CAMBRIDGE SYSTEMATICS

Opportunities for Transportation System Operations Improvements in Oregon

draft

report

prepared for

Oregon Department of Transportation,

Transportation Development Division

prepared by

Cambridge Systematics, Inc.

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1.0 Opportunities for Transportation System Operations Improvements in Oregon

The purpose of this paper is to provide background information to support discussion of an aggressive transportation systems operations strategy. This "Maximum Operations" strategy will be evaluated as one alternative scenario in the Oregon Transportation Plan (OTP) development. The paper describes transportation system operations and summarizes some of the efforts already in place in Oregon. Examples are provided of several additional strategies that are being utilized in other American cities and states, as well as in other countries, that may be useful as Oregon considers a more aggressive approach to transportation operations in the future. The final section recommends the key components of a Maximum Operations strategy for Oregon, focusing on actions that could reasonably be expected to take place in the first 10 years of the OTP, utilizing proven technology. Detailed information about the likely benefits arising from different components of the 10-year Maximum Operations approach is presented in a series of tables attached as Appendix A to this paper. Longer-term strategies based on emerging technology that could take place in subsequent years (i.e., years 10 through 25 of the OTP planning horizon) will be evaluated in the OTP on a more qualitative basis, using available data on costs and benefits.

1.1 What is System Operations, and How Does it Improve Transportation?

System operations can be simply described as an approach to delivering, managing and maintaining transportation facilities and services in a way that maximizes the utility or benefits of available infrastructure. "Utility" can be defined in a number of ways that reflect the objectives of the agency carrying out the strategies, but typically includes increased system capacity, accessibility, reliability, safety, and efficiency as desired outcomes. Secondary benefits such as reduced energy consumption, lower investment cost, and other environmental benefits are often cited as additional objectives.

Major components of an operations strategy typically include the following actions or capital improvements:

- Incident management, that is, the rapid detection and clearance of stalls, accidents, and other incidents that can severely erode freeway and roadway capacity;
- Freeway management, including well-known techniques such as ramp metering and High-Occupancy Vehicle (HOV) lanes, designed to preserve freeway capacity through smoother traffic flow and higher average vehicle occupancy;
- Advanced public transit systems, such as vehicle tracking, traffic signal priority, and dynamic demand-responsive scheduling;
- Arterial traffic management, including actions such as coordinated traffic signal control, access management, and integrated arterial/freeway management; and
- Traveler information systems, which support all of the above strategies and provide a great variety of information to the traveler, whether auto or transit, private or commercial operator, urban or rural, pretrip or *en route.*

Although operations include traditional activities such as traffic signal timing and enforcement, newer strategies increasingly rely on application of advanced technology to derive the most benefit from a given amount of capital investment. Current examples include vehicle positioning and tracking systems to provide accurate schedule information to transit riders and "adaptive-responsive" traffic signal control systems that change timing plans in response to near real-time changes in traffic patterns. The evolution of such "Intelligent Transportation Systems" (ITS) strategies and technologies has significantly expanded the capabilities and potential impact of transportation system operations and management, and in some cases the terms "ITS" and "operations" are used interchangeably. For purposes of the OTP, however, we use the broader-term operations to include many traditional transportation engineering, operations, and management techniques that predate the appearance of ITS, and will acknowledge that many operational strategies rely upon ITS applications.

Whatever the technology or particular application, the typical common advantages of advanced system operations strategies include gaining additional capacity from existing infrastructure (whether highway, transit, or other), managing travel demand to achieve more efficient utilization of infrastructure (such as utility companies do through peak-period pricing), and improving the overall utility and benefit to the traveler by making the system more accessible, predictable, reliable, safe and efficient. Not all benefits of system operations strategies can be measured in terms of reduced congestion or delay, and indeed for many strategies this is not the intended objective.

Pricing

Many discussions of transportation operations include strategies that involve "pricing" of the transportation system as a means of generating revenue and/or

effecting travel behavior that is more efficient or more consistent with stated public policy. Congestion pricing, variable pricing, and tolls are all forms of pricing that attempt to achieve a specific response. Bridge tolls and toll roads are fairly traditional forms of pricing where the primary intent is or was to generate revenue to pay for the piece of infrastructure that is tolled, rather than to consciously change travel behavior.

In the context of operations and ITS today, the concept of pricing more often is to change travel behavior in a way that is deemed positive by policy-makers or system operators. Simple examples include charging more for transit trips or toll roads during congested peak periods than during off-peak periods. More innovative or aggressive forms of pricing now in use include variable tolls set according to the levels of traffic flow and congestion on a facility (as opposed to simply the time of day) or areawide tolls charged to all vehicles entering a defined geographic area such as a downtown. Offering a reduced price or free passage to HOVs is an example of how variable pricing can be used to encourage more efficient travel behavior. The current Oregon Mileage Fee Pilot Program, described below, is a local example of a potential future pricing application that is designed to both generate revenue (as a replacement to the motor fuel tax) and encourage more efficient travel decisions.

The benefits and impacts of several pricing strategies will be tested in the OTP scenarios, but pricing is not synonymous with the maximum operations scenario. The two concepts, operations and pricing, will be evaluated separately so that the potential benefits and impacts of one are not inadvertently ascribed to the other.

1.2 WHAT IS OREGON ALREADY DOING?

Oregon has ambitious and extensive operations programs statewide. These are delivered not only by ODOT but by a number of system owners and operators such as TriMet, the City of Portland and others. Aggressive investment in public transportation, cutting-edge growth management, and system operations are three ways in which Oregon has helped mitigate the transportation impacts of increased population, employment, and economic growth. While roadway congestion has increased over the past 15 years, commuting times in Portland have increased at a slower rate than in peer cities, the rate increase in transit ridership is greater than in most other U.S. cities, and the rate of increase in passenger transit miles was far greater than highway miles of travel in Portland for the decade from 1990-2000.

Public Transit

The large investment in public transportation that has been made in the State's larger cities is an example of the systems approach to addressing multimodal corridor capacity rather than highway capacity in isolation. Strong public transportation system ridership relieves demand on the roadways and provides

many other benefits as well. The manner in which Oregon's major transit systems are operated includes sophisticated applications of communications technology, for example, to improve customer knowledge about routes and schedule, and to improve schedule adherence of the vehicles. Tri-Met is working with the City of Portland and other regional municipalities and counties to identify bus transit corridors for the deployment of Transit Signal Priority, or TSP. This technology allows traffic signal controllers to extend the green time at intersections for approaching transit buses that are running behind schedule (as determined by on-board monitoring systems). TSP improves transit schedule reliability and has potential for cost savings to TriMet. More low-tech solutions such as "queue jumping lanes," which allow a transit vehicle to safely skip ahead of auto traffic after stopping at a traffic signal, also are part of the overall transit operations approach.

Traffic Operations and Traveler Information

Oregon has a strong and effective operations program in place, and the statewide approach is effective in addressing the needs of both urban and rural communities. An extensive surveillance and freeway management system is in place in Portland, but smaller cities and some rural locations have surveillance capability as well. A statewide approach is generally more cost-effective in providing services, avoiding the fragmentation and multiple systems that have plagued many states. Sophisticated traffic management centers have been implemented to allow more centralized operation and management of the roadway system. These are supported by data collection devices such as cameras and detectors, and use information distribution techniques such as variable or dynamic message signs (referred to as both VMS and DMS in industry literature) to deliver timely information about a variety of traffic and roadway conditions to travelers. A statewide traveler information program is delivered to customers through the Internet (TripCheck) and the telephone "511" system. Extensive weather monitoring and safety warning systems are used for both roadway operations purposes and public travel information. Ramp metering, which promotes smoother and safer traffic flow by regulating the rate at which vehicles are allowed onto access-controlled highways, has been implemented in the Portland area. An initial HOV system has been constructed in the Portland area as well, promoting higher average vehicle occupancy, one of the more cost-effective methods for squeezing additional person-carrying capacity out of a highway. Some U.S. cities have implemented "HOV bypass lanes" at metered ramps that allow HOVs to bypass the ramp meter entirely or to use a metered HOV-only lane, which typically has a shorter queue than the general metered lane.

Oregon's Mileage Fee Pilot Program

In addition to these well-established programs, Oregon also is researching progressive ideas such as congestion pricing via the Mileage Fee Pilot Program. Responding to a legislative mandate, a Road User Fee Task Force was established to develop a design for revenue collection for Oregon's roads and highways to replace the current fuel tax. The Task Force recommends a mileage fee based on a set charge per mile driven within the State. Each vehicle would contain a device to track mileage driven and transmit that data to a computer for application of a fee rate per mile. Vehicle-Miles Traveled (VMT) data would be transmitted electronically from an on-vehicle device at fueling stations via short-range communications. The mileage fee would be imposed as part of the fuel purchase price, and the existing fuel tax would be deducted from the purchase price (i.e., motorists pay either gas tax or mileage fee, but not both). The Task Force recommends that the on-vehicle technology be placed in new vehicles only. Unequipped vehicles will continue to pay fuel tax.

In terms of operational and congestion management benefits, the new system would facilitate eventual peak-period pricing. The mileage fee rate could be adjusted to a higher level when a vehicle travels within a congested area during congested time periods. The revenue raised from VMT-based congestion pricing would be used for transportation improvements. Currently, there are legal requirements that the revenue be used for highway system improvements only. It also is likely there would be political and community interest in ensuring that the revenues are expended on projects within the area in which they are generated.

While VMT-based fees could begin to replace fuel tax for at least some of the fleet relatively soon, there are additional obstacles to be overcome in order to implement area-based congestion pricing. Area pricing could not be implemented until most or all vehicles subject to congestion pricing contain the necessary on-board equipment. As noted above, the OTP policy analysis will evaluate the potential benefits of pricing strategies separately from the operational strategies that are the focus of this paper.

1.3 ESTIMATE OF BENEFITS FROM CURRENT PROGRAMS

A Texas Transportation Institute (TTI) Study estimates the impact of operational strategies on congestion in metropolitan areas. There are about 33 million hours of delay annually in the Portland region. About 6.5 million annual hours of delay are avoided through the combination of freeway and arterial management strategies in use. In comparison, the public transportation system results in 14 million hours of avoided delay. Without these strategies, the annual hours of delay would be 62 percent higher than current values.

It is important to note that since public transportation investment has focused on the most densely traveled commuter markets, additional gains in delay avoidance through public transit expansion or operations may come at a relatively higher investment price per unit of benefit. Freeway and arterial management strategies, on the other hand, are relatively less expensive and can be implemented over a larger region with reasonable expectation of benefits. It is clear, however, that a multimodal approach combining a variety of complementary operational strategies is needed to address congestion and to improve overall utility of the system.

The following table summarizes the hours of delay saved and the percentage of current delay represented by each strategy in the Portland region.

Table 1.1 Impact of Operations strategies in Portland Region

Current Operations Strategies in Portland Region	Delay Avoided with Strategy, Hours per Year	Avoided Delay, as Percent of Current Delay
Ramp Metering	2,053,000	6.3%
Freeway Incident Management	1,788,000	5.5%
Arterial Signal Coordination	1,374,000	4.2%
Arterial Access Management	1,370,000	4.2%
Public Transportation	14,185,000	43.3%

Expansion of Intelligent Transportation System (ITS) deployments to other parts of the State will bring additional benefits. For example, the "Regional Operations and ITS Implementation Plan" for the Eugene-Springfield Metropolitan Area (ODOT *et al*., 2003) describes a number of proposed ITS deployments for that region, and presents analysis of the potential benefits of the various components of the implementation plan. Results of this benefits analysis is incorporated into Tables 1 through 10 in Appendix A, which summarize several sources of operations and ITS benefits.

2.0 Opportunities for More Aggressive System Operations

2.1 AGGRESSIVE STRATEGIES IN THE UNITED STATES

Freeway – Arterial Integration

Oregon DOT recently conducted a demonstration project of freeway-arterial integration in the I-5 Barbur Boulevard Corridor in Portland. Freeway-arterial strategies work toward management of the entire transportation system in a coordinated fashion. Traffic managers would actively encourage rerouting of traffic between freeways and major arterials in order to optimize capacity. Timing of ramp meters and signals would be adjusted to accomplish this and supplemented with traveler information. System performance reviews would be conducted on a regular basis and adjustments made to response plans. Many agencies use these strategies during major incidents or construction but have generally not implemented them to relieve day-to-day congestion.

Reversible Lanes

This strategy involves the reallocation of one or more traffic lanes to provide additional capacity in the peak direction of travel. They are most effective in areas where there is a significant imbalance in the directional flow of traffic during peak periods. Reversible or "contraflow" lanes have been implemented on freeways as well as arterial highways and streets to take advantage of unused capacity in the off-peak direction. They also are employed over shorter distances on bridges and tunnels, where adding capacity may be prohibitively expensive. While reversible lanes are not a new idea, improved technology has made them safer, less expensive to operate, and more feasible in a greater number of locations. Automated barrier systems and VMS are increasingly used to facilitate lane changes and to improve safety.

Capital costs can be significant due to potential right-of-way (ROW) and bridge widening requirements. However, such lanes can be designed to minimize ongoing operating costs through use of newer technologies. Some agencies have used this strategy to provide additional capacity for all vehicles, while others have limited access to HOVs, including transit. Addition of reversible lanes is generally most economical where median capacity is available. Even where right-of-way is available, however, expensive bridge work may be needed, and some new ROW may be necessary to accommodate access and egress ramps. A case in point is on the segment of I-5 between Portland and Vancouver that does exhibit an imbalanced traffic pattern characteristic of the commute from

residential areas to jobs in the central area of Portland. In the four-mile stretch of I-5 that serves most of the origins and destinations of these travelers, however, there are eight interchanges, effectively making a median reversible lane infeasible.

Where capacity does not exist to develop a new lane, another option is to take a lane from the off-peak direction and use it provide peak direction travel. This requires moveable physical barriers which until recent technological developments was difficult and expensive to achieve. Safe entry and exit points must be established, and limited right-of-way means that special accommodations must be made for incident management. Capital costs are generally less than those of a permanent reversible lane, but operating costs can be substantial.

Work Zone Information Interface

Traveler information systems such as Oregon's 511 system can be expanded to include work zone information so travelers know where and when road work is taking place. A system of this kind is under development at the Missouri DOT. Called the Work Zone Information Interface, this system integrates existing disparate databases and geographic information systems (GIS) relating to work zones in Missouri to provide a central repository for traveler information. The information will then be provided through the State's various web sites, including Kansas City's Scout web site and St. Louis' Gateway Guide's site. The system also will provide data to the Statewide 511 System. The Work Zone Information Interface displays the latest roadway work activity on an interactive map. It provides information on scheduled lane closures, work zones, construction and maintenance.[1]

Road and Congestion Pricing

High-occupancy toll lanes are an innovation now in place on two highways in California, SR-91 in Riverside and Orange Counties and I-15 in San Diego County. The SR-91 project consists of toll lanes constructed in the median of an existing freeway and varies the toll based on demand in order to maintain free flow in the lanes. The I-15 project allow single occupant vehicles to buy their way into an HOV lane. There are a number of similar projects being considered, including the use of exclusive toll lanes for commercial vehicles.

Congestion pricing structure is complex, as evident in the SR-91 system where tolls range from $1.05 during late night hours to $6.25 during peak Friday afternoons. Electronic signs inform motorists of the price before they enter the lane, giving them the choice to opt out and use free lanes if the price is too high.

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[1] http://www.modot.org/road_conditions/index.htm#.

The most aggressive pricing schemes have been implemented overseas in London and Singapore. Both these cities charge a toll to drive vehicles into the downtown area. There are a complex series of regulations and major enforcement issues. Singapore uses a more traditional toll collection system, while London, which has numerous entrances to the zone, uses roving enforcement cameras and license plate matching software. Those wishing to enter London during weekday business hours must buy a permit and have their license plate entered into a database.

Transit Operations

Major transit operators around the country are beginning to address fundamental changes in their traditional rider markets and service areas. As regions decentralize, job and labor markets become more difficult to serve efficiently with traditional high-capacity fixed route services. Various programs are under investigation that would increase flexibility of fixed route services, dynamically redistributing vehicle capacity to routes and locations where it is needed most. Organizational changes in the transit industry are desirable as well to shift the focus from one dominated by concerns about fleet operations and labor efficiency to one focused on the consumers' trip making needs. Similar paradigm shifts have transformed the airline and package delivery services, for example, and may offer future benefits to transit users. Other agencies are reevaluating their rider and non-rider populations as a combination of unique market segments, applying sophisticated commercial market research techniques to better understand the true needs and wants of these different segments. Services would then be tailored to anticipate and meet these needs and increase ridership particularly among discretionary riders.

2.2 AGGRESSIVE INTERNATIONAL STRATEGIES

While there is no clear definition for a Maximum Transportation Operations Strategy suitable for the Oregon Transportation Plan, a good working description would be a combination of strategies that have potential for substantial improvement in congestion management, safety, and multimodal coordination. Aggressive strategies tend to be more visible to the public and have a greater direct impact on their travel behavior, and as a result can be more controversial and carry a higher risk for successful implementation. They require new ways of thinking on the part of public agencies about operating the system as an integrated whole and on the part of travelers in terms of access to the system and appropriate allocation of costs according to benefits derived. These newer concepts need to be reflected in the structure and the operations of the responsible agencies and in how consumers pay for transportation services. The following international examples of aggressive operational strategies are categorized by highway (including arterials and parking) and transit.

Highway

- **Japan's Vehicle Information and Communication System (VICS).** This digital data delivery system uses in-vehicle navigation units to deliver updated traffic information graphically to drivers. Information provided includes congestion levels, construction works, and traffic queues. As of March 2004, 9.2 million units are reported to be in use. Coverage has been expanded from major cities to all regions throughout Japan. Benefits include fewer traffic accidents, faster- and smoother-moving flows, reduced fuel consumption, and more efficient use of highways.[2]
- **Germany's BAYERNINFO** is a national traffic information system in Munich. In addition to highway travel, the system included the expansion of the electronic timetable information to a statewide information system for public transportation, and the web site "Bayernnetz für Radler" (Bavarian network for cyclists) describing approximately 100 cycle tracks with an overall network length of about 7,300 kilometers. BAYERNINFO also includes signal preemption for buses and light rail; dynamic message displays; beacon-based on-board traffic guidance; trip planning kiosks; real-time parking guidance; and traffic information on the Internet at www.bayerninfo.de. Other systems, including a hand-held "personal travel assistant" now in the demonstration stage, are coming on-line to provide individual travelers with optimum trip choices. The overall benefits include improved traffic flows for the traveling public at large.[3]
- **London's Parking Permit Management System** is a comprehensive system of electronic parking permits, cashless on-street parking, and ticketless car parks. A permit is only issued once and is automatically renewed if the holder pays on time and has complied with all other obligations. Transponder card permits are displayed in the windshield and checked by parking attendants using scanners. The system can replace all existing permits, irrespective of the regulations and rates related to it, including visitors' passes, permits for events, exemptions, day tickets, permits for the disabled or special professional groups such as contractors. The system is cost saving, easy to use, flexible, and improves convenience for residents, businesses and the public. Congestion related to hunting for parking, double parking, etc., can be reduced through comprehensive integrated permit systems such as this one. Proponents note that this system generates more income from parking with substantial overhead savings from both permitting and enforcement activities.[4]

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[2] *Nine Years from Yokohama*; ITS International; September/October 2004.

[3] www.bayerninfo.de.

[4] *Keeping Meters at Bay*; Traffic Technology International; February/March 2004.

- **Holland's Parking Guidance System**[5] provides motorists with accurate, continuously updated information about the occupancy status of parking facilities so as to allow motorists to select in advance the most convenient parking location. When traffic managers see the level of occupancy in any of the car parks, they can change the message on a number of VMS signs making sure that drivers are guided to the nearest free space. Parking guidance systems may be used to facilitate access to parking garages in central business districts, surface parking lots on the periphery of downtown areas, park-and-ride lots serving suburban commuter rail stations, satellite parking lots at airports, and parking areas surrounding sports and entertainment complexes.[6] A comparable system is in place at Portland International Airport.

Transit

- **Hiroshima's i-Mobility center** provides traveler information via a large video wall display and a series of touch-panels kiosks at the Kamiya-cho Intersection, one of the major traffic nodes in Hiroshima City. This location has so many stops for buses, trams, and the new subway system that it was difficult for the public to understand which stop to go to and which mode was most effective for different trips. Additionally, there was a growing demand for information on paratransit services. In response, the Hiroshima National Highway Work Office and the Kamiya-cho underground business complex jointly completed the i-Mobility Center at the central square beneath the Kamiya-cho Intersection. Information provided includes real-time transit information (i.e., next bus arrival time), paratransit service information, traffic conditions, weather, regional activities, and sight-seeing opportunities. On-site staff also handles inquiries at a counter.[7]
- **Kansai Region Smart Card System** is a railway and public transit bus passenger ticketing system using contact-less smart cards. With this post-pay system, a wide range of fare discounting has been made possible, at the same time making possible the simultaneous payment of admission to tourist spots and facilities. In this tour, each participant will use a single smart card to travel on train and shuttle riverboats, as well as to have lunch at restaurants and tour sightseeing facilities in Kobe. Integrated ticketing schemes such as this are helpful in reducing confusion and lost time particularly in areas that attract significant visitors.
- **Nakamura Machi-Bus** is a demand-responsive bus system using the grid road network in Nakamura City. With the growth of car ownership, transit

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[5] http://www.tenetsystems.com/solution/telematics/parking.htm.

[6] https://dspace.mit.edu/bitstream/1721.1/1566/11/section+3.pdf.

[7] http://www.jice.or.jp/itschiiki-e/areas/p62-imobility.html.

ridership in Nakamura City in Kochi Prefecture has been in decline. In order to promote the increased use of transit, Nakamura machi-bus was initiated. The users inform the bus operator of their desired boarding time, and boarding and leaving stops by telephone, fax, or information terminal. The request is automatically processed, and the users receive a time table close to their desired boarding time. The number of bus stops has been increased from 27 to 57. One of the new stops is close to a hospital, which allows users to wait for a bus in its lobby. The system greatly improves the convenience and predictability for riders, and the number of bus users has increased to four times that before system introduction.[8]

2.3 NEW STRATEGIES BEING STUDIED

In addition to the innovative operational strategies being used overseas, other new strategies currently are in the research stage. These strategies are in the early stages of development or testing and have not yet been proven in general service. Again, the strategies have been separated out by mode.

Highway

- **FHWA's Crash Avoidance Technologies.** Several crash avoidance technologies were developed and tested under the Federal Highway Administration's (FHWA) *Intelligent Vehicle Initiative (IVI) Program*. Avoidance technologies include systems that have the potential to prevent typical types of incidents such as truck rollover, rear-end, road departure, lane change, and intersection crashes. These systems require on-board sensors and a driver-vehicle interface.[9]

  The *Vehicle-Infrastructure Integration (VII) Initiative* is a cooperative program of the Federal Highway Administration, several state DOTs and the automotive industry. The technologies build on the findings from the IVI program and employ not just in-vehicle devices, but system infrastructure components along the roadway as well. Vehicle-to-vehicle communication is used to warn motorists of impending accidents. Roadside-to-vehicle communication is used along freeways and at intersections to prevent red light running accidents and to warn motorists about hazardous conditions ahead. The initiative is focused primarily on safety, but congestion benefits would result as well through reduction of incidents.

- **Melbourne's Dynamic Speed Control System** is a system where the posted speed limit on a section of road changes according to traffic conditions. The system is used on the Western Ring Road and the West Gate Bridge. Under

[8] http://www.jice.or.jp/itschiiki-e/areas/06-1nakamura_change.html.

[9] http://www.its.dot.gov/ivi/ivi.htm.

light traffic flow, variable message signs display a speed limit of 100 kilometers an hour, and during periods of heavy traffic flow this may be incrementally reduced to 80 or 60 kilometers an hour.[10] Reports indicate that varying the posted speed limit allows system operators to maintain smoother traffic flow, reduce the erratic variations in speed that begin to occur when traffic density increases, and reduce the likelihood of crashes.

Transit

- **FHWA's Vehicle-lane Assistance System for Bus Rapid Transit** assists bus operators with steering in a narrow lane. This project was carried out as part of FHWA's *Intelligent Vehicle Initiative (IVI) Program*. Vehicle-lane assistance is especially helpful in cases where buses have been granted permission to ride in shoulder lanes alongside travel lanes filled with heavy, stop-and-go traffic. Metro Transit in Minneapolis and the University of Minnesota conducted a survey and workshop to assess what the industry would like to see with regard to vehicle-lane assistance technologies. Using the results of these outreach activities, they identified system requirements.[11] Similar technology has been demonstrated to help bus rapid transit (BRT) operators guide vehicles to a precise stop at raised station platforms, providing the same ease of boarding offered at platform-level light rail transit stops.
- **India's Ground Traffic Control (GTC) System** is a bus terminal operations pilot project located in the city of Chennai, in the southern State of Tamilnadu. This system serves the largest bus terminal in South Asia, handling an average of 2,000 buses and 200,000 passengers per day. GPS and GIS will be used to provide bus drivers with digital route mapping and driving information, including guidance on where to position the bus at the terminal. The system also will provide dispatchers with remote vehicle diagnostics for bus condition monitoring and provide passengers with information on bus locations, destinations, and departure/arrival times. The GTC also will track bus travel times, distances, and traffic violations (including speeding). Anticipated benefits include improved overall service, routing efficiency and bus terminal bay allocation. Initial project cost is estimated at U.S. $650,000. If successful, the GTC will be implemented throughout India, partnering with the automotive industry.[12]
- **Liverpool's "live'smart" Global Smart Media (GSM) Pilot Project** allows people to travel on buses, trains, ferries and eventually trams using the single "live'smart" ticket. A pilot scheme will allow the new cards to be used on limited buses on the waterfront network in the city and on the Mersey ferries

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[10] http://www.theage.com.au/text/articles/2004/11/28/1101577351646.html.

[11] http://www.its.dot.gov/ivi/ivi.htm.

[12] *India's New Agenda*; ITS International; September/October 2004.

and other selected venues. Buses will be fitted with scanners that will read the information stored on the card. The card will enable people to buy a travel Smartcard with extra entitlements loaded on them to be used at entertainment venues, making it attractive to visitors.[13] While operations strategies such as "live'smart" do not directly address congestion concerns, they do improve overall accessibility and utility of the multimodal system to the consumer, encourage greater use of public transit, and contribute to broader system efficiency goals.

[13] http://icliverpool.icnetwork.co.uk/0100news/0100regionalnews/tm_objectid=14910949&method=full&siteid=50061&headline=smart-card-revolution-will-access-transport-network-name_page.html.

2.4 A MAXIMUM OPERATIONS STRATEGY

The Oregon Transportation Plan policy analysis will test the potential benefits of an aggressive operations- and maintenance-focused scenario. Table 2.1, below, offers recommendations for key components of a Maximum Operations strategy for Oregon. This table identifies several important program areas, the key components of each program, and several examples of the specific strategies and actions that would make up the program. For most of the tested operations strategies, such as incident management, ramp metering, smart cards and integrated fare payment, there is sufficient data from Oregon and/or other North American deployments to support a quantitative estimate of the costs and benefits of expanding these programs to a much larger percentage of the system. Further examples of numerous operations strategies, as well as the type and general magnitude of benefits that can be expected from a given strategy, are presented in Tables 1-10 of Appendix A. This information will be used to conduct quantitative performance evaluation of the OTP Maximum Operations and Maintenance scenario.

Estimates also will be developed of the potential costs and benefits of deploying more innovative or as-yet untested programs in Oregon, such as some of the examples provide above in Sections 2.2 and 2.3. These will be evaluated as a second phase, longer-term (i.e., 25-year) strategy to complement and extend the near-term (10-year) Maximum Operations strategy. These estimates of costs and benefits will be less precise, since some of the more innovative programs are relatively new and only limited evaluation data are available.

Additionally, there may be different cultural and political obstacles to implementing innovative operations strategies in the United States than have been experienced overseas. The experience with congestion pricing in the United States suggests this may be the case; despite many years of study and attempted demonstration projects, there are relatively few examples of dynamic highway facility pricing in the United States, and no area congestion pricing programs in place. There may be insufficient political will or public support for aggressive system operations and management strategies, even though the necessary technologies are available.

Table 2.1 Maximum Operations Strategy for Policy Analysis of Scenario 2, Maximum Operations and Maintenance

Operations Program Area	Key Components of Program	Partial List of Example Strategies and Actions*
Arterial and Freeway Management	Arterial Traffic Control	Traffic Signal Transit Priority and Emergency Vehicle Preemption; Adaptive Traffic Signal Control
	Arterial Access Control	Access Management; Temporal Turn Prohibitions
	Freeway Access Control	Ramp Metering with HOV Bypass
	Lane Management and Control	Dynamic Message Signs; Variable Speed Limits And Automated Enforcement; Reversible Flow Lanes
	Special Event and Emergency Transportation Management	Temporary Traffic Management Plans
	Work Zone Management	Various Temporary Traffic Control Strategies Such As Lane Control, Variable Speed Limit, And Work-Zone Intrusion Detection and Alert
Public Transit Management	Surveillance and Credentialing for Safety and Security	In-Vehicle Surveillance; Facility Surveillance; Employee Credentialing; Remote Disabling Systems
	Transit Demand Management	Ride Sharing and Matching; Variable Fares
	Service Coordination	Paratransit Scheduling and Routing System
	Fleet Management	Dynamic Routing and Scheduling; Automated Vehicle Location and Computer-aided Dispatch
	Information Dissemination	Regional Trip Planner; 511 and Other Advanced Traveler Information Systems; Real-Time Customer Information Displays
Incident and Emergency Management Systems	Surveillance and Detection	Traffic Flow and Density Detectors; Video Imaging; Wireless E911; Call Boxes
	Mobilization and Response	Automated Vehicle Location; Response Management and Detour/Evacuation Routing; Motorist Assistance Patrols
	Hazardous Materials Management	On-board Automated Collision Notification (ACN) Systems
Advanced Traveler Information Systems	Pretrip Planning and Travel Services	"511" Internet- and Telephone-based Comprehensive Pretrip Planning and Transportation System Information;
		TV and Radio Information Channels (e.g., Dedicated Highway Advisory Radio, Commercial Radio and TV Information Services, etc.); Traveler Information Kiosks
	En Route Information	In-vehicle Information Systems; 511; Other Wireless and Radio Information Distribution Systems
	Prearrival Parking Information	Dynamic Message Signs at Parking Facilities

Operations Program Area	Key Components of Program	Partial List of Example Strategies and Actions*
Commercial Vehicle Operations	Credentials Administration	Electronic Registration/Permitting; "Green Light" Preclearance
	Safety Assurance	Automated Inspection; Safety Screening and Information Exchange; Downhill Speed Warning
	Electronic Screening	Border Clearance; Weigh-in-motion/Weight Screening; Credential Checking
	Carrier Operations and Fleet Management	Automated Vehicle Location; On-board Monitoring and Driver Information
	Security Operations	Remote Disabling System
Roadway Weather Information Systems and Management	Surveillance, Monitoring, and Prediction	Roadway Surface and Atmospheric Condition Monitoring and Reporting
	Information Dissémination	Dynamic Message Signs, Internet/Wireless/Phone, Highway Advisory Radio (HAR)
	Temporary Traffic Control	Variable Speed Limits
Crash Prevention and Safety	Road Geometry Warning Systems	Ramp Rollover Warning; Curve and Downhill Speed Warning; Overheight/Overwidth Warning
	Highway-Rail Crossing Systems	Intersection/rail Crossing Collision Prediction and Avoidance Systems; Automated Horn-warning Systems; Improved Crossing Maintenance Procedures
	Intersection Collision Warning	On-board Impending Collision Warning Systems
	Pedestrian Safety Systems	Automated In-pavement Lighting at Crosswalks;
	Bicycle Safety Systems	Bicycle Detectors at Intersections; Warning Systems such as "Bicyclist in Tunnel" Motorist Advisories
	Range Animal Warning Systems	Radar Detection and motorist Warning Systems

* See Appendix A, Tables 1-10 for comprehensive list of potential actions.

2.5 SUMMARY

Increased roadway congestion and delay are a real and documented phenomenon in Oregon with impacts to all Oregonians, not just the driving public. Public transportation investments, highway operations and ITS strategies, and growth management policies have had a significant mitigating impact however, and there has evolved a widespread appreciation of the importance of taking a comprehensive approach to transportation that is multimodal, system-based, and integrated with land use, economics, and other policies. Aggressive and innovative system operations strategies have great potential to further address mobility, accessibility, safety, and related concerns. These solutions are likely to be controversial from a number of perspectives and will require effective consensus building in order to be implemented

successfully. And while some of the most aggressive strategies presented above may not be suited for Oregon in the timeframe of the OTP, there are aspects of many programs that can be pieced together to develop an aggressive, effective statewide approach to operations that complements and leverages investments in roadway capacity, transit system expansion, and continued smart growth practices and policies.

A. Maximum Operations Benefits Summary

Maximum Operations Benefits Summary, Table 1. Arterial Management Systems

Program Area	Components	Benefit Measure	Example/Benefit Summary
Arterial Management Systems	*Traffic Surveillance* *Traffic Control* - Transit Signal Priority - Emergency Vehicle Preemption - Adaptive Signal Control - Advanced Signal Systems - Variable Speed Limits - Bicycle & Pedestrian - Special Events *Lane Management* - HOV Facilities - Reversible Flow Lanes - Pricing *Lane Control* - Variable Speed Limits - Emergency Evacuation *Parking Management* *Information Dissemination* - Dynamic Message Signs (DMS) - In-Vehicle Systems (IVS) - Highway Advisory Radio (HAR) *Enforcement* - Speed Enforcement - Stop/Yield Enforcement	**Safety Improvements**	Automated enforcement of traffic signals has reduced red-light violations 20-75%.
		Delay Savings	Field studies in several cities have shown that adaptive signal control systems can reduce peak period travel time 5-11%.
			In California, signal-synchronization projects undertaken along 76 travel corridors across the state decreased the number of “vehicle-hours” of delay by 25%.
		Throughput	
		Customer Satisfaction	In Michigan, 72% of surveyed drivers felt "better off" after signal control improvements.
		Cost Savings	Transit signal priority on a Toronto transit line allowed same level-of-service with less rolling stock.
		Environmental	Model estimates showed advanced traffic signal control systems can reduce fuel consumption 2-13%.
Oregon Example			
Coordinated signal timings in Multnomah County	Adaptive Signal Control	**Delay Savings**	Up to 85% reduction in stops.
			Up to 33% reduction in travel time.
		Cost Savings/ Environmental	Over 85,000 gallons of fuel saved per year.

Note: Benefits are actual measured numbers unless noted otherwise.

Maximum Operations Benefits Summary, Table 2. Freeway Management Systems

Program Area	Components	Benefit Measure	Example/Benefit Summary
Freeway Management Systems	*Traffic Surveillance* *Ramp Control* - Ramp Metering - Ramp Closures - Priority Access *Lane Management* - HOV Facilities - Reversible Flow Lanes - Pricing *Lane Control* - Variable Speed Limits - Emergency Evacuation - Special Events Transportation Management - Occasional Events - Frequent Events - Other Events - Temporary TMCs *Information Dissemination* - Dynamic Message Signs (DMS) - In-Vehicle Systems (IVS) - Highway Advisory Radio (HAR) *Enforcement* - Speed Enforcement - High Occupancy Vehicles (HOV) - Ramp Meter Enforcement	**Safety Improvements**	Studies of traffic management centers using ramp meters show freeway management systems reduce accidents 15-50%.
			In Texas, the deployment of dynamic message signs, closed-circuit television cameras and other ITS technologies along 29 miles of highways near San Antonio eased congestion and reduced the number of traffic accidents by nearly 3%.
		Delay Savings	Advanced Traffic Management Systems (ATMS) in the Astrodome area reduced street congestion delay by 46%.
			In New Jersey, the implementation of the E-Z pass electronic toll-collection system reduced delay at toll plazas by 85%, saving motorists an estimated $19 million in otherwise lost productivity time and $1.5 million in fuel costs every year.
		Throughput	After ramp meters were experimentally turned off in the Twin Cities of Minnesota, freeway volume declined 9% and peak period throughput decreased 14%.
		Customer Satisfaction	After the Twin Cities ramp meter shutdown test, support for a complete shutdown fell from 21% to 14%.
		Cost Savings	Variable speed limits with lane controls on the German Autobahn reduced injury accidents 20 to 29% saving approximately $4 million per year.
		Environmental	In Denver, CO, dynamic message signs (DMSs) that displayed real-time vehicle emission levels motivated most motorists surveyed to consider repairs.
Oregon Example			
Ramp Metering in Portland Metropolitan Area	Ramp Metering	**Delay Savings**	ITS Deployment Analysis System (IDAS) model runs estimated 61% reduction in travel time on Interstate 5.
		Safety	IDAS estimated 43% reduction in accidents on Interstate 5
Ramp metering on Beltline Highway (Coburg Road to Pacific Highway)	Ramp Metering	**Delay Savings**	IDAS estimated travel time savings: 55 Hrs/day
		Environmental	IDAS estimated fuel consumption (gallons): 55 additional gallons consumed per day.
		Safety	IDAS estimated 7% fewer accidents.

Note: Benefits are actual measured numbers unless noted otherwise.

Maximum Operations Benefits Summary, Table 3. Transit Management Systems

Program Area	Components	Benefit Measure	Example/Benefit Summary
Transit Management Systems	*Safety & Security* - In-Vehicle Surveillance - Facility Surveillance - Employee Credentialing - Remote Disabling Systems *Transit Demand Management* - Ride Sharing/Matching - Dynamic Routing & Scheduling *Service Coordination* *Fleet Management* - AVL/CAD - Maintenance - Planning *Information Dissemination* - In-Vehicle Systems (IVS) - In-Terminal/Wayside - Internet/Wireless/Phone	**Safety Improvements**	
		Delay Savings	Computer Aided Dispatch (CAD) and Automatic Vehicle Location (AVL) technologies improved on-time bus performance 9-23%.
		Throughput	In Portland, Oregon, models of transit data showed AVL/CAD may allow same level-of-service to more travelers using the same rolling stock.
		Customer Satisfaction	In Denver, installation of a AVL/CAD system contributed to improved schedule adherence. Customer complaints decreased 26% per 100K boardings.
		Cost Savings	In San Jose, CA, a paratransit scheduling and routing system increased shared rides 45% and reduced operating costs $500K the first year.
		Environmental	
Oregon Example			
Regional Trip Planner	Information Dissemination via Internet/Wireless/Phone	**Customer Satisfaction**	Efficient use of the Internet will increase the availability and amount of transportation information, including schedules, routes and fares.
		Cost Savings/ Environmental	National and international studies suggest that improving travel information may increase transit usage by 5% to 13%.
Transit Signal Priority at Tri-Met		**Cost Savings**	Saving the operational costs of a bus and a driver over selected routes.
		Customer Satisfaction	Enhancing service to transit riders through systemwide on-time schedule reliability.
			Operational savings and improved service from optimized schedules.
Transit Tracker (Real Time Customer Information Displays)	Information Dissemination	**Customer Satisfaction**	Increased information for travelers.
Bus Dispatch System (TriMet)	Fleet Management	**Delay Savings**	Tri-Met's overall on-time performance improved from 69% to 83%.
			Early arrivals declined from 15% to 5%.
		Customer Satisfaction	Schedules have been improved based on information provided by the Bus Dispatch System (BDS).

Note: Benefits are actual measured numbers unless noted otherwise.

Maximum Operations Benefits Summary, Table 4. Incident Management Systems

Program Area	Components	Benefit Measure	Example/Benefit Summary
Incident Management Systems	*Surveillance & Detection* - Detectors - Imaging/Video - Wireless E911 - Mayday/Automated Collision Notification (ACN) - Call Boxes - Traveler Reported *Mobilization & Response* - AVL/CAD - Response Routing - Motorist Assistance Patrols *Information Dissemination* - Dynamic Message Signs (DMS)	**Safety Improvements**	In Pennsylvania, Traffic and Incident Management Systems (TIMS) decreased