10 ANALYZING ALTERNATIVES

10.1 Purpose

This chapter provides guidance on facility level alternative transportation analysis for corridor plans, refinement plans, and project development with or without National Environmental Policy Act (NEPA) involvement. If NEPA is involved or is intended to be involved in the future such as in the creation of an Environmental Impact Statement (EIS) or an Environmental Assessment (EA) then the NEPA guidance for alternative analysis must be followed. Most projects are deemed "CE" for Categorical Exclusion (CE) as there are little to no adverse impacts and typically do not go through the NEPA process. An exception is if the CE project goes through federal lands such as Forest Service or Bureau of Land Management. The NEPA process is usually done by the federal agency, but ODOT can still prepare the environmental document.

The traffic analysis portion of the alternative development is only a small part. A NEPA process requires a much broader analysis of the alternative encompassing many diverse areas. Other areas such as right-of-way, air quality, socio-economics, or noise may have an equal or greater influence on the decisions made. The purpose of alternatives analysis is to analyze Existing or Future No Build needs or deficiencies in order to develop and evaluate solutions. This process is similar for both planning and project development, the main difference being level of detail of the analysis. The guidance covered in this chapter is based on an adaptation of the EIS process, as it is the most comprehensive and most closely follows the planning process. Smaller CE projects may not go through all of the steps described. More and more the planning process is linked to the NEPA process to minimize rework and to speed up the ordinary long timelines. This Planning and Environmental Linkage (PEL) creates NEPA-compatible planning documents with a proper purpose and need, goals and objectives, preliminary screening of alternatives and documentation. The preferred alternative out of a PEL-compatible plan could be rolled straight into a NEPA EA process to be compared with the no-build without any new analysis work or rework for example.

Analysis of alternatives includes definition of the project evaluation criteria, creation of screening processes and documentation for multiple types of solutions. Needs and deficiencies can relate to mobility, safety, multimodal, geometric design, water quality, land use, utilities, etc. Solutions can be either interim or long term, may involve capacity improvements as well as operational elements or strategies. It is necessary to evaluate trade-offs between solutions as part of the decision making process. This includes practical design considerations. Contact the Geo-Environmental Section or the regional environmental coordinator for additional guidance, review, or questions on the overall alternatives analysis process especially if NEPA is involved.

10.2 Project Coordination

The development of potential improvement alternatives should be done in cooperation with any groups within ODOT or other agencies that will be involved in the design, implementation, construction, maintenance or operations of the facilities. The district and regional units within ODOT that may be contacted during this process are listed in Chapter 2.

10.2.1 Traffic Analyst

The traffic analyst may be solely a resource to the project team, providing technical analysis results. In some cases the analyst may be a voting member of the project team, being a part of the decision making process. The technical results that the analyst provides are objective conclusions from the traffic analysis. These need to be vetted and considered along with many other objectives by the larger project team. The traffic analysis results are only part of the overall picture and may not be a primary objective or a deciding factor in the alternative selection process. For more information see APM version 1 Chapter 12.

10.2.2 ODOT Staff

Geo-Environmental or Planning Region staff leads the NEPA process in project development or PEL-compatible plans. Environmental Project Managers govern over the typical contractor that is developing the environmental document and are responsible for ensuring that the NEPA process is followed. Project teams may also have Regional Environmental Coordinators as team members. Geo-Environmental Headquarters staff are the subject-matter experts on NEPA guidance, noise, air & water quality, etc. and may also be involved on project teams directly or as resources.

Typically, the highway design and traffic operations engineers within ODOT have a key role in assisting the review and confirmation of the selected alternatives. This includes both headquarters staff as well as at the regional technical centers. For example, Traffic Roadway Section (TRS), specifically the State Traffic Engineer, must approve certain traffic control devices. Design Exceptions are also approved at the headquarters level. It is a good idea to have headquarters staff perform a preliminary review of project alternatives as they may find issues that may be an impediment to approval. This coordination should occur early in the alternatives evaluation process. Planning staff should also be coordinated with to ensure the project does not potentially conflict with past or current planning efforts. The regional technical center staff that would be responsible for the design and implementation of the selected alternative should be included in the concept development, performance assessment and suggested for further refinements.

The Rail Section, which is part of the Rail and Public Transit Division based in Salem, 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 Section should be contacted any time a project will have an impact directly to or within 500 feet of a railroad or rail crossing.

10.2.3 Other Federal, State and Local Agencies

Other agencies such as FHWA, the Oregon Aviation Department, State Marine Board, Department of Forestry, and BLM may need to be coordinated with depending on the context of the project. Projects on the interstates or NHS system require FHWA coordination. FHWA approves interchange modification requests and oversees the NEPA process for Federal Aid projects. The local authorities for affected roadways, other than the state, should be included in the selection and review of alternatives. Typically this includes local cities, counties, regional metropolitan planning organizations, transit agencies, etc. Tribal governments need to be coordinated with as applicable.

10.2.4 Project Teams/Committees

The project team(s) control the overall flow of the project. The actual teams and composition of them is dependent on the specific planning or project development effort at hand. For more information see ODOT's Project Delivery Guide. This group may also be known as a Technical Advisory Team (TAC) on a planning project. Typical attendees are ODOT /consultant staff representing different technical areas (i.e. traffic, roadway, environmental, right-of way, mode experts, etc.) and local jurisdiction staff (i.e. planners, public works, etc.). Some other state or federal agencies (i.e. FHWA) may be represented. The Project Development Team (PDT) reviews the information provided from the analyst, consultants, other staff, other committees, and provides direction, comments, and decisions/recommendations on next steps. The PDT may have voting to screen down alternatives or may have encompassing discussions on an alternative evaluation matrix to help decide what alternatives move into the next step of the alternative development process.

The Citizen's Advisory Committee (CAC) consists of local stakeholders such as business owners, city council members, bike/pedestrian advocacy groups, freight companies, police and fire departments, transit agencies, legislators, tribal representatives, and private citizens. The CAC reviews and provides comments on information (reports, presentations, etc.) and gives comments. Preferences and priorities may be given on alternatives but the decisions here are not binding and only in an advisory capacity. CAC's may be more common on planning efforts or in EIS's and not every project will have one. There also may be a "Stakeholders" team instead that has similar make-up. Sometimes the PDT-CAC are combined and there may be cross-over in the attendees between both groups.

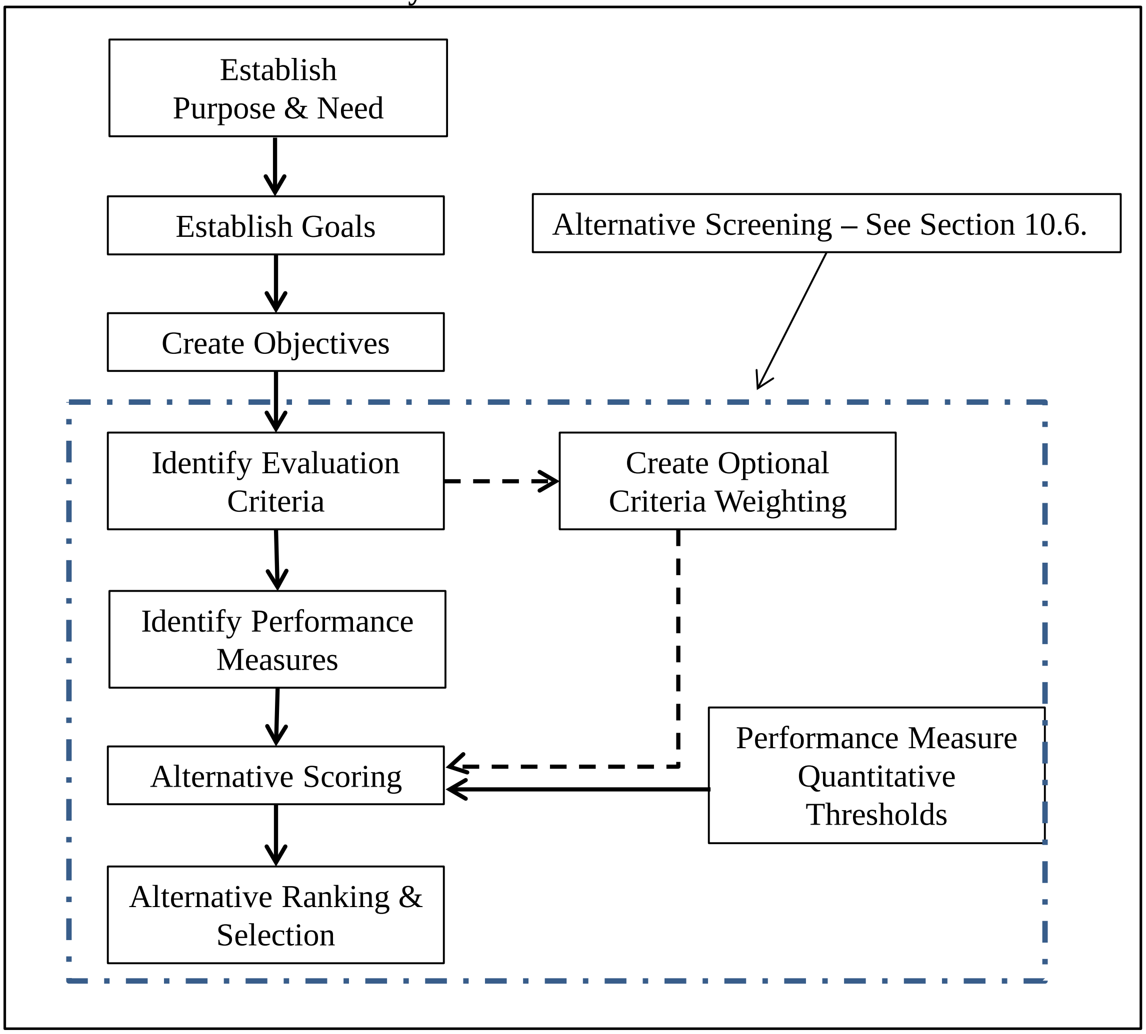
Some regions may also have a Steering Team (ST) or Steering Committee which controls overall direction of the project. These teams come in many forms, but their purpose is to ensure that the project moves forward. The ST is typically made up of high-level officials such as an ODOT Region Planning Manager, mayor or city manager, and county commissioners. When these exist, recommendations from the PDT are given to the ST and the ST makes the final decision on a proposal or alternative that is not delegated to an individual or agency. If an alternative includes a traffic control device for example, the State Roadway/Traffic Engineer has the approval authority over that element and not the ST.

10.3 Overall Alternative Evaluation Process

Every project or plan must have a purpose (what is trying to be done) and a need (what is the project justification) which is developed by the project teams. Alternatives are developed to meet the purpose and to address the need(s). An objective alternative analysis process is necessary to compare and contrast the alternatives without bias so the alternatives can be reduced to a final set or to a single preferred alternative. However, it may be necessary to use professional judgment and some subjectivity when deciding on alternatives as the process can be complex. Exhibit 10-1 illustrates the overall evaluation process.

The purpose and need is developed into goals and objectives which are quantified with evaluation criteria and related performance measures. Plans may also develop policies in concurrence with the goals and objectives. The alternatives analysis results using the performance measures are converted into scores which are then totaled and ranked and the top alternative(s) selected. The screening process can repeat a number of times with increasing detail and specificity for the evaluation criteria and performance measures.

Exhibit 10-1 Alternative Analysis Process



Goals are overarching principles that are sorted based on different considerations such as safety, mobility, multimodal, environmental impacts, livability, socio-economic impacts, accessibility, economic development, etc. Typically safety, mobility, and multimodal goals are required based on current statewide policies and others may be added based on discussions with the project team(s) and stakeholders. Some planning projects will focus on policies in addition to goals. Some example goals are:

- Provide transportation improvements that will accommodate future travel demand safely and efficiently
- Improve transportation system connectivity
- Improve bicycle and pedestrian safety and connectivity
- Provide local and regional access
- Develop a cost effective and environmentally sustainable project that can be funded within the planning horizon
- Consider economic development opportunities
- Minimize impacts to the natural, or built, environment
- Compatibility with local and statewide plans
- Improve freight mobility

Each goal has multiple objectives to provide direction in how to meet the goal. Objectives are specific to one topic so they can be quantified. For example, objectives for mobility and safety goals or improving transportation system connectivity goals could be stated as:

Goal - Improve mobility and safety:

Objective:

- Provide improvements that safely accommodate demand for 20 years
- Provide improvements that are consistent with the classification of the highway per the Oregon Highway Plan

Goal - Improve transportation system connectivity:

Objective:

- Identify local street impacts
- Maintain or improve function of state highway route
- Maintain or improve emergency service response times

Goals may conflict with each other as trying to achieve one may cause significant impact to another. The overall alternative analysis process is a matter of compromise, cooperation, and collaboration with all the involved team members and stakeholders.

From the objectives, evaluation criteria are created to guide the alternative analysis. Evaluation criteria can be weighted, but weighting is optional and more often done in plans rather than projects. It is important that weights be determined before performing any alternative analysis to avoid accidentally creating a biased process. Many methods for weighting exist, but generally may be performed to develop quantitative index values which total into a single value for each alternative. Weights are typically assigned based on the relative importance of each goal via a consensus or vote of the project team(s). If weighting is used, then it needs to be clearly defined to state why a certain criteria was selected to be weighted versus other criteria. The use of weighting needs to be specifically documented as much as possible to avoid creating the appearance of subjectivity. Weighting can be used to help address tradeoffs between disparate goals such as the need for mobility versus minimizing environmental impacts. However, turning this process into a mathematical exercise is not always possible, especially if there are multiple sensitive issues, and can create more issues if done improperly.

The evaluation criteria should be readily explainable, quantifiable, and data driven. In addition, evaluation criteria should be tracked through the development of performance measures. The evaluation criteria will change based on the level of detail that the alternative process is in, such as purpose and need based screening (fatal flaw), goals and objectives based screening (shown in this section), and operational based screening (full detailed, micro-simulation, etc.). From the sample objectives above, the corresponding evaluation criteria could be stated as:

- Objective - Provide improvements that safely accommodate demand for 20 years
  Evaluation Criteria:
    - Conflict points
    - Relative degree that interchange spacing standards are met on the corridor
    - Relative degree that interchange crossroad spacing standards are met
    - Relative degree that weave/merge-diverge spacing are met

- Objective - Provide improvements that are consistent with the classification of the highway per the OHP classification
  Evaluation Criteria:
    - Volume-to-capacity (v/c) ratio

- Objective - Identify local street impacts
  Evaluation Criteria:
    - Demand-to-capacity (d/c) ratio
    - Are there parallel local facilities that can capture trips currently on the state highway?
    - Relative extent that local streets are severed by alternative

- Objective - Maintain or improve function of state highway route
  Evaluation Criteria:
    - Compatibility of highway with OHP spacing standards
    - Volume-to-capacity (v/c) ratio

- Objective - Maintain or improve emergency service response times
  Evaluation Criteria:
    - Travel distance
    - Clearance width for emergency responders

Performance measures/indicators and analysis methods (i.e. how to measure performance) are assigned to each evaluation criteria in order to measure the impacts of the alternatives. Established or potential performance measures are in Chapter 9.These need to be achievable within the project schedule, consistent with the level of detail of the alternatives, and understandable to project team members. From the sample evaluation criteria listed above, possible performance measures could be:

- Conflict points = Number of conflict points
- Relative spacing met = Number of exceptions when standard could not be met
- Demand-to-capacity ratio = Number of locations on state highways with a d/c ratio of 0.90 or higher
- Demand-to-capacity ratio = Number of locations on local streets with a d/c ratio of 1.0 or higher
- Parallel network = Number of local facilities available
- Relative extent of severed facilities = Number of local facilities that are severed by alternative
- Compatibility to OHP spacing standards = Number of deviations required
- Travel distance = Average distance between fixed provider origin and neighborhood destination pairs
- Emergency vehicle clearance width = Number of locations with substandard widths

Each of the performance measures may have additional thresholds applied in order to classify the results into groups such as Met, Partially Met, Not Met or Good, Fair, Poor. For example, for spacing standards, no exceptions would be Good, one exception would be Fair and two or more would be Poor. These thresholds can be quantified by assigning values to each (i.e. 2 pts for Good, 1 point for Fair and 0 points for Poor). Additional weighting of the evaluation criteria would further modify the values for each alternative, eventually resulting in a single alternative score.

To screen alternatives, an evaluation matrix should be developed and applied to all alternatives, and those alternatives that do not meet the basic criteria should be removed from further consideration. Exhibit 10-2 shows a sample evaluation matrix based on the sample goals, objectives, and evaluation criteria used in this section. Thresholds, weights and scores were added for each alternative following the indicated performance measure. For Example, Alternative 1 had four total locations where the d/c ratio exceeded 1.0, had no parallel local facilities, and one severed facility. The project team determined threshold rankings for each performance measure, along with criteria weighting, giving parallel facilities three times the impact and severed local roadways twice the impact of an over capacity segment. These are applied to the alternative screening results to convert the screening results into a score for the transportation system connectivity goal. This would be repeated for each goal and a total score computed for each alternative.

Alternatives that passed the initial screening should be advanced to the broader assessment of operational performance analysis, project refinement, and preliminary cost estimates, as appropriate. The alternative evaluation process needs to be done in a team environment using the project team, TAC, CAC, stakeholders, decision makers, etc.

Exhibit 10-2 Sample Alternative Evaluations Screening Matrix

Goal: Improve transportation system connectivity						
Objective	**Evaluation Criteria**	**Performance Measure**	**Threshold**	**Criteria Weight**	**Alt 1**	**Alt 2**
Identify local street impacts	d/c ratio	Number of local street locations with d/c higher than 1.0	2 pts = none 1 pt <5 0 pts> 5	x1	4	2
	Parallel local facilities	Number of parallel local facilities available	1 pt = Yes 0 pts = No	x3	No	Yes
	Relative extent of severed facilities	Number of severed facilities	2 pts = none 1 pt <5 0 pts >5	x2	1	6
Total Score					3	4

All solutions should take into consideration the context of the study area and address the project purpose.

10.4 Practical Design

Practical design is an integral part of the project and alternative development process. Practical design is about creating the appropriate scope for a project based on a system context, but developed within existing resources to deliver specific tangible results. Projects need to be evaluated on a system basis. For example, a district highway route that is duplicated by other faster high capacity routes would likely remain in its current form; as it would not make much sense to widen a section of it when most of it will never be improved in terms of the long-term vision for the highway. Tangible results can include safety, mobility, condition, multimodal, livability, economic growth, and the environment. Practical design is handled through the project design process by collaborative multi-discipline project teams that rely on good project descriptions, purpose and need statements, and a clear long-term system vision of the particular corridor. Detailed information on the practical design approach for ODOT is available in the Practical Design Strategy.

Project alternatives must address the overall purpose and need of the project. These alternatives need to make the system better as a whole, address changing needs, and maintain current functionality by meeting (but not exceeding) the project's purpose, need, and related goals and objectives. Potential alternatives need to have key issues (i.e. advantages/disadvantages) identified, be screened using an evaluation process, and result in a single choice or range of recommended alternatives that can gather the buy-offs of the major project sponsors (i.e. ODOT HQ/Region, local communities, etc.). The five key Practical Design values (SCOPE) below will help project teams and members meet these basic goals.

- Safety: Overall system safety will not be compromised, but will be made as safe as practical by maintaining or improving the facility safety level.
- Corridor Context: A corridor approach should be used in determining design and other criteria and applied consistently along it. Facilities need to match the overall context and character of the area (see Section 10.4).
- Optimize the System: Developing specific strategies that optimize the life-cycle investment in a particular asset (i.e. interchange, bridge, sidewalks, etc.).
- Public Support: Must work together with local communities in creating solutions and considering needs on a multimodal basis.
- Efficient Cost: Making the best decisions that benefit the entire system by prioritizing the most critical elements. Elements of solutions can be incremental improvements as long as the specific project purpose and need is met.

Project team members will work together to determine the project's purpose and need, identify goals, objectives and related criteria to evaluate the proposed alternatives, and document the decisions made regarding the alternatives. The traffic engineer/analyst as part of the project team must participate in the project and alternative development processes by sharing how their individual discipline contributes to the total project. The project teams must be aware of when potential shifts occur (i.e. an access change that would require future volumes and analysis to be revised) that change the original assumptions or parameters of the project, and they must inform the project team of how those changes may affect different elements of the project, the project schedule, or the project cost.

10.5 Context Sensitive Solutions

The facility design concepts are initially generated based on their potential ability to meet the needs of the project, but each concept must further balance its features against the physical, social, and environmental constraints found at that location. A planning study should provide sufficient preliminary information about a range of constraints that could complicate or preclude a particular solution. Environmental criteria should be established as part of the project's evaluation and selection process. Environmental impacts may be allowed only if there are no other feasible alternatives. The analyst should coordinate with the Project Leader and Environmental Program Manager on these issues.

The typical environmental and physical issues to be considered include the following:

- **Exclusive Farm Use (EFU) Lands**: State regulations are very restrictive about the nature of highway improvements that are allowed within these lands. Without exceptions, no facility improvements are allowed that add capacity to serve nearby urban areas. Limited safety improvements are acceptable.
- **Environmentally Sensitive Zones**: Proximity of fish bearing streams, open space, riparian zone, etc., requires substantial setbacks from any improvements. In federal environmental parlance these are known as "4(f)" zones and may include wildlife refuges, riparian zones in designated recreational area or parks, historic sites, parks, schools and cemeteries. Impacts should be minimized to these areas as mitigation will generally involve more analysis to see if impact can be avoided. Parks and other

recreational properties purchased with all or partial federal funds are referred to as a "6(f)" zone and generally cannot be converted into a roadway use without an extensive approval process. Generally solutions that avoid these kinds of environmental impacts are required to be selected over those that do not with everything else being equal.

