annual)	Annualized Costs
Basic Infrastructure Equipment				
TMC Hardware for Information Dissemination	5	$ 7,500	$ 375	$ 1,875
TMC Software for Information Dissemination	5	$ 20,000	$ 1,000	$ 5,000
TMC System Integration	20	$ 100,000	$ 5,000	$ 10,000
TOTAL Infrastructure Cost		$ 127,500	$ 6,375	$ 16,875
Incremental Deployment Equipment (Per Sign Location)				
Communication Line	25	$ 750	$ 900	$ 930
Variable Message Sign	25	$ 92,500	$ 4,400	$ 8,100
Variable Message Sign Tower	25	$ 125,000	$ 275	$ 5,275
TOTAL Incremental Cost		$ 218,250	$ 5,575	$ 14,305
INPUT Enter Number of Infrastructure Deployments	1			**$ 16,875**
INPUT Enter Number of Incremental Deployments	5			**$ 71,525**
INPUT Enter Year of Deployment	2016			
Average Annual Cost				**$ 88,400**

The annual benefits calculated by TOPS-BC focus on travel time savings for both recurring and non-recurring congestion, energy/fuel savings, and savings due to reduced crashes. A tab marked "Parameters" includes all of the assumptions used to calculate the benefits such as the cost of fuel, fuel economy of autos and trucks, the cost of hourly travel for autos and trucks, the typical percent of trucks on the facility, the cost of crashes by severity, typical emissions, typical crash rates by facilities, speed-flow relationships, and typical incident delay factors. Exhibit 18-18 shows a section of the parameters tab. If local information is known, in particular the percent of trucks on the facility and crash rates on the facility by severity, those should be modified to provide a more accurate benefits assessment. However, if local factors are not known, the default values make the tool ready to use for an approximation of the benefit for the desired TSMO countermeasure.

Exhibit 18-18: Parameter Tab in TOPS-BC

Benefit Estimation Parameters

General Parameters

Year of Dollars Displayed	
Year of Dollar Display	2014
Inflation Rate	3%
Adjustment Factor	1.13
Annualization Factor	
Number of Periods per Year	250
Net Present Value Calculation	
Default Time Horizon (Years)	20
Traffic Mix	
Percentage Trucks	10%
Percentage "On-the-Clock" Travel Purpose (Autos)	20%
Average Auto Occupancy	1.67
Discount Rate	
Discount Rate (for 20 year analysis)	7.0%
Analysis Time Horizon	
Years	20

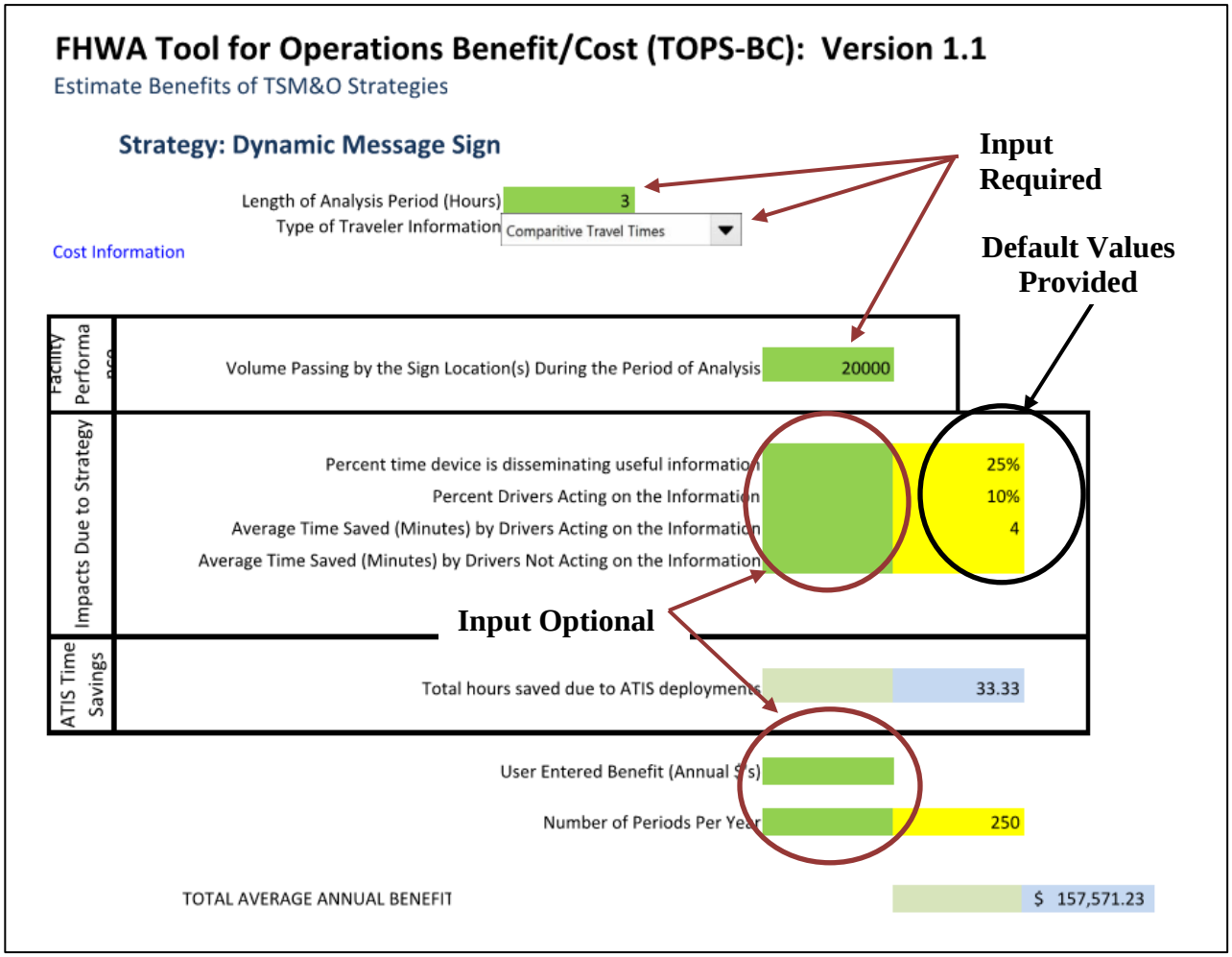
Benefit Valuations

Recurring Travel Time (per hour)		
"On the Clock" Travel Time	$	31.51
Other Auto Travel Time	$	15.76
Truck Travel Time	$	31.51
Non-Recurring Travel Time (per hour)		
"On the Clock" Travel Time	$	31.51
Other Auto Travel Time	$	15.76
Truck Travel Time	$	31.51
Crashes (per occurrence)		
Fatality	$	10,129,579
Injury	$	75,409
Property Damage Only (PDO)	$	2,589
Fuel Use		
Per Gallon (Excluding Taxes)	$	4.13
Non-fuel Operating Costs (per VMT)		
Auto		0.25
Truck		0.37
Emission Cost (per ton)		
CO	$	79
CO2	$	42
NOx	$	18,346
PM10	$	148,342
VOC	$	1,283
Noise (per VMT)		
Auto	$	0.0012
Truck	$	0.0371

Similar to the cost component in this tool, each strategy has its own tab to calculate benefits. Again, color coded cells are used to easily identify where input is required. Green cells indicate user defined input; however, not all green cells require user input. Often a default value will be used, as is the case when a yellow (default) cell is adjacent to a green one. In the Exhibit 18-19, there is also a green cell at the bottom that can be used to add additional benefits not represented by the TOPS-BC sheet, but input there is not required. For the dynamic message sign shown in Exhibit 18-16, the user is required to provide three pieces of information:

- Length of the analysis period
- Type of traveler information (three options are provided on a pull down menu). In the example shown below the “Comparative Travel Times” option is selected. The other two options include “Congestion Warning” and “Alternative Route Recommendation”
- Traffic volume passing the sign location(s) during the period of analysis

Exhibit 18-19: Example of the benefits calculated for dynamic message signs



There are additional categories where default values are provided or the user can override those values when location specific information is known. For example, in Exhibit 18-19, default values are provided in the yellow cells for four items. The user can input their own values in the adjacent green cells if more precise information is known, or opt to use the default values.

Using the information from the benefit and cost tabs, the user can easily create a benefit-cost ratio since both elements are provided in terms of an annual cost and annual benefit. Based on the DMS example, the benefit-cost ratio is 1.78.

In addition to the benefit tabs for each strategy, the tool provides a "generic link based" analysis tab that can be used to enter benefits related to a TSMO strategy not specifically identified, as shown in Exhibit 18-20. This tab allows the user to customize a benefits calculation that may not fit precisely into any of the other categories. In this tab, the user must input information about the facility characteristics, and expected impacts of the strategy such as changes in capacity, crash rates, delay, speed, and energy.

Exhibit 18-20: Link Based Benefits Tab

FHWA Tool for Operations Benefit/Cost (TOPS-BC): Version 1.1

Estimate Benefits of TSM&O Strategies

Strategy: Generic Link Analysis

Length of Analysis Period (Hours) 3

Facility Characteristics

Link Facility Type: Urban Freeway

		Baseline Override	Baseline	Improvement Override	Improvement	Change
Link Length (Miles)	1					
Total Number of Lanes	2		2		2	0
Link Capacity (All Lanes - Per Period)	13200		13200		13200	0
Free Flow Speed (MPH)	55					

Facility Performance

		Baseline Override	Baseline	Improvement Override	Improvement	Change
Link Volume (Per Period)						
Congested Speed			54.326		54.326	0.000
Vehicles Miles Traveled (VMT)			0.0000		0.0000	0.0000
V/C			0.0000		0.0000	0.0000
Vehicle Hours of Travel			0.0000		0.0000	0.0000
Incident Related Delay (hours) per vehicle per mile			0		0	0
Number of **Fatality** Crashes			0.00000E+00		0.00000E+00	0.00000E+00
Number of **Injury** Crashes			0.00000E+00		0.00000E+00	0.00000E+00
Number of **Property Damage Only** Crashes			0.00000E+00		0.00000E+00	0.00000E+00
Fuel consumption (Gallons)			0.0000		0.0000	0.0000

Impacts Due to Strategy

Facility improvement models	
Change in Capacity (%)	0%
Change in Speed (%)	0%
Change in # of Lanes	0
Reduction in Crash ***Rate*** (%)	0%
Reduction in Crash ***Duration*** (%)	0%
Reduction in Fuel Use (%)	0%
Traveler information models	
Percent time device is disseminating useful information	0%
Percent drivers using information	0%
Minutes saved by drivers saving time	0

Travel Time

Average Person Hours of Travel Saved per Period		0.0000
$ Value of Person Hour (per hour) "On-the-Clock" Auto	$ 31.51	
$ Value of Person Hour (per hour) Other Auto	$ 15.76	
$ Value of Vehicle Hour (per hour) Truck	$ 31.51	
Total Recurring Travel Time Benefit per Period		$ -

ATIS Tim

Total hours saved due to ATIS deployments		0.00

Travel Time Savings: Non-Recurring Delay

Average Total Person Hours of Non-Recurring Delay Saved per Period		0.0000
$ Value of Person Hour (per hour of ***Delay***) "On-the-Clock" Auto	$ 31.51	
$ Value of Person Hour (per hour of ***Delay***) Other Auto	$ 15.76	
$ Value of Vehicle Hour (per hour of ***Delay***) Truck	$ 31.51	
Total Non-Recurring Delay Benefit per Period		$ -

Energy

Average cost per gallon of fuel (excluding taxes)	$ 4.13	
Total Fuel Savings Benefit		$ -

Safety

$ Value of a Fatality Crash	$ 10,129,579	
$ Value of a Injury Crash	$ 75,409	
$ Value of a Property Damage Crash	$ 2,589	
Total Modeled Crash Related Benefit per Period		$ -

User Entered Benefit (Annual $'s)		
Number of Analysis Periods per Year	250	
TOTAL AVERAGE ANNUAL BENEFIT		$ -

The TOPS-BC tool also provides a summary tab that allows the user to select some or all of the strategies for a total benefit-cost summary.

For more information and access to the TOPS BC tool, refer to FHWA TOPS BC website.[80]

Crash Modification Factors

Crash modification factors (CMFs) are used to determine the effect a specific countermeasure will have on future crashes at a given location or along a corridor. In terms of TSMO related strategies, CMFs apply directly to the objectives-driven, performance-based approach, by providing the likely quantifiable change in crashes. Section 18.3 introduces CMFs and Chapter 4 also goes into great detail on using CMFs, especially related to predictive crash analysis.

In most cases the CMF targets a specific type of crash, severity, or type of facility. When calculating benefits for a strategy at a specific location, it is important to ensure that the CMF is applied to those same types of crashes and severity categories. For example, if a countermeasure has a CMF that reduces fatal crashes by 20 percent, and the location where it is being applied had an annual average of five fatal crashes and 15 non-fatal injury crashes, the benefit from that CMF would be the reduction of one fatal crash per year. That CMF would not apply to the non-fatal crashes.

In general when two countermeasures are being applied to a location, the CMFs are not additive. For example, if both variable speeds and ramp metering are installed along a freeway segment, you should use either the CMF related to variable speeds or the CMF related to ramp meters, but not both. The only time you might use two (or more) CMFs for combined countermeasures are when the CMFs each target different types of crashes or severity of crashes at a given location. However, even then, one should use judgement to minimize any sort of exaggerated additive benefit from using more than one CMF.

Dynamic Traffic Assignment

While this section provides an overview of DTA relative to corridor management, APM Chapter 8.5 provides a broader overview of DTA concepts and tools, as well as publication by the Transportation Research Board[81].

DTA models can provide a tool for measuring corridor management within the context of the broader (subarea or regional) travel network. Many attributes or variables in DTA models provide an enhanced ability to measure operational impacts at the corridor level. While such impacts could also be assessed in microsimulation models, such models do not provide the routable nature of “trips” present in a DTA network (which are typically replaced with pre-defined intersection-level turn movements). Further, microsimulation

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[80] TOPS-BC website: http://www.ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm

[81] *TRB Transportation Research E-Circular E-C153: Dynamic Traffic Assignment: A Primer*, Transportation Research Board, Washington DC, June, 2011. http://www.trb.org/Publications/Blurbs/165620.aspx

models typically require more effort to prepare than DTA models (for a given size network).

While there are many differences between different DTA platforms, the following general characteristics are common:

- Time-dependent paths where the path through the network is influenced by travel times that vary depending on when travelers arrive at a given network link, as opposed to assuming that travel times are constant throughout the period being simulated.
- Travel routes typically change at shorter intervals than static models (typically minutes instead of hours).
- Network congestion estimates, which are often based on traffic operations, are typically more detailed than a static model to account for travel time difference between routes.
- Vehicles queue on the network and are not forced through over-capacity conditions due to a timer interval constraint. Thus some demand may remain unserved during the analysis period.
- Individual vehicle "simulation" (whether visualized or not) is generally present to account for vehicle interaction and operational impacts.
- Like static assignment, multiclass assignment (including trucks) can be captured in DTA tools, which allow for different path sets and attributes among classes.
- Transit elements are included in varying degrees based on each DTA tool, but may include the ability to include service information including routes, stop locations, and schedules. Next generation DTA tools are starting to model individual transit persons as well.

A key differentiator among DTA models is the overall fidelity and detail for which traffic flows are captured along a road. The two types of models are referred to as "link-based" and "lane-based:"

- Link-Based Models – Traffic flow along a roadway is analyzed macroscopically, where the total number of lanes is considered as an overall link capacity. Differences among individual lanes (including the amount of traffic demand for an individual lane), interactions among individual vehicles, and friction related to movement and lane changing are not directly modeled. Examples: Visum Dynamic User Equilibrium (DUE), DTALite/NeXTA, and DynusT.

- Lane-Based Models – Traffic flow along a roadway is analyzed for each lane, using car-following algorithms that account for interactions among vehicles and flow differences in each lane. Storage of vehicles related to turn bay lengths and other differences between lanes along a given link may influence operations at the adjacent node/junctions/intersections. Examples: Dynameq and Vissim DTA.

In general, lane-based DTA platforms will provide additional detail needed to evaluate corridor operations, including the following considerations:

- Intersection control (approach geometry and signal timing)

- Transit stop treatment

- Lane-changing friction caused by weaving between intersections or access density
- Time of day lane management (such as reversible lanes or closures)
- Bottleneck impacts can be better captured with the additional operational detail

18.5 System Management

This section provides an overview, considerations, and analytical procedures for a collection of TSMO strategies that are programmatic and applied systemically. Whereas corridor management focuses on TSMO strategies applied to a specific facility or set of parallel facilities, system management addresses programs that are implemented across the transportation system in a given geography (i.e. city, county, regional or state). This section discusses seven system management program areas including:

- **Traffic Incident Management** is the practice of coordinating resources across partner agencies and the private sector to quickly detect, respond to, and clear traffic incidents to reduce impacts on safety and congestion.
- **Emergency Operations** is the planned, coordinated response to man-made or natural events causing or threatening injury or loss of life, property damage, human suffering, or financial loss.
- **Road Weather Operations** is the use of strategies to minimize or eliminate the impacts of weather events such as rain, snow, high winds, or flooding on safe and reliable travel.
- **Work Zone Management** is the practice of managing traffic impacts during construction to maximize traveler and worker safety, minimize traffic delay, maintain access for adjacent land uses, and support timely completion of construction.
- **Planned Special Event Management** is the advanced planning and coordination to manage travel before, during and after an event.
- **Traveler Information** includes strategies to deliver pre-trip and en-route information about travel options and conditions.
- **Transportation Demand Management** is the policies and strategies aimed at enhancing travel opportunities and choices that make more efficient use of the transportation system.
- **Connected and Automated Vehicles** is the emerging technology in vehicles that will enable the communication between vehicles, infrastructure and mobile devices to make travel safer and more efficient.

18.5.1 Traffic Incident Management

Traffic Incident Management (TIM) is the practice of planned and coordinated detection, response, and clearance of traffic incidents. TIM is a multi-disciplinary effort among incident responders to manage and clear traffic incidents as quickly as possible while maximizing responder safety and minimizing traffic impacts during the incident. Exhibit

18-21 lists several examples of hazardous traffic incident events. Traffic incidents are said to account for up to one-quarter of congestion on US roadways[82]. Swift clearance of incidents has two main benefits: safety and system efficiency. Clearing an incident as quickly as possible limits the amount of time incident responders and travelers are exposed to dangerous conditions, decreases the chances of a secondary crash, and more quickly restores the roadway to normal capacity.

Exhibit 18-21: Examples of Hazardous Traffic Incident Events

Abandoned Vehicle – Hazard	Downed Power Lines	Pedestrian in Roadway
Animal on Roadway	Fatal Crash	Pothole
Animal Struck – Hazard	Hazard Tow (minor)	Rock Fall
Closure	Hazardous Debris	RR Crossing Equipment Failure
Crash	Hazardous Tree/Vegetation	Signal Not Working
Crash Investigation	Hazmat Spill (minor)	Spilled Load
Damaged ODOT Property	High Water	Vehicle Fire
Disabled Vehicle – Hazard	Obstruction on Roadway	

Oregon adopted its first TIM Strategic Plan in 2011 and recently completed a 2015 update[83]. Oregon's TIM Strategic Plan identifies and prioritizes actions to implement statewide over the next five years. The updated plan identifies over sixty actions in the areas of technology integration, agency and stakeholder collaboration, public outreach, policy and regulatory, system evaluation, and responder training.

Successful TIM programs and strategies rely on cooperation and coordination across a broad range of partners. The Oregon TIM Strategic Plan identifies over twenty stakeholders. A multi-agency approach ensures that all response agencies are acting toward a common goal while understanding each partner's unique roles and responsibilities.

Traffic incidents can severely reduce the capacity of roadways, even when incidents occur in the shoulder area. Exhibit 18-22demonstrates the loss of freeway capacity due to lane blocking incidents. For example, on a two-lane freeway if one lane is blocked, the freeway is limited to just 35% of its normal capacity (not 50% as one might linearly assume).

[82] http://ntimc.transportation.org/Documents/Benefits11-07-06.pdf

[83] Oregon Traffic Incident Management Strategic Plan. Prepared by DKS Associates, in cooperation with ODOT and Oregon State Police (OSP). 2015. Web link: *http://www.oregon.gov/ODOT/HWY/ITS/Pages/Traffic-Incident-Management.aspx*

Exhibit 18-22: Proportion of Freeway Segment Capacity Available Under Incident Conditions

Number of Lanes (One Direction)	Shoulder Disablement	Shoulder Accident	One Lane Blocked	Two Lanes Blocked	Three Lanes Blocked
2	95%	81%	35%	0%	N/A
3	99%	83%	49%	17%	0%
4	99%	85%	58%	25%	13%
5	99%	87%	65%	40%	20%

Source: *Highway Capacity Manual 2010*, Exhibit 10-17

When considering which strategies are most appropriate for a given area, there are numerous factors to consider. The following list documents a number of the key factors including:

- Crash data (see Chapter 4 for safety and crash analysis procedures)
- Traffic volumes
- Geographic context
- Facility type
- Existing capital infrastructure
- Existing ITS infrastructure
- Proximity to detour routes
- Available resources and resource sharing between agencies
- Status of integrated corridor management

Common Traffic Incident Management Strategies

The following list includes common traffic incident management strategies currently in place in Oregon. For a complete list of TIM Strategies Oregon is pursuing, Oregon's TIM Strategic Plan should be referenced.

- Safety Service Patrols arrive at the scene and provide preliminary traffic control, assist the motorist to the side of the road, or other safety measures to improve safety. Oregon has a total of 23 Dedicated Incident Responders that cover key state roadways in regions 1, 2, 3, and 4. The service patrol hours of operation vary by district and may also vary seasonally.

- Driver Removal Laws require drivers to remove their vehicles out of travel lanes after a traffic incident if there are no serious injuries or fatalities. Drivers can then exchange information in a safe location and wait for law enforcement assistance. Oregon's Move It Law requires drivers involved in an incident to remove their vehicle from the travel lanes as long as there are no serious injuries.

- Authority Removal Laws allow a pre-designated set of public agencies to remove damage or disables vehicles (and/or spilled cargo) from the roadway that is safety concern for travelers. Typically, these laws include liability protection for the designated agencies. Oregon's Authority Removal Law allows law enforcement to remove vehicles or debris so the incident is not blocking traffic.

- Move Over Laws require drivers approaching a scene where incident responders are present to either change lanes or reduce speeds. The exact requirements and penalties vary from state to state. In Oregon, the current law requires drivers to either move to a lane not adjacent to that of the response vehicle, or, if changing lanes is not possible, reduce the speed to five miles per hour under the speed limit. Note that in Oregon's TIM Strategic Plan, there is an action to determine whether the Oregon law should be stricter (requiring a larger speed reduction), and if so, to begin the required legislative process.

- Shared Quick Clearance Goals sets a specific clearance time target that the incident must be cleared from the roadway. Oregon legislature established a 90-minute quick clearance goal for all incidents in 2013.

- Pre-established Towing Service Agreements set the requirements for tow companies to meet in order to be on a tow rotation list. When a tow is needed for a traffic incident, these agreements allow the agency to easily contact the appropriate tow company using a central point of contact.

  In Oregon, the Oregon State Police (OSP) set the requirements tow companies must meet to be on the tow rotation list. When an incident occurs, either ODOT or OSP will initiate a tow request if necessary. The tow company called to the scene depends on which agency initiates the request.

  The Portland region is unique in regard to towing regulations in the state. In the Portland region, several agencies coordinate to allow for a central point of contact when an incident requires a tow. Those agencies include Portland Police, Multnomah County, City of Portland, TriMet, and ODOT. The vetting to get on the Portland tow list is different than the statewide list, so the list of tow companies is different, although some tow companies may be on both lists. Creating a formal process that unites all transportation agencies under a single Tow Board in the Portland area allows for a forum to present and implement new towing strategies much easier than other areas in the state.

- Incentivized Towing offers a financial incentive for tow companies to clear an incident in an allotted time period, and can institute a penalty if the tow company takes longer than that time period. Oregon does not currently have any incentivized towing contracts in place.

- Instant Towing or Staged Towing Contracts initiate a tow request as soon as an incident is reported. If it turns out the tow is not necessary, the tow company receives a "no service" fee. Staged towing strategically stations tow trucks near areas of frequent accidents, and tow companies are paid for the full time they are stationed, regardless of whether they are actually called to a tow incident.

  In Oregon, the Portland region participates in Instant Towing year round, and during winter events the Portland region has Staged Towing contracts where tow companies locate trucks at specific pre-determined locations and are ready as incidents occur. An action in Oregon's TIM Strategic Plan is to identify if there are other regions in the state that could benefit from tow contract plans.

- Dispatch Co-location can improve communication between response agencies and transportation agencies.

- TIM Task-Force is an organization of first responder agencies that convene on a regular basis to discuss TIM challenges, procedures, resources, and other TIM areas to improve upon. In Oregon, there is a statewide TIM Task Force, and TIM teams that meet regularly in the Portland area, Rogue Valley area, and Central Oregon area, as well as an annual statewide winter operations meeting. Oregon's TIM Strategic Plan identifies other regions along the I-84 and I-5 corridors where additional TIM Teams may be beneficial.

- Strategic Highway Research Program (SHRP2) Training created a coordinated, multi-disciplinary training program for all emergency responders, which helps put all incident responders on the same page, leading to a safer, faster, integrated responder team.

- After Action Reviews are incident debriefing sessions where all involved response agencies discuss the incident and determine what worked well and what can be improved.

After TIM projects are selected and implemented, monitoring TIM performance measures is critical for agencies to demonstrate accountability and program effectiveness in order to support future TIM planning.

FHWA identified three national TIM performance measures:

- Roadway clearance time – the amount of time between the first recordable awareness of the incident by a responsible agency to the time that all lanes are available for traffic flow

- Incident Clearance time – the amount of time between the first recordable awareness of the incident by a responsible agency to the time that all responders have left the scene
- Number of secondary incidents – the number of unplanned incidents beginning with the time of detection of the primary incident where an incident occurs as a result of the original incident either within the incident scene or within the queue in either direction.

Oregon currently collects and monitors the first two performance measures, as well as roadway closure time and the number of responders trained in the National TIM training program. Oregon legislature set the current goal for incident clearance – clear 100 percent of all lane-blocking crashes within 90 minutes. Tracking the number of secondary incidents is marked as a high priority action in the 2015 Oregon TIM Strategic Plan. Developing a method to track incident responder fatalities and struck-bys is also noted in the plan.

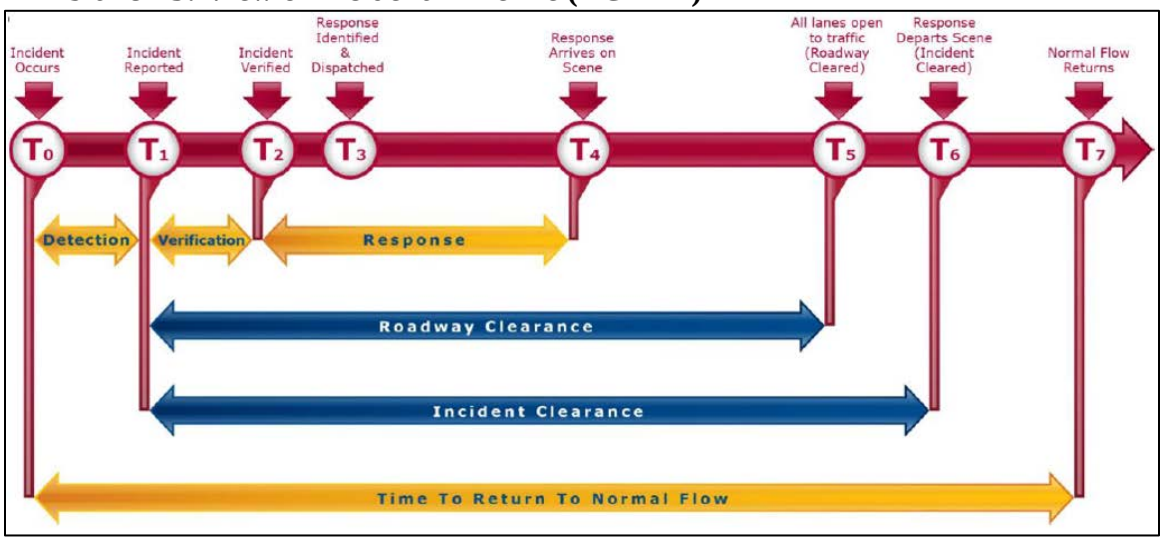
The National Cooperative Highway Research Program (NCHRP) advanced the TIM performance measure element and recently created a website to help guide performance measurement related to TIM: http://nchrptimpm.timnetwork.org/. The purpose of the website is to provide guidance on consistent use of TIM performance measures and to support the overall efforts of TIM program assessment. NCHRP website goes beyond the three national TIM performance measures by recommending other key performance measures, listing common sources of TIM data, and identifying challenges in collecting and analyzing TIM data. The NCHRP website also provides recommendations for developing TIM databases and model scripts.

As shown in Exhibit 18-23, NCHRP recommends tracking six key time intervals during incident response:

- Detection time
- Verification time
- Response time
- Roadway clearance time (also recommended by FHWA)
- Incident clearance time (also recommended by FHWA)
- Time to return flow to normal

A seventh time interval not captured by the NCHRP timeline but worth considering, is the time for upstream platoons caused by the incident to dissipate. In some cases, the flow at the scene of the incident may return to normal while long platoons are still present upstream.

Exhibit 18-23: View of Incident Timeline (NCHRP)



NCHRP highlights other performance measures to consider including: number of secondary incidents involving first responders, percentage of fatal crashes that are secondary, queue lengths, travel delay, service patrol statistics, and several others. Oregon already tracks incident data involving the crash location, severity, fatalities, type, involved vehicles, and others information captured in the crash database.

For incidents, the following three databases provide information: Transportation Data Section (TDS) Crash Reports, Highway Traffic Operations Center System (HTOCS), and Highway Travel Conditions Information System (HTCIS). The information within these systems includes:

- TDS Crash Reports – This database is compiled from individual driver and police crash reports submitted to ODOT. The reports in this crash database include information about the crash (such as location, time, type, and severity), information about the vehicle (such as ownership, type of vehicle, and vehicle movement), and information about the participants (such as age, sex, injury severity, and drug or alcohol use).
- HTOCS Events and Unit Status – This database includes most of the information about each incident such as time, location, primary unit in charge, description of incident, and response result. It also contains status timestamps for each unit (i.e., person) as they are notified and respond to incidents.
- HTCIS Traveler Information – This database includes the status updates that are shared with the public on the ODOT TripCheck website, through 511, and ODOT's Traveler Information Portal (TTIP), which allows external sources to access ODOT's data for redistribution. It includes which lanes are affected and what the expected impact is to travelers (i.e., delay experienced). Each incident usually has multiple status updates throughout the duration of the incident. This

database also includes weather related information when available (atmospheric and the resulting road conditions).

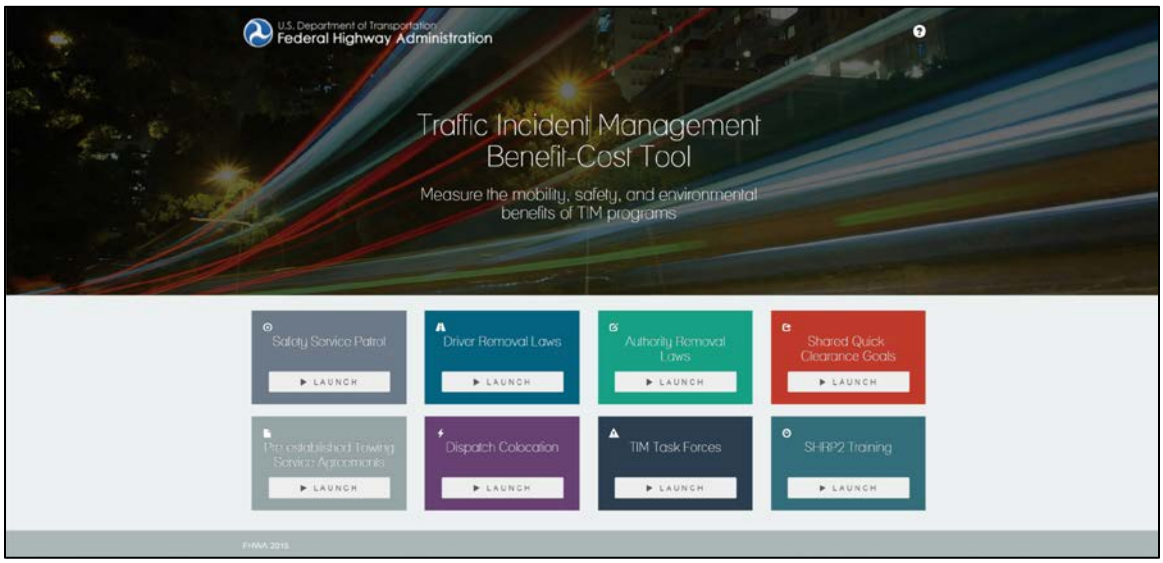
Traffic Incident Management Analysis Tools

The USDOT ITS Knowledge Resources website, described in Section 18.3.6, is a useful tool for identifying benefits and costs for a wide variety of TIM strategies under the categories of surveillance and detection; mobilization and response; information dissemination; and clearance and recovery. The website compiles evaluation findings about TIM-related projects from across the globe and documents benefits, costs, and lessons learned. The benefit and cost sections can be easily searched by application, specific goals, and geographic location. The USDOT ITS Knowledge Resources website can be found at http://www.itskrs.its.dot.gov/

FHWA's Office of Operations and Research Development recently developed a tool, the Traffic Incident Management Benefit-Cost (TIM-BC) tool, which can be used to evaluate the benefits of TIM strategies as shown in Exhibit 18-24. It is a web-based software tool (http://www.fhwa.dot.gov/software/research/operations/timbc/) that evaluates eight of the most common TIM strategies:

- Safety Service Patrols
- Driver Removal Laws
- Authority Removal Laws
- Shared Quick Clearance Goals
- Pre-established Towing Service Agreements
- Dispatch Co-location
- TIM Task-Force
- Strategic Highway Research Program (SHRP2) Training

Exhibit 18-24: FHWA's TIM-BC Tool



FHWA's Incident Management Benefit Cost Tool allows the user to customize project information and obtain benefit cost information. For optimal results the tool requires the user to have a considerable amount of data for each roadway segment the strategy targets. For example, the user needs to enter the average incident duration and number of incidents categorized as shoulder blockage or one lane blockage, as well as the percentage of estimated secondary incidents for each roadway segment. In some cases, default values are available. There is also an element of subjectivity in the data entry area for "Project Savings", requiring the user to input the proportion of incidents in which clearance times would decrease by implementing the strategy.

Once all of the information is entered, the program calculates savings for delay, fuel, secondary accidents, and emissions. The tool also produces a formatted pdf report of the analysis.

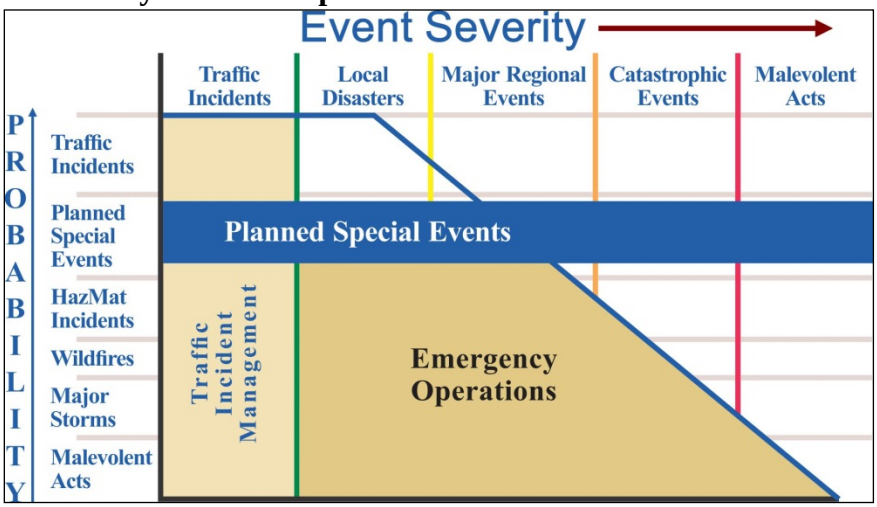
18.5.2 Emergency Operations

Emergency operations is broadly defined as the response and management of the transportation system during a wide range of non-recurring events including major traffic incidents, special planned events, and disasters such as flooding or evacuations. For the context of this sub section, emergency operations refer to less probable and more severe types of non-recurring events such as natural disasters, evacuations, and large-scale hazardous materials events. Exhibit 18-25 lists examples of emergency events and Exhibit 18-26 illustrates the relation of event probability with event severity, with the shaded region indicating the type of event addressed in this section. Both traffic incident management and planned special events are covered in other sections (18.5.1 and 18.5.5 respectively).

Exhibit 18-25: Examples of Emergency Operation Events

Air Crash	Explosion	Other Disaster
Avalanche	Evacuation	Rail Crash
Bomb	Flood	Road Surface Collapse
Earthquake	Landslide	Tsunami
Erosion	Major Hazmat	Wildfire

Exhibit 18-26: FHWA's Emergency Transportation Operations – Severity and Probability Relationship



The federal government provides extensive guidelines and recommendations for emergency operations through FHWA's Emergency Transportation Operations website,[84] and through FEMA's National Incident Management System (NIMS) website.[85] Additionally, Oregon has its own Emergency Operations Plan[86] that provides the framework to respond and recover from major emergencies and disasters. Oregon's plan documents the roles and responsibilities of state agencies while managing emergency response efforts.

Successful emergency operations rely heavily on TSMO strategies and multi-agency coordination to ensure mobility is maintained and that real-time data is accurately communicated to both the public and transportation operators.

FHWA describes three phases of emergency response, with most of the TSMO related strategies linked to the first two phases.

[84] FHWA website accessed on December 9, 2015: http://www.ops.fhwa.dot.gov/eto_tim_pse/about/eto.htm
[85] FEMA website for NIMS access on December 10, 2015: https://www.fema.gov/national-incident-management-system
[86] State of Oregon Emergency Operations Plan. Oregon Office of Emergency Management. Publication date: July 2010; Latest Revision Date: March 2014.

1) Preparation and Activation. Emphasized TSMO strategies include ITS infrastructure investments and creating transportation management centers.
2) Response. Emphasized TSMO strategies include communication systems, information sharing, and resource management.
3) Re-entry and Return to Readiness. This phase is more about debriefing and documentation, and does not have much emphasis on TSMO strategies.

Overview of TSMO Emergency Operation Strategies

Key TSMO strategies to successfully implement Emergency Operations include:

- Integrated Corridor Management. When emergencies close transportation facilities, require a detour, or even a mass evacuation, integrated corridor management can ensure that all transportation facilities within and across corridor boundaries are being used at maximum efficiency. For example, if a segment of freeway is closed, integrated corridor management can be used to modify traffic signal timing on surface streets to accommodate a sudden spike in traffic or unexpected direction of flow. See Section 18.4.4 for more information about Integrated Corridor Management.
- Real-Time Traveler Information. During an emergency it is critical to share current and accurate information with the public. Agencies need to be able to connect to a traveler information system and quickly update the information as it changes. See Section 18.5.6 for more information about Traveler Information strategies.
- Communication between Agencies. In the case of emergency operations, the scale is likely large enough that multiple transportation facilities and services will be impacted. For optimum mobility, it is critical that agencies communicate plans before implementing. For example, if a freeway segment needs to be closed, it is critical to notify the agencies whose facilities will be impacted. Notifying the appropriate agencies ensures that available resources can be optimized (detour routes, variable message signs, signal timing adjustments, etc.).
- Integration of ITS into Emergency Response Plans. On the planning spectrum, agencies should integrate ITS/TSMO strategies into emergency response plans. See Sections 18.4.1 and 18.4.2 for Arterial and Freeway Management strategies.
- Statewide Communication Interoperability Plan (SCIP)[87]. This plan establishes protocol to communicate with agencies across the state and enables a unified approach to enhance interoperable communications.

Considerations for Effective Emergency Operations

Effective emergency operations are closely related to integrated corridor management requiring institutional, operational, and technical integration. Institutionally, there needs to be collaboration between agencies. Operationally, agencies need to share assets and communicate asset availability to all involved agencies. Technically, the means to communicate and interface with agencies and traffic devices needs to be available.

[87] Website: *http://www.oregon.gov/SIEC/pages/SCIP_Page.aspx*

Benefits of Fully Integrated Emergency Operations

When Emergency Operations are fully integrated, there are several benefits to the transportation system and the general public:

- Improved mobility during large scale emergencies
- Improved safety of the public and responders
- Ability for the public to make well informed decisions

Emergency Operations Analysis Tools

The USDOT ITS Knowledge Resources website, described in Section 18.3.6, has a limited database of studies that identify benefits and costs for Emergency Operations strategies such as freeway lane reversal and hazmat technologies. The USDOT ITS Knowledge Resources website can be found at http://www.itskrs.its.dot.gov/.

18.5.3 Road Weather Operations

Adverse weather can have many negative impacts on travel in the areas of safety, mobility, productivity, and operational decisions. FHWA, through their Road Weather Management Program, summarizes the most common impacts weather can have on roads, traffic, and operational decisions as shown in Exhibit 18-27.[88]

[88] http://ops.fhwa.dot.gov/weather/q1_roadimpact.htm

Exhibit 18-27: Weather Impacts on Roads, Traffic and Operation Decisions

Road Weather Variables	Roadway Impacts	Traffic Flow Impacts	Operational Impacts
Air temperature and humidity	N/A	N/A	• Road treatment strategy (e.g., snow and ice control) • Construction planning (e.g., paving and striping)
Wind speed	• Visibility distance (due to blowing snow or dust) • Lane obstruction (due to wind-blown snow or debris)	• Traffic speed • Travel time delay • Crash risk	• Vehicle performance (e.g., stability) • Access control (e.g., restrict vehicle type, close road) • Evacuation decision support
Precipitation (type, rate, start/end times)	• Visibility distance • Pavement friction • Lane obstruction	• Roadway capacity • Traffic speed • Travel time delay • Crash risk	• Vehicle performance (e.g., traction) • Driver capabilities/behavior • Road treatment strategy • Traffic signal timing • Speed limit control • Evacuation decision support • Institutional coordination
Fog (smoke and dust also limit visibility in some parts of Oregon)	• Visibility distance	• Traffic speed • Speed variance • Travel time delay • Crash risk	• Driver capabilities/behavior • Road treatment strategy • Access control • Speed limit control
Pavement temperature	• Infrastructure design	N/A	• Road treatment strategy
Pavement condition	• Pavement friction • Infrastructure damage	• Roadway capacity • Traffic speed • Travel time delay • Crash risk	• Vehicle performance • Driver capabilities/behavior (e.g., route choice) • Road treatment strategy • Traffic signal timing • Speed limit control
Water level	• Lane submersion	• Traffic speed • Travel time delay • Crash risk	• Access control • Evacuation decision support • Institutional coordination

The first step in setting up a road weather operations strategy is to determine the adverse

weather situation that needs to be addressed. A corresponding strategy can be selected to reduce or eliminate the impacts of the adverse road weather condition.

Road weather operations strategies are typically separated into three main categories:

- Advisory strategies aim to inform users and managers of a facility of current and future road weather conditions. These strategies may be directed to users of a system by way of radio, variable message signs, social media, or the Internet.
- Control strategies actively manage a facility to restrict, permit, or regulate operations based on weather conditions. Control strategies can be in the form of variable speeds, highway closures, chain requirements (chain-up laws, chain-up areas, and checkpoints, or altered traffic signal timing.
- Treatment strategies aim to reduce the impact on weather events to users or maintainers of a roadway or facility. In a winter weather situation, this might be by plowing the roadway, applying sand or salt to a highway, or applying liquid deicer during icy conditions. It may also include asset tracking such as snow plow tracking that may also be used to provide traveler information under advisory strategies.

FHWA has compiled a list of road weather management best practices used throughout various states called the Road Weather Management (RWM) Best Practice Library (BPL). Version 3 of the BPL was released in 2012 that provides 27 innovative mitigation strategies and practices for varying adverse weather situations. The most recent version of the RWM BPL can be found at http://www.ops.fhwa.dot.gov/weather/mitigating_impacts/best_practices.htm.

Some strategies, like variable speed control, variable message signs, and altered traffic signal timing require new or existing infrastructure to be in place to support their operation. Having reliable power and communications infrastructure, especially during inclement weather, is necessary for their operation. Other strategies require a support structure to facilitate their operations. This can be in the form of social media like Twitter or updated traveler information via the Internet. ODOT operates TripCheck (https://tripcheck.com) that provides up-to-date information and camera images of road weather travel conditions in Oregon.

Road Weather Operations Analysis Tools

The analysis tools described in Section 18.3.6 may be considered for analyzing the potential effectiveness of road weather operations strategies. In particular, the TOPS-BC tool provides sketch level planning support for road weather operations and the crash modifications factors clearinghouse also provides guidance. Crash analysis (see Chapter 4) can also be used to help identify crash rates where there is a correlation to the weather. Analysis of maintenance logs and other agency asset tracking tools can be done to analyze how and where maintenance resources are allocated to help determine locations or activities that may benefit from road weather strategies.

Factors to consider when evaluating the applicability of road weather operations

strategies:

- Known locations that impact travel during adverse weather conditions (e.g. mountain passes, low water crossings, bridges with high winds)
- Crash data with a correlation to weather conditions
- Weather conditions (weather service information, data from road weather information systems)
- Maintenance resource allocation (e.g. locations, activity types, frequency)

18.5.4 Work Zone Management

Work zone management includes all policies and practices related to minimizing travel delays and maintaining the safety of all travelers and workers from construction or maintenance work zones and associated detour routes. This section provides an overview of TSMO strategies for work zone management, evaluation considerations, and a summary of tools for work zone analysis. FHWA's Work Zone Mobility and Safety Program website provides a wealth of information and resources to support work zone management: http://www.ops.fhwa.dot.gov/wz/index.asp. ODOT also provides work zone management resources:

- Work Zone Safety: http://www.oregon.gov/ODOT/TS/pages/workzonesafety.aspx
- Traffic Control Plans Unit: http://www.oregon.gov/ODOT/HWY/TS/Pages/traffic_control_plans.aspx

The most comprehensive set of work zone management strategies is included in FHWA's Work Zone Operations Best Practices Guidebook, 3rd edition, at http://ops.fhwa.dot.gov/wz/practices/best/bestpractices.htm, which covers approximately 40 topics and numerous subtopics grouped in these overarching categories:

- Policy and Procedures
- Public Relations, Education, and Outreach (Program-Level)
- Modeling and Impact Analysis
- Planning and Programming
- Project Development and Design
- Contracting and Bidding Procedures
- Construction/Maintenance Materials, Methods, Practices, and Specifications
- Traveler and Traffic Information (Project Related)
- Enforcement
- ITS and Innovative Technology
- Evaluation and Feedback

This guidebook includes 12 best practices from Oregon such as 20-minute maximum delay specifications, media and public outreach, and work zone incident management.

Some of the most commonly used TSMO strategies for work zone management include

closure policies, stakeholder coordination and planning, public outreach and traveler information, work zone incident management, dynamic warning systems, and traffic control as described in the following sub-sections.

Closure Policies

Minimizing closures of lanes, ramps, and roadways during peak travel times goes a long way towards maintaining travel mobility. All travel modes should be considered when developing closure policies. For example, freeway work zone projects should consider Interstate design vehicles, over-dimension vehicles, and bus routes. Alternatively, an urban work zone projects should consider accommodations for pedestrians, bicycles, transit, passenger vehicles, and the appropriate types of freight vehicles.

ODOT has a standing policy for all freight routes that any lane closure that is expected to cause traffic delays triggers a mandatory coordination process with mobility stakeholders. For this purpose, delay is expected when the hourly volumes during construction exceed an established free-flow threshold. These thresholds are defined in the corridor-specific Traffic Management Plans that were established during the OTIA-III bridge rehabilitation efforts.

The work zone analysis tools discussed later in this subsection provide input on procedures for analyzing closures.

Stakeholder Coordination and Planning

Planning efforts for work zone management should include a variety of stakeholders such as transportation agencies, construction management divisions within agencies, contractors, transit agencies, traffic management centers, 911 centers, law enforcement, fire and rescue agencies, emergency medical agencies, utility agencies/companies, area businesses, freight community, freight distribution centers, event centers, school districts/school bus operators, and neighborhood associations. Transportation Management Plans (TMPs) can be used to identify strategies for work zone management. TMPs are required for significant federally funded projects but can also be scaled to any size project. ODOT uses three levels of TMPs: program-level (overarching statewide safety and mobility policies), corridor-level (targeted for high-volume freight and passenger travel routes), and project-level (as needed for individual projects). See the FHWA and ODOT TMP websites for more information:
http://www.ops.fhwa.dot.gov/wz/resources/tmp_factsheet.htm and
http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/ODOT%20TMP%20Project%20Level%20Guidance%20Manual.pdf.

ODOT's TripCheck Local Entry (TLE) feature allows transportation agencies within Oregon to share information about construction and maintenance projects between one another. This system also feeds pertinent traveler information to the media and the public. ODOT strongly recommends all transportation agencies in Oregon actively use TLE. Contact ODOT to get started: https://www.tripcheck.com/Pages/ATCU.asp.

Public Outreach and Traveler Information

Key components of successful work zone management include public outreach during design, public outreach immediately preceding work zone activities, and traveler information while construction is underway. Public outreach can be done through many forums such as workshops, websites, social media, and partnerships with the media. Traveler information systems (see Section 18.5.6) can be used to provide work zone schedules, travel impacts, real-time or predictive travel times through work zones or alternate routes, and estimated delay.

Work Zone Traffic Incident Management

Traffic incident management (TIM) strategies (see Section 18.5.1) can be applied to specific work zones, particularly for longer-duration construction projects. This may include TIM teams for the work zone as well as incident detection sensors and camera surveillance to quickly identify incidents so a coordinated response can be initiated. Although TIM teams have not specifically been established for Oregon construction projects to date, ODOT does work closely with construction teams and is available to provide incident response as needed.

Some ODOT projects include a full-time traffic control supervisor to periodically patrol the work zone (mostly to supervise the temporary traffic control procedures) and who can also be on-call 24 hours per day. This traffic control supervisor coordinates with ODOT incident responders as needed. Some ODOT regions pre-position tow vehicles in or near work zones to support incident management and have maintenance personnel work overtime to support incident management.

Some states, such as Utah, are experimenting with performance incentives for keeping traffic moving safely and efficiently. This includes incentives for quick clearance of incidents.

Dynamic Warning Systems

A variety of dynamic warning systems can be used to detect existing traffic, vehicle, or road weather conditions and provide warnings via roadside dynamic message signs or emerging connected vehicle technologies:

- Queue or congestion warning
- Over dimension vehicles
- Work space intrusion

- Construction vehicle activities (e.g. merging, crossing, exiting)
- Hazardous road weather conditions (e.g. ice/water on road, visibility)
- Geometric conditions (e.g. curves)

Traffic Control

Beyond traditional work zone traffic control measures, these strategies may also be considered:

- Speed management (e.g. driver feedback speed advisory signs, variable speed control, automated speed enforcement)
- Dynamic merge control (see Section 18.4.2)
- Temporary ramp metering
- Adaptive or traffic responsive temporary traffic signals

ODOT has developed a mobile speed management system for stationary and moving maintenance activities that uses driver feedback speed advisory signs. Future applications aimed at improving worker safety include applications such as automated truck-mounted impact attenuators.

A variety of factors should be considered when evaluating what strategies to apply to a work zone:

- Planned construction/maintenance activities and duration:
    - For the work zone under evaluation
    - For any nearby projects that impact area mobility
    - For any projects on the same corridor that impact regional or statewide mobility
- Transportation conditions of the work zone roadways and areas of influence (e.g. parallel routes where travelers may detour):
    - Average daily traffic (including freight presence)
    - Seasonal traffic variations/factors
    - Posted speed
    - Peak period travel speeds
    - Travel time reliability
    - Average daily hours of congestion
    - Intersection traffic control devices (e.g. stop signs, traffic signals)
- Existing systematic or local TSMO strategies in place (e.g. TIM program, roadside traveler information, dynamic speed or warning systems)

Work Zone Analysis Tools

This section provides a summary of work zone analysis tools that can be used at the program level (SWIM2, WISE, CA4PRS, dynamic traffic assignment) or when analyzing

specific projects (ODOT Work Zone Analysis Tool, Highway Segment Analysis, QuickZone).

Statewide Integrated Model, 2nd Generation (SWIM2)

SWIM2 is an Oregon model that allows testing of regional and statewide policies and potential projects to inform decision makers on the complex interactions between land use, the transportation network, and the economy. The SWIM2 model can be used for a bigger picture evaluation of the impacts of significant work zones and other closures. A work zone example is provided in Chapter 7 along with more details about the SWIM2 model. Additional SWIM2 information is available at http://www.oregon.gov/ODOT/TD/TP/pages/statewide.aspx. Contact TPAU for SWIM2 analysis applicability and requests.

Work Zone Impact and Strategy Estimator (WISE)

WISE was created by FHWA to support work zone planning and scheduling at the regional program level to minimize delays to the traveling public and costs to the agency. The WISE tool builds on existing traffic simulation software used by transportation agencies and MPOs. It uses basic network geometry (link/node and number of lanes) and basic traffic volume information along with a user-defined library of demand-based and duration-based strategies to determine project sequencing based on user and agency costs. Optimized project sequencing can be developed using the Operation Module, which uses TransModeler from the DynusT dynamic traffic assignment model. More information on WISE is available at http://www.fhwa.dot.gov/goshrp2/Solutions/Reliability/R11/WISE_Work_Zone_Impacts_and_Strategies_Estimator_Software.

Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS)

Caltrans developed CA4PRS to help state transportation agencies and paving contractors develop construction schedules that minimize traffic delay, extend pavement service life, and reduce agency costs. The tool takes into consideration project alternatives for different pavement design, construction logistics, and traffic operations options. More information on CA4PRS is available at http://www.dot.ca.gov/research/roadway/ca4prs/index.htm.

Dynamic Traffic Assignment

Some dynamic traffic assignment programs (see Sections 9.5 and 18.4.5) can be used to support decision making for regional work zone management.

ODOT Work Zone Analysis Tool

ODOT has developed a Work Zone Traffic Analysis Tool and User's Guide to determine lane closure restriction recommendations and construction delay estimates for ODOT roadways. It also includes a section for analyzing non-ODOT

facilities. This tool determines when highway segment lane closures should be allowed based on traffic volumes (see Chapter 5 for developing design volumes) and free flow thresholds. Lane closures are discouraged when traffic volumes exceed free flow thresholds. Note- this tool is not designed to analyze intersection operations. The User's Guide is available at http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/wzta_manual.pdf.

The tool can also be used to estimate delay, or the average additional travel time as a result of the work zone activities. These estimates are based on traffic microsimulation tools and regression analysis. The estimated delays can be used to help determine work zone staging and detours. ODOT has a maximum delay standard of 20 minutes. Exceptions are sometimes granted for exceeding the delay threshold.

Highway Segment Analysis

Chapter 6 includes analysis procedures for highway segments, ramps/ramp junctions, merging, diverging, weaving, and passing and climbing lanes that can be used for analysis of work zones as applicable.

QuickZone

QuickZone is a spreadsheet-based traffic analysis tool that compares the traffic impacts of work zone management strategies (e.g. project phasing, diversions, travel demand measures) for both urban and rural work zones. It looks at each strategy's impact on traffic delays, potential queues, and costs. QuickZone is available at http://ops.fhwa.dot.gov/wz/traffic_analysis/quickzone/index.htm.

18.5.5 Planned Special Event Management

Planned special events can have major impacts on travel based on when and where the event is held, how many people are in attendance, and what travel modes are available. This section describes special event management, the TSMO strategies that may be applied, and the evaluation considerations. Additional information can be found on FHWA's Traffic Management for Planned Special Events website: http://ops.fhwa.dot.gov/eto_tim_pse/about/pse.htm.

The list of special events held in Oregon is a long one but typically includes happenings such as sporting events, concerts, conventions, fairs, festivals, motorcades/parades, public/political events, or heavy shopping days (e.g. Thanksgiving through Christmas). Venues can be as varied as arenas, stadiums, theaters, fairgrounds, recreational facilities, public open spaces, and public roadways closed to vehicular traffic. Event frequency also varies. Some events are one-off events (e.g. political rallies) while others occur annually (e.g. state and county fairs), seasonally (e.g. sporting events), or frequently (e.g. venues that hold a variety of events year-round).

Special event management is the application of coordinated operations strategies to inform the traveling public about travel conditions, monitor changing travel conditions, and manage travel demand associated with the planned special event. The level of effort from both a staffing and investment standpoint varies and can be scaled to the level of traffic impacts. For instance, a venue with year-round events may require more capital investments in parking systems, transit infrastructure, and traffic signal operations whereas smaller, less frequent events may have more of a focus on traveler information and smaller day-of-event traffic control (e.g. police on hand directing traffic).

The evaluation of special event management is similar to analyzing TSMO strategies for a sub-region with the primary difference being the origin-destination pairs and the time-of-day/day-of-week. A typical sub-region analysis uses home-employment origin-destination pairs whereas special events have a venue as the destination and the origin depends on when the event is held. Special event analysis also varies by both time-of-day and day-of-week whereas sub-region analysis focuses on the weekday AM and PM peak commute periods. Any of the tools in Section 18.3.6 used for TSMO evaluation can be applied to special event management. Often existing models (e.g. travel demand, simulation, traffic signal optimization) have already been developed for the area surrounding a venue for weekday commute conditions and these models can be tailored to reflect special event conditions.

The evaluation of special event management should take into consideration:

- Venue size and typical attendance
- Time-of-day and day-of-week of planned special event
- Mode split of available travel options
- Capacity impacts to roadways and transit systems for event ingress and egress
- Capacity impacts to venue parking facilities and nearby parking facilities (on-street, public facilities, and privately operated facilities)
- Impacts to traffic signals on event travel routes
- Availability of existing TSMO strategies (e.g. traveler information, surveillance systems, traffic signal systems, dynamic traffic control)
- Staff availability for events during non-standard work hours

TSMO strategies that may be considered for special event management include the following:

Stakeholder Coordination

Coordination between all applicable stakeholders can greatly improve the management of special event travel demand. Stakeholders may include transportation agencies, transit agencies, law enforcement, 911 centers, special event promoters, venue management teams, parking facility operators, media, and any sectors of the public affected by event traffic. Face-to-face meetings to coordinate in advance of the event are key and a post-event meeting to review best practices and areas for improvement is helpful for events

held with some regularity. Staffing considerations are also important for all affected agencies since many events are held outside non-standard hours and special accommodations may need to be made to allow for staff support.

Temporary Traffic Control
Several temporary traffic control strategies may be considered:

- Temporary traffic control devices (e.g. temporary traffic signals, portable VMS, tubular markers, barricades) may be used to modify roadway traffic control near an event venue.
- Flaggers or law enforcement personnel may be used to help direct traffic at bottlenecks.
- Detours around the event venue may be used for commercial vehicles and other non event-related traffic.
- The standard ODOT special provisions boilerplates provide a place for construction projects to list special events that will prohibit the use of lane closures or sidewalk closures.

Surveillance
Existing and temporary systems may be used to monitor travel conditions before, during, and after a planned special event:

- Vehicle detection systems
- CCTV cameras
- Event service patrol- by foot, vehicle, or aerial surveillance

Consider making surveillance video and data available in a central location for all stakeholders.

Traffic Management Center (TMC)
An existing TMC, a satellite TMC (e.g. room at the venue), or portable TMC (e.g. traveling vehicle set up with TMC systems) may be used to manage operations for an event. This may require additional staff or the use of existing staff after hours.

Traffic Signal Operations
Many of the traffic signal strategies discussed in Section 18.4.1 may be considered for special events. In particular, special timing plans may be developed to handle event traffic that may be turned on manually from a central signal system or enabled using a trigger, such as volume thresholds from a system detector.

Dynamic Traffic Control
A variety of dynamic traffic control may be considered:

- Reversible lanes or changeable lane assignment on corridors with a dominant travel direction during event ingress or egress
- Dynamic trailblazer signs to route travelers to and from an event

- Existing dynamic traffic control already in place near the event such as variable speed control, adaptive ramp metering, dynamic merge control, dynamic warning systems, and dynamic re-routing

Transit Management
For less frequent events at venues without transit infrastructure, transit shuttle service may be considered. This service could use existing park-and-ride lots or new ones could be negotiated at public or private parking facilities, including retailers with large under-utilized parking lots. Shuttle stops or dedicated transit lanes should be considered at the venue. For venues with year-round events, permanent transit infrastructure (e.g. bus routes and stops) may be considered. Service frequency may need to be increased before and after an event to handle demand.

Parking Management
On-site and off-site parking capacity should be evaluated to determine what is needed to meet parking demand for motor vehicles and bicycles. Parking traveler information and electronic payment systems help make parking operations more efficient. Active parking management strategies (see Section 18.4.3) may also be considered: dynamic overflow transit parking, dynamic parking reservation, dynamic wayfinding, and dynamically priced parking.

Traveler Information
All available traveler information systems (see Section 18.5.6), including permanent and portable roadside VMS, should be used to provide travel impacts in advance of special events as well as to provide real-time travel conditions on the day of the event. This also includes close coordination with the media.

18.5.6 Traveler Information

Traveler information systems provide relevant information on travel options and conditions before and during travel. The intent of these services is to give travelers actionable information that can change their behavior in ways that improve the efficiency of the transportation system.[89] Traveler information strategies support many of the TSMO strategies described in this chapter, particularly the transportation demand management strategies (also called transportation options) discussed in Section 18.5.7. An overview of the types of information delivered to travelers and the various media used to do so is presented below. A discussion of considerations for implementation, and summaries of safety benefits and operational impacts of traveler information systems follows the overview. Additional information on traveler information systems is available at:

[89] Chorus, C.G., Molin, E.J. and Van Wee, B., 2006. Use and effects of Advanced Traveler Information Services (ATIS): a review of the literature. *Transport Reviews*, *26*(2), pp.127-149.

- FHWA Real-Time Travel Information website: http://www.ops.fhwa.dot.gov/travelinfo/
- NCHRP Web-only Document 192: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w192.pdf
- NCHRP Synthesis 399: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_399.pdf

Overview of Information Types and Media

Common types of traveler information include:

- Alternate routes can aid travelers in making real-time route choices. Alternate routes go hand-in-hand with construction zones, special events, traffic incidents, abnormal travel times, and adverse weather.
- Congestion information can notify travelers of levels of congestion relative to normal traffic, the lanes affected, and congested roadway segments.
- Live traffic cameras record traffic conditions visually at specific camera locations. They allow travelers to see roadway conditions and make decisions accordingly.
- Parking availability information allows drivers to save time and fuel by knowing where parking options are available. It is useful primarily in dense urban areas and parking garages.
- Public safety information can include Amber alerts, Silver alerts, and evacuation information. These types of information prompt travelers to attend to or do something, for example look for a certain type of vehicle from an Amber alert.
- Road work/construction zones allow travelers to change plans by avoiding a particular area or allowing for extra travel time. Examples include locations of tree trimming, bridge closures, lane closures, and construction activities.
- Special events can disrupt normal traffic. Large events can cause road closures, traffic diversions, traffic volume changes, and changes to parking options. Recurring events like sports games can have similar effects as well. Information pre-trip and during trips can help travelers make according travel decisions.
- Traffic incident information includes incident type, times of occurrence, location, number of lanes affected, and when lanes will reopen.
- Travel times aid travelers in route, departure time, and mode decisions prior to a trip. During a trip, information on travel times to certain points can help travelers with route choices.
- Weather information includes severity of weather conditions, road closures, alternate routes, evacuation routes, and advisories to travelers (e.g. snow chains required).

Traveler information is disseminated in many ways. Some information sources are more established and readily available (e.g. radio, television) while others are newer and less widely available (e.g. smartphone apps). Sources vary in their ability to reach travelers as well. Sources like radio and television may provide information passively; travelers

receive information relevant to their trip while not actively seeking it. Other sources, like websites and apps, require the user to actively seek out information. Technology innovations continue to expand the sources and flow of information. Many common information sources are described below.

- 511 phone systems allow users to simply dial 5-1-1 on the phone to hear travel information. In Oregon, most of this information is the same as displayed on TripCheck and includes roadway conditions by highway, roadway conditions for mountain passes, roadway conditions for major cities, commercial vehicle restrictions, and chain requirements.
- Mobile smartphone apps can provide a wide range of information to users to help trip planning and decision making. There is a trend toward agencies allowing private developers to access real time data to develop apps and solutions. ODOT offers the TripCheck Traveler Information Portal (TTIP) for this purpose. Example applications include Waze providing incident and detour information, Google Maps providing travel times and trip planning options, and Pango providing parking information and reservations. Smartphone technology continues to evolve: hardware improvements enhance their capabilities, and software improvements in non-transportation apps like calendars and scheduling create opportunities for traveler information to integrate with these products.
- On-board devices like TomTom, Garmin, and OnStar provide information such as alternate routes and congestion. Some of these services require a paid subscription.
- Radio is available in almost every vehicle and in some areas has more reliable coverage than cellular networks. Many radio stations broadcast travel information like closures, delays, emergencies, and adverse weather as part of news content. ODOT also utilizes Highway Advisory Radio (HAR) to broadcast warnings, advisories, directions, and other non-commercial information of importance to motorists on dedicated radio stations. ODOT provides the Guidelines for the Operation of Highway Advisory Radio and Travelers Advisory Radio on State Highways document to aid operators of HAR. The document can be found at http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/guidelines_for_the_operation_of_highway_advisory_radio_on_state_highways.pdf. For example, HAR messages are intended to be under one minute in duration and repeated continuously so that travelers can hear the message at least twice while passing through a station's coverage area.
- Social media provides agencies with a venue to interact with travelers directly. The ODOT twitter feed (@OregonDOT) posts updates on advisories, delays, incidents, weather, road closures, and photos. There are also several TripCheck Twitter accounts that provide similar information for certain corridors (e.g. @TripCheckUS97A). Social media also allows user-to-user exchanges of traveler information.
- Subscription-based email and short message service (SMS) messaging services allow users to receive email or text messages about weather and roadway

conditions. The Amber alert and Silver alert systems use SMS messaging to disseminate information.

- Television is similar to radio in that it is widely accessible and travel information is broadcast as part of regular news coverage. But, it is limited to providing pre-trip information.
- Websites, from both public agencies and private entities, can provide every type of travel information listed above. ODOT's award-winning TripCheck website (https://www.tripcheck.com) provides summarized information by roadway and by category, real-time photos from CCTV cameras, and offers an interactive map-based platform for users to retrieve data. The TripCheck Local Entry (TLE) tool allows local agencies to input information about their roadway network to the TripCheck system. TripCheck Mobile (https://www.tripcheck.com/mobile) also provides a platform optimized for low-bandwidth and mobile phone users. TripCheck TV (https://www.tripcheck.com/tv/) provides camera images, alerts, and delays and is designed for display on televisions at public locations where travelers are waiting such as lobby areas and transit stops. Data collected on roadways are sent to the TripCheck system, and is then shared via TTIP with other information outlets like 511, the ODOT Twitter feed, and smartphone apps.
- Variable message signs (VMS) are traffic control devices along roadways that display dynamic messages containing traveler information to motorists. VMSs can be temporary (located on trucks or trailers parked along the side of roadways) or permanent (affixed to permanent supports or bridge structures). Along with variable advisory speed signs and travel time signs, permanent VMSs comprise the ODOT Real Time system. VMSs should be placed strategically at locations that allow motorists to change travel plans depending on the message, where there is sufficient sight distance, and where access to power and communications is available. ODOT provides recommendations for VMSs in the Guidelines for the Operation of Permanent Variable Message Signs document: http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/guidelines_for_vms_on_state_highway.pdf. Connected vehicle technology is an emerging area for traveler information. As vehicle-to-vehicle and vehicle-to-infrastructure technology matures, opportunities for in-dashboard and in-vehicle travel information alerts will arise.

Considerations for Effective Deployment

NCHRP Web-only Document 192 (available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w192.pdf) presents results of a study on the use and deployment of traveler information systems across six regions of the US. The study provides many recommendations for successful implementation of traveler information systems. Primarily, traveler information "should be targeted, easy to use, relevant, clear, trustworthy, reliable, and accurate." The report emphasizes four main features for successful deployment:

1. Provision of information on non-recurring events in real time. Non-recurring events like traffic incidents and special events disrupt the transportation system

substantially, and providing relevant information can lessen their negative impacts.

2. Dissemination across a wide array of media. Travelers have varying levels of access to information and needs, so providing many options to obtain information is beneficial. A central agency need not control all information streams, and information sharing with private entities and third parties can aid in circulation. ODOT's TripCheck Traveler Information Portal (TTIP) is a prime example of information sharing in action.
3. Aligning information with the needs and wants of the traveling public. Information providers must be aware that different travelers have different needs and wants. Trip purposes (e.g. commuting, business travel to a meeting, leisure, etc.), departure/arrival time constraints (e.g. the need to travel during peak hours), familiarity with the geographic area of travel, mode options, and market penetration of smartphones are all examples of factors that affect wants and needs for information of travelers.[90]
4. Evaluation. Traveler information programs should be evaluated to ensure they are producing desired and intended results. Data collection efforts like surveys, usage statistics, and focus groups can inform agencies about effectiveness of traveler information systems. However, a critical first step is to define performance measures that can assess whether traveler information systems meet goals.

Traveler Information Analysis Tools

The benefits of deployment of traveler information systems are well documented. The sketch planning tools described in Section 18.3.6 may be used to screen traveler information strategies. In particular, the USDOT ITS Knowledge Resources website is a repository of benefit summaries from traveler information systems. Case studies are organized by types of information sources and whether information is related to pre-trip information, en-route information, tourism, and special events. The TOPS-BC tool also provides analysis of pre-trip and en-route traveler information.

18.5.7 Transportation Demand Management

Transportation demand management (TDM), also called transportation options, includes actions or programs aimed at reducing the motor vehicle demand for transportation infrastructure, which often improves the efficiency of transportation systems. Example TDM strategies include rideshare programs, transit fare discount programs, telecommuting, and individualized trip planning. TDM strategies have long been a part of transportation planning in Oregon. Goal 2 of the *Oregon Transportation Plan* is "to improve the efficiency of the transportation system by optimizing the existing transportation infrastructure capacity with improved operations and management." The target strategies for achieving this goal come from TDM and transportation system management (TSM). The Oregon Transportation Planning Rule (OAR 660-012) requires

[90] Chorus, C.G., Molin, E.J. and Van Wee, B., 2006. Use and effects of Advanced Traveler Information Services (ATIS): a review of the literature. *Transport Reviews*, *26*(2), pp.127-149.

urban areas with a population greater than 25,000 people to evaluate TDM and TSM strategies as part of their transportation system planning efforts. It also encourages urban fringe areas to consider low-cost TDM and TSM strategies as applicable. The Oregon Transportation Options Plan provides an overview of existing transportation options programs in use in Oregon, challenges/trends/opportunities, and policies and strategies for 10 goals to support the state's vision for transportation options. It also includes an implementation section with guidance for integrating transportation options into the planning process.

Additional information and a comprehensive description of the many available TDM strategies may be found at:

- Oregon Transportation Options Plan: http://www.oregon.gov/ODOT/TD/TP/Pages/toplan.aspx
- FHWA Travel Demand Management: http://www.ops.fhwa.dot.gov/tdm/
- FHWA Integrating Demand Management into the Transportation Planning Process: A Desk Reference: http://www.ops.fhwa.dot.gov/publications/fhwahop12035/index.htm
- Victoria Transport Policy Institute's Online TDM Encyclopedia: http://www.vtpi.org/tdm/
- Drive less. Connect. (Oregon's ride-matching tool): http://www.drivelessconnect.com/
- Commuter Choice: http://www.commuterchoice.com/

The full menu of available TDM strategies is too long to list here. TDM strategies can generally be grouped as:

- Physical measures (e.g. transit or parking infrastructure)
- Operational measures (e.g. active transportation and demand management, see Section 18.4)
- Institutional measures (e.g. sustainable travel planning)
- Financial/pricing measures (e.g. congestion or parking pricing).

TDM strategies can also be grouped by type of travel choice: mode, time, location, and route. Exhibit 18-28 provides an overview of the effectiveness of the most common TDM strategies in addressing key policy objectives (mobility, congestion relief, air quality, economic development, land use interaction, goods movement, and livability). Appendix 18A includes some of the high-level TDM strategies most commonly used in Oregon. Marketing and outreach to individual travelers, businesses, and transportation agencies are all typically part of successful TDM programs.

Exhibit 18-28: TDM Strategies and Their Relative Effectiveness in Addressing Key Policy Objectives

Strategies	Mobility	Congestion Relief	Air Quality	Economic Development	Land Use Interaction	Goods Movement	Livability
Traditional TDM							
HOV/HOT Managed Lanes	◐	○	○	○	◔	◔	◔
Employer Trip Reduction Programs	◐	◔	◐	x	-	◔	◔
Alternative Work Arrangements	◐	◔	◐	◔	◔	◔	●
Individualized Marketing*	◐	◐	◔	◔	-	◔	◔
School-Based Trip Reduction	◐	◔	◐	○	○	-	●
Event-Based Trip Reduction	◐	◔	◔	○	○	◔	◔
Recreation-Based Trip Reduction	◐	◔	◔	○	○	◔	◔
Car-Sharing	◐	x	◐	◔	◔	-	◐
Ridesharing*	◐	x	◐	◔	◔	-	◐
Vanpool Programs	◔	◔	●	◔	○	◔	◔
Land Use/Active Transportation							
Developer Trip Reduction	◔	◔	◔	x	◐	-	◔
Land Use Strategies	◐	◔	◔	◔	◐	-	●
Access Management*	◐	x	x	◔	◐	◔	◔
Car-Free or Access-Restricted Zones	◔	◐	◐	x	◐	◔	●
Bicycle Facilities and Programs	◐	◔	◐	◔	◐	○	●
Pedestrian Facilities and Continuity	◐	◔	◐	◔	◐	○	●
Transit							
Transit Service Improvements	◔	◔	◐	○	◔	○	◔
Transit Prioritization/ BRT	◐	◔	◐	◔	◔	x	◔
Transit Fare Discounts	◔	◔	◐	◔	◔	x	◔

Strategies	Mobility	Congestion Relief	Air Quality	Economic Development	Land Use Interaction	Goods Movement	Livability
Parking							
Parking Information	◐	◔	◔	◔	◔	◔	◔
Parking Supply Management	x	◐	◐	x	◐	-	◐
Parking Pricing	x	◔	◐	x	◐	◔	◐
Pricing							
Cordon Pricing	x	●	●	○	◔	◐	○
Congestion Pricing	x	●	●	○	◔	◐	○
General Financial Incentives	●	◔	●	◐	◔	◐	◔
Vehicle Miles Traveled (VMT) Tax	x	●	●	x	◐	◐	○
Systems Management							
Traffic Signal Optimization*	◐	◐	◔	x	-	◔	x
Ramp Metering	x	◐	x	-	-	◔	x
Traffic Incident Management*	◐	◐	◔	-	-	◔	x
Integrated Corridor Management	◔	◔	○	○	-	◐	-
Traveler Information	◐	◐	◔	◔	-	◔	◔
Eco-Driving	-	x	◔	x	x	◐	◐

Key: ● = highly effective; ◐ = moderately effective; ◔ = nominally effective; ○ = likely effective (but undocumented);

x = minimal to no impacts; - = not applicable

Source: *Integrating Demand Management into the Transportation Planning Process: A Desk Reference*. FHWA-HOP-12-035. Table 10.6

* Strategy was not evaluated in the FHWA Desk Reference but is commonly used in Oregon.

The evaluation of TDM strategies should take into consideration:

- Mode split
- Person throughput on key facilities or corridors
- Ratio of travel times on all travel options to one another
- Vehicle miles traveled and vehicle trip reduction
- Emission reduction

- Transit ridership
- Rideshare program usage
- Parking utilization
- Breakdown of employment by location
- Enrollment in employee incentive programs
- Demand estimates based on parking or tolling costs
- Satisfaction with travel options and incentives to use them

TDM Analysis Tools

The typical tools for analyzing TSMO strategies discussed in Section 18.3.6 have limited ability to evaluate TDM strategies. Emerging TDM strategies, such as rideshare programs, may have a big impact on transportation demand but the extent of that impact are still unknown.

Tools that may be used to evaluate TDM:

- Travel Demand Models: Some planners in Oregon apply trip reduction factors in travel demand models based on data from the Oregon Department of Environmental Quality's *Guidance for Estimating Trip Reductions from Commute Options* (1996) to represent TDM strategies.
- Trip Generation Rates: Section 6.6 of this APM talks about incorporating TDM into trip generation rates. Sections 9.4.3 and 10.3.2 discuss considering TDM strategies as a part of the future transportation alternatives analysis.
- Regional Strategic Planning Model (RSPM) (See Sections 7.6 and 18.3.6): The RSPM may be used as a screening tool to understand the tradeoffs and first order average day impacts of non-auto modes.
- Worksite Trip Reduction Model (WTRM) (http://www.nctr.usf.edu/pdf/473-14.pdf): This sketch-planning tool uses either an online worksheet or look-up tables to predict the changes in vehicle trip rates or parking rates for TDM strategies.
- EPA COMMUTER Model (http://www.nctr.usf.edu/clearinghouse/software.htm): This basic computer model is 20 years old and calculates the transportation and emissions benefits based on TDM incentives (e.g. public transportation service improvements) and disincentives (e.g. parking charges). This program relies heavily on professional judgment.
- Trip Reduction Impacts of Mobility Management Strategies (TRIMMS) (http://trimms.com/): This tool is a visual basic application spreadsheet that estimates the impacts of TDM strategies, including their benefit-cost ratios.
- Business Savings Calculator (http://www.bestworkplaces.org/resource/calc.htm): This web-based calculator helps employers considering commuter options to calculate the financial, environmental, traffic-related, and other benefits.

18.5.8 Connected and Automated Vehicles

Rapidly emerging connected and automated vehicle technologies are posed to disrupt long-standing practices in planning, designing, maintaining and operating the transportation system. While ODOT is taking initial steps to understand and prepare for the coming changes, the state of the practice for analysis procedures related to this new transportation paradigm is thin. This sub-section provides an overview of Connected and Automated Vehicles (CAV) as currently understood. For more information on connected and automated vehicle, see USDOT ITS Joint Program Office website.

Connected vehicles include on-board technology that enables communication with their environment using a variety of different wireless communication technologies as appropriate to the level of communication needed. Depending on the application, dedicated short range communication (DSRC), cellular, or Wi-Fi communications may be appropriate. Connected vehicles can "talk" to:

- Other vehicles on the road, termed Vehicle to Vehicle (V2V)
- Roadside infrastructure, like traffic signals, termed Vehicle to Infrastructure (V2I)
- Everything else, like mobile devices, termed Vehicle to Everything (V2X)

Automated vehicle technology is focused on removing the driver (partially or entirely) from controlling the vehicle's operations. National Highway Transportation Safety Administration (NHTSA) identifies five levels of automation[91]:

- **No-Automation (Level 0):** The driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – at all times.
- **Function-specific Automation (Level 1):** Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.
- **Combined Function Automation (Level 2):** This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.
- **Limited Self-Driving Automation (Level 3):** Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The second-generation Google car is an example of limited self-driving automation.

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91 http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development

- **Full Self-Driving Automation (Level 4):** The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles. The third-generation Google car is an example of full self-driving automation. **Vehicles with level 4 automation may also be referred to autonomous vehicles.**

CAV aim to benefit transportation in three areas:

- Safety: CAV may reduce crashes and injuries by providing tools to drivers and vehicles to better anticipate and prevent a crash, or if a crash is imminent, the technology could provide adjustments to minimize injuries.
- Mobility: CAV technology can provide information to transportation system users and operators that allow them to make informed choices and reduce travel delay. Automated vehicles may open more mobility options for disabled and aging populations, and expand last mile connections for transit. The automated parking feature may reduce the number of vehicles circulating in search of parking and potentially decrease the allocation of space for vehicle parking.
- Environment: CAV technology can enable drivers (and vehicles) to use real time information to operate more efficiently to reduce energy use and emissions.

These are developing technologies, and although the systems are not yet mature, agencies should begin preparing for the impacts of CAV technologies on the transportation system. Ways to prepare include but are not limited to:

- Assessing the impacts on planning practices and processes:
    - How will travel demand models consider CAV effects?
    - How will longer term road capacity needs be re-assessed?
    - What are the effects to funding and programming?
    - What are the equity impacts of CAVs?
    - How will vehicle ownership patterns change?
- Assessing impacts on infrastructure
    - What are the impacts on signing and striping?
    - Do lane widths change?
    - What are the effects on traffic control systems?
    - What road side infrastructure, including communications, is needed in the future?
    - How is the design and use of curb space impacted?
    - How are transit, bicycles and pedestrian facilities impacted?
- Assessing the impacts on agency operations:
    - What workforce skills are needed?
    - How does this change licensing, regulations, and enforcement policies and procedures?
    - How are procurement processes updated to support new public-private partnerships?

Connected Vehicle Analysis Tools

USDOT is supporting research and developing guidance to help agencies consider and plan for connected and automated vehicles. The Connected Vehicle Reference Implementation Architecture (CVRIA) tool is directed at incorporating CAV into ITS architectures.[92] The tool includes information about the many CAV applications being developed such as eco-traffic signal timing, eco-multimodal real-time traveler information, and eco-smart parking. It identifies the various categories of information flows; standards necessary for implementation; and other resources to support integration into ITS architectures. USDOT has also supported the development of a software tool, Systems Engineering Tool for Intelligent Transportation (SET-IT)[93], which links drawing and database tools with the CVRIA to visualize the architecture elements and information flows.

Appendix 18A – Summary of TSMO Strategies

[92] http://www.iteris.com/cvria/html/about/about.html

[93] http://www.iteris.com/cvria/html/resources/tools.html

19 NOT YET WRITTEN – SEE APM VERSION 1

Appendix 19A – Example Tech Memos

Appendix 19A.1 – Fern Valley Interchange Existing Conditions Technical Memo

Appendix 19A.2 – Constitution Area Refinement Study Future No-Build Technical Memo

Appendix 19A.3 – Grandview – Nels Anderson Traffic Analysis Technical Memo

Appendix 19B – Example Narratives

Appendix 19B.1 – US 97 Bend North Corridor Solutions Project (Example of a System Project)

Appendix 19B.2 – Constitution Area Refinement Study (Example of a Point Project)

Appendix 19B.3 – US 199 Expressway Upgrade Project (Example of a Linear Project)

GLOSSARY

The purpose of this glossary is to define terms as used for ODOT-specific analysis. It is written in plain language as much as possible to enhance understandability. It is not intended to change definitions in other engineering publications.

NOTE: This is a work in progress and currently incorporates terms from APM Version 2 Chapters 1-8.

30th Highest Hour (30 HV) – Also see Design Hour. This is the 30th highest hour of the year, which is typically the design hour for ODOT plans and projects. It is typically the average p.m. peak hour for most urbanized areas. Hours higher than the 30th are typically holidays and other high-traffic days of the year. The concept of using the 30th highest hour is that it would not be appropriate to design for the highest hours of the year as the design may be overbuilt.

95th% Queue Length – Queue length (in vehicles) that has a 5% probability of being exceeded during the analysis period.

Accessibility – degree to which the system is usable to as many individuals as possible.

Access Management – The proactive management of vehicular access points to land parcels adjacent to all manner of roadways.

Access Spacing – The practice of increasing the distance between intersections to improve the flow of traffic on major arterials, reduce congestion, and improve air quality within heavily traveled corridors.

All Roads Transportation Program (ARTS) – A safety program address safety needs on all public roads in Oregon (formerly known as Jurisdictionally Blind Safety Program).

Annual Average Daily Traffic (AADT) - The total traffic for the year divided by 365 (or 366 in a leap year). Can either be actual values from automatic traffic recorders or estimated with seasonal factors.

Annual Average Weekday Traffic (AAWDT) – AADT considering only Monday-Thursday volumes.

Average Daily Traffic (ADT) – The total traffic volume during a given period (1-365 days) divided by the number of days in that period.

Average Weekday Daily Traffic (AWD or AWDT) – ADT considering only Monday-Thursday volumes.

Air and Noise (Traffic) Data – An assembly of hourly and daily volumes, speeds, and level-of-service for peak vehicle and truck hours broken down by directional links by analysis year for a

build or no-build alternative. These are input into specific models by environmental specialists to determine impacts of air quality and noise.

Air Quality Conformity – a method to ensure that Federal funding and approval goes to those transportation activities that are consistent with air quality goals. Conformity applies to transportation plans, transportation improvement programs (TIPs), and projects funded or approved by the Federal Highway Administration (FHWA) or the Federal Transit Administration (FTA) in areas that do not meet or previously have not met air quality standards for ozone, carbon monoxide, particulate matter, or nitrogen dioxide.

Alternate Mobility Standards – Adopted by the Oregon Transportation Commission and developed in accordance with Action 1.F.1 in the Oregon Highway Plan, these modify the mobility targets for a specified corridor/area/intersection via an adopted plan. These can be volume-to-capacity ratios or based on other substituted performance measures.

Aggregate Probabilistic Limiting Velocity Model (APLVM) – HERS-ST model used to calculate free-flow speed based on curve geometry, pavement roughness and posted speed.

Arterial – A roadway with primary function being mobility rather than property access

Automatic Traffic Recorder (ATR) – Electronic counting site on a roadway that counts vehicles continuously.

Assignment (Model) – The placement of travel demand model volumes on the model roadway network.

Automatic Vehicle Classifier (AVC) – Similar to an ATR, but these new installations also record the 13 FHWA vehicle types including passenger cars, buses and trucks.

Back of Queue – Refers to how far back it is to the last car lined up at a traffic signal. Maximum extent of the queue relative to the stop line during a signal cycle. The last queued vehicle that joins the back of queue is the last vehicle that departs at the end of the saturated part of green interval or the available gap interval.

Benefit Cost Ratio (B/C or BCR) – The relative monetized (can be tangible or non-tangible) benefits divided by the cost, typically expressed as a decimal. Accepted ratios are 1.0 or greater.

Blocking Percentage – The proportion of time expressed as a percentage of the peak hour that a queue obstructs an upstream turn lane or intersection or other significant point (i.e. railroad crossing).

Buffer Index – The percentage additional travel time (or time cushion) users must add to their average travel time to ensure on-time arrival 95 percent of the time.

Build Volume – The volume used for a build alternative. Also known as the design hour volume (DHV).

Built Environment – refers to the human-made surroundings that provide the setting for human

activity, ranging in scale from buildings and parks (green space) to neighborhoods and cities. This includes supporting infrastructure such as water supply, and energy networks.

Calibration – Calibration refers to comparing the output from travel demand models run using data on existing population, employment and travel patterns with current traffic counts. Adjustments are made to the model when inconsistencies are identified between the models and actual counts. Calibration also applies to micro-simulation models.

Capacity – The maximum sustainable flow rate at which vehicles or persons can reasonably be expected to traverse a point or uniform segment of a lane or roadway during a specified time period under given roadway, geometric, traffic, environmental, and control conditions; usually expressed as vph, pcph, or pph. In other words, capacity is the maximum number of cars per hour that can travel on a particular stretch of roadway, with consideration given to the number of lanes, lane width, traffic signals, speed limit and other features.

Centroid Connectors – Links that connect centroid nodes with the model network. These can represent local streets not included in the model network. Centroid Connectors provide the linkage between the trips associated with the TAZ land uses and the roadway segments (or links).

Centroids – They represent the center of activity for a transportation analysis zone (TAZ). This is not the geometric center of the zone.

Channelized Intersection – intersection with restricted turn movements either by signs, pavement markings, medians, or other types of traffic control.

CMF Clearing House – A database produced by the FHWA that contains over 2500 crash modification factors for over 700 safety countermeasures.

Collision Diagram – See Crash Diagram

Congestion Management System (CMS) – A systematic process which provides information on transportation system performance and alternative strategies to alleviate congestion and enhance the mobility of persons and goods.

Comprehensive Plan – A generalized, coordinated land use map and policy document of a local government that interrelates all functional and natural systems and activities relating to the use of lands, including but not limited to sewer and water systems, transportation systems, educational facilities, recreational facilities, natural resources and air and water quality management programs.

Conflict Points – The crossing, merging or diverging of two vehicular, bicycle, or pedestrian traffic movements on a roadway. These are the points where collisions are likely to occur.

Congestion – A condition on road networks that occurs with increased traffic volumes, and is characterized by slower speeds, longer trip times and increased queueing.

Congestion Pricing – The policy of charging drivers a fee that varies with the level of traffic on

a congested roadway. Congestion pricing is designed to allocate roadway space more efficiently. Congestion pricing is also known as relief tolling, variable pricing and road pricing.

Context Sensitive Solutions (CSS) – a collaborative interdisciplinary approach involving all shareholders to provide a transportation facility that integrates well within the physical environment and preserved the local scenic, aesthetic, historic and environmental resources while maintaining safety and mobility.

Coordinated (Signals) – Signals that are adjusted or connected so that they provide for continuous flow of traffic between intersections at a given speed. Coordinated signals all have the same speed. Coordinated signals can be timed, interconnected, or controlled from a central operations center.

Cordon – An imaginary boundary (non-linear) strategically drawn across an area. The volumes on the links crossing the cordon are typically summed to understand the amount of trips entering and exiting an area.

Corridor Plan – A transportation plan that addresses a specific segment of the transportation system. Can address a single roadway or more likely, parallel multimodal facilities.

Cost Effectiveness Index Analysis Spreadsheet – adaptation of the HSM spreadsheets to analyze countermeasures for bicycle and pedestrian crashes on urban and suburban arterials.

Crash Coding Manual – A publication produced by ODOT that compiles data from reported motor vehicle traffic crashes occurring on city streets, county roads, and state highways.

Crash Diagram – A graphical illustration of historical crashes at a location including position, time of day, number of injuries and other conditions present.

Crash Decoder Tool – a macro based spreadsheet tool that converts information from the PRC crash listing. This tool eliminates the need to use the ODOT Crash Code Manual.

Crash Modification Factor (CMF) – A multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site.

Crash Reduction Factor (CRF) – As used in ARTS, the inverse of CMF.

Critical Crash Rate – a crash rate that has been statistically adjusted based on other roads with similar characteristics to remove random chance elements.

Critical Hour Listing – Typically the top 100- 500 hours at a location used to determine when the 30th highest hour or other design hour occurs.

Cycle Length – The time it takes for a signalized intersection to go through all movements and indications.

Delay – The additional travel time experienced by a vehicle, bicycle, or pedestrian with reference to a base travel time, e.g., the free-flow travel time.

Design Hour Volume – The design hour volume is the amount of traffic that a new facility is designed to accommodate. The 30th highest hour traffic is generally used as the design hour for most highway facilities.

Design Life – The number of years into the future that a project element operates satisfactorily considering increases in traffic demand volumes.

Design Speed – The maximum safe speed that can be maintained over a specified section of highway. The design speed of a roadway dictates which geometric design standards are used, such as stopping sight distance, radius of curves, and banking (super-elevation) of road surfaces. This differs from posted speed.

Desirable Condition – The ideal maneuver and PIEV distance used for calculating intersection functional area.

Detector – A device by which vehicle or pedestrian traffic registers its presence. The most common detectors are the inductive loop detectors in the pavement for vehicles and the push-button detectors for pedestrians. The most common use of detectors is at intersections where they can be used to manage the traffic and pedestrian signals. However, detectors are also used on freeways and freeway ramps to provide information such as speed and volumes for freeway traffic.

Deterministic – A mathematical model that is not subject to randomness. For a given set of inputs, the result from the model is the same with each application.

Diverge – A movement in which a single stream of traffic splits into two separate streams without the aid of traffic control devices.

Division 51 – General reference to OAR 734-051, which pertains to Highway Approaches, Access Control, Spacing Standards and Medians.

Downstream Functional Area – Functional area for vehicles leaving an intersection.

Downtown Plan – A type of area plan focusing on the central business district usually evaluating pedestrian/bicycle/vehicle safety and operations and parking.

Enhanced Interchange Safety Analysis Tool (ISATe) – tool from the HSM used to predict the frequency and characteristics of crashes on freeways and interchanges.

Environmental Justice – Process that ensures that highway projects do not disproportionately impact one segment of the population, e.g., low-income or minorities.

Exponential (compound) – Compound growth is an accelerating growth curve typically associated with brand new growth in an area that has plenty of land and road capacity. This is typically limited to five years or less. Use of an exponential curve over a prolonged period can seriously overestimate future growth.

Expressway – An expressway is a divided highway facility usually having two or more lanes for

the exclusive use of traffic in each direction and incorporating partial control of access.

External Station – A location where a roadway crosses the outside boundary of a travel demand model or zonal cumulative analysis.

Facility Plan – A study that focuses on a specific facility. A facility can be any roadway, bikeway, or pedestrian path made up of multiple segments.

Fatal Flaw – A flaw in the design that would ultimately keep the facility from functioning as intended and/or violates certain policy or minimum design standards (where design exceptions would be unsafe).

Floating Car – A probe vehicle traveling with the traffic flow for the purpose of recording travel times, where the car is driven such that the number of vehicles that pass the "floating car" is equal to the number of vehicles that the "floating car" passes. This is how the floating car approximates the average travel time of the given section.

Flyover – A directional ramp structure that is typically used to remove a left turn movement out of an at-grade intersection to improve operations.

Focusing Model – A model with additional refinement and detail within a subarea. The additional resolution may be added to the transportation network or the zone structure.

Free-Flow Speed – Speed at which vehicles travel unimpeded by effects of other vehicles. Typically taken as five mph over the posted speed for planning and preliminary engineering applications.

Freight Route – A highway that has been recognized for its overall importance in intra and interstate commerce. May have specific mobility and design considerations applied.

Frontage Road – A roadway that parallels a major transportation facility, such as a freeway, and provides access to residents and businesses.

Functional Area – (See also: Influence Area) The area in which an intersection affects vehicle paths such as influencing driver decisions, vehicle movements, and vehicle queues.

Future Volume Table – Table that shows future AADT volumes for state highway segments based on historical traffic counts or travel demand model based growth trends.

Freeway (fwy) – A divided highway facility having two or more lanes for the exclusive use of traffic in each direction and full access control.

Goals and Objectives (G & O) – Primary desired outcomes on a project or plan. Evaluation criteria are based on these.

Grade – The slope (ratio of change in elevation to change in distance) of a roadway typically given in percent. For example, a 2% grade represents a 2-foot elevation change over a 100-foot distance.

Grade Separation – A vertical separation between intersecting roads or railroad tracks. One facility travels over the other via an overpass or other structure.

Gravity-Based Distribution – Trip distribution based on the gravity model which illustrates the distance, time and cost relationship between activities and their respective locations.

Growth Factor – A percentage increase applied to current traffic demands to estimate future demands. Expressed as 1 + the decimal percentage of the change (i.e. 1.34).

Growth Rate – This is the rate at which traffic volume is expected to increase annually on a specific facility.

Headway – The time between two successive vehicles as they pass a point on the roadway, measured from the same common feature of both vehicles (for example, the front axle or the front bumper), expressed in seconds.

Highway Classification (Per OHP) – Classification based on FHWA (federal) Functional Class.

Highway Safety Improvement Program (HSIP) – FHWA program that provides federal aid for safety projects on all public roads.

Historical Trends – Long-term trends identified from analysis of historical data

Hot/Cold Start Percentages – These are calculations used in air quality analysis. They provide an estimate of the amount of time vehicles have been running when they enter a section of roadway.

HOV Lane – An exclusive road or traffic lane limited to buses, vanpools, carpools, emergency vehicles, and, in some cases, single occupant motorcycles. HOV lanes typically have higher operating speeds and lower traffic volumes than adjacent general-purpose lanes.

Incident – An event or condition on a roadway that impedes the normal flow of traffic.

Influence Area – The overall length of a segment controlled by the operation of a geometric or other traffic control feature. This is much longer than the feature itself. Typically involves merge/diverge points or traffic signals.

Intelligent Transportation Systems (ITS) – Transportation technology that allows drivers, vehicles, devices, and system operators to gather and use real-time information to improve vehicle navigation, roadway system operations, or both.

Interchange Area Management Plan (IAMP) – A plan to determine transportation solutions or land use/policy actions needed in an interchange area and how best to balance and manage transportation and land use issues over time.

Interim Year – A forecast year between the base/existing year and the design or horizon year.

J-turn – An intersection design to facilitate a minor street left turn onto a major street where a non-traversable median is present. This design accommodates all vehicles including trucks via a right turn followed by a larger radius U-turn.

KABCO – A scale of crash injury severities.

Least Cost Planning – The process of comparing direct and indirect costs of demand and supply options to meet transportation goals, policies or both, where the intent of the process is to identify the mix of options with the best value.

Link Diagram – A link and node representation of an intersection or transportation facility.

Links – A length of roadway between two nodes or points.

Logarithmic – A decelerating growth curve which tapers off as land approaches built-out status and capacity of roadways. Future growth is mainly contributed by growth in background (through) traffic.

LOS (Level of Service) – A quantitative measure describing operational conditions within a traffic stream and motorists' perceptions of those conditions. For example, LOS A represents free flow - almost complete freedom to maneuver within the traffic stream. LOS F represents forced flow - more vehicles are attempting to use the highway than can be served, resulting in stop-and-go traffic.

LOS C Volume – Term used in noise analysis. LOS C represents the level of congestion where speeds begin to reduce in a meaningful way. Therefore LOS C represents the maximum volume at the maximum speed that produces the maximum noise.

Macroscopic Model – an aggregate model with a high-level view of the transportation system, which does not include many transportation network details. Macroscopic models are generally large and focus on the general flow of travel and route/mode choice from one area to another. System details are usually approximates, or averages including number of lanes, free-flow speed, and vehicle capacity.

Merge– A movement in which two separate streams of traffic combine to form a single stream without the aid of traffic signals or other right-of-way controls.

Mesoscopic Model – A hybrid model that includes combinations or approximations of elements from both macroscopic and microscopic models. May include a routable network similar to a macroscopic model, while also incorporation more detailed operation elements of the transportation network to better estimate travel time based on traffic operation similar to a microscopic model. Accounts for queuing on each link but not at the individual vehicle level.

Methodology & Assumptions Memorandum – A memorandum describing all of the volume development and analysis assumptions for the existing and future conditions. Submitted for approval before analysis tasks begin.

Microscopic Model – A calibrated highly detailed model simulating individual vehicles and

driver behaviors on a transportation network requiring a high degree of detail.

Mitigation –An action that avoids, addresses or modifies a negative impact. Typically used in environmental analysis and development review.

Mobility – The ability of the transportation system to facilitate the movement of people, goods and services to and from desired destinations.

Mobility Target – An Oregon Highway Plan volume-to-capacity ratio that indicates a desirable level of performance on a facility.

Mode Choice – The process used to determine the modeled choice in which a user will reach their intended destination (i.e. Car, bus, bike, walk...etc.).

Modernization – The process of updating current infrastructure for the purpose of increasing safety or functionality of the system.

Metropolitan Planning Organization (MPO) – An association of local agencies established by federal law to coordinate transportation planning and development activities within a metropolitan region.

Multi-Modal – Multiple modes of transportation consisting but not limited to automobile, bus, bicycle, and pedestrian travel.

Multi-Resolution – An integrated series of models, each built or scaled for the appropriate level of detail given the context of the project application and need.

No-build Volume – Can refer to existing conditions or more commonly to a set of future conditions without any of the subject plan/project improvements in place. The no-build will usually include other projects in the area that might be in a funded capital improvement and/or financially constrained plan. In the context of a travel demand model, no-build is thought of as a "do nothing" with no other project improvements assumed.

Nodes – Indicates the intersections of links.

Nomograph – a graph containing three parallel scales graduated for different variables so that when a straight line connects values of any two, the related value may be read directly from the third at the intersection point.

Non-Attainment Area – An area where air pollution levels persistently exceed the nation ambient air quality standards.

OHP Mobility (V/C) Target – Targets set by the Oregon Highway Plan for volume to capacity ratios for each specific facility classification.

Operational Analysis – An application of a methodology where the user supplies all or nearly all required inputs to the procedure instead of using defaults. Should not be confused with the analysis of operations which could occur at any detail level.

Operations – Strategies and solutions that optimize or preserve the existing transportation system for mobility and safety through the process of improving the flow of the existing system.

Origin – Destination (O-D) Study- Conducted as a part of an overall regional transportation study in order to identify travel patterns between the starting (origin) and ending (destination) points of trips within the region.

ORS 366.215 – Oregon Revised Statute written to restrict the permanent reduction of vehicle-carrying capacity along identified freight routes.

Overlay Zone – Area established with special regulations that address specific subjects in addition to, and used to modify the regulations of the base zone. Overlay Zones can exist in multiple types such as Buffer Zones, Environmental Zones…etc.

Park-and-Ride – Park-and-Ride lots are designed for automobile parking at outlying locations along transit routes.

Peer Review – An evaluation of work performed by one or more individuals of similar field and competence to the producers of the original work. Peer review is used as a method to maintain standards of quality, improve accuracy and provide credibility.

Performance Measure – An individual quantitative or qualitative value that identifies the degree that a facility/strategy/action meets a certain goal, objective or policy.

Phase – The part of the signal cycle allocated to any combination of traffic movements receiving the right-of-way simultaneously during one or more intervals. A phase can include green, yellow change, red clearance, pedestrian, and bicycle intervals.

Phase Split – Duration of an individual signal interval in a signal cycle.

Planning Analysis – An application of a methodology where most or all of the required inputs are defaulted.

PLANSAFE – A regional scale safety analysis tool.

Posted Speed – The posted speed is a regulatory sign identifying the legal speed on a roadway. It is based on a statistical sampling of existing traffic speeds, safety issues, etc., and is typically lower than design speed.

Post-processing – Refers to additional processing of data after it's been collected in order to enhance the data, or make the original data easier to understand. In the context of the APM this refers to the future volume development process merging traffic counts with relative changes between different travel demand model scenarios.

Practical Design – A design philosophy that is used to conserve resources while meeting system needs, balancing cost with system value, and following business practices.

Predictive Method – A detailed Highway Safety Manual Part C methodology that calculates

future crash frequency.

Preservation – Projects that maintain facilities but do not add significant safety or capacity improvements. Typically these are pavement, shoulder, curb/gutter/sidewalk and striping/signing projects.

Progression Analysis – Study conducted to optimize speed and delay in the traffic flow along a signalized corridor.

Project Limits – the physical boundaries of a project usually defined by milepoints.

Project Prospectus – document that defines the major features of a project, and includes enough detail to fairly scope the project.

Purpose and Need (P & N) – Explanation of what the project intends to address (purpose) and why it is necessary (need).

QCEW (Quarterly Census of Employment and Wages) Data – A quarterly report on employment and wages by industry, provided by the Oregon Employment Department.

Queue – A line of vehicles or pedestrians waiting to proceed through an intersection or bottleneck. Slow-moving vehicles or pedestrians joining the back of the queue are usually considered part of the queue.

Queue Spillback – When traffic queues at an intersection or bottleneck build up to the point that they block turn lanes, driveways, or even upstream intersections. See Blocking Percentage.

Refinement Plan – Level of transportation plan that focuses on a specific topic, feature, mode, or highway segment in a sub-area.

Riparian – relating to or situated on the banks of a waterway.

Road Diet – A reduction in through-lanes for a given roadway; occurs within a "complete street" process that optimizes the available pavement width across all modes. Typically occurs with the conversion of a four-lane street down to two travel lanes and a two-way left turn lane.

Roadway Functional Class – Federal classification of a roadway according to a jurisdiction by typical use and volume. Major categories typically include Interstates, other freeways, arterials, collectors, or locals.

Rural – Areas with less than a population of 5,000 outside of established urban growth or metropolitan planning boundaries.

Safety Priority Index System (SPIS) – A method developed by ODOT to flag safety issues on state highways.

Safe Routes to School – A set or programs sustained by community leaders, local, state and federal governments to improve the health and well-being of children by enabling and

encouraging them to walk and bicycle to school.

Saturation Flow Rate – The maximum departure (queue discharge) flow rate achieved by vehicles departing from the queue during the green period at traffic signals.

Screening – The process of evaluating and reducing the potential number of alternatives.

Screenlines – Imaginary lines that are strategically drawn across network links. The volumes on the links crossed by the screenlines are summed. Typical use of a screenline is to compare the volume of traffic entering and leaving the study area for each alternative.

Scoping – the process of identifying approach, tools and efforts based on analysis need prior to beginning a project.

Seasonal Adjustment – the process to adjust traffic volumes to reflect a specific time of year. This is typically the summer peak or the average weekday conditions.

Seasonal Factor – the calculated value used for adjusting traffic volumes to specific time of year.

Seasonal Trend Table – An ODOT-produced table of factors calculated from yearly patterns of automatic traffic recorder data used to estimate seasonal traffic count adjustments.

Segment-Based Analysis – Facility analysis performed between intersections or ramp junctions.

Sight Distance – A distance a vehicular driver needs to be able to see in order to have adequate room to stop or otherwise avoid an obstacle or collision.

Signal Progression – The timing of signals such that a group or platoon of cars arrives at a succession of green lights and proceeds through multiple intersections without stopping.

SimTraffic – performs micro simulation and animation of vehicle traffic, modeling travel through signalized and unsignalized intersections and arterial networks, as well as freeway sections, with cars, trucks, pedestrians and buses. SimTraffic includes the vehicle and driver performance characteristics developed by the Federal Highway Administration for use in traffic modeling.

STIP (State Transportation Improvement Program) – A multi-year, statewide, multi-modal program of transportation projects. The STIP must be consistent with the Oregon Highway Plan, Oregon Transportation Plan and regional and local transportation system plans.

Stochastic – Describes an outcome derived from random probability distribution that may be analyzed statistically but may not be predicted precisely (repeated attempts result in different results).

Storage Length – The available lane distance for holding queued vehicles.

Straight-Line Growth – Steady (linear) growth over time.

Study Area – The geographical area selected for analysis.

Sub-Area Modeling – Process for increasing the detail level in an existing travel demand model. The two major methods are Focusing and Windowing.

System (Systemic) Level – Consideration of all transportation facilities and modes in a particular region.

System Peak Hour – The predominant peak hour used for all locations within a study area.

Transportation Analysis Zone (TAZ) – A geographic unit used in travel demand models. These contain data population, employment, and household characteristics, as well as other land use attributes.

Transportation Demand Management (TDM) – Actions or programs that encourage people to travel at alternative times or with fewer vehicles, e.g., rideshare/carpool programs, transit fare discount programs, and flextime.

Travel Demand Model (TDM) – A computerized model which estimates travel patterns based on network characteristics (e.g., number of lanes, access points), demographics (e.g., population characteristics, employment) and observed travel patterns for a given of roadways.

Travel Time – The time taken to travel between two points.

Transportation Strategy – A general approach to solving a transportation problem which can consist of policies, plans, and /or physical projects.

Transportation System Management (TSM) – Operation-based actions (e.g., ramp metering) that control or improve the flow and safety on the roadway system.

Transportation System Plan (TSP) – A plan required by the Transportation Planning Rule (TPR) establishing a system of transportation facilities and services to meet state, regional and local needs.

Trip Distribution – The number of trips that occur between each origin zone and each destination zone.

Trip Generation – The number of trips created from a specific type of land use. The ITE Trip Generation Manual provides the accepted source for estimates of vehicular traffic generation for various land use types. It is also the first step in the transportation forecasting process for travel demand models that estimates person trips based on housing and employment data.

TruckSum – An ODOT-produced spreadsheet for calculating directional factors, k-factors, and hourly truck factors from individual counts.

Upstream Functional Area – functional area for vehicles approaching an intersection.

Urban – Areas with moderate to high densities of development and population.

Volume-to-Capacity Ratio (v/c) – The ratio of the traffic flow rate to the capacity of the road. A v/c ratio over 1.0 indicates the road or intersection is over-capacity; a v/c ratio under 1.0 indicates there is still room to accommodate additional vehicles.

Validation –Testing a calibrated model under different conditions for reasonability.

Variable Messaging – practice of using variable message boards with the capability of displaying a different message based on system needs or changing conditions.

Vehicle Hours of Travel (VHT) – the sum of the travel times incurred by all motor vehicles in a specified system of highways for a given distance. VHT is calculated by multiplying the AADT value for each section/segment of road by the section/segment travel time (in hours) and summing all sections to obtain the VHT for the complete route.

VISSIM Protocol – The ODOT document used to guide the proper creation of VISSIM-based microsimulations.

Vehicle Miles of Travel (VMT) – the sum of the distances traveled by all motor vehicles in a specified system of highways for a given period of time. VMT is calculated by multiplying the AADT value for each section/segment of road by the section/segment length (in miles) and summing all sections to obtain the VMT for the complete route.

Volume Balancing – Mathematically balancing the traffic volumes between two points.

Weave – A section of a highway where two or more vehicle flows must cross each other's path. Weaving areas are usually formed when merge areas are closely followed by diverging areas.

Weigh-In-Motion (WIM) – a permanently installed device for weighing vehicles in the traveled lanes.

Windowing Model – A cut out portion or “window” of an existing model that contains a subarea of the transportation network and creates cordon areas at the edge of the subarea. The window allows additional refinement, and greater detail while still maintaining consistency with the original model.

Zero-Volume Delay – Delay associated with traffic control devices. This is the expected delay that a single vehicle would encounter even if it were the only vehicle on the road.

Zonal Cumulative Analysis – A manual three-step analysis that involves the creation of zones and utilizes ITE Trip Generation methodologies, external trip O-D pairs, and gravity based distribution.

Zoning Maps – Map of the local geographic area that defines current zoning designation and land use.

ABBREVIATIONS AND ACRONYMS

NOTE: This is a work in progress and currently incorporates terms from APM Version 2 Chapters 1-6.

AADT – Annual Average Daily Traffic

AASHTO – American Association of State Highway and Transportation Officials

ABM – Activity Based Demand Model

ACT – Area Commission on Transportation

ADT – Average Daily Traffic

AES – Average Effective Speed

ALD – Aggregate Land Development

AMP – Access Management Plan

AMStrat – Access Management Strategy

AMU – Access Management Unit

APLVM – Aggregate Probabilistic Limiting Velocity Model

APM – Analysis Procedure Manual

AQMA – Air Quality Maintenance Area

ArcGIS – Geographic Information Software by ESRI.

ARTS – All Roads Transportation Safety Program

ATR – Automatic Traffic Recorder

AVC – Automatic Vehicle Counter

Ave – Avenue

AWDT – Annual Weekday Traffic

AWSC – All Way Stop-Controlled

BCR – Benefit Cost Ratio

BLI – Buildable Lands Inventory

Blvd – Boulevard

BMP – Beginning Mile Post

CAC – Citizen's Advisory Committee

CAR Unit – Crash Analysis and Reporting Unit

CHAMPS – Central Highway Approach Maintenance Permit System

CIP – Capital Improvement Program

CMF – Crash Modification Factors

CMS – Congestion Management System

COG – Council of Governments

CORSIM – Corridor Simulation Software by FHWA

CRF – Crash Reduction Factor

CT – Commercial Transport

d/c – demand-to-capacity ratio

DDI – Diverging Diamond Interchange

DHV – Design Hour Volumes

DLCD – Department of Land Conservation and Development

DMV – Department of Motor Vehicles

Dr – Drive

DTA – Dynamic Traffic Assignment

DUE – Dynamic User Equilibrium

EA – Environmental Assessment

EB – Empirical Bayes

ED – Economics and Demographics

EFU – Exclusive Farm Use

EIS – Environmental Impact Statement

EMME/2 – Travel demand modeling software by INRO

EP – Excess Proportion

EPM – Environmental Program Managers

ET – External Transport

EZCA – Enhanced Zonal Cumulative Analysis

FADT -– Future Average Daily Traffic

FC – Functional Class

FEIS – Final Environmental Impact Statement

FFS – Free Flow Speed

FHWA – Federal Highway Administration

FONSI – Finding of No Significant Impact

FR – Freight Route

FTA – Federal Transit Authority

GHG – Greenhouse Gas

GIS – Geographic Information System

GISU – GIS Unit

GreenSTEP – Greenhouse Gas Strategic Transportation Energy Planning Model

HCM – Highway Capacity Manual

HCS – Highway Capacity Software

HDM – Highway Design Manual

HERS-ST – Highway Economic Reporting System – State Version

HOC – Hours of Congestion

HOV – High Occupancy Vehicle

HPMS – Highway Performance Monitoring System

HSEC – Highway safety Engineering Committee

HSIP – Highway Safety Improvement Program

HSM – Highway Safety Manual

Hwy – Highway

IAMP – Interchange Area Management Plan

ICU – Intersection Capacity Utilization

IDAS – ITS Deployment Analysis System

IHSDM – Interactive Highway Safety Design Model

ISATe – Enhanced Interchange Safety Analysis Tool

ISD – Intersection Sight Distance

ITE – Institute of Transportation Engineers

ITIS – Integrated Transport Information System

ITS – (Intelligent Transportation Systems

LCDC – Land Conservation and Development Commission

LCOG – Lane Council of Governments

LCP – Least Cost Planning

LRT – Light Rail Transit

LSN – Local Street Network

LUSDR – Land Use Scenario DevelopeR

MAZ – Micro-Analysis Zone

MEV – Million Entering Vehicles

MIS – Major Investment Study

MMA – Multimodal Mixed-Use Areas

MMLOS – Multi-Modal Level of Service

MOVES – MOtor Vehicle Emission Simulator

MP – Milepoint

MPMLUC – Modeling Procedures Manual for Land-use Changes

MPO – Metropolitan Planning Organization

MR3ST – Multilane Rural 3-leg, minor stop

MR4ST - Multilane Rural 4-leg, minor stop

MR4SG - Multilane Rural 3-leg, signalized

MRD – Multilane Rural Divided

MRU – Multilane Rural Undivided

MUTCD – Manual of Uniform Traffic Control Devices

MVM – Million Vehicle Miles

MVMT – Million Vehicle Miles Traveled

MWVCOG – Mid-Willamette Valley Council of Governments

NCHRP – National Cooperative Highway Research Program

NEPA – National Environmental Policy Act

NHI – National Highway Institute

NHS – National Highway System

NHTSA – National Highway Traffic Safety Administration

OASIS – Oregon Adjustable Safety Index System

OAR – Oregon Administrative Rules

O-D – Origin-Destination

ODME – Origin-Demand Matrix Estimation

ODOT – Oregon Department of Transportation

OFP – Oregon Freight Plan

OHP – Oregon Highway Plan

OPL – Office of Project - Letting

ORS – Oregon Revised Statutes

OTC – Oregon Transportation Commission

OTP – Oregon Transportation Plan

P&N – Purpose and Need

PCE – Passenger Car Equivalent

pcph – Passenger Cars Per Hour

pcphgl – Passenger Cars Per Hour of Green Per Lane

pcphpl – Passenger Cars Per Hour Per Lane

PDLT – Project Delivery Leadership Team

PDO – Property Damage Only

PDT – Project Development Team

PE – Professional Engineer

PHEV – Plug-in Hybrid Electric Vehicles

PHF – Peak Hour Factors

PHV – Peak Hour Volume

PIEV – Perception, intellection, emotion and volition

PI – Productions and Interactions

PM – Particulate Matter

PMS – Pavement Management System

PRC – Comprehensive (Crash) Report

PSA – Public Service Announcement

PSU – Pavement Services Unit

PSW – Preliminary Signal Warrants

PT – Project Team

PT – Person Travel

PUD – Planned Unit Development

R2 – rural 2 land undivided

R3ST – Rural 3 leg minor stop

R4SG – Rural 4 leg signalized

R4ST – Rural 4 leg minor stop

RAME – Regional Access Management Engineer

Rd – Road

REA – Revised Environmental Assessment

RICS Unit – Roadway Inventory and Classification Services Unit

RIRO – Right-In/Right-Out

RM – Residential Urban Medium Density

ROW – Right of Way

RPAT – Rapid Policy Assessment Tool

RS – Residential Urban Standard Density

RSPM – Regional Strategic Planning Model

RTM – Regression to the mean

RTP – Regional Transportation Plan

RV – Residual Value

RVMPO – Rogue Valley Metropolitan Planning Organization

SCFT – Small Community Forecast Tool

SHRP2 -– Strategic Highway Research Program 2

SIDRA – Signalized and Unsignalized Intersection Design and Research Aid

SIGCAP2 – Signalized Intersection Capacity Analysis Program Version 2 (by ODOT)

SIP – State Implementation Plan (Air Quality)

SOW – Scope of Work

SPF – Safety Performance Functions

SPG – Synthetic Population Generator

SPIS – Safety Priority Index System

SPR – State Planning and Research Program

SPUI – Single Point Urban Interchange

SSAM – Surrogate Safety Analysis Method/Model

St – Street

STA -– Special Transportation Area

STIP – Statewide Transportation Improvement Program

STS – Statewide Transportation Strategy

SWIM – Statewide Integrated Model

TAZ – Transportation Analysis Zone

TCM – Traffic Count Management

TCQSM – Transit Capacity Quality of Service Manual

TDD – Transportation Development Division

TDM – Transportation Demand Management

TDS – Transport Data Section

TGM – Transportation and Growth Management Program

TIA – Traffic Impact Analysis

TPR – Transportation Planning Rule

TRI – Transportation Research Institute

TRS – Traffic-Roadway Section

TEV – Total Entering Volume

TGM – Transportation Growth Management

TIA – Traffic Impact Analysis

TIP – Transportation Improvement Program

TIS – Transportation Impact Study

TM – Technical Memorandum

TPAU – Transportation Planning Analysis Unit

TPOD – Transportation Planning Online Database

TPU – Transportation Planning Unit

TRB – Transportation Research Board

TS – Transport Supply

TSM – Transportation System Monitoring

TSP – Transportation System Plan

TSRM – Technical Services Resource Manager

TTI – Texas A& M Transportation Institute

TTI – Travel Time Index

TUDI – Tight Urban Diamond Interchange

TVT – Transportation Volume Tables

TWLTL – Two-Way Left-Turn Lane

TWSC – Two-Way Stop Controlled

U2U – Urban 2 lane undivided

U3T – Urban 3 lane with two-way left turn lane

U3SG – Urban 3 lane signalized

U3ST – Urban 3 leg minor stop

U4D – Urban 4 land divided

U4SG – Urban 4 leg signalized

U4ST – Urband4 leg minor stop

U4U – Urban 4 land undivided

U5T – Urban 5 lane with two-way left turn lane

UBA – Urban Business Area

UGB – Urban Growth Boundary

UTDF – Universal Traffic Data Format

v/c – Volume to capacity ratio

VCR – Volume to capacity ratio

vdf – volume delay function

VMS – Variable Message Sign

Vph – Vehicles Per Hour

vphpl – Vehicle Per Hour Per Lane

VR – Volume Ratio