- **Environmental Justice (EJ):** Disproportionate impacts to a sector of the community, such as low-income or minority populations. Impacts to EJ-affected properties are not ideal and could include displacement, relocations, or increased traffic through a neighborhood. EJ impacts may require substantial mitigation measures.
- **Built Environment**: Impacting existing buildings and structures generally should be avoided. It is usually very difficult as part of a typical project not to disturb the built environment to some degree. This requires consideration of historic buildings, schools, hospitals, parks, large developments, low income areas, utilities, land use, visual impacts, noise, economic impacts, and environmental justice issues.
- **Right-of-Way (ROW)**: In general, improvements should be limited to minimize right of way impacts. Acquisition of additional right-of-way adds costs and may not be feasible in some locations.
- **Multimodal**: There will be the need to service pedestrians and bicycles in solutions as applicable. Where applicable, transit and freight will also need to be considered as well as impacts to air, rail, marine, and pipeline facilities. Multimodal aspects must be considered through all stages of the alternative development process from initial concepts to preferred alternative selection. Concepts should be developed that serve all allowed modes and should address adverse conditions for non-auto travel.
- **Physical Limitations**: Topography and other geographical features may physically create challenges of full implementation of an alternative. Examples include slope stability, rivers, wetlands, other roadways, railroads, utilities, power lines, etc., which may make it impractical to reroute or widen to the fullest extent required. Other full or interim solutions may need to be considered. For example, an interchange that has one ramp terminal hemmed in by a nearby river and the other ramp terminal by a railroad would make it impractical to try to increase the terminal spacing to allow for longer turn lanes. In this case the structure would need to be widened to accommodate side-by-side turn lanes.
- **Access Management**: Alternatives may impact property access points or access rights which may not be able to be resolved or mitigated. Resolving access issues may be challenging and are governed by statutes and Oregon Administrative Rules (OAR).
- **Funding Feasibility**: Current funding limitations may preclude many alternatives. It is important to document the reasons why a particular alternative cannot meet funding restrictions. It is important to be realistic and not create a whole set of alternatives that are too expensive to build or have phases that cannot be broken down further into manageable pieces. Phases (or sub-phases) need to have some sort of independent utility that will incrementally work toward the final solution. Alternatives need to be able to be broken into phases either with interim short to medium range solutions or a series of phases for long term implementation. A project may start with larger more expensive alternatives then screen them down to a set that is more manageable. The project leader and Region planning generally take the lead on identifying funding availability. The determination of funding availability should be made as early as possible to avoid analysis of alternatives that may not be feasible.

- **Fiscally Constrained**: Alternatives are evaluated and a preferred is selected and becomes a project after being adopted into a Regional Transportation Plan (RTP) or Transportation System Plan (TSP). Projects within RTPs and state highway projects within TSPs must be fiscally constrained. Generally, projects within TSPs should be fiscally constrained[1]. Fiscally constrained means the at least the first phase of the project is likely constructible within the funds available in the plan horizon. Other projects may be identified in an illustrative list which is a list of projects that cannot be relied on in reviewing land use changes. For RTPs, Tier 1 is a common nomenclature for the financially constrained list while Tier 2 is the illustrative list. Within the Tier 1 financially constrained list, projects are sorted by short/medium/long term based on yearly funding projections.

10.6 Considerations for Evaluating Build Alternatives

A Build Alternative refers to any combination of proposed or potential facility improvements to the current transportation system within the study area. Alternatives that are substantially similar except for some distinct areas are usually called "Options" instead. Build Alternatives are compared to each other as well as to the No-Build scenario to assess relative performance benefits of the various alternatives and options using the selected evaluation criteria. Comparisons are usually done on a quantitative basis, but some resources may require use of qualitative data.

The No-Build is a viable alternative. The No-Build includes committed (funded in a City CIP or ODOT's STIP) projects other than the subject project being analyzed. The No-Build alternative needs to be analyzed in same way as all Build alternatives for consistency.

The alternatives selected for evaluation should be reviewed to determine if new model forecasts (or new manual traffic forecasts) are required to reasonably represent the traffic flow conditions with the proposed improvements. For larger study areas, typically a travel demand model is the best tool for evaluating changes in travel patterns associated with potential system improvements and access management plans. However, in smaller studies these changes can be reasonably represented by making manual re-assignments of travel demand, assuming sufficient background volume and travel pattern data are available. For more information see Chapter 6 discussion on latent demand.

Typically, the horizon year travel demand forecast used for the No-Build scenario should be applied for each build scenario unless it is determined that the Build scenario would alter the future forecasts for that alternative. For example, where the No-Build scenario is heavily capacity constrained, it is likely that diverted traffic will return in the build scenario. If a model is available, both scenarios would be modeled separately. There are two major aspects to consider in making the new travel forecasts: the effects on travel demand and any reasonable changes to the network or operating parameters.

[1] PBLT Operational Notice on Financial Feasibility in System Planning, PB-03, 09/04/2014

10.6.1 Travel Demand Issues

One outcome of the new travel forecasts may be higher overall volumes on a facility compared to the no-build scenario. This is a common result in a highly congested corridor where a share of existing trips use parallel routes and when sufficient capacity is provided nearby, the trips will be re-assigned to the new facility. Typically travel demand model assignments consider the total travel times between the beginning and end of a trip. When new routes are added with shorter travel times, the model compensates by assigning more trips to the improved facility. For a smaller study area, the total travel demand within the system remains constant, but the locally assigned traffic volumes may be re-distributed. This is a common outcome for most projects.

In a larger regional system, the latent demand for travel that was constrained by corridors with severe delays during commute hours can experience changes in both travel mode and time-of-day when new facilities are introduced. The net result is a higher total travel demand compared to no-build. For example, if a new interstate bridge were constructed across the Columbia River between Portland and Vancouver, several changes to the no-build demand forecast would occur. First, the number of commute bus trips would likely decrease as more travelers opted to drive to take advantage of faster travel times. Second, because the peak travel times would be shorter, more commuters would leave their home closer to the start of their work shift. The combination of these factors would dampen the effectiveness of the new bridge facility because of higher total vehicle trips and more vehicle trips during the peak hour.

10.6.2 Network and Operational Issues

Care should be taken to consider network or access changes that would substantially change the no-build forecasted volumes on the build network. For example, if the build alternative includes a parallel street extension, major access closure, traffic control change, or other action that could re-route traffic flows from one facility to another or one access point to another within the study area, these adjustments should be made before re-evaluating performance. These types of changes indicate the no-build forecast should not be used for the build analysis. If a travel model is being used, then the analyst should review the build assignments to ensure that they reasonably reflect the proposed improvements, including comparing to the no-build assignments. If these forecasts are done by manual methods, a controlling factor in making these adjustments is to maintain the total trip origins and destinations for each land use generator within the study area.

For example, if the build alternative consolidates access to a shopping center, the sum of vehicle trips in and out of the shopping center should be the same before and after the project. The volumes that used the driveways that would be closed by the project must be re-assigned to other driveways that are accessible from the shopping center. This is an example of maintaining the same trip totals around a periphery of an activity center.

Another example would be where a street extension is proposed to offload local trips from the highway. In this example, the study area includes a one-mile section of a north-south highway that connects to east-west arterials at either end. Before the project there is only one route for all north-south trips. After the project a new parallel north-south collector road is proposed that connects to both of the east-west arterials. The reasonable check in this case would use a screenline across where the north-south routes connect to the east-west arterials. The total two-way north-south volume should be approximately the same, except for shifts in travel that may have occurred due to the project, for all facilities connecting to the arterials before and after the street extension. For more information see Chapter 6 guidance on screenlines.

10.6.3 Traffic Signal Optimization or Coordination

The background traffic signal timing parameters should be modified to be consistent with the proposed improvement. Caution should be applied when changing the background signal cycle assumptions for the purposes of future analysis. Signal timing is continually re-adjusted over time, so future signal timings should be optimized within the typical cycle maximums. The analyst should coordinate with the agency responsible for operating the signals to identify how the signals would likely operate in the field. Typically the cycle length for the analysis should not exceed 60 seconds for a two-phase traffic signal, 90 seconds for a three-phase traffic signal (e.g., protected highway left turns and permissive side streets left turns) or 120 seconds for a four- or more phased traffic signal. In larger or more complex intersections or systems, the cycle length may be longer than 120 seconds. Demand-responsive or adaptive traffic control systems continually vary the cycle length, so the use of optimized timings for base and future conditions is necessary. Coordinate with TRS if analysis indicates that cycle lengths in excess of 120 seconds are likely. For more information on signalized intersection analysis see APM version 1 Chapter 7.

10.6.4 Intersection Approach Lane Changes or Additions

Any proposed additions or revisions to an intersection approach should be reflected in the capacity analysis and signal phasing, as appropriate. A typical example is adding left turn lanes to serve higher demands during peak hours. New turn lanes may require changes to the background signal phasing to operate safely and the phasing changes should also be reflected in the analysis. In addition, the geometry of the intersection should be reviewed to determine if the added approach lane can be served on the exit leg. For the example above, a second left turn lane on one approach requires a second exit lane on the receiving leg of that intersection for a minimum distance to operate effectively.

10.6.5 Storage Length Changes

Another change would be the modification of storage lengths as indicated by the capacity and/or micro-simulation analysis. Phasing or cycle length changes will also likely cause the storage needs to change. Caution should be exercised if storage lanes exceed 300 feet and especially if a bike lane is located between a long left and right turn lane as this will cause a “sandwich” effect on the bicyclist having to travel between two lines of vehicles without any additional buffering. It is recommended that the analyst coordinate with Region Traffic and/or Traffic-Roadway Section in these cases.

10.6.6 Multimodal and Safety Tradeoffs

Both benefits and disbenefits of all solutions need to be identified and evaluated with the project team. Modal staff from Region, Bike/Ped, Motor Carrier, Rail, and Traffic-Roadway Section, should be involved in these considerations.

Some potential solutions to improve flow and safety for one mode may have adverse impacts on other modes. For example, building a long right turn lane may create an effect of sandwiching bicycle riders between the through lane and right turn lane, creating a deterrent for bicyclist use of that facility segment. All modes need to be considered from the beginning as each concept or alternative is created, instead of evaluating impacts to other modes as an afterthought. Some solutions may be deemed unworkable and dismissed due to multimodal or safety impacts.

For more information on multimodal analysis see Chapter 14. Other examples:

- Increasing a turn radius to mitigate rear-end vehicular crashes will result in an increased crosswalk distance thus increasing pedestrian exposure and risk.
- Adding turn lanes or auxiliary through lanes to improve flow will increase crosswalk distance and likely will increase speeds through the intersection
- Adding sidewalk bulb-outs, landscaped medians, or reducing the number of lanes or lane widths to reduce pedestrian exposure may impact the ability to move oversize vehicles. Reducing widths on certain freight routes is covered by the ORS 366.215 approval process. For more information see the ORS 366.215 Implementation Guidance.
- Traffic signal timing changes could increase queuing at a railroad crossing, creating a safety concern.
- Certain designs such as an overpass could interfere with an airport runway protection zone.

10.6.7 Evaluating Severely Congested Facilities

The performance analysis of severely congested roadways and intersections should recognize that many of the conventional (or default) assumptions used in computer software tools are not necessarily appropriate in these cases. For this discussion, severe congestion occurs when the observed demand exceeds facility capacity (v/c is over 1.0). The HCM analysis methods for roadways and intersections are not appropriate in cases where the volume substantially exceeds facility carrying capacity.

When the facility is presently heavily congested, the analyst should verify through field studies, additional surveys or other measurements that the observed conditions are reasonably similar to the computer software results. For example, if an intersection analysis indicates v/c ratio near 1.0, it should be noted that intersection evaluations are based on the number of vehicles entering the intersection during the assessment period and may not be the same as the total demand at that location. A field observation may show that heavy vehicle queuing occurs during the peak hour and a substantial share of the actual demand is queued and not served at the intersection during the peak analysis period (refer to Chapter 3 section on counting congested conditions). In this case, the demand is greater than the actual count of traffic that enters the intersection during the analysis period.

When facilities approach capacity levels during the peak hour, one result is for commuters to shift their travel times outside of the busiest hour to reduce their overall travel times. This phenomenon is referred to as peak hour spreading. Refer to Chapter 8 section on peak spreading analysis methodologies.

For future analysis, a v/c ratio calculation may result in a value higher than 1.0 for an isolated intersection. This condition may result from existing latent demand or excessive future demand of vehicles at an intersection. This should be considered as a d/c rather than an actual v/c ratio and would indicate conditions where mitigation could be considered to improve intersection operations.

Severe forecasted congestion at one location may influence and impact conditions at other intersections within the local transportation system. For example, spillback from one intersection may block traffic from proceeding through a nearby intersection, even when the traffic signal indication permits it. In addition to the intersection v/c ratio analysis, the analyst should review average and 95^{th} percentile vehicle queues within a congested local system to identify potential cases of secondary congestion impacts, which could reduce the performance otherwise indicated by an isolated intersection analysis for that location. In these types of situations, it is not sufficient to only conduct isolated intersection methods. A more reasonable tool would be either micro or mesoscopic simulation, which accounts for interaction between locations, queue spillbacks, blocked intersections and serving excessive demand between signal cycles. See details in APM Version 1's Chapter 8.

Large numbers of alternatives need to be reduced first with an established screening process (See Section 10.7.2), such as with a transportation demand model. It will take too long (which will also have a large budgetary impact, especially if contractors are used) to analyze alternatives at the full micro-simulation detail at a month apiece versus a couple weeks for a dozen or more at the screening level. No more than three to five alternatives should be fully analyzed in detail to keep the workload, schedule, and budget reasonable.

10.6.8 Benefit-Cost Analysis

Overview

Benefit-cost analysis (BCA) is often used to compare the cost of projects relative to the benefits to evaluate whether investments make good business sense. Theoretically, all benefits and all costs associated with a project are monetized to produce a ratio of benefits to cost. A ratio greater than one indicates the benefits are greater than the costs, indicating a positive outcome for the investment. When BCA is required, the analysis is prepared by economists, either consultants or the economists in the ODOT Program Implementation and Analysis Unit (PIAU). Most BCA tends to require customized applications as the methods used are very specific to an individual project's goals and objectives, issues and questions being asked. An increasing proportion of ODOT projects require BCA, making it important for traffic analysis to generate the information needed for economists to prepare this metric.

Some BCA may be required as part of grant or other funding programs such as Better Utilizing Investment to Leverage Development (BUILD) grants or Highway Safety Improvement Program (HSIP). Such programs may have specific methodological requirements such as the use of national travel time values instead of local values.

Much of the time project level BCA is performed as part of programming or final design. BCA of environmental studies, such as EAs and EISs, tend to be larger efforts involving an assessment of a wider range of impacts and are usually done by the contractor responsible for the environmental document. If a Planning and Environmental Linkages (PEL) study, Environmental Impact Statement (EIS), or Environmental Assessment (EA) are being conducted, there will likely be an a Socio-economic technical report prepared to analyze the alternatives' economic impacts and benefits, which are disclosed in the NEPA document.

Sketch level BCA can be prepared by non-economists for planning or project analysis to obtain general order of magnitude estimates of certain types of benefits and costs. Simplifications are made, and as such, it is supporting information which should not be used as a sole factor in deciding between alternatives. The limitations of sketch level BCA and level of uncertainty should be clearly stated and documented. The more common project parameters estimated in sketch level BCA analysis include the change in travel time, miles traveled, crashes, emissions, and vehicle operating costs. The largest components are typically travel time, crashes and miles traveled. Change in distance traveled due to a project is occasionally a large component as well.

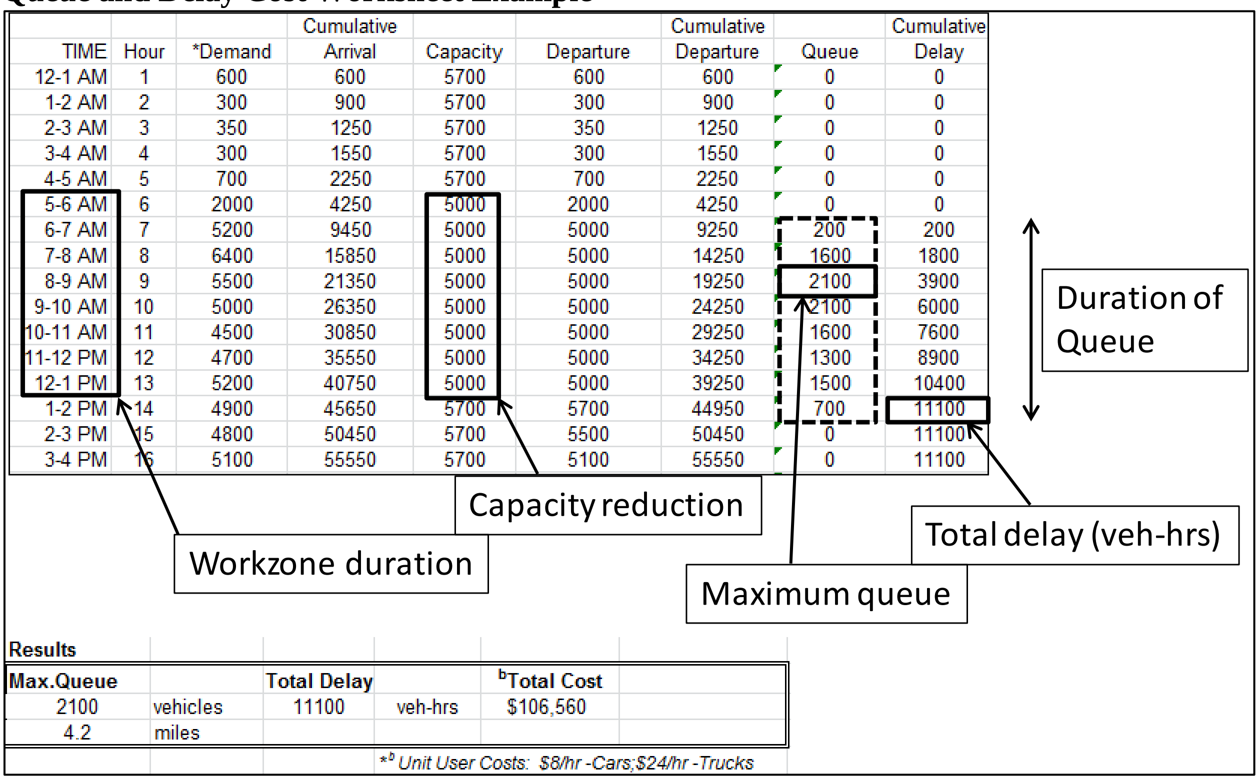
Estimates of delay are obtained from models or other tools including simulation. Value of travel time differs by automobile versus trucks versus bus so truck and bus percentages are needed.

A quick way of estimating the economic impact of delay is to use a Queue and Delay Cost worksheet. This spreadsheet uses an hourly volume profile over a day and a measure of the directional hourly roadway capacity. Capacity can be varied during the day to show impacts of a short or long-term workzone or other reduction such as an incident. Queues and delay are created when the hourly arrival rates exceed the capacity of the segment, and will continue until the demand drops enough that the segment can discharge all of the extra demand. The spreadsheet will show estimates of queue length, queue duration, delay and delay cost. Example 10-1 shows part of this spreadsheet with the important values highlighted.

Example 10-1 Queue and Delay Estimates

An analyst is trying to determine the impacts of a short-term workzone during the day on a section of urban freeway. The freeway has a nominal hourly capacity of 5700 vph with a reduced workzone capacity of 5000 vph. The workzone will be in place from 5 AM to 1 PM. The hourly volume profile from a nearby count (or ATR) is entered into the worksheet along with the hourly capacities and the current estimates of the value of travel time. The results come back with queuing starting at 7 AM and continuing until about 2 PM with a maximum queue of 2100 vehicles at around 8-9 AM (which is approximately four miles). This creates a total of 11,100 vehicles –hours of delay at a cost of over $106,000 daily.

Queue and Delay Cost Worksheet Example



TIME	Hour	*Demand	Cumulative Arrival	Capacity	Departure	Cumulative Departure	Queue	Cumulative Delay
12-1 AM	1	600	600	5700	600	600	0	0
1-2 AM	2	300	900	5700	300	900	0	0
2-3 AM	3	350	1250	5700	350	1250	0	0
3-4 AM	4	300	1550	5700	300	1550	0	0
4-5 AM	5	700	2250	5700	700	2250	0	0
5-6 AM	6	2000	4250	5000	2000	4250	0	0
6-7 AM	7	5200	9450	5000	5000	9250	200	200
7-8 AM	8	6400	15850	5000	5000	14250	1600	1800
8-9 AM	9	5500	21350	5000	5000	19250	2100	3900
9-10 AM	10	5000	26350	5000	5000	24250	2100	6000
10-11 AM	11	4500	30850	5000	5000	29250	1600	7600
11-12 PM	12	4700	35550	5000	5000	34250	1300	8900
12-1 PM	13	5200	40750	5000	5000	39250	1500	10400
1-2 PM	14	4900	45650	5700	5700	44950	700	11100
2-3 PM	15	4800	50450	5700	5500	50450	0	11100
3-4 PM	16	5100	55550	5700	5100	55550	0	11100

Results

Max.Queue		Total Delay		[b]Total Cost
2100	vehicles	11100	veh-hrs	$106,560
4.2	miles			

*[b] *Unit User Costs: $8/hr -Cars;$24/hr -Trucks*

Traffic Data for Benefit Cost Analysis (BCA)

To prepare project benefit-cost analysis, the economist requires project-specific traffic data from the project traffic analyst. The traffic data is typically requested for both the No Build and Build alternative. The data is generally needed for both the base year (existing conditions) and future year (typically 20 years from opening). The build year (year of opening) data will be automatically interpolated by the BCA spreadsheets used to enter the data. The data typically includes design hour or peak period traffic volumes, section travel time/delay, and crash reduction factors for the Build alternative. Other data may be needed as well such as percent heavy vehicles and average daily traffic. The data are used by the economist to monetize project benefits such as reduced travel time and crash cost savings.

Usually, the road sections for which traffic data are needed are defined by the beginning and ending mileposts of the project as identified by the Region. If the traffic impact area extends beyond these mileposts, the analyst should coordinate with the economist to define the road sections for which data are needed. Road sections needed may also depend on the type of facility, the context of the project, the stage the project is in, the type of BCA being performed, and other factors. It is important that all requested traffic data values are clearly identified and data sources documented.

The traffic data typically requested are listed below, for both No-Build and Build alternatives and for both base year or year of opening and future year. The aggregation of the data by roadway sections will be defined by the economist.

- Traffic Volume
    - AADT
    - Percent trucks and percent buses
    - Percent annual growth rate
- Demand-to-Capacity Ratio
    - Design hour or peak period d/c ratio, by direction of travel
- Travel Time and Delay
    - Design hour or peak period hours of travel, by direction of travel
    - Design hour or peak period vehicle-hours of delay, by direction of travel
- Safety
    - Crash reduction factors applicable to the Build alternative

Projects Requiring a Benefit-Cost Analysis due to ORS 184.659 (HB 2017)

Scoping-level traffic data are needed for those projects that require a benefit cost analysis under ORS 184.659 (HB 2017) for OTC consideration of project adoption into the STIP. The traffic data need to be prepared as part of project scoping activities.

New modernization projects (that were not earmarked in HB 2017) having a cost estimate near or over $15 million are required to have a benefit-cost analysis prepared by an economist prior to being adopted into the STIP. Project traffic data are needed to support this analysis. These traffic data must be prepared as a project scoping activity.

Traffic data for BCA will be needed prior to preparation of the project traffic analysis. Timelines will typically not allow for detailed data collection and volume development, and the project will not be fully defined at this stage, so the traffic data usually will be developed at a scoping level. Volumes will be based on AADTs, K factors and D factors. The analyst needs to coordinate with the economist early on regarding traffic data needs and assumptions.

Further details on the criteria and process for BCA is contained in [ODOT Scope & Select Leadership Team Operational Notice SS-03]() on Benefit/Cost Analysis for Large Projects

<u>Grant Application BCA (Post-Project Traffic Analysis)</u>

At the stage of a grant application, the project-level analysis should have been completed. Traffic data needed for grant application benefit-cost analysis should be obtained from the project analysis. The project level analysis is likely to have been prepared at a greater level of detail using different tools than those used in scoping. For example, if the analysis created a microsimulation model, the traffic data for BCA would be obtained from the microsimulation model results. It should be noted that other federal grant requirements may apply.

In many cases it will be necessary to supplement the project traffic analysis with additional computations, such as calculating peak hour VHD or VHT, or reporting different segments as requested by the economist. The procedures presented in the section on Scoping Level Traffic Data can be followed for such supplemental calculations. For HSM predicted crash frequency, historical crash data can be used by the economist to estimate other values such as the number of persons injured or number of vehicles involved in the PDO crashes. If historical crash data were reported out as part of the project analysis, should be provided to the economist to check for and reconcile any significant differences from the economist's historical crash data.

If travel time reliability analysis was performed in the project study, it may be used for the traffic data for BCA if a more refined estimate of the variation in travel time and delay due to non-recurring events (such as incidents and weather) is desired. If non-recurring delay values are provided, they should be clearly identified and provided separately from recurring delay values, since the value of travel time for non-recurring delay is different than that for recurring delay.

For projects that are not fully funded, traffic data may need to be provided separately for each component of the project that has independent utility.

The project-level traffic data are entered into the economists' spreadsheet similar to the scoping level traffic data illustrated in Example 10-2.

Scoping-Level BCA (Pre-Traffic Analysis)

In the scoping stage, the design of the Build alternative is in general terms, not detailes. For example, it may only be known that the project will add expand a roadway from two travel lanes to four. Individual elements of the project such as connections, intersection treatments and auxiliary lanes may be unknown. In addition, available data may be limited and/or impractical to collect in detail at this early scoping stage. For these reasons, a sketch planning-level methodology is recommended to develop scoping level traffic data. Default values will generally be used except where project-specific information is readily available. For the purpose of the BCA, the scope of the Build alternative will be provided by the Region. Where there are gaps in project scope decisions, the economists may be required to make assumptions about the project, which should be clearly documented, in order to complete the BCA.

The overall steps for the scoping level process are as follows:

1. Working with the project manager and economist, define the roadway sections needed for both the No Build and Build alternatives. Section boundaries may vary by facility type and direction of travel. Sections may be segmented at major junctions or intersections where highway volumes change significantly, at lane adds or drops, or at changes in terrain type. Establish the years for which data are needed. Define the roadway configurations for both the No Build and Build alternatives.
2. Establish the analysis hour or period.
3. Gather input data for each roadway section and direction of travel.
4. Calculate the performance measures identified below, for each roadway section in each direction of travel, for No-Build Existing, No-Build Future, Build Existing, and Build Future.
    - Free-flow speed
    - Capacity
    - Demand
    - Demand-to-capacity ratio
    - Section length
    - Average speed
    - Travel time
    - Delay
    - Crash reduction factors (Build Alternative)

Typical methodologies, data sources and assumptions to develop scoping level traffic data are described below. These are generally based on the 6th Edition of the Highway Capacity Manual (HCM) and the Planning & Preliminary Engineering Applications Guide (PPEAG). Use of default values is likely needed to minimize data collection. The calculations are typically performed manually or with spreadsheets.

The methodology for demand estimation uses AADTs, K factors, D factors and other readily available input data. Results are provided for the design hour or peak period, typically based on the 30th highest hour. The economist may estimate values for other time periods if needed. The analyst should clearly identify the analysis time period the data represent, i.e., peak hour, peak two hours, etc.

Free-Flow Speed

At a scoping level, the base free-flow speed of existing roadway sections can be assumed equal to the posted speed plus either 5 mph or 10 mph depending on the facility type, as discussed further below and in the PPEAG.

Where a speed differential exists for autos versus trucks, a weighted average base free-flow speed is calculated. The base truck FFS is estimated as the auto FFS minus the difference in the posted auto and truck speed limits. Then the weighted average base free-flow speed is calculated using the following formula, based on the proportion of trucks in the traffic stream P_T (refer to Appendix A of Chapter 11).

$$BFFS = (1-P_T)S_{auto}FS_{auto} + (P_T)FFS_{truck}$$

Freeways

The base FFS for freeways is estimated using the default value (Appendix C of Chapter 11) of posted speed + 5 mph. The adjusted FFS is calculated using HCM Equation 12-2:

$$FFS = \text{BFFS} - f_{LW} - f_{RLC} - 3.22 \times TRD^{0.84}$$

where

f_{LW} = lane width adjustment:
- 0.0 mph (12-ft or wider lanes) (default)
- 1.9 mph (11-ft lanes)
- 6.6 mph (10-ft lanes)

f_{RLC} = right-side lateral clearance adjustment factors. Refer to HCM Exhibit 12-20

TRD = total ramp density, the total number of on- and off-ramps in one direction for 3 miles upstream and 3 miles downstream, divided by 6 miles

Multi-lane Highways

The free-flow speed on multi-lane highways is calculated using HCM Equation 12-3:

$$FFS_{adj} = BFFS - f_{LW} - f_{TLC} - f_M - f_A$$

where

BFFS = base free-flow speed. Use section design speed or estimate using a default value of posted speed plus 5 mph.

f_{LW} = lane width adjustment. Same as for freeways

f_{TLC} = total lateral clearance adjustment (left and right). Refer to HCM Exhibit 12-22.

f_M = median type adjustment. Refer to HCM Exhibit 12-23.

f_A = access point density adjustment (right side). Refer to HCM Exhibit 12-24.

Rural Two-Lane Roadways

The free-flow speed on rural two-lane highways can be calculated using HCM Equation 15-2:

$$FFS = BFFS - f_{LS} - f_A$$

where

BFFS = base free-flow speed. Use section design speed or estimate using a default value of posted speed plus 10 mph.

f_{LS} = lane and shoulder width adjustment. Refer to HCM Exhibit 15-7.

f_A = access point density adjustment (right side). Refer to HCM Exhibit 15-8.

Urban Streets (Arterials and Collectors)

For scoping level analysis, the simplest way to estimate free-flow speed on urban streets is to use a default value of posted speed plus 5 mph. If more detailed information is readily available, the following methodology from the HCM can be used.

Calculate the Base FFS per HCM Equation 18-3. Adjustment factors are found in HCM Exhibit 18-11.

$$S_{fo} = S_{calib} + S_0 + f_{cs} + f_A + f_{pk}$$

Where

S_{fo} = base free-flow speed (mi/h)

S_{calib} = base free-flow speed calibration factor (mi/h) – can be assumed to be zero for scoping level analysis

S_0 = speed constant (mi/h)

f_{CS} = adjustment for cross section (mi/h)

f_A = adjustment for access points (mi/h)

f_{pk} = adjustment of on-street parking (mi/h)

Calculate the adjustment for signal spacing per HCM Equation 18-4.

$$f_L = 1.02 - 4.7 \times \frac{Sfo - 19.5}{\max(Ls, 400)} \leq 1.0$$

Where

f_L = signal spacing adjustment factor

S_{fo} = base free-flow speed (mi/h)

L_s = distance between adjacent signalized intersections (ft)

The adjusted FFS is calculated using HCM Equation 18-5.

$$S_f = S_{fo} \times f_L \quad \geq S_{pl}$$

Where

S_f is the free-flow speed (mi/h)

S_{pl} is the posted speed limit

Capacity

The methodology for computing section capacities varies by facility type. Computation procedures are provided below.

Freeways

For scoping-level analysis, generalized capacities for freeways can be estimated by applying Exhibit 129 of the PPEAG.

If more detailed information is available, freeway section capacities given as flow rates in pcph/ln under base conditions can be determined from HCM Equation 12-6.

c (base freeway segment capacity) = 2,200 + 10 × ($FFSadj - 50$)

The base freeway capacity is adjusted for driver population using HCM Equation 12-8:

$$c_{adj} = c \times CAF$$

Default values for CAFpop are provided in Appendix C of Chapter 11.

If greater detail is desired, methodologies in Sections H.5 or H.6 of the PPEAG may be used.
<u>Multi-lane Highways</u>

Multi-lane highways are uninterrupted flow roadways where traffic signal spacing is greater than 2 miles. Use the urban street method for multi-lane highway sections preceding a traffic signal.

For scoping-level analysis, generalized capacities for rural multi-lane highways can be estimated by applying Exhibit 129 of the PPEAG.

If more detailed data is available, the capacity of a multi-lane highway section can be estimated using HCM Equation 12-7:

$$c = 1900 + 20 \times (FFS_{adj} - 45)$$

<u>Rural Two-Lane Roadways</u>

For scoping level analysis, generalized capacities for rural two-lane highways can be estimated by applying Exhibit 129 of the PPEAG.

If more detailed data is available, PPEAG Equation 198 can be used

$$c = PCCap \times f_{hv} \times f_g \times PHF$$

where

c = capacity (veh/h)

PCCap = HCM passenger car capacity = 1,600 for a single direction (pc/h/ln)

fhv = heavy vehicle adjustment factor for average travel speed (unitless)

$$f_{HV} = \frac{1}{1 + P_{HV} \times (E_{HV} - 1)}$$

P_{HV} = proportion of heavy vehicles. Heavy vehicle percentages on state highways can be obtained from TransGIS

E_{HV} = heavy-vehicle equivalency (PPEAG Exhibit 37) based on terrain type (level, rolling, mountainous). Specific grades (where a grade is at least ±3% and at least 0.6 miles long) can also be considered but are not required

fg = grade adjustment factor for average travel speed (unitless), refer to HCM Exhibit 15-9 and 15-10. Default value = 1.00

PHF = peak hour factor, default = 0.88

Urban Streets (Arterials and Collectors)

For scoping-level analysis, generalized arterial and collector capacities can be estimated by applying Exhibit 129 of the PPEAG. The values in the table for downtown, urban and suburban arterial and collectors outside of large MPOs (Portland, Salem and Eugene) need to be reduced by 8%.

If more detailed information is available for signalized roadways, Equation 199 of the PPEAG can be used. Alternatively, the PPEAG urban street segment planning tool may be used.

Peak Period Demand

Existing Year Volumes

Section directional demand (veh/h) is obtained by converting AADT into design hour volume by applying K factors and D factors.

1. Calculate the two-way design hour volume by multiplying the AADT by the average K-30 factor. Both AADT and the K-30 factor for state highways can be obtained from TransGIS. Calculate the average K-30 factor using a representative ATR and following procedures in Chapter 5.
2. Calculate the directional design hour volume (DDHV) using the D-30 factor, obtained from the TCM Ranked Hour report (see Traffic Count Management (TCM) Program Count Report Guide).

DDHV = AADT × K × D
where

DDHV = directional design-hour volume (veh/h)

AADT = annual average daily traffic (veh/day)

K = proportion of AADT occurring in the design hour (decimal)

D = proportion of design hour traffic in the peak direction (decimal)

Where K and D values are not available, typical K and D values from PPEAG Exhibit 7 and 8 may be used.

fhv = heavy vehicle adjustment factor for average travel speed (unitless)

$$f_{HV} = \frac{1}{1 + P_{HV} \times (E_{HV} - 1)}$$

P_{HV} = proportion of heavy vehicles. Heavy vehicle percentages on state highways can be obtained from TransGIS, for default values refer to Appendix 11C

E_{HV} = heavy-vehicle equivalency (PPEAG Exhibit 20)

$c = PCCap \times N \times f_{hv} \times PHF \times CAF$

where

c = capacity (veh/h)

PCCap = HCM passenger car capacity from PPEAG Exhibit 127 (pc/h/ln)

N = number of through lanes, ignoring auxiliary lanes

PHF = peak hour factor, default value = 0.88(rural), 0.95 (suburban)

CAF = capacity adjustment factor (locally developed and applied to match field measurements of capacity, when available), default value = 1.00

fhv = heavy vehicle adjustment factor for average travel speed (unitless)

$$f_{HV} = \frac{1}{1 + P_{HV} \times (E_{HV} - 1)}$$

P_{HV} = proportion of heavy vehicles. Heavy vehicle percentages on state highways can be obtained from TransGIS, default values = 5% (urban), 12% (rural)

E_{HV} = heavy-vehicle equivalency (from PPEAG Exhibit 20)

Existing Year Build Alternative

The Build alternative with existing volumes is not normally fully developed but is needed to perform the interpolation calculations for the build year in the BCA spreadsheets. The build volume can be estimated by shifting the previously created Existing volumes based on the following potential methods.

Potential methods to estimate redistribution of trips

- The rerouting of traffic due to simple network modifications, such as basic connection changes or interchange ramp reconfigurations, may be apparent and can be estimated manually.
- Volume difference plot from urban travel demand model.
- Volume difference plot from statewide integrated model (SWIM).
- Manual screenline method. Shift in demand can be ignored if anticipated to be less than 10%. Refer to APM Chapter 6.

For many projects the Build alternative may be expected to result in a shift in traffic volumes from existing conditions which is known as latent demand. Examples include new roadways or connections or added lanes. If the project is located within a travel demand model area, a model run may be undertaken to compare the no build and build alternative volumes. For example, if a new roadway or crossing is proposed, the travel demand model could be used to estimate relative changes in demand on sections across a screenline. At a scoping level the model results should be applied as relative percent changes in No Build volumes rather than as actual volumes. Refer to Chapter 6 for additional guidance. If located outside a travel demand model area, use of the statewide integrated model (SWIM) may be considered for major roadways if the project is of substantial scope to likely cause a significant change in demand (regional impact). Contact TPAU for further information.

Future Year No-Build Volume

Scoping-level future year No-Build volumes are typically developed by applying growth factors from the Future Volume Tables to the Existing No-Build volumes. If available, a travel demand model may also be used to develop growth factors. Refer to Chapter 5 for methodology.

Future Year Build Volume

Scoping-level future year Build volumes are typically developed by applying growth factors from the Future Volume Tables to the Existing Build volumes. If available, a travel demand model may also be used to develop growth factors. Refer to Chapter 5 for methodology.

Latent Demand

The economist may request the percentage of additional demand or VMT of the Build alternative over the No Build alternative in the peak period. This may occur as latent demand, where an increase in travel within the project area may result from Build alternative network improvements which provide more attractive travel paths than are available under the No Build network. This is typically estimated from a travel demand model run. Build demand is assumed equal to No Build demand unless a travel demand model run shows a change in demand of greater than 10%. If latent demand is modeled, the additional Build demand is represented in the traffic data provided, i.e., there should be no further factoring up of the traffic data provided. Latent demand can be expressed as the percentage change in peak period demand or VMT over the No Build alternative within the project area. The causes of shifts in demand should be noted.

Peak Period Demand-to-Capacity Ratio

The d/c ratio is calculated for the analysis peak period for each scenario by dividing the DDHV by the directional capacity. Both demand and capacity must be in the same units, such as pcph/ln.

$$\text{Demand-to-Capacity ratio} = v_p \,/\, \text{capacity}$$

Section Length

No-Build and Build section lengths are needed in order for link changes in vehicle operating costs (through link VMT) to be calculated (by the economist).

Average Speed

Average speed for the peak period is estimated using a version of the Bureau of Public Roads (BPR) curve that has been fitted to approximate HCM results for different combinations of facility type and free-flow speeds (Equation 203 of PPEAG). This formula calculates speed as a function of v/c ratio. As the v/c ratio approaches 1.0, speed drops due to the effects of increasing traffic volumes.

$$S = FFS/(1 + Ax^B)$$

where

- S = average peak hour speed (mph)
- FFS = Free-flow speed (mph)
- A = speed-at-capacity ratio = (FFS / SC) – 1, values provided in PPEAG Exhibit 129
- SC = speed at capacity
  = (capacity [pc/h] / density at capacity [pc/ln/mi])
- x = demand-to-capacity ratio. Demand-to-capacity ratios are calculated by dividing the DDHV by the capacity of the section. For sections that end with stop or roundabout control, the higher v/c ratio of the section or the intersection is used in the formula.
- B = calibration parameter used to match HCM results when demand greatly exceeds capacity (d/c = 1.9), values provided in PPEAG Exhibit 129

Travel Time

The average travel time in the peak period can be calculated by dividing the length of the section in miles by the previously calculated average speed (mph).

Average travel time (sec)

$$T = \frac{Length\ (mi)}{Speed\ (mi/h)} \times 3600\ sec/h$$

Alternatively, travel time can be calculated using a rearrangement of the BPR average speed curve:

$$T = T_0(1 + Ax^B)$$

where

T = section travel time (h),

T_0 = section travel time at low near-zero volumes (h),

Peak period travel time can also be converted to vehicle-hours of travel (VHT) by multiplying the average travel time per vehicle by the peak hour volume.
Projects may reduce travel time in two ways, by reducing delay due to congestion (v/c ratio),

and/or by constructing new links or connections that result in shorter and/or faster paths. The total savings in travel time is represented by the difference in VHT between the Build and No Build alternatives, summed across all sections.

Delay

The portion of the travel time greater than the travel time at the speed limit is considered to be delay. The average delay on a section is calculated by subtracting the average section travel time from the travel time at the posted speed (section length divided by posted speed).

The total delay for the design hour in vehicle-hours (VHD) is calculated by multiplying the average delay per vehicle by the peak period volume:

$$\text{Vehicle-hours of delay in peak period} = \text{Average peak period delay} \times \text{volume} / 3600$$

If there are multiple peak hours in a peak period, the VHD in the peak period is the VHD in the peak hour multiplied by the number of hours in the peak period. Clearly state the number of peak hours included in the calculation.

Crash Data

The economist is responsible for obtaining historical crash data as needed. The analyst furnishes crash reduction factors (CRF) for the Build Alternative. The All-Roads Transportation Safety (ARTS) Crash Reduction Factor Appendix is the first source of crash reduction factors that should be investigated. If a CRF from the ARTS Appendix/List is not available/applicable, a CRF derived from the Crash Modification Factors (CMF) in the HSM Part D and/or the FHWA CMF Clearinghouse may be used if applicable. The ODOT CMF standard is to only use CMF's with a quality rating of 3 stars or better.

If an HSM predictive analysis was performed, the analyst furnishes the predicted crash frequency and severity from the project analysis.

An example of developing scoping level BCA traffic data is provided in Example 10-2.

Example 10-2 Scoping-Level BCA Traffic Data

Scoping-level traffic data are needed for a benefit cost analysis of a proposed freeway improvement project. The purpose of the project is to reduce congestion on an 18-mile section of I5 northbound between Albany and Salem. The Build alternative would add one travel lane in each direction.

In the northbound direction of travel, the project is broken into four sections as follows:

Section A: milepoint 234.00 to 234.99, 2 lanes, urban, level, 1 mile
Section B: milepoint 235.00 to 245.99, 2 lanes, rural, level, 11 miles
Section C: milepoint 246.00 to 248.99, 3 lanes, rural, rolling, 3 miles,
Section D: milepoint 249.00 to 251.99, 2 lanes, urban, rolling, 3 miles

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The following sample calculations are provided for Section B in the northbound direction of travel only. A spreadsheet showing computations for this example is provided for the purpose of illustration at https://www.oregon.gov/ODOT/Planning/Documents/BCA_ExmplCalc.xlsx.

Gather Input Data

Section B is located in a rural area with level terrain. The following values were obtained from TransGIS. The posted speed is 65 mph for autos and 60 mph for trucks. There are two travel lanes in each direction. The two-way AADT is 68,100 with K = 9.0 and D = 52, with 18.4 percent heavy vehicles.

Free Flow Speed

The base auto FFS is estimated using the default value (Appendix C of Chapter 11) of posted speed + 5 mph:

$$BFFS_{aut}BFFS_{au} = 65 + 5 = 70 \text{ mph}$$

In Section B a speed differential exists for autos versus trucks. A weighted average base free-flow speed is calculated. The base truck FFS is estimated as the auto FFS minus the difference in the posted auto and truck speed limits:

$$BFFS_{truck} = 70 - (65 - 60) = 70 - 5 = 65 \text{ mph}$$

The weighted average base free-flow speed is calculated using the following formula, based on the proportion of trucks in the traffic stream PT (refer to Appendix A of Chapter 11).

$$BFFS = (1-P_T)S_{auto}FS_{auto} + (P_T)FFS_{truck}$$

$$= (1-0.184) \times 70 + (0.184) \times 65 = 69.1 \text{ mph}$$

The base free flow speed is adjusted for lane width, lateral clearance, and ramp density using HCM Equation 12-2.

$$FFS = BFFS - f_{LW} - f_{RLC} - 3.22 \times TRD^{0.84}$$

Lane width – for Section B, the lane width is 12 feet. From Exhibit 12-20, f_{LW} = 0.0

Lateral clearance – for Section B, the right side lateral clearance is 6 feet or greater. From Exhibit 12-21, f_{RLC} = 0.0

Total ramp density TRD – for Section B there are 1.4 ramps per mile as measured starting from 3 miles upstream of the section and ending 3 miles downstream of the section.

Therefore the Section B adjusted free flow speed is

$FFS = 69.1 – 0 – 0 – 3.22 \times 1.4^{0.84}$
= 64.8 mph

Capacity

Freeway section capacities given as flow rates under base conditions are determined from HCM Equation 12-6.

For Section B, the weighted average adjusted FFS was calculated as 64.8 mph.

The base capacity from HCM Equation 12-6 for Section B is

c (basic freeway segment) = 2,200 + 10 × ($FFSadj - 50$)
= 2200 + 10 × (64.8-50)
= 2348 pc/h/ln

Adjusted capacity is calculated using HCM Equation 12-8

$$c_{adj} = c \times CAF$$

The default adjustment factor CAFpop for Section B is 0.939 for a rural area (Appendix C of Chapter 11). The adjusted capacity for Section B is

C_{adj} = 2348 × 0.939 = 2205 pc/h/ln

Demand

The DDHV in mixed vehicles per hour (30^{th} highest hour volume) is calculated as follows, per APM Chapter 5.

DDHV = AADT × K × D
For Section B, No Build

Existing Year 2017 = 68,100 vpd
Future Year 2042 = 96,672 vpd

Heavy Vehicle Adjustment

The heavy vehicle adjustment factor for Section B is calculated as follows.

fhv = heavy vehicle adjustment factor for average travel speed (unitless)

$$= \frac{1}{1 + P_{HV} \times (E_{HV} - 1)}$$

Section B has 18.4% trucks. From Exhibit 20 of the PPEAG, for freeways in level terrain, E_{HV} = 2.0. Therefore

$$f_{HV} = \frac{1}{1 + .184 \times (2 - 1)}$$

= 0.845

PHF Adjustment

The local value for PHF is the default value obtained from Appendix C of Chapter 11. For Section B, in a rural area, the default PHF is 0.88.

Demand Adjustment

The DDHV is converted to an equivalent flow rate in pcph.
Equation 12-9 of HCM:

$v_p = V/(PHF \times N \times fHV)$

$$v_p = \frac{DDHV}{PHF \times N \times f_{HV}}$$

Example calculation for Section B, Year 2017, No-Build, flow rate in pcph
Flow rate per lane
v_p = 3044/(0.88×2×0.845)
= 2321 pcphpl

For this project, latent demand is not anticipated to be significant.

Demand-to-Capacity Ratio

v/c ratio = v_p / capacity

where

v_p = demand flow rate in pc/h/ln

Example Calculation for Section B, No-Build, Year 2017:

No-Build Existing v/c ratio = 2144 / 2205 = 0.97

Average Speed

Section B average speed

$$S = FFS/(1 + Ax^B)$$

where x = v/c ratio

Values for speed-flow equation parameters A and B are found from Exhibit 129 of PPEAG for a rural freeway; A = 0.31; B = 7

S = FFS / (1+Ax^B)

Example calculation for Section B, No-Build, Year 2017:

No-Build Existing peak hour average speed
= 64.8 / (1 + 0.31 × 0.97^^{7}) = 51.6 mph

Travel Time

The average peak hour travel time for Section B is the section length divided by the peak hour average speed. Example calculation for Section B, No-Build, Year 2017:

No-Build Existing travel time = (11 mi / 51.6 mi/hr) × 3600 = 767 sec

Travel time can also be expressed in terms of vehicle hours of travel (VHT) by multiplying the average travel time per vehicle by the peak hour volume. Example calculation for Section B, No-Build, Year 2017:

No-Build peak hour Existing VHT
= 767 sec/veh x 3,187 veh / 3600 sec/h = 679 veh-hrs

Delay

Section B travel time at the weighted average posted speed
Existing = (11 mi / 69.1) × 3600 = 573 sec

Delay per vehicle is the average per vehicle peak hour delay. Example calculation for Section B, No-Build, Year 2017:

No Build peak hour Existing average delay
= 767 – 573 = 194 sec/veh

VHD – The peak hour vehicle hours of delay is the average delay per vehicle multiplied by the peak hour volume. Example calculation for Section B, No-Build, Year 2017:

No-Build Existing peak hour delay VHD
= 194 × 3187 / 3600 = 171 veh-hours delay

Crash Data

For scoping level analysis, crash reduction factors are provided for the Build alternative. In this example, no applicable CRFs were found from the ARTS Crash Reduction Factor Appendix. A study identified in the FHWA CMF Clearinghouse indicated that crashes were reduced by 25% due to a freeway lane addition (CRF = 0.25) for K, A, B, and C type crashes. PDO crashes did not change. (Source: Operational and Safety Trade-offs: Reducing Freeway Lane and Shoulder Width to Permit an Additional Lane).

Summary of Traffic Data

Once calculations are complete, the traffic data results are input into the economists' spreadsheet, as shown in the example screen captures below (inputs in yellow-colored cells). Note that in this example, only I5 northbound sections are shown. Actual traffic data would include sections in the southbound direction as well.

Example Traffic Data Input - Economist Worksheet

Modeled Base Year 2017 peak hour Sub-Project:	Old Length	New Length	Change	Average Daily Traffic	Peak Period Analysis – NO BUILD – VHD: VHD by Sub-Project:	NO BUILD: V:C Ratio	NO BUILD: V:C Ratio > 1? (enter Yes or No)	BUILD	BUILD – VHD: VHD By Sub-Project:	BUILD: V:C Ratio	BUILD: V:C Ratio > 1? (enter Yes or No)
A - I5 Northbound N. Santiam Exit 234 to Albany UGB MP 235	1.00	1.00	0.00	67,700	6.2	0.86	No		2.6	0.57	No
B - I5 Northbound Albany UGB MP 235 to Terrain Change MP 246	11.00	11.00	0.00	68,100	171.3	0.97	No		41.5	0.65	No
C - I5 Northbound Terrain Change MP 246 to Salem UGB MP 249	3.00	3.00	0.00	68,100	12.5	0.75	No		7.5	0.56	No
D - I5 Northbound Salem UGB MP 249 to Kuebler Exit 252	3.00	3.00	0.00	66,100	41.9	0.98	No		12.9	0.66	No
Name #5			0.00								

Modeled Future Year 2042 peak hour Sub-Project:	Old Length	New Length	Change	Peak Period Analysis – NO BUILD: Assumed Annual Traffic Growth [1 + % Change] Between A3&A16	NO BUILD – VHD: VHD By Sub-Project:	NO BUILD: V:C Ratio	NO BUILD: V:C Ratio > 1? (enter Yes or No)	BUILD: Assumed Annual Traffic Growth [1 + % Change] Between A3&A16	BUILD – VHD: VHD By Sub-Project:	BUILD: V:C Ratio	BUILD: V:C Ratio > 1? (enter Yes or No)
A - I5 Northbound N. Santiam Exit 234 to Albany UGB MP 235	1.00	1.00	0.00	1.060	37	1.12	Yes	1.060	5.1	0.75	No
B - I5 Northbound Albany UGB MP 235 to Terrain Change MP 246	11.00	11.00	0.00	1.080	2321.1	1.38	Yes	1.080	180.6	0.92	No
C - I5 Northbound Terrain Change MP 246 to Salem UGB MP 249	3.00	3.00	0.00	1.080	104.4	1.06	Yes	1.080	22.3	0.79	No
D - I5 Northbound Salem UGB MP 249 to Kuebler Exit 252	3.00	3.00	0.00	1.080	619.1	1.42	Yes	1.080	51.4	0.95	No
Name #5	0.00	0.00	0.00					0.000			

Assumptions:					
Peak Hour (K) Factor for Delay Calculations	9.0		**Emission Type:**	**$ / ton ($2017)**	
Benefit per unit of measure (light vehicle)	$27.05		**Carbon dioxide (CO2)**	$1	metric
			Volatile Organic Compounds (VOCs)	$2,000	short
Benefit per unit of measure (truck driver)	$28.60		**Nitrogen oxides (NOx**	$8,300	short
Assume percentage trucks	18%		**Particulate matter (PI**	$377,800	short
Benefit per unit of measure (Bus)	$657.90		**Sulfur oxides (SOx)**	$48,900	short
Assume percentage of Buses	0.2%				
Benefit per unit of measure	$28.59		**Induced VMT in API**	**0%**	
			Maintenance costs per state hwy lane-mile in 2017 $s:	**$7,305**	

Sub-Project:	CRF A	CRF B	Source
A - I5 Northbound N. Santiam Exit 234 to Albany UGB MP 235	0.25		Study Title: C
B - I5 Northbound Albany UGB MP 235 to Terrain Change MP 246	0.25		Study Title: C
C - I5 Northbound Terrain Change MP 246 to Salem UGB MP 249	0.25		Study Title: C
D - I5 Northbound Salem UGB MP 249 to Kuebler Exit 252	0.25		Study Title: C
Name #5			

10.7 <u>Screening Alternatives Overview</u>

The alternatives analysis for potential improvement projects should be consistent with the established evaluation criteria. Alternatives for facilities should be developed, assessed and evaluated relative to the matrix of performance measures selected for the study. Depending on the scope and complexity of the study, it may be appropriate to have a tiered screening process. This process would begin with a brainstorming –type screening process that allows for a large range of potential alternatives (the “universe” of alternatives) to be defined (typically through a workshop or open house process). This enables many stakeholders to express any outstanding concerns and potential solutions at a sketch or concept level format.

These initial alternatives are then filtered to a reduced set of alternatives through the first screening process. How many alternatives are filtered out at this point depends on the screening criteria. Initial alternatives are usually filtered using a “fatal-flaw” analysis which involves comparing alternatives against the purpose and need or minimum design (i.e. AASHTO) standards. The remaining alternatives would then be advanced to the next level in order to select the best candidates for the purposes of alternative performance evaluations based on the goals and objectives. Alternatives are typically refined, combined or new ones created through the development process. Alternatives that are screened out should be documented as to why and tracked in the project files. This helps document the entire project selection process as well as reference to answer questions about alternative development. As the project advances through alternative development to project design, the process that was applied to develop alternatives should be documented to carry forward into an environmental review document. It is important to describe any initial alternatives that were developed and set aside from further consideration (based on the evaluation criteria) for this purpose. Any alternatives in an EA or EIS need to follow the appropriate NEPA requirements. These discarded alternatives should be included in the Alternatives Considered but Dismissed appendix in the traffic narrative report as frequently details on the “why” something was dismissed are overlooked .An EIS will also normally have a “Alternatives Considered” chapter that describes the overall alternative development process and timeline, and the traffic narrative appendix can be used to help re-construct this.

> *For many projects, alternative naming conventions can change, often more than once as the project progresses especially when alternatives are combined in the screening process. It is important to track the history of the name changes along with the alternatives, so that the appropriate variations can be included in the documentation. Many times early versions are referred to as “Concepts” or “Scenario” and only when it has proved to be reasonably viable in the screening process it is referred to as an “Alternative”.*

The end result may be a preferred alternative or a set of final alternatives depending on the type of project or plan. TSPs will end up with multiple projects defined by short (0-5 yr), medium (5-10 yr), or long term (10 yr +) periods. Interchange Area Management Plans (IAMP) or refinement plans can also identify multiple projects. For projects to be considered officially they would need to be adopted into the TSP as part of implementation of the corridor or refinement plan. Projects may also have multiple final alternatives to be analyzed further in a project development process. For more details on TSPs refer to the TSP Guidelines.

> *Solutions identified in TSPs should not be too specific and they should allow some flexibility as the improvement may be years off. An example of this overly specific language would be to specify "traffic signal" instead of a more general "intersection improvement" for a particular location in a TSP.*

Once a TSP is adopted by the local jurisdiction, amending the TSP will require new hearings, probably new analysis, and can take months or years for approval. TSPs in MPO areas may also require amending the RTP, RTSP, and re-working any air quality conformity especially if the "new" project is elevated into the fiscally constrained list. Sometimes if there are many issues it is best to specify a follow-on refinement plan to look at these issues in greater detail and to provide a more detailed solution.

10.8 Screening the Alternatives

At many points in the alternative screening process, there will be a need to apply different transportation analysis tools and methodologies to address the traffic-related criteria. Typically there are three levels or tiers of screening, Fatal Flaw (Purpose & Need), Goals & Objectives (Modeling), and Operations. Overall, in the broader NEPA analysis, the overall screening levels and approach are responsibilities of the Environmental Project Manager so not all of the following sections will apply or to the same level of detail on every project.

10.8.1 Fatal Flaw/Purpose & Need Screening

At the beginning of the process, many designs will be drafted up and the basic viability usually compared against "fatal-flaw" criteria. These criteria more than likely will be based on AASHTO or ODOT Highway Design Manual (HDM) or local design standards as applicable. This will eliminate transportation concepts that will not work on a geometric, policy, or general nominal safety basis. If a project has a purpose and need (P&N), then concepts are evaluated against it to see if they meet or generally meet the P&N with modifications. Concepts that do not meet the P&N are dropped. The concepts that pass the fatal-flaw and the general P&N screening also need to be evaluated on a transportation operation basis. For simple projects, the transportation screening can be a volume-to-capacity or other performance measure comparison at key locations. Urban areas typically have larger more complex interdependencies that make a simple isolated point-by-point comparison insufficient. Travel demand models are one tool that allow for many concepts to be evaluated quickly and to arrive at a set of reasonable recommendations for forwarding onto the next step.

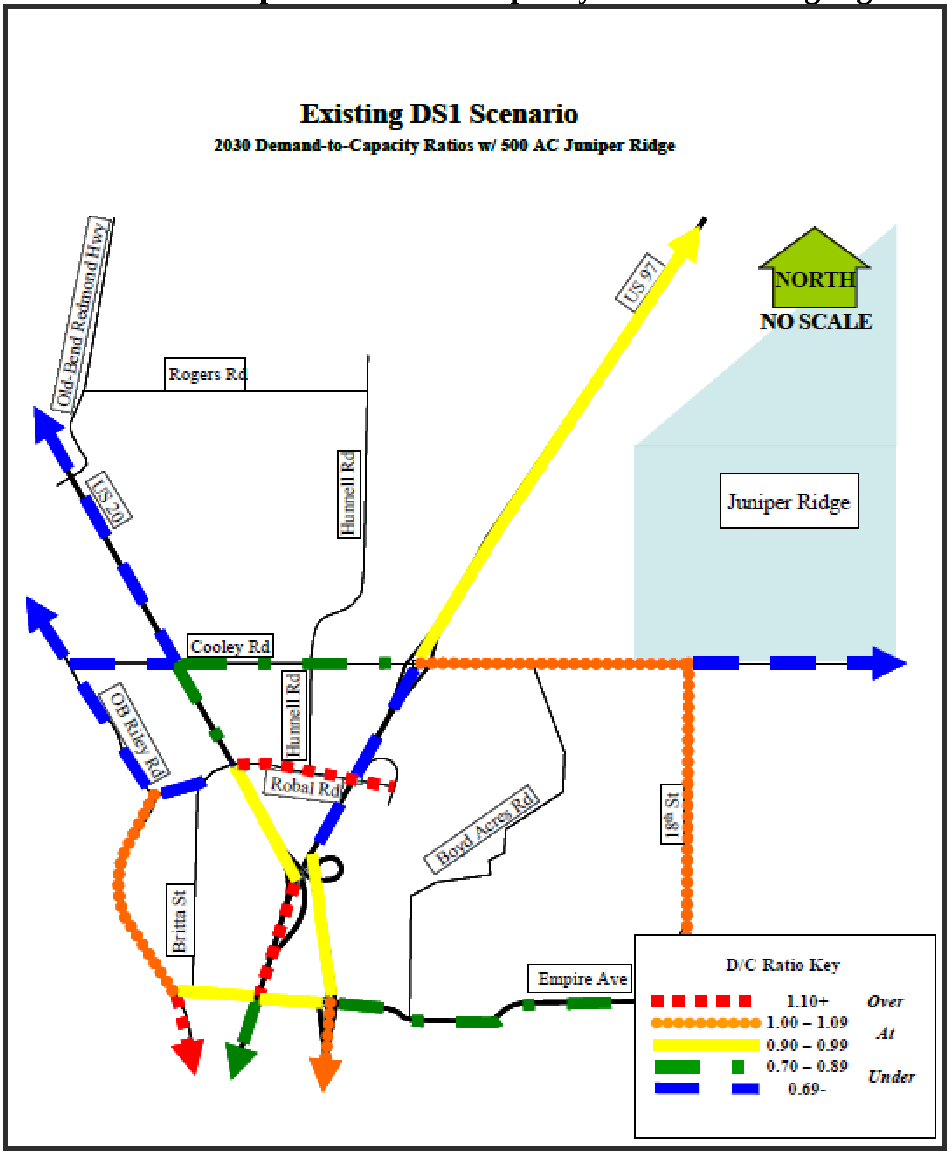
10.8.2 Goals and Objectives Screening

Goals and objective –based screening is more detailed and will focus on many different transportation elements such as mobility, safety, and operations and many non-transportation ones such as water quality, displacements, and historic resources. Typically this level is guided by evaluation criteria arranged in matrices. This is more objective and quantitative than the preliminary level.

Models can provide system level performance measures which can be useful in screening preliminary alternatives. Use of model outputs for preliminary screening can reduce the time and cost of full analysis of all alternatives and any variations. These initial assessments typically focus on more general performance indicators, such as d/c ratios on arterials and highways, d/c ratios across screenlines or approach volumes at major intersections and junctions. These findings can be useful for quickly assessing the general feasibility of a preliminary improvement concept and provide a basis for eliminating or further refining an initial concept. Tables and figures are preferred to summarize the issues rather than detailed text descriptions.

For example, a model scenario can be constructed for an individual design concept and a demand/capacity ratio plot could be requested to compare links on a relative basis to each other. The d/c ratios cannot be directly compared to the published OHP/HDM targets. Instead, they can be categorized as below (less than 0.70), near (0.70 – to 0.90), at (0.90 to 1.10) or over (greater than 1.10) capacity. Model links that are shown to be over capacity in a d/c plot have proven to be a good predictor of bottlenecks that are difficult to mitigate. Links that are at capacity generally can be addressed with mitigation, while links that are below likely will not have problems in the detailed analysis. Exhibit 10-3 shows an example from the US97 North Corridor Solutions project. It is preferred to show the d/c on a base map that reflects the actual roadway network with major street names shown. Model networks by themselves are simplified and may be difficult to tell locations apart. A simple graphical figure (note the use of colors and patterns so it can be discernable in black and white) such as this can quickly show the overcapacity areas that may or may not be addressable, which might be grounds for dropping an alternative.

Exhibit 10-3 Example Demand-to-Capacity Ratio Screening Figure



Use of screenlines to cut across multiple roadways at multiple points in different alternatives/scenarios can to be used to compare the relative changes in volumes on those roadways or the effect of a specific issue/change on the overall travel patterns. For example, where adding another river crossing would remove at least 25% of volumes from other roadways. Volumes are compared where study-area roadways cross the different screenlines to keep locations consistent between scenarios (See Exhibit 10-4 and 10-5). Use of shading in the result tables can quickly show the reader positives and negatives of the scenarios. Significant positive or negative changes (greater than +/-10%) can be used as justification to drop or forward a particular scenario.

Exhibit 10-4 Sample Screenline Locations

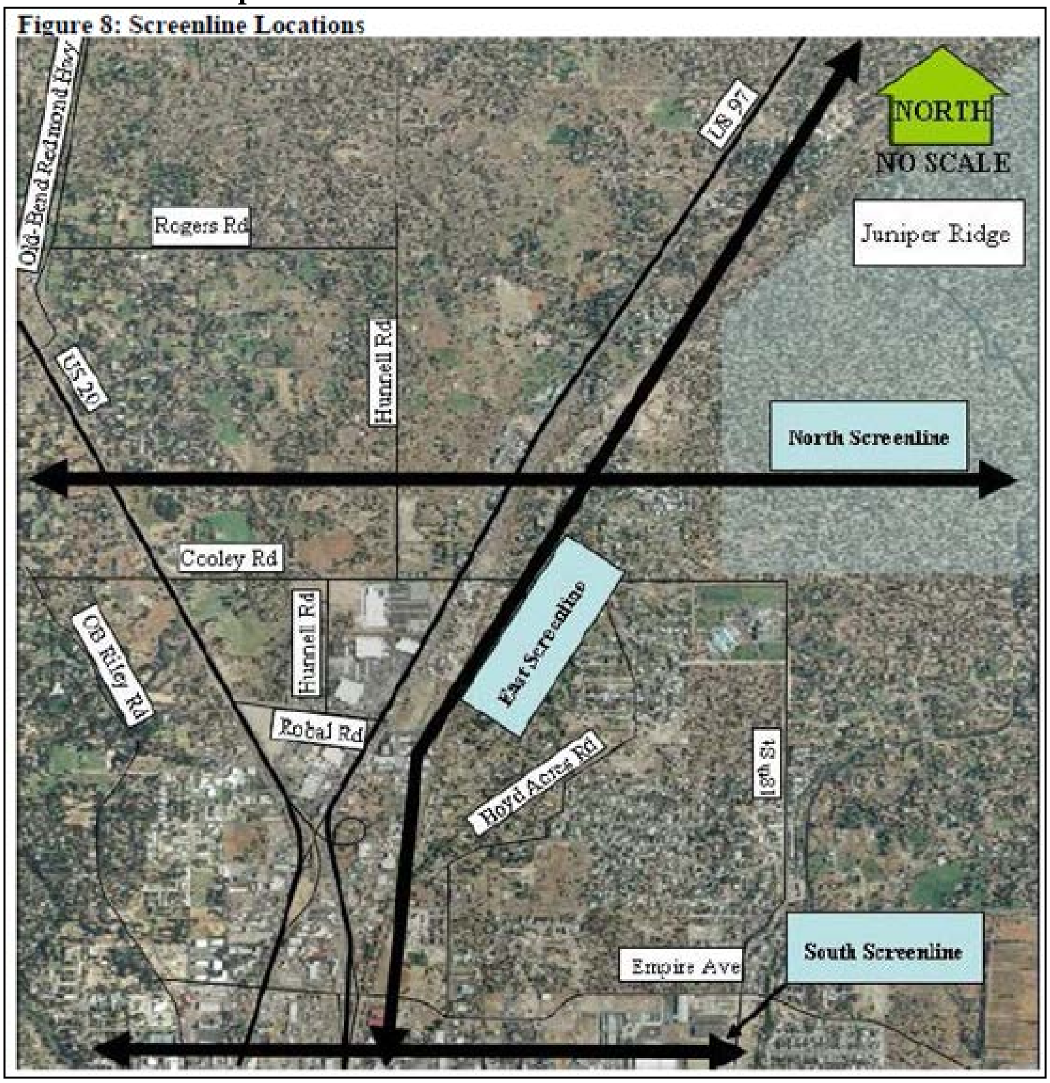


Exhibit 10-5 Volume Difference Screening between Scenarios

Table 1 North Screenline Percent Difference from Committed Scenario[1]

	US97		US20		Local Roads[2]	
Scenario	**w/o JR**	**w/JR**	**w/o JR**	**w/JR**	**w/o JR**	**w/JR**
Committed	0	**46**	0	4	0	**59**
MM-1	**-26**	**23**	-1	6	**-16**	**42**
RRA-1B	**-22**	**20**	**-21**	**-10**	4	**63**
RRA-2-2	**-29**	**-18**	4	**-13**	-2	**45**
RWA-1-2	**-35**	0	-7	0	2	**58**
RWA-3B-2	**-31**	**-35**	**-16**	**-19**	1	**60**
RWA-4	**-35**	**12**	**-16**	**-17**	-3	**34**

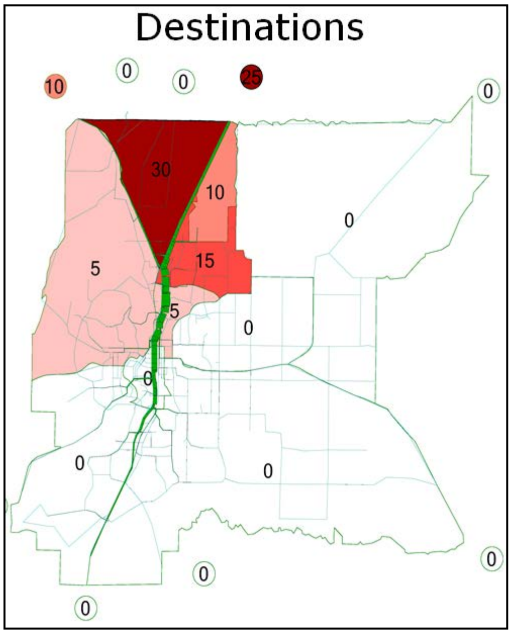
[1] Black shaded cells indicate a significant negative impact at the screenline because of increased volumes. Gray shaded cells indicate a significant positive impact at the screenline because of decreased volumes.
[2] Local roads include O.B. Riley and Deschutes Market Roads.

Summing volumes across a single screenline can determine if a scenario is simply shifting traffic between different roadways if differences are not significant (less than 10% additional volume) or may be attracting traffic into an area. Significant traffic increases (greater than 10% additional) might indicate latent demand issues as volumes shift to study area roadways from other congested facilities nearby. These kind of shifts may not be desirable (but might be expected) as they may require “improvements” to be larger than originally intended.

Summing volumes at study area boundaries can be used to determine whether a specific alternative creates significantly more vehicle-miles-traveled or greenhouse gases than others. Changes in other modes can use this method if the model is sufficiently detailed to represent these modes and is sensitive to them.

For larger regional areas, the model area TAZs can be aggregated into districts that represent areas such as a CBD or general sectors (i.e. West Salem or South Beach, Newport) or travel sheds (east county) or individual cities within an MPO model (i.e. Gresham from the METRO model). The general travel patterns between districts can then be determined. Using a select-link plot of the district to district flows, the analyst can answer traffic flow questions, such as percentage of through trips in the study area or distribution of trips to/from a specific location/district. Exhibit 10-6 shows the destinations aggregated by districts and external areas (circled values) from a location (where the volumes bars are the thickest – this is the location of the specific chosen link for the select-link analysis) on US97 north of downtown Bend.

Exhibit 10-6 District Plot of Destinations



Scenarios can also involve proposed or future land use changes along with network changes. This could be at the regional level all the way down to a specific development proposal. Models can be used to evaluate policy type questions such as land-use scenario planning with UGB expansions, nodal development, significant Comprehensive Plan changes and multiple growth scenarios. These changes between a base and a proposal should be modeled as referred to in the ODOT Modeling Procedures Manual for Land Use Changes. The results from these changes can be reflected in d/c plots, screenlines, or districts as shown above.

If the model is detailed enough, other measures can be screened. Mode split can be evaluated if the model is at a regional level. Models can also be used to evaluate policies other than land-use related where parameters are included in the model such as restricting the overall capacity of arterials or changes to standards. Policies related to monetary issues such as parking, tolling, or VMT taxation require models with economic components. There are other models that are not travel demand-based such as land use, greenhouse gas/emission, and economic-based models that can be used in preliminary screening of related concepts.

Adding model travel times on the specific links that comprise a specified route can be used on a relative basis to determine the effectiveness of certain scenarios. Routes are typically determined on a shortest path by time method from a specific origin to a specific destination. Multiple routes can be averaged together to judge performance of a scenario as shown in Exhibit 10-7. The model travel times can be used to estimate emergency response times, freight trip times, school route trips, etc on a relative basis keeping in mind that many models do not account for intersection congestion. These travel times can also be used as a surrogate for micro-simulation travel times when the origin or destination is outside of the project/study area.

Exhibit 10-7 Relative Average Model Scenario Travel Times

Table 7 Average Travel Time Percent Differences with the Committed Scenario[1]

Scenario	US20	US97	Overall Study Area
Committed	0	0	0
Juniper Ridge	8	24	13
MM-1	6	-17	0
MM-1 w/ Juniper Ridge	6	-12	1
RRA-1B	22	-15	11
RRA-1B w/ Juniper Ridge	27	-9	18
RRA-2-2	-1	-18	-5
RRA-2-2 w/ Juniper Ridge	23	-17	12
RWA-1-2	6	-8	2
RWA-1-2 w/ Juniper Ridge	9	1	7
RWA-3B-2	4	-14	-2
RWA-3B-2 w/ Juniper Ridge	6	-9	8
RWA-4	10	-9	3
RWA-4 w/ Juniper Ridge	10	-5	4

[1]Gray shaded cells indicate that travel time is significantly less than the committed scenario and black shaded cells indicate travel times that are significantly greater.

10.8.3 Operational Level Screening

Screening using operational-level measures is typically applied after fatal flaw or first cut screening such as using models. It generally is the third and final level of screening and involves a detailed evaluation of goals and objectives and is applied to a lesser number of alternatives. See Chapter 9 for details on performance measures.

- **Volume-to-Capacity Ratio**: This could apply to individual turning movements, average intersection conditions for all movements, roadway or highway segments, weaving movements and highway merge/diverge operations. This is the primary performance evaluation criterion for ODOT facilities.
- **Level of Service**: Many local jurisdictions use Level of Service ratings in their development code as performance criteria. Most facility evaluation methods provide both a v/c ratio result and a Level of Service result.
- **95% Queue Length**: Safety and operational impacts associated with the likelihood of a vehicle queue frequently blocking circulation or access. Use the 95th percentile queue and compare to storage length.
- **Queue Blocking Percentage**: Generally applied to through travel lanes, this is the portion of the study period (percent of time) where standing queues block the advance of vehicles from the adjoining upstream intersections or block the entrance to turn lanes.
- **Other Operational Indicators**: Travel time (by corridor or by segment), travel time reliability, total delay and total number of vehicle stops. HERS-ST (see Chapter 7) can be used for determining segment or corridor v/c ratio, speed, travel time and delay.
- **Safety:** Screening for safety includes Highway Safety Manual (HSM) Part B methods such as critical crash rate and excess proportion of crash types which are detailed in Chapter 4. Other safety methodologies such as Crash Modification Factors (CMF), functional area, and spacing standards are also included in Chapter 4.
- **Multimodal:** Level of Traffic Stress methodologies can be used for screening pedestrian

and bicycle systems. Multimodal Level of Service (MMLOS) methodologies may be used to identify impacts to transit and may be used for pedestrian or bicycle modes. See Chapter 14 for further information.

- **Other Screening Measures:** Other typical screening measures that may be identified in evaluation matrices that may have traffic or design components include right-of-way, environmental (acres of impervious surface, air quality, noise, etc.), socio-economic (displacements, disproportionate impacts), emergency vehicle access, freight travel times, and access points.

10.9 Documentation of Screening Process - Alternatives No Longer Considered

As the screening process proceeds from the fatal flaw through the operational level, it is important to actively document the concepts and alternatives as they are eliminated. Frequently, concepts and alternatives change names, are combined with others, or completely dropped from consideration. It is very difficult to reconstruct this history after the fact due to the sheer number of concepts and alternatives that are typically developed in the project process. It is not uncommon that concepts/alternative naming conventions can change multiple times thus further obscuring their origins. Concepts can come from multiple sources – staff, consultants, project team(s), and the public. For each concept or alternative through each level of screening, the name/title, a detailed description including figures if available, and the disposition and reason (name change, combination, drop etc.) should be documented chronologically. Documentation is important, as alternatives that were previously dismissed may be re-introduced without realizing they were already dropped, potentially causing re-work or delay. Exhibit 10-8 shows an excerpt of the alternatives no longer considered in the US199 Expressway Plan traffic analysis report. Note that one alternative was dropped because it did not meet purpose and need, one was dropped as it was not unique, and one was dropped as it had the largest right-of-way and displacement impacts. This documentation is a critical appendix in traffic analysis reports and in any project that falls under an EA or EIS under the NEPA. While tracking of alternatives is the responsibility of the ODOT Environmental Project Manager, the traffic analyst should also document the alternative development.

Exhibit 10-8 Example Alternatives No Longer Considered Documentation

West 2 – This concept consists of a continuous two-way left turn from Midway Avenue to Dowell Road and included removal of the Willow Lane restriction. The CAC and PDT determined that this alternative did nothing to improve safety which was part of the purpose and need, therefore it was dropped.

West 3 – This concept has full median from Midway Avenue to Dowell Road except for three items: 1) Hubbard Lane improved south to Demeray Drive; 2) US 199 at Hubbard Lane is signalized; and 3) Dawn Drive is connected north to Redwood Avenue. All the components of this alternative were included in other ones, so this was not forwarded.

West 4 – The concept is referred to as a mini-couplet with a wide median (50'+) between Willow Lane and Midway Avenue with indirect left turns centered around Willow Lane and Midway Avenue. Hubbard Lane would be right-in/right-out only and a left-in only to Rogue Community College would be allowed. Dawn Drive would have a frontage road that would connect across from Arbor Ridge Drive with full access having stop-controlled medians. This alternative was dropped because it had the greatest right of way acquisition and relocations.

10.10 Final Alternative Selection

The project team will select a single alternative from the final group of alternatives, or a hybrid of alternatives, which could necessitate additional analysis. If the selected alternative is significantly different from the alternatives described in the Draft EIS then a Supplemental EIS will also be required so the analysis of all alternatives is consistent. For EIS projects, the Preferred Alternative may, or may not, be identified in the Draft EIS, however, a Preferred Alternative should be identified in the Final EIS. The Final EIS and Record of Decision (ROD) identify the "selected" alternative. For EAs, frequently only a Build Alternative and No-Build Alternative are evaluated, in which case the Build Alternative is typically considered the Preferred Alternative.

10.11 NEPA Projects – Post Draft EA/EIS

Following the publication of the draft EA or EIS, there is a required comment period, in which the local, state and federal agencies, stakeholders, and the general public may comment on the preferred alternative. Depending on the scope or level of controversy, additional time and analysis may be required to address the comments. Once all comments have been addressed, the final EA or EIS is published. After the comment period and the resolution of comments, FHWA will either issue a Finding of No Significant Impact (FONSI) for an EA, or require an EIS if there is a significant impact, or a ROD for an EIS. Once a FONSI or ROD is secured, the project is eligible for obtaining federal funds and may proceed into final design and right-of-way purchase. TSP amendments and IAMPs are considered land use actions and need to be completed before issuance of a FONSI or ROD. For more information visit ODOT's NEPA Coordination webpage.

10.12 Potential Solutions

10.12.1 Purpose

This section is intended as a general summary of a representative range of practical solutions for ODOT plans and projects. This guidance is not intended to duplicate or conflict with ODOT design guidance such as in the HDM, Bike/Pedestrian Design Guide or Traffic Manual. The analyst will frequently need to refer to these manuals for more detailed guidance and needs to coordinate early on and closely with Region Tech Center and TRS staff. Many solutions such as those involving new or modified traffic control devices are subject to review and approval of the State Traffic-Roadway Engineer or Region Traffic Engineer/Manager as discussed the Traffic Manual.

The solutions identified in this section are not an exhaustive list but a reasonable starting point. Solutions can be for the HDM standard 20-year design life or can be shorter interim or incremental improvements if a design exception or concurrence is approved.

> *All alternative solutions for plans and projects need to be reviewed by Region Roadway/Traffic or Traffic-Roadway Section staff for reasonableness, need for design exceptions, other preferred options, or other potential concerns. This will be especially needed if representatives are not already part of the technical advisory committee or project development team. Alternatives should follow ODOT Design Standards or the project team can seek a design exception. Alternatives not meeting design standards need to have a design exception approved for projects within 5 years of construction. For projects between 5 and 10 years from construction, an indication or concurrence is needed from Roadway Engineering in Technical Services that a design exception would be approved.*

Potential solutions to address existing or future deficiencies can range within following categories:

- Transportation System Management & Operations
- Potential Land Use or Regulatory Changes
- Access Control and Local Circulation Improvements
- Multimodal & Intermodal Improvements
- Safety Solutions
- System Improvements
- Segment Improvements
- Intersection Improvements
- Interchanges

In general, the analyst should first consider the least impact to existing development, natural systems and cost, then progress towards improvements that have potentially larger investments and associated impacts until the identified need is resolved. The impacts of long-term maintenance and other life-cycle costs should be considered when choosing between solutions. This includes cost for power for signals and illumination, software upgrades for dynamic message signs, and even extra emissions from standing vehicle queues.

Many of the solutions in the following sections can either be stand-alone or interim projects. Interim solutions can be used to delay or phase in the implementation of more complex projects. Solutions should be phasable and also limit throwaway (improvements needing to be replaced or reconstructed in the near future, inconsistent with the long term design) for most efficient use of funds. Solutions need to strike a balance between safety, operations, and multimodal as it is unlikely that full standards for all areas will be achievable. For example, pure mobility-based solutions may adversely affect safety as speeds and crossing widths increase. Many solutions need to be evaluated as part of a larger system or corridor in order to capture potential effects. For example, downstream intersection spacing may cause backups into a signalized intersection or roundabout. Study areas should generally cover a larger area than the solution itself, at least to the next intersection or interchange and in some cases further. Bottleneck improvements should be evaluated to ensure the bottleneck is not just moving to another location.

Many solutions may overlap one or more of the categories discussed below. For example ramp metering could be considered a TSM, TDM, and an operational strategy.

10.12.2 Transportation System Management & Operations (TSMO)

TSMO strategies are covered in more detail in APM Chapter 18. The following summarizes the basic types of TSMO strategies.

Travel Demand Management (Transportation Options)

The future analysis may also include elements that modify the initial travel demand that are expected in the future no-build forecasts. There are many techniques and programs that effectively manage future traffic demands, both on a temporal and modal basis, to work towards reducing the overall travel demands within the project area. The initial assessment for the project area should consider solutions that do not require physical improvements to the transportation system. Travel demand management generally includes the following types of programs and services that can marginally reduce the estimated travel demand where these types of programs are not in place. In general, these types of programs are most suitable for urban areas where commute traffic represents a significant component of the study period flows. Common demand management techniques could include:

- Increase or enhanced transit services.
- Carpooling/ridesharing
- Transit fare subsidies
- Flextime/compressed work week
- Bike parking/on-site lockers and showers
- Telecommuting
- Parking management can range from time-based measures to increase turnover to cost-based strategies to manage long-term monthly parking demand.
- Comprehensive Travel Demand Management (TDM) programs applied to larger

employment centers that increase auto occupancy, bus ridership and help to spread out the peak demand levels for a given site.

It is recommended that the alternatives development process give consideration to TDM components that can augment physical or operational improvements within the study area. Refer to Chapter 18 for more details about TDM options.

The effectiveness of these types of programs can be estimated based on surveys conducted for the Employee Commute Options Rule compliance. Typically, these measures can reduce commute travel demand for a given activity center by 1 to 10 percent or more, if the management takes aggressive measures. For more details, refer to the 1996 study[2] that assessed the marginal reduction in traffic generation associated with various TDM options.

Transportation System Management (TSM)

TSM are improvements that do not require additional right-of-way and are relatively low in cost. As such, TSM solutions are sometimes implemented as interim projects prior to construction of final solutions. Substandard performance at highway intersections can be addressed by adding capacity to critical movements or upgrading the traffic control schemes to serve higher demand levels. These types of improvements need to consider multiple time periods of the day instead of just a single peak period. For example, turn movement patterns could be different between the morning and afternoon so a given lane configuration may not work well in all cases. The analysis for these types of improvements may be discussed further in APM version 1 Chapter 18. The range of potential solutions includes:

<u>Reconfiguring Lanes</u>

This involves revising existing lane designations. An example would be revising a two lane approach, where you have a shared left/through lane and an exclusive right turn lane into an exclusive left turn lane and a shared through/right lane. This may or may not involve phasing changes at a signalized intersection.

<u>Signal Phasing</u>

This involves signal phasing changes such as adding a right turn overlap or adding a U-turn, converting left turn phasing Protected/permissive signal phasing, changing cycle lengths, split times. Effect on signal progression should be evaluated.

<u>Added Turn Lane Without Widening</u>

An example would be converting available shoulder or parking space for use as a turn lane. Potential impact on bicyclists needs to be evaluated.

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[2] Guidance for Estimating Trip Reductions from Commute Options, Oregon Department of Environmental Quality, August 1996.

Road Diet/Reconfiguration

A road diet is typically a conversion of a four-lane facility to a three lane facility having one through travel lane in each direction plus a two-way left turn lane. This involves reallocating roadway space to improve safety, operations and encouraging multimodal. Road diets can range from simple restriping on a preservation project to a full reconfiguration of the roadway including hardscaping improvements such as curb extensions and other pedestrian and bicycle and parking improvements. A simple restriping may not achieve the desired goals of creating a more multimodal environment.

Some road diets are built as interim projects prior to widening a facility to five lanes. The two-way left turn lane improves through movement flow by removing turn movements from the through lanes if there are a significant number of left turns. However, applying a road diet to a roadway with few turning movements may adversely impact through movement flow. Many times there is enough left over space to accommodate multimodal facilities such as bike lanes, wider sidewalks, bulb-outs, etc. Items to consider include:

- The evaluation needs to include a 20-year analysis to assess the design life of the facility. This needs to include a full predictive-level safety and multimodal analysis including of parallel facilities. If the 20-year HDM mobility standards are not met, the project team may seek a design exception. Depending on the project scope and context a 10-year interim analysis may be considered.
- Estimates of diverted volumes and evaluation of potential impacts from diversion onto parallel facilities. See APM Version 2 Chapter 6 for analysis procedures.
- Assessment of the potential magnitude of a shift in modes if possible, such as by using an MPO travel demand model.
- Road diets through small cities need to consider effects on passing opportunities on facilities leading into or away from the community.
- If on a designated ORS 366.215 freight route, the evaluation process in the ORS shall be followed; see ORS 366.215 Guidance. Early involvement of freight and active transportation stakeholders is necessary.
- Parking considerations need to include impacts of removal and/or replacement of parking either on both sides, on one side or even a few spaces, the impact on maneuvering into and out of parking spaces, and potential impacts on the safety of bicyclists.

Freeway Auxiliary Lanes

These are lanes added between closely spaced interchange on and off-ramps which improve operations by reducing impacts of weaving, entering and exiting traffic flows. These typically extend from one interchange to the next or through several interchanges. While auxiliary lanes can improve operations on freeways by keeping local trips off the freeway through lanes, longer auxiliary lanes may cause drivers to assume it is an additional travel lane. These can result in problematic weaving forms especially if lengths are short or if one or more lane changes are required which need to be evaluated using procedures in APM v1 Chapter 6. Weaving sections that do not require lane changes to remain on the mainline are preferred.

These may encourage short hop local trips which are not desirable but may not be avoidable due to lack of parallel facilities. Shoulder width reductions should be evaluated for safety and capacity impacts.

Extension of Freeway Acceleration or Deceleration Lanes

These will generally improve operations and safety by allowing more room for vehicles to enter and exit the through traffic streams. The length should be sufficient to allow the design vehicle speed to be within 10 mph of the posted speed. Refer to the HDM for proper spacing of acceleration and deceleration lanes.

Active Transportation Demand Management (ATDM)

Chapter 18 and the Chapter 18 Appendix provide detail on specific ATDM solutions, strategies and considerations for application. Some of these strategies may require legislative changes such as hard shoulder running. Ongoing operations, maintenance, and staffing costs can be a significant portion of an ATDM-based solution.

10.12.3 Potential Land Use or Regulatory Changes

Land use and/or regulatory changes are considered in planning rather than project development, for example IAMPs and TIAs. In addition, other planning actions taken by the local jurisdiction may have substantial effects on the initial horizon year forecasts that would reduce the future demand and partially (or fully) mitigate the identified need. These actions could include:

- Re-zoning land to generate fewer motor vehicle trips.
- Restricting the intensity allowed within the current zoning by imposing trip caps/budgets that are regulated by local ordinance. The trip cap is based on the amount of traffic a facility can handle at a decided-upon v/c ratio level.
- Supporting mixed use development that minimizes trips onto the roadway system. A potential tradeoff is that mixed use development may reduce trips region-wide, but may increase the number of trips in the local area. This may potentially reduce the capacity available to the auto mode since the capacity will be used by walk and bike.
- Designation of a multimodal mixed-use area (MMA) by a local jurisdiction. This is for areas meeting specific characteristics as defined in TPR OAR 660-012-0060 that, once adopted, allows a local jurisdiction to approve plan amendments without applying motor vehicle congestion related performance standards. Other performance standards such as safety still apply. Plan amendments within MMAs are still subject to other transportation performance standards or policies that may apply including, but not limited to, safety for all modes, network connectivity for all modes (e.g. sidewalks, bicycle lanes) and accessibility for freight vehicles of a size and frequency required by the development.

These actions require coordination with local agencies that are responsible for land use review and approval and it may require a separate review and approval process to be implemented.

10.12.4 Access Control and Local Circulation Improvements

State facilities should be reviewed to compare background access provisions on state highways according to adopted standards in ORS 374 and OAR 734-051. Local facilities should be reviewed against local adopted access management standards. Consideration of access management solutions requires close coordination with the Region Access Management Engineer. See APM Chapter 4 for more information on access management and related solutions.

Access management in state highway facility plans is addressed in ORS 374.331 and OAR 734-051-7010. The location of county roads and city streets within the area described in the facility plan is determined through collaborative discussion and agreement between the department and the affected cities and counties. For state highway facility plans that propose to modify relocate or remove existing public or private connections to a state highway, a methodology is developed which balance the economic development objectives of real properties with safety, access management and mobility and which inform the affected real property owners of the potential for modification, relocation or closure of existing private connections. The department develops a methodology to weigh the benefits of a highway improvement or modernization project to public safety and mobility against local TSPs and land uses permitted in local comprehensive plans and the economic development objectives of property owners who require access to the state highway. Affected property owners may request a review through a collaborative discussion process, and/or an Access Management Dispute Review Board Process.

Access management for highway improvement projects in the Statewide Transportation Improvement Program (STIP) is addressed in ORS 374.334, OAR 734-051-5120 and PD 03. An access management strategy is developed for the project by the department in collaboration with cities, counties and property owners abutting a state highway. The access management strategy identifies the location and type of public and private approaches and other necessary improvements that are planned to occur primarily in the highway right of way and that are intended to improve current conditions on the section of highway by moving in the direction of the objective standards in ORS 374.311 and OAR 734-051. The strategy establishes the methodology by which private approaches will be considered for modification, relocation or closure and which balances the economic development objectives of properties abutting the state highway with the transportation safety, access management objectives, and mobility. Affected property owners may request a review of the methodology through a collaborative discussion process, and/or an Access Management Dispute Review Board Process.

Consolidating (or eliminating) existing vehicular access can substantially improve travel speeds and reduce vehicle and pedestrian/bicycle conflicts along the highway, improving safety for all users. Improving safety will also reduce non-recurring delay and will improve reliability. Reduced access will typically increase capacity to some degree as well. This requires coordination with affected property owners and implementation of necessary permits and easements to develop an alternative local circulation plan. This approach is most effective on a site that is making development application and has substandard existing access spacing provisions.

In addition, the local agency could implement alternative local circulation plans that reduce the volume of traffic using the highway and shifts a portion of the local vehicle trips onto local roadway facilities. This can be accomplished through connecting circulation routes within adjoining uses across parking lots or via alleys, frontage roads and backage roads.

10.12.5 Multimodal/Intermodal Improvements

Refer to Chapter 14 for the multimodal analysis methodologies. All of the improvements below have related design elements (HDM, etc) and freight/design vehicle impacts. Ongoing maintenance such as slab replacement, grinding, resurfacing, cleaning of debris, removal of obstructions such as sign poles, protruding vegetation, poor driveway cross slopes, non-standard corner ramps needs be considered as part of the solution evaluation process.

Pedestrians

Pedestrian Segments

- **Sidewalks –** Sidewalks should be provided on both sides of the road and connected to other facilities in urban areas. Wider sidewalks need to be provided where pedestrian volumes are higher such as in pedestrian-oriented areas such as CBDs, plazas, transit centers, etc. When filling gaps, locations near or that connect to pedestrian-oriented areas should be a higher priority.
- **Buffers –** should be provided where possible to improve the walking experience. A wide sidewalk can act as a buffer as well. Buffers can include bike lanes, parking, street furniture zones, landscape strips, retaining walls, ditches, drainage swales, etc. Where possible buffers should be wide enough to support landscaping. Landscaping can include trees as these provide the lowest-stress walking environment but tradeoffs with sight distance, potential for fixed-object collisions, clogged gutters, broken sidewalks, etc.

Pedestrian Crossings

For pedestrians it is important to consider the availability and potential of having regularly-spaced crossing opportunities. Pedestrian travel can be diminished if out-of-direction travel is too large or be potentially unsafe if improved crosswalks are needed but spaced too far apart.

- **Traffic Signal Phasing/Right Turn on Red Restrictions –** Including left/right turn protected movements can increase the overall safety level by removing potential turn conflicts. Restricting right-turn-on-red at crossings with high pedestrian volumes should be considered when right-turns can be adequately served with a separate phase.
- **Protected/Enhanced Crossings –** NCHRP 562 provides methodologies to evaluate pedestrian crossing enhancements. The road diet mentioned previously can incorporate many of the crossing enhancements below.
    - **Pedestrian Activated Beacons (PAB) –** user-activated traffic control devices with yellow flashing lenses that require vehicles to stop and yield to pedestrians at midblock crossings and uncontrolled intersections. PABs provide increased motorist awareness of pedestrian crossings, makes a lower stress crossing, particularly where signalized crossings are widely spaced or out of direction

travel is excessive. A specific type of PAB is the rectangular rapid flashing beacon (RRFB), which is an option available under FHWA Interim Approval IA-21. The Traffic Manual provides specific criteria for installation including speed, volume and spacing. Installation of these devices requires approval from the State Traffic Engineer.
    - **Pedestrian Hybrid Beacons (PHB) –** user-activated traffic control devices that provide a red signal indication requiring vehicles to stop for pedestrians at midblock crossings and uncontrolled intersections. Vehicles cannot proceed until the red indiciation turns off. A WALK signal is provided for pedestrians. PHBs are generally used for for higher pedestrian volume and higher speed locations than PABs. The Traffic Manual and MUTCD provide specific criteria for installation including speed, volume and spacing. Installation of these devices requires approval from the State Traffic Engineer.
    - **Raised Pedestrian Refuge Medians –** allows for two-stage crossing of wider roadways, providing a lower level of traffic stress and the ability to cross higher volume roadways. May be combined with other techniques such as illumination, bulb-outs and beacons.
    - **Bulbouts –** can reduce pedestrian exposure while crossing the street. Could constrict freight movements, particularly with full-width lane bulbouts. Important to be aware of vehicular composition and heavy vehicle turn movement patterns. Where substantial truck volumes exist, investigation of alternate routes should be evaluated.
    - **Turn Radius Reduction –** provides for slower right turning vehicles, reduced crossing distance, and creates improved visibility between drivers and pedestrians. However, the radius needs to be large enough so that large trucks or buses do not overrun the curb, which is a safety concern for pedestrians.
- **Grade Separated Crossings –** limited to the highest volume and speed roadways such as freeways and expressways where at-grade crossings are not permitted or where safety is an issue. The extra distance required to access the overcrossing due to length of ramps needs to be considered, particularly if the structure is over an arterial. If the extra time required is excessive, pedestrians may cross at grade. Undercrossings are generally preferred, but need to be well lit and have sufficient clearance and width to provide a natural walkway. Culvert-style passages generally deter use especially in urban areas because of personal security concerns. Grade separated crossings are usually an order of magnitude greater in expense than at grade crossings.

Bicycles

Low stress tolerant riders require a high degree of separation between themselves and the adjacent traffic lanes. While the addition of a bike lane to a facility may accommodate the bike mode, to achieve the highest modal share, greater separation is desirable. Generally the higher the speed and greater the volume, the more separation is desired. See the Oregon Bicycle and Pedestrian Design Guide for more information on these solutions including the Urban/Suburban Bike Facility Separation Matrix. Separate facilities can include (from most separation to least):

Bicycle Segments

- **Separated/Multi-Use Paths –** provides a wide separation from a parallel roadway or can be in a wholly separated right-of-way such as a creekside greenway or rails-to-trails corridor, and can serve both commuter and recreational functions. Out of direction travel should be minimized for access on and off these paths. Additional considerations/analysis is necessary where these routes cross roadways and will likely require crossing enhancements such as median islands, beacons, or potential grade separation.
- **Separated Bikeways (Cycle Tracks) –** Similar to a buffered bicycle lane but with some sort of physical separators such as posts, planters, or parked cars. There can also be vertical separation from the roadway grade or sidewalk. These are typically located on higher speed and or volume streets that also have a significant bicycle volume. Separated bikeways also need to be connected to other bicycle facilities and not as an isolated facility.
- **Buffered Bike Lanes –** A bike lane with a painted non-physical buffer area. These should be used wherever possible where right of way allows as they provides a lower stress experience resulting in greater usage than a standard bike lane. Any angle parking should be changed to parallel parking to be compatible. Back-in angle parking may be appropriate in some circumstances such as on a one-way street.
- **Bike Lanes** - Caution should be exercised where bike lanes are adjacent to right turn lanes especially on high speed facilities or if the length is in excess of approximately 200 feet. Buffered bike lanes should be considered in these situations to avoid the 'sandwich' effect. Any angle parking should be changed to parallel parking to be compatible, although back-in angle parking may be appropriate in some circumstances such as on a one-way street.
- **Wider Shoulders –** Applied in rural conditions for higher speed/volume facilities.
- **Wider Outside Travel Lane**. Not preferred, but may be considered where right of way does not permit installation of even a narrow bike lane. Parallel routes/bike boulevards should be considered if proper on-street accommodations cannot be made. By law, vehicles must give adequate room to bicyclists when overtaking.
- **Bike Boulevards –** while these are local functionally-classed (not for collectors or arterials) on-street facilities, through traffic is usually restricted and can offer a low stress experience. These should be parallel with major arterials/higher stress facilities and should not have too much out of direction travel in proportion to their overall length (less than 25%). These can be a good solution if the major roadway cannot be significantly improved, but may not be a good solution if the destinations are on the parallel arterial.
- **Sharrows –** shared bicycle lane markings for lower speed (25 mph or less) and volume environments such as CBDs where bicyclists can feel comfortable traveling within the traffic stream. Bicyclists are supposed to take the center of the lane when sharrow markings are present.
- **Green Paint –** used to delineate bicycle facilities through intersections or other complex roadway arrangements.
- **Bike Warning Beacons –** Warning systems for narrow roadways across significant bridges and through tunnels where motorists would not necessarily be expecting a bicyclist. These may be activated by a bicycle push button or by a passive detection system or both.

Bicycle Intersection Treatments

- **Bike Boxes –** Previously experimental, now approved for provisional use (FHWA Interim Approval dated October 12, 2016)). At signalized intersections where there is a demonstrated high volume of bicyclists, to allow bikes to proceed ahead of the motor vehicles.
- **Two-Stage Turn Boxes –** Used to facilitate bicyclist left turns, typically used in locations where bicyclists may have difficulty with weaving over multiple lanes of through traffic. Two stage turn boxes may require Experimental approval from FHWA. Contact Region Traffic or TRS staff if there is interest in using this device.
- **Bike Signals –** to separate conflicting bicycle and vehicular traffic flows in certain complex situations such as when a right lane drop is to the left of a bike lane, or where the bike lane needs to weave through the intersection. May require analysis of additional signal phase. Bike signals can have a frequent violation rate where bike signals are uncommon and/or volumes are low as bicyclists may be less willing to wait for the bike phase, so use of these devices should be limited to complex situations with high volumes.

Transit

Transit improvements suggested in plans and projects are subject to the availability of funding from the transit provider (includes transit districts, cities, counties, non-profits, tribes, school districts, colleges and universities, the state of Oregon, and others). Capital projects (stop improvements, transit centers) are funded separately from vehicle purchases (typically included in the STIP) and from operating budgets. Budget limitations may prevent new routes from being added or frequencies shortened for example. However, local, regional, state and federal funding sources such as grant programs may be sought. Coordination with the transit agency is required for any alternatives involving transit. For more information and assistance in coordinating with local transit agencies contact the ODOT Public Transit Section. A good primer on public transit in Oregon is the publication Transit in Small Cities.

- **Transit (Bus) Signal Pre-emption –** Buses are detected by the system which can allow for earlier and/or longer green indications which minimizes delays.
- **Bus Stop Pullouts** should be downstream (far side) of intersections to minimize impacts to through traffic. Mid-block pullouts can be considered especially where there is a mid-block pedestrian crossing. Some transit agencies prefer not to have pullouts. Pullouts should be considered in locations with high boardings (longer dwell time for passengers to pay for tickets from the bus driver) or bus transfer locations where a bus may wait for passengers transferring from another bus route.
- **Busways/Guideways (Bus Rapid Transit or BRT) –** Buses run in their own separated bus way either in the median, outside travel lane, or parallel to the roadway. Stops usually have higher platforms and are double-sided as both directions are separated. Stops are generally further apart and serve higher volume locations. Delay and interference with the rest of the traffic stream is minimized which allows for a higher capacity and short

headways (high frequency). These are for high passenger volume routes. Busways can also be completely in their own right-of-way and can be even grade-separated in places although the cost can approach the level of a light rail system in this case.

- **Bus-Only Lanes –** These are exclusive lanes for transit operations which might be found in central business districts, transit mall areas or even dedicated on/off ramps at interchanges for access to bus stops, park and ride lots, and transit centers.
- **Stop Improvements** - Benches, shelters, larger landing areas for mobility-impaired users, arrival/departure information, and illumination are amenities that can increase ridership or encourage riders to wait longer especially if frequencies are greater than 15 minutes. Most bus stops come in pairs and require crossing a street to access the opposite direction, so safe and nearby crossings are important.
- **Frequency Changes –** if the overall surrounding land use is supportive and if operating budgets can allow, additional frequency is one of the biggest improvements that can be made to improve transit service on a route to encourage/increase ridership.
- **Route Changes/Additions –** Routes are typically added either for coverage or for ridership. Coverage routes will generally loop through residential areas and likely will have lesser frequencies. Ridership routes will be on high ADT roadways and serve major pedestrian attractors and generators (downtown, schools, medical facilities, etc). The analysis needs to consider the surrounding land use in estimating potential ridership.
- **Transit or Multimodal Hubs –** Creation of hubs with multiple transit routes, park and ride lots, bicycle racks, and good pedestrian and bike connections with the surrounding neighborhood can encourage more non-auto use in the community.

Freight

- **Local Truck Routes –** Used to reroute trucks out of a downtown or constricted areas to more suitable roadways. This may require improvements to the designated roadway. Requires coordination with the local jurisdiction as they usually establish the local truck routes by ordinance. If the local government is proposing to take trucks off a state highway they need to go through the ODOT Approval Procedure for Local Truck Routes.
- **Chain-Up Areas –** Used in areas with defined snow zones for large trucks and other vehicles to install or remove chains.
- **Climbing Lanes (Chapter 11) -** These are used on steep or long grades to maintain the traffic flow and speed by minimizing delay on the overall traffic stream. Unlike a passing lane, a climbing lane is not considered a capacity improvement. The length that extends over the crest needs to be long enough to accelerate the truck to within 10 mph of the posted speed. Driveways and intersections within the climbing lanes are highly discouraged. Evidence of heavy truck driving on the shoulder is a good indication that a climbing lane may be needed.
- **Truck Only Lanes –** These are exclusive lanes typically used to maintain truck speeds up when climbing grades in congested locations (an exclusive climbing lane).
- **Extending Green –** This is an operational improvement at signalized intersections to detect approaching trucks and extend the green time to reduce trucks stopping and re-starting, improving safety and efficiency.
- **Truck Aprons –** Paved areas used at roundabouts on approaches and on the center island and other locations to accommodate oversized vehicles. Curbs are of a mountable type

that do not limit truck use but are uncomfortable for smaller vehicles. Broken signposts, bent signs, and broken curbs/sidewalks are indications that aprons may be needed.

- **Mountable Curbs –** Can be used on channelization islands, median barriers to allow for overrunning large vehicles or for emergency access. For example, an intersection may be limited to traffic as a right-in-right-out but the mountable curbs allow for a fire truck to quickly access the side street without a lot of out-of-direction travel and a quicker response time.
- **Accommodations for Freight and Oversize/Overweight (OSOW) Vehicles** can include the above apron and curb allowances but should also consider needs for turning radius at intersections, impacts of curb extensions, painted medians in lieu of landscaped medians/ barriers, narrow lanes and other restrictions. Certain highway routes are covered by ORS 366.215 which requires coordination with freight stakeholders when a project proposes to reduce vehicle-carrying capacity, as described in Guidance for Implementation of OR 366.215.
- Note that making freight accommodations (wider radius, limited curb extensions and the like) will have an impact on pedestrians and bicyclists, so these kind of improvements need to be discussed in an open project team environment and coordinated with the various stakeholders and local jurisdictions.

Rail

Any alternative solutions within 500' of any rail line or railroad crossing (at/over/under) or where in-street rail running is present need to be coordinated with the Rail-Transit Division. This includes public or private roadway crossings, multi-use path crossings, and roadways or paths running parallel to rail lines. This also includes any ownership of the track including whether it is public such as ODOT or Tri-Met or a private railroad. It is important to coordinate as early as possible with the Rail Section as the potential rail crossing order coordination and application process can be very time consuming. Refer to the ODOT Rail website for contacts and more information.

Public crossing improvements require rail crossing orders which can involve many elements. Some of the more common elements requiring rail crossing orders are listed below, although this is not an exhaustive list and any proposed improvements within 500 feet of the crossing need to be coordinated with *Rail-Transit Division*. Most private crossings involve the property owner working directly with the railroad and do not require a crossing order, although coordination with *Rail-Transit Division* is still necessary. In some cases a private crossing may need to become a public crossing which requires a crossing order. Usually to add a new public crossing, one or more existing public and/or private crossings may need to be closed.

- **Medians –** Prevent vehicles from going into the opposite lane to go around a down crossing gate. They can also be used to eliminate turning movements from streets and driveways that are too close to the railroad crossing or prevent movements that could create a standing queue across the tracks.

- **Quiet (Horn-Free) Zones –** These are zones which use of the train horn is prohibited except in emergency situations. These zones typically require improvements to crossings by adding gates, interconnects, and other safety improvements.
- **Signal Pre-Emption –** In order to clear vehicles potentially stopped on the tracks when a train arrives, interconnection is required for traffic signals located within 215 feet of the railroad crossing and should be considered for signals located further away depending on factors including traffic volumes, highway vehicle mix, highway vehicle and train approach speeds, frequency of trains, and queue lengths. For more information refer to Manual of Uniform Traffic Control Devices (MUTCD) standards.
- **Roadway Realignment –** Reducing the skew angle of the crossing which will reduce the potential of a bicyclist or motorcyclist from getting a wheel stuck in the flangeway and losing control. A ninety degree crossing angle is recommended for better sight distance from the crossing user's perspective.
- **Street Closure** - Wherever possible it is preferred to eliminate at-grade crossings. This could be by construction of an over/under crossing or by closing the actual street crossing. Adding an at-grade crossing requires closure of one or more crossings elsewhere.
- **Spacing –** It is desirable to have adequate spacing from railroad crossings to nearby intersections and driveways to avoid queuing back into upstream intersections or roundabouts. Turn lanes at locations where the railroad crossing is at an intersection need to be long enough to accommodate the waiting turning queues so they do not block into the non-stopped through lanes. An example of a roundabout near a crossing in a 25 mph speed zone would need to be approximately a minimum distance of 200 feet from a rail crossing.
- **Sidewalks –** Sidewalks and ramps must comply with ADA standards. Any deficiencies must be reviewed and addressed at crossings.
- **School Bus Pullouts –** Subject to Rail Section review and approval, it may be desirable for left-turn locations with school bus volumes where rail crossing exist on the receiving lane consider a school bus pullout if space permits, so vehicles behind the school bus in the left-turn lane do not get blocked in accessing the receiving lane when a bus has to stop in front of the track to open and close the doors as required by state law.

10.12.6 Safety Solutions

Many of the solutions listed in this chapter also have significant safety benefits. The All Roads Transportation Safety Program - Crash Reduction Factor (ARTS CRF) Appendix is an extensive toolbox that has specific safety solutions and considerations for both spot locations and systemic improvements. The ARTS CRF list should be the primary source for countermeasures on ODOT plans and projects. Systemic improvements really require application over a wider area (city, county, region, statewide) to have the full impact realized. Most APM analyses will be of spot locations as the traffic analysis process will indicate specific needs. The project context and site conditions will determine the overall impact of the safety benefit. Refer to Chapter 4 for safety analysis procedures.

10.12.7 System Improvements

A long term vision for a corridor or system should be established, typically at the ODOT Region level. The OHP state highway and freight route classifications and designations should be considered. There may be more importance placed on mobility and freight movement for example. The long term vision is used to determine the categories of improvements to be considered.

When evaluating potential alternatives on a corridor, the effects of potential changes to the facility type or function should be considered, such as whether the facility is interrupted flow or free-flow. For example, for a rural high speed corridor that is currently free-flow, introducing interruption such as a stop sign or roundabout will change the facility type and may not meet driver expectations. Introducing any type of intersection control into a free flow section will reduce the capacity of the mainline dramatically – in some cases capacity can be cut in half.

Couplets

Couplets are one way to increase the capacity of a facility in an urban area without need to expand beyond the existing right-of-way. Typically two one-way opposing direction parallel roadways a block apart (can be more) designated as a single route. These can create better multimodal connections and facilities with lower stress levels as cross-sections are typically narrower. These can reduce the number of conflict points but may require more out of direction travel to access local destinations. The best implementation of this uses a second street with compatible land uses (i.e. both commercial versus a commercial street and a residential street).

Bypasses

A bypass is a route that allows through traffic to pass a town center or other urban/congested area without interruption. These typically will have limited connections with other roadways, otherwise the bypass will no longer function as intended for the long term. Land use measures as part of a facility plan are generally needed to help preserve the function of the facility. Refer to the OHP 2003 Amendment on ODOT's Bypass Policy for more information.

Street Grid

Creation of parallel streets to the state highway can improve connectivity, accessibility and allows local trips to occur off the main street. Walk and bike trips to destinations and to transit will be shorter than with street systems that have many dead-end streets. This will allow congestion on the main street to be reduced thus limiting capacity impacts. More urban areas may have a network of one-way streets in one or both directions that are usually in a central business district. These help to alleviate overall congestion and promote accessibility. Signal progression on one-way streets tends to have better results along with shorter cycle lengths, fewer phases, and less overall delay.

Signal Systems

A signal system is a series of signalized intersections that have coordinated timings that improve the efficiency of the traffic flow by reducing unnecessary starts and stops, fuel use and emissions. The system needs continual monitoring and periodic adjustments as traffic flows and patterns change. Systems come in a variety of configurations with increasing emphasis on demand responsive or adaptive systems that change based on current flows versus fixed time of day timing plans. These advanced systems require more detection and may be more complex and costly to install.

Roundabout Corridors

In urban or suburban areas a series of roundabouts may be considered in some cases as an alternative to a traditional corridor of coordinated signalized intersections. Potential benefits of a roundabout corridor include improved safety and reduced speeds as well as in conjunction with non-traversable medians in order to reduce driveway conflicts by providing indirect left turns. In rural areas where approach speeds are high and bike and pedestrian use is low, the design objectives are significantly different, so the addition of multiple roundabouts will reduce mobility for through travel which needs to be evaluated in the context of the vision and function of the highway.

Ramp Meters

Reduces the flow of on-ramps onto freeways to forestall total congestion on the mainline which increases travel speeds, improves safety, and reliability. For effectiveness, these need to be installed in groups of interchanges rather than at a single installation (unless filling a system in). Ramp meters break up platoons of traffic that can cause significant delay to mainline traffic. Ramp meters can have fixed on/off times or can respond dynamically to changing flows. These require ramps of adequate length for storage or may require ramp widening upstream of the meter to two or more lanes. Ramp meters can also have HOV or bus bypass lanes. These may create controversy (requires extensive public involvement) as it does delay time it takes to get onto the freeway and may create equity issues as lower income areas closer in are metered while higher-income suburban areas are not.

10.12.8 Segment Improvements

Additional lanes and roadways can improve capacity, reduce congestion, and improve flow, travel time, and reliability. Many new lane additions are special purpose such as auxiliary lanes, passing lanes, and high occupancy vehicle (HOV) lanes instead of full length general purpose expansions. However, capacity needs may still drive the need to expand the cross-section of a roadway especially for high volume or urban facilities. Solutions for other modes or operational strategies may serve to delay an expansion that will be likely needed in the future. Latent demand will likely increase volumes on improved sections beyond the future no-build. These improvements can be combined with other multimodal improvements such as additional transit lines, or bus express lanes.

Multimodal needs may have a higher priority to be accommodated with the roadway cross-section depending on the facility type and project-area context, so new general purpose travel lanes may not be practical or desirable. The limits of the recommended improvements should consider operational and safety performance, study area intersections and the appropriate transitions back to the existing highway cross-section.

Added Travel Lane

The addition of travel lanes on a highway facility may be appropriate to serve forecasted travel demands. Within urban areas the cross-section requirements of the highway may be influenced by the approach and departure lane requirements at the major intersections, available right-of-way, the local environment, and other context-sensitive considerations (see Section 10.5). Outside of urban areas, added through lanes may be needed to serve forecasted long-range growth in nearby communities. It is preferable to avoid multiple lane adds and drops in succession, by keeping a constant cross section instead. Trap (drop) lanes on mainline sections should be avoided where a travel lane unexpectedly becomes a turn lane.

Passing Lane

Lane additions on rural highways may be done to improve operations by enabling vehicles to pass reducing delay and travel time. Safety is also improved as the chance for improper passing maneuvers and the inherent risk of head-on crashes decreases particularly where passing opportunities are limited. Passing lanes should be approximately one-half to one mile in length as longer lengths tend to function like a multilane highway section. The effects of a passing lane can improve operations like follower density up to several miles downstream depending on volumes (lower volumes have longer effective lengths). It is desirable to provide a passing lane every five miles as this is the typical downstream effective limit for a passing lane’s benefits. Driveways or intersections within the passing lane section are not desirable because drivers do not expect other vehicles to be slowing or stopping in the passing lane.

Collector-Distributor Roadways

Similar to auxiliary lanes but these roadways run parallel to a freeway which connect entrance and exit ramps. These eliminate weaving maneuvers on the mainline by consolidating points to a single on and off connection to the mainline. These can be one or more lanes in width depending on the volume of ramps they connect to and can just span one or multiple interchanges.

Frontage/Backage Roads

Frontage and backage roads may be either one-way or two-way, and are typically local access or service roads parallel to a highway. The purpose of these is to eliminate access points and related conflicts on the highway for safety. These are typically used as an access management improvement and will need to conform to the access management coordination process. A frontage road is an opportunity if there is plenty of right-of-way available, keeping in mind that intersections could be problematic if there is not adequate spacing from the highway. Backage roads may be more common at interchanges or in areas where right-of-way is not restrictive or built up too much.

HOV (High Occupancy Vehicle) Lanes

HOV lanes are lanes designated for vehicles with two or more occupants to encourage carpooling and transit use. These may be tolled (High Occupancy Toll (HOT)) lanes to better control usage if allowed by legislation.

10.12.9 Intersection Improvements

An intersection traffic control study is needed when significant changes to an intersection are under consideration. The analyst should coordinate with Region Traffic and TRS staff in preparing this study. Further guidance is provided in the Traffic Manual. Intersection safety performance should be a primary consideration in evaluating intersection control alternatives. The HSM may be used to evaluate safety performance of intersection control alternatives.

Improving Skew Angles

High intersection skew angles reduce sight distance and visibility for on-coming vehicles and pedestrians. Skew angles require drivers to look back over their shoulders. One set of turns is typically a shallow angle which creates a too-high turning speed and the possibility for encroachment as vehicles cut corners into other through lanes and bicycle lanes which is very problematic for pedestrians or bicyclists . While the other corner set is very sharp and low speed, pedestrian visibility can still be a problem and may warrant a channelization island. Skewed crosswalks also increase the crossing time for pedestrians as well as creating longer delay to other movements in the cycle.

New Turn Lane

Turn lanes isolate the different turning movements from mainline volumes which can create additional capacity and improved safety by removing the turning vehicles from the through traffic stream. However, the additional width required can increase speeds, make sight distance more difficult, and increase the total crossing width for users. Guidance on right and left-turn lanes at unsignalized intersections is found in APM Version 1, Chapter 7. These are minimum thresholds only. It is important that all benefits and disbenefits of turn lanes are fully considered, including safety and multimodal performance. For planning level analysis at signalized intersections a turn lane should be considered as an option when turning volumes exceed roughly 150 to 200 vehicles per hour. On high speed facilities right turn lanes at unsignalized intersections may create sight distance issues for vehicles on the stopped minor approach and should be buffered.

Channelized Right Turn Lanes

Typically, channelized right turn lanes allow a right turn movement to be separated from the main signalized intersection to allow for an improved turning radius or to break up the total pedestrian crossing distance, thus limiting exposure. These right turn lanes can be yield or signal controlled (for dual right turns). Where possible, the channelized island should be a low-speed design to allow for maximum visibility of oncoming traffic and/or pedestrians.

Free-Flow Right Turn Lanes

When an exclusive right-turn lane volume approaches or exceeds 1,000 vehicles per hour and is not controlled by a traffic signal, the intersection can be modified to provide an exclusive receiving lane (add lane on the side street) that requires no merging with other movements. This results in a free-flow movement with no conflict points. This kind of arrangement is generally not recommended as it sets up a direct conflict with any pedestrians or through bicyclists unless it is in an area with no regular pedestrian or bicycle use such as may be the case in a rural highway-highway system connection.

Dual (Signalized) Left or Right Turn Lanes

If the volumes satisfy criteria, review the intersection geometry to determine if improvements are required on the receiving side of the intersection to adequately serve the extra approach lane. Typically a single left or right turn lane can carry about 300 vehicles per hour when intersecting another major cross-section. Higher volumes typically have major vehicle queue spillback and delay issues. It is preferred that the dual turn lanes are located on receiving streets that already have two lanes to avoid a lane drop. There should be no major driveways located just downstream from the dual turn lane to avoid creating a high lane imbalance and a poor operation not to mention the functional area overlap and related conflicts with closely spaced features. Another example that can be less intuitive is when a left turn lane is suggested, the opposite side should also be considered for a turn lane since the cross-section on the receiving side needs to be widened anyway to align the through lanes. If the receiving roadway requires widening to accommodate the dual turn lane, then the downstream length of the receiving lanes has to be considered for the lane utilization of the dual turn lane. These lanes could drop at the next major intersection or may merge together at a certain downstream point. Coordination with Traffic-Roadway Section or local jurisdiction is required to determine the termination point of the receiving lanes. This condition is undesirable and should be avoided where possible. Furthermore, the corridor needs of extra lanes between intersections may necessitate widening of the highway to add travel lanes to reduce merge/diverge and weaving issues between intersections. This is particularly the case in urban areas with closely spaced intersections. The approach and departure lanes at major intersections may dictate the cross-section of the highway between these major junctions.

When proposing dual turn lanes, impacts on crosswalks need to be considered. Adding a dual turn lane on the approach increases the exposure length for pedestrians. Closing a crosswalk on the receiving lane side may be necessary in some cases to eliminate multi-threat conflicts. However, closing crosswalks is not desirable as out of direction travel and delay is increased for pedestrians. If the crosswalk is left open additional treatments such as signing, striping, signalization enhancements will need to be considered.

Typically a dual left or right turning lane at an intersection can carry up to 500 vehicles per hour. When forecasted volumes exceed this level, analysis of alternative solutions is needed. Alternative solutions may include improved adjacent accesses, better connecting linkages, interchange and signal phasing adjustments.

Excessive Intersection Size

When the width of an intersection leg starts to exceed approximately 110 feet curb to curb, further widening results in diminishing returns in terms of additional capacity, due to longer pedestrian crossing times and other factors. Pedestrian exposure is also unacceptable at this level even with multiple median refuges and channelized islands as total pedestrian delay and crossing distance makes the crossing undesirable. Bicyclists will also tend to avoid such an intersection as the overall number of lanes, distance and complexity will result in a high-stress environment which will deter all but the most tolerant riders. Also, when analysis appears to indicate need for triple turn lanes, then other types of intersections or grade-separated solutions should be investigated.

Intersection Spacing

Intersections should be spaced adequately following the OHP spacing standards. At a minimum, there should be adequate distance to accommodate the upstream and downstream functional area requirements needed to minimize the potential of overlapping intersection conflicts and so that movements can be made legally. Spacing should also be large enough to accommodate excess demand to minimize queue spillback into upstream intersections. Signalized corridors need regularly- spaced intersections to maintain progression and to allow for crossing opportunities for pedestrians.

Right-Turn Acceleration Lanes

Right-turn acceleration lanes are generally not allowed at at-grade intersections. In some situations can be considered where criteria in the HDM and Traffic Manual are satisfied and approval is obtained from the State Traffic-Roadway Engineer through the design exception process. Used for right-turning vehicles joining the traveled way of the highway from a side street for the purpose of enabling drivers to make the necessary change between the speed of operation on the highway and the lower speed of the turning movement. These can also be used to help accelerate heavy vehicles to within at least 10 mph of the posted speed so adequate length is needed. These are not for use in urban areas as they are not compatible with nearby downstream intersections or driveways. Special considerations are required for cyclists and pedestrians. For more information and criteria refer to Chapter 8 of the HDM and Section 6 of the ODOT Traffic Manual.

Median Acceleration Lanes

Median acceleration lanes are used at an unsignalized intersection to allow left turning vehicles to gain speed and merge with mainline traffic to improve intersection operations or safety, especially where no alternative routes exist. Vehicles only have to yield with one direction of through traffic and then accelerate to merge into the through traffic lane. These are typically installed where a signal is not desirable such as in a rural area. These are generally only used at a T-intersection. A roadway or access across from the minor leg would need to be converted to a right-in-right out to avoid conflicts with left turning traffic. The left-turn acceleration lane needs to be of adequate length to accelerate the typical vehicle to within 10 mph of the posted speed. These also need considerable distance downstream to the next driveway or intersection.

Two-Way Left Turn Lanes (TWLTL)

TWLTLs are used to assist left turning movements into and out of driveways and to remove the potential of stopped vehicles from the through lanes. These can improve flow in the through lanes. These require properly spaced driveways to that turn movements cannot overlap or create the potential for a collision if two vehicles turn into the TWLTL at the same time for a two-stage movement. If there are no driveways in a section, then a TWLTL should not be used and a painted median used instead.

All-Way Stop Controls

If the side street approach to the highway carries roughly the same volume as the highway, an all-way stop control may be appropriate to reduce delays on the minor streets in cases where the existing controls are stop signs on the minor approaches only. This improvement needs to be coupled with a variety of advance warning devices such as signs, markings, beacons, rumble strips, etc. to avoid creating a safety issue with vehicles failing to stop. However, this solution should consider volume levels and any functional designations for priority freight movement on the highway. An all-way stop control is not recommended when freight movement is a priority, since it adds recurring delays on the highway regardless of volume levels. High volumes on all approaches generally will not have too much operational benefit as capacity will be exceeded. This can be an inexpensive interim solution for an operational issue especially if right-of-way or funding is constrained.

Roundabouts

The ODOT approval process and guidelines for consideration of roundabout facilities on state highways are contained in the Traffic Manual and the HDM. In addition to the list below, overall cost and right-of-way need to be considered. Initial consideration should be with a single-lane roundabout. Analysis needs to be progressive in adding right turn bypass lanes and additional circulatory lanes to avoid overdesigning. Multilane roundabouts are more complex and can lead to more driver confusion, improper left-turn exiting movements and additional conflict points. The HDM (2012 English Manual) includes the following list of considerations for roundabouts on state highways (Section 8.6.3).

The Department has developed a list of considerations that should be addressed in the Engineering Investigation that is submitted for proposed roundabout locations. These considerations should not be interpreted as roundabout warrants nor should they be considered pass/fail criteria for installation of a roundabout. Rather, they have been identified as important considerations to take into account when proposing roundabout intersections on state highways.

1. Freight Mobility needs should be sufficiently defined and addressed prior to Conceptual Approval.
2. Motorized user mobility needs must be balanced with the mobility needs of non-motorized road users. The ability for bicyclists and pedestrians to safely move through the roundabout intersection is equally important as the mobility needs of motorized vehicles. Bicyclists should be given the option to use either the circulating roadway with other vehicles or the pedestrian crossings outside the circulatory roadway. Special design

considerations should be given for the pedestrian crossings at the entrances and exits on all legs of the roundabout where vehicles are either decelerating to enter the roundabout or accelerating to exit the roundabout. Multi-lane roundabouts, like other multi-lane intersections, have potential for “multiple threat” conflicts between vehicles and pedestrians, particularly vision impaired pedestrians. Refer to the HDM and Traffic Manual for more information.

3. Roundabout design should consider the needs and desires of the local community including speed management and aesthetics.
4. Intersection safety performance should be a primary consideration when pursuing a roundabout for intersection control. Predicted reductions in fatal and serious injury crashes should be compared with other types of intersection control such as traffic signals or other alternatives supported by CMFs from the AASHTO HSM.
5. Roundabout entrance geometry, circulating geometry and exit geometry should be designed to allow the design vehicle to traverse the roundabout in a reasonable and expected manner commensurate with best design practices as shown in NCHRP Report 672, Roundabouts: An Informational Guide, Second Edition and the ODOT Highway Design Manual. This design should utilize a representative template of the design vehicle and the vehicle path should be demonstrated through the use of computer generated path simulation software.
6. Roundabouts should meet acceptable v/c ratios for the appropriate Design Life. (See the Design Life subsection for possible exceptions to this consideration.)
7. Roundabouts proposed for the state highways with posted speeds higher than 35 mph will require special design considerations (e.g. longer splitter islands, landscaping, possibly reversing curve alignments approaching the roundabout, etc.) to transition the roadside environment from higher to lower speeds approaching the roundabout intersection.
8. For Roundabouts with more than 4 approach legs, special design considerations should be made for the layout of the approach legs.
9. Roundabout proposals should address how roundabout operations would impact the corridor immediately upstream and downstream from the roundabout intersection. (If the proposed roundabout is in a location where exiting vehicles would be interrupted by queues from signals, railroads draw bridges, ramp meters, or by operational problems created by left turns or accesses, these problems should be addressed by the Engineering Investigation.)

Traffic Signal Controls

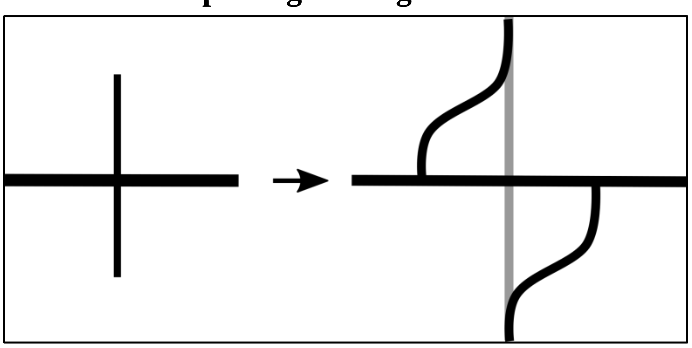
The ODOT standard intersection traffic control analysis is required to justify new signal installations. It is important that all benefits and disbenefits of traffic signals are fully considered, including safety and multimodal performance. Issues to be considered include safety performance such as using methodologies from the HSM, traffic volumes, freight volumes, pedestrian volumes, and spacing relative to existing signal and the accepted standards for the highway facility. Traffic signals reduce the capacity by approximately half and increase delay of the mainline roadway allowing the side-street approaches to have more capacity and less delay. Traffic signals generally are not compatible in high-speed rural areas as they are not generally expected by drivers and could lead to high speed rear-end or angle crashes. Signals generally convert a lower number of fatal/serious injury high-speed angle and turning crashes into higher numbers of less serious rear-end crashes (still much higher than a roundabout). Queues from traffic signals may block upstream intersections and driveways impeding the flow of traffic onto or off the roadway. Signalized intersections also create lower stress locations for pedestrians and bicyclists to cross the roadway and ideally should be spaced so out-of-direction travel is minimized. However, complex intersections can make it more difficult for bicyclists to travel through and long crossing distances can be intimidating to pedestrians. Shorter cycle lengths and fewer phases will have lesser delays and shorter queues versus more complex intersections with longer cycle lengths and more phases.

Other Intersection Types

<u>Offset T</u>

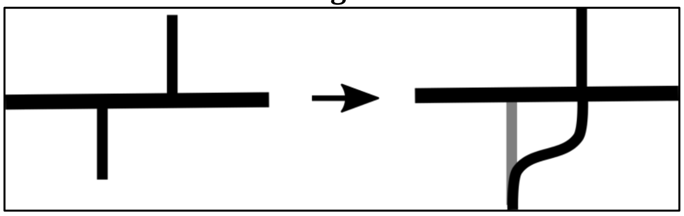
Offset T intersections may be formed by splitting a four-leg intersection into two three-leg "T" intersections to reduce the number of conflict points at each location as shown in Exhibit 10-9. The former side street straight through movement has additional out-of-direction travel as it now needs to turn left at one intersection and right at the other. The distance between the intersections needs to meet the functional area requirements and spacing standards.

Exhibit 10-9 Splitting a 4-Leg Intersection



This should not be confused with a pair of closely spaced T-intersections that may create overlapping turn movements and really should be combined into a single four-leg intersection, as shown in Exhibit 10-10.

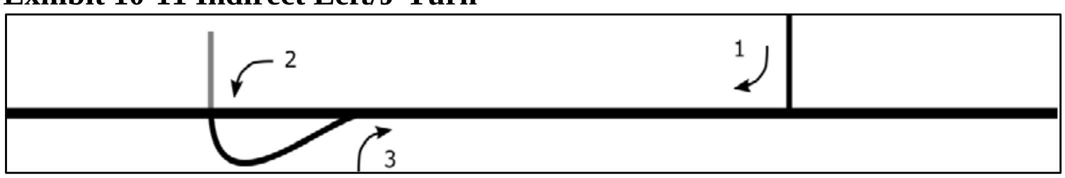
Exhibit 10-10 Combining Two Offset T-Intersections



Indirect Left/J-Turn

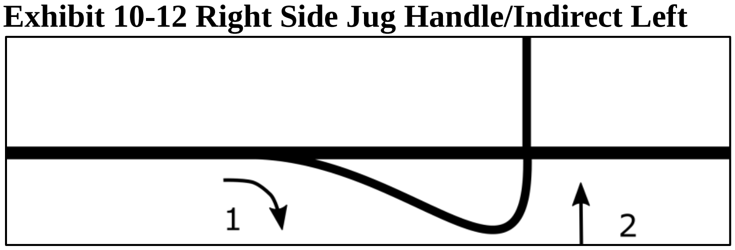
An indirect left turn or J-turn removes the conflict of the minor street left turn and through movements by creating a two-stage movement (one direction at a time) as shown in Exhibit 10-11. Minor street through movements would need to make an additional right turn plus potential mainline lane changes downstream from the two-stage left turn. The J-turn concept has vehicles crossing the second direction and then merging back into the traffic flow. J-turns are preferred when trucks are the design vehicle. Both of these types help facilitate installations of raised medians. The distance required downstream from the intersection to the indirect left or J-turn needs to be considered especially if there are multiple lanes and high speeds. Vehicles will need to merge into, accelerate, change lanes and then decelerate into the left turn lane which could create substantial out-of-direction travel.

Exhibit 10-11 Indirect Left/J-Turn



A variation on the indirect left is the right side jug handle. In this case, the major street left turn is replaced by an advance right turn followed by a through movement as shown in Exhibit 10-12.

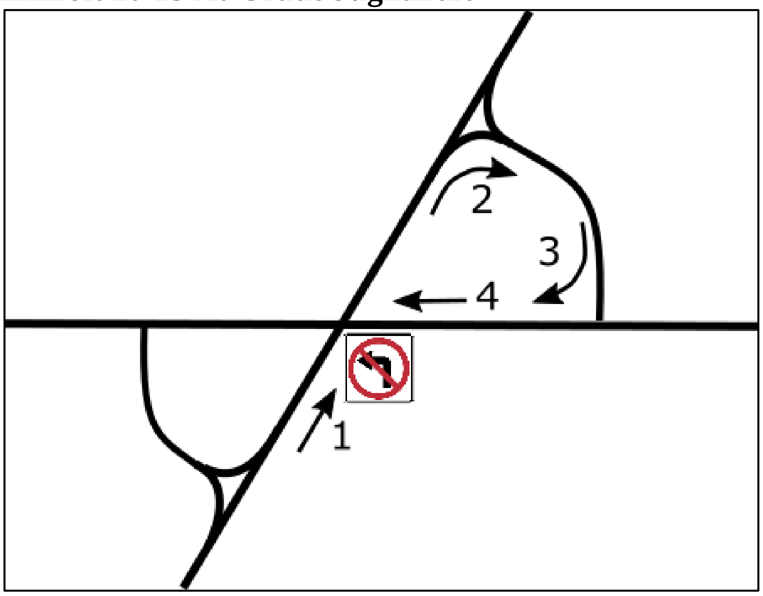
Exhibit 10-12 Right Side Jug Handle/Indirect Left



At-Grade Jughandle (One or More Quadrants)

This is a version of an indirect left as the left turn off the mainline is converted into a right turn followed by a second right turn and then a through movement as shown in Exhibit 10-13. It can also remove right and left turns from the main intersection turning the main intersection into a two-phase signalized intersection. The jughandle roadway could be one or two way. If the mainline roadway had a median then another jughandle would be required in the opposite quadrant. If both roadways had medians then a jughandle would be required in all four quadrants. The main disadvantage of these is that the left turning traffic can travel twice through the intersection if right turns are only allowed onto the jughandle roadways from the mainline or if the jughandle is on the far side of the intersection. These are confusing to unfamiliar drivers who still may try to turn left at the main center intersection even with appropriate signing. These can also reserve right-of-way for a future interchange as these do take substantial room.

Exhibit 10-13 At-Grade Jughandle



10.12.10 Interchanges

When traffic volumes exceed these levels or if the functional integrity of the facility requires it, an interchange or grade-separated junction should be considered. This could take the form of an interchange or it could be a series of overcrossings on parallel routes to reduce the demands on the major arterials to a level that could be served by at-grade facilities.

Interchanges on highways are appropriate on all freeway facilities and most expressway facilities to reduce conflicts and to give priority to through movements on the state facility. ODOT and FHWA policies govern the different levels of interchanges which may be considered depending on whether a facility is an interstate, a non-interstate freeway or an expressway. Modifications to (or new) interstate freeway interchanges require a FHWA interchange modification request that is coordinated through the Traffic-Roadway Section. For example, partial directional interchanges could be considered on expressways, but generally not on interstate freeways, although there may be specific locations where a partial directional interchange would be an appropriate treatment that would need to be approved by FHWA. In addition, some arterial locations may have grade-separated solutions when volume demands exceed the levels that can reasonably be served by an at-grade intersection.

Grade-separated configurations should be developed to serve the forecasted travel demands consistent with the layout and spacing standards recommended in the HDM. Refer to that manual for more specific details that are useful in laying out interchange concepts. A planning level method for use in interchange type selection is available in HCM 2010 Chapter 22, as part of the analysis of interchange ramp terminals. The HCM method compares delay for signalized ramp terminals at diamond, SPUI, and Parclo interchanges, but does not evaluate unsignalized ramp terminals or other interchange types such as DDI.

The following is a short review of the common elements of an interchange and a discussion of the conventional layout configurations that could be considered during alternative development as shown in Exhibits 10-14 through 10-23.

Ramp terminals should be developed to avoid spillback issues between the terminals or between the ramp terminal and nearby intersections.

Exit ramps and ramp terminals should avoid queueing onto the deceleration portion of the ramp. This should especially be avoided where sight distance is limited. Although not ideal, in some cases at signalized ramp terminals and on the crossroad special signal detection/timing ("dump loops") or other treatments may be appropriate.

Refer to HDM Chapters 5 and 9 as well as OAR 734, Division 51 for appropriate interchange spacing and spacing on the mainline between ramp junctions.

Ramp meters should provide for adequate storage of queued vehicles, avoiding spillback onto the crossroad ramp terminal. Dual lanes and/or bypass lanes may be appropriate in some cases.

Ramp Types

Jughandle Ramps (connection)

These ramps are generally used at low-level interchanges or grade-separated intersections, not for freeway connections and are characterized by low speeds. These generally start and end at an intersection and do not have any acceleration or deceleration areas. These have some sort of traffic control (signal, stop or yield) at the endpoints. They may be considered at major private approaches to a state highway. When used for non-interchange at-grade intersections they are termed connections as opposed to ramps.

Diagonal (Straight) Ramps

The carrying capacity of a ramp is determined by the conflicting movements at the ramp terminals. Typically a single lane straight ramp can carry 1,500 to 1,800 vehicles per hour. Ideally the ramp terminal spacing is great enough to allow for future loop ramps to avoid having to realign roadways in the future.

Loop Ramps

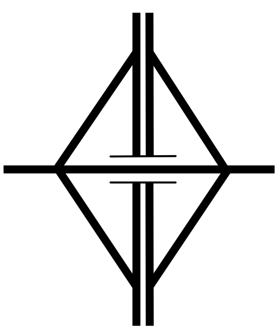
Typically a single lane loop ramp can carry 1,200 to 1,500 vehicles per hour. A loop ramp is appropriate to reduce left turning volumes at ramp terminal intersections. As noted above, when left turning volumes exceed 500 vehicles per hour, the typical at-grade intersection cannot generally accommodate it. For example, if a highway approach to a freeway interchange forecasted 700 left turns in the peak hour onto a freeway on-ramp, in most cases, the v/c ratio at this intersection would exceed guidelines. One solution would be to add a loop ramp so that this traffic demand could turn right at the intersection, in advance of the signal and loop onto the freeway rather than making a left turn, which requires a major share of the intersection capacity. These can be confusing to drivers as they turn in the opposite direction of expected travel. On-loops are generally preferred over off-loops, because of concerns regarding the speed differential between the off-loop and the mainline and difficulties encountered on off loops during adverse weather conditions. Loop ramps can also be problematic for pedestrians and bicyclist because of the higher speed diverge areas.

<u>Directional Ramps</u>

A directional ramp always bends toward the desired direction of travel. These are free-flow non-looping ramps that generally operate at high speeds for system movements. A semi-directional ramp exits a road in a direction opposite from the desired direction of travel, but then turns toward the desired direction of travel. Many “flyover ramps” (as in a three-level interchange) are semi-directional.

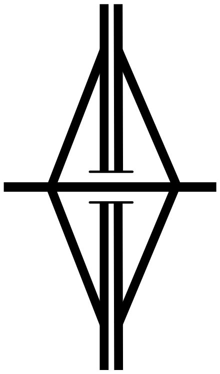
Interchange Types

Exhibit 10-14 Diamond Interchange



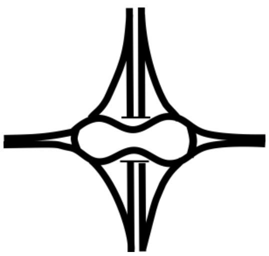
Diamond Interchange: An interchange that has straight ramps in all four quadrants is referred to as a diamond-shaped interchange. The capacity of this facility is typically determined by the operational analysis at the ramp terminals and merge/diverge areas on the mainline. The spacing of the intersections on the crossing street or highway will dictate the available vehicle storage and transition area. A standard diamond interchange has ramp terminal spacing greater than 800 feet. These would have adequate ramp terminal separation that could allow for future loop ramps. When volume forecasts are high at the terminal intersections and the spacing is limited, these could be factors that influence the need for an alternative layout concept. An operational analysis of the two ramp terminal intersections and any nearby intersections that could influence these locations will be required. The ramp terminals could also be separate roundabouts for interchanges. Some variations on the diamond interchange are described below.

Exhibit 10-15 Compressed Diamond Interchange



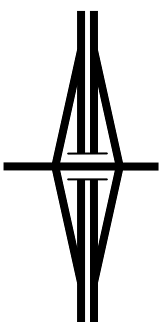
Compressed Diamond Interchange: A typically older interchange design where less than ideal ramp terminal spacing is present, between 400 and 800 feet. Sometimes the two ramp terminals can be operated with a single signal controller. Turn storage is done between the ramp terminals. Queue spillback between the ramp terminals is a common problem. Precludes any easy future construction of loop ramps. Some of these may have inadequate sight distance approaching and between the ramp terminals because of steep vertical curves.

Exhibit 10-16 Dog Bone Roundabout Interchange



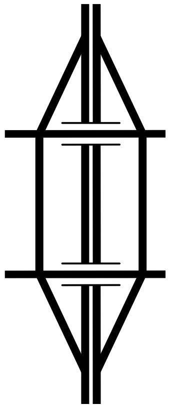
Dog Bone Roundabout Interchange: If roundabouts are desired as a ramp terminal treatment, then a connected “dog bone/peanut” style single roundabout as shown may be more feasible.

Exhibit 10-17 Tight Diamond Interchange



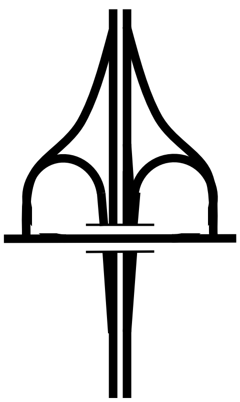
Tight Diamond Interchange: Typically found in urban areas, with ramp terminal spacing less than 400 feet. Requires signalized control. Usually the two ramp terminals can be operated with a single signal controller. Turn storage is done outside of the ramp terminals. Precludes any easy future construction of loop ramps.

Exhibit 10-18 Split Diamond Interchange



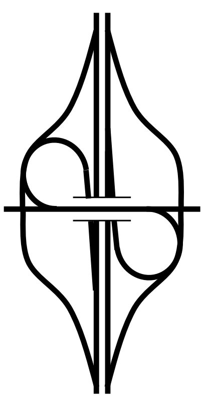
Split Diamond Interchange: Typically found on an urban grid system. Connections between each “half” of the interchange are one-way and are access-controlled. Requires signalized control of all 4 intersections which must work together in both directions to avoid inordinate queuing effects.

Exhibit 10-19 Folded Diamond Interchange



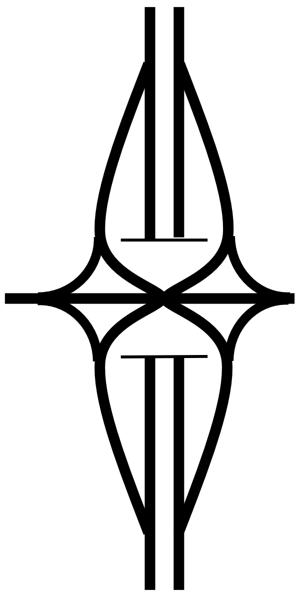
Folded Diamond Interchange: This interchange type “folds” one or two legs of the configuration to minimize impacts in one or two quadrants. Loop ramps can be located where topographical or environmental constraints adjacent to the interchange site do not favor the use of conventional straight ramps, e.g., where a railroad parallels the cross road. Loop ramps that are located on the same side of the mainline facility can create weaving sections on the mainline or crossroad that may not be desirable.

Exhibit 10-20 Partial Cloverleaf Interchange



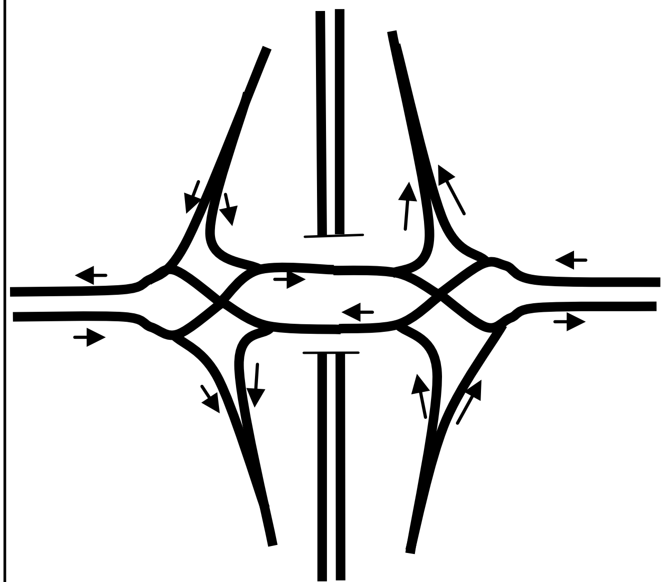
Partial Cloverleaf Interchange: A partial cloverleaf layout combines loop ramps and straight ramps to better serve areas with expected high turning volumes at the ramp terminals. In general, a partial cloverleaf configuration has a higher carrying capacity than a diamond interchange. The preferred configuration is where loop ramps are located in opposite quadrants of the interchange. Loop ramps can also be recommended where topographical or environmental constraints adjacent to the interchange site do not favor the use of conventional straight ramps, e.g., where a railroad parallels the facility. Loop ramps that are located on the same side of a facility can create weaving sections on the mainline that may not be desirable.

Exhibit 10-21 Single Point Urban Interchange



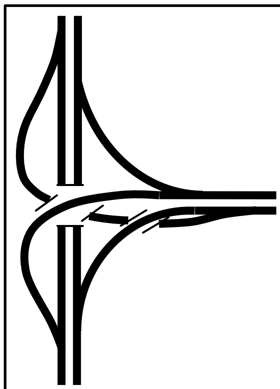
Single Point Urban Interchange (SPUI) also known as Single Point Urban Diamond (SPUD): The SPUI is a relatively recent development that evolved out of the need to limit ROW acquisition in built-up urban areas. SPUIs are a variation of the diamond interchange, which has two ramp terminals with the local arterial. A SPUI combines those two ramp terminal intersections into one larger intersection so that all turning movement to or from the freeway utilize the same intersection. The ramp terminal is typically signalized, although another option could be a roundabout. Having a single ramp terminal resolves the queue spillback issue that can congest standard diamond intersections, and can be effective in serving high volumes of turning vehicle traffic. SPUI's need cross-street angles close to 90 degrees. High volume right turns may need to be signalized. SPUI's have nearly the same ROW costs as tight diamonds and the structure costs are often high. SPUIs are not very pedestrian-friendly as they do not allow for a crossing of the minor roadway. A crossing would have to occur at a downstream and/or upstream signalized intersection.

Exhibit 10-22 Diverging Diamond Interchange



Diverging Diamond Interchange: This is a new type of interchange design that has very few installations in the U.S. This form of diamond interchange has the two directions of minor street traffic cross to the opposite side of the roadway under/over structure. This allows for two-phase signal operations since the left turns occur between the two signals in such a way that they do not cross the opposing through movements. Pedestrians are typically taken down the middle when the minor roadway is overcrossing the freeway and on the outsides when the minor roadway is an undercrossing. The advantage of the "down the middle' approach is that pedestrians can stay on the same side of the roadway or cross to the other side in the interchange area efficiently.

Exhibit 10-23 Directional Interchange



Directional Interchange: This type of interchange is more common in urban areas or at junctions of freeways or expressways with other freeways or expressways. An example would be I-5 at I-205. They are high speed high volume connections with all free flow movements. There are configurations with full or partial trumpet or flyover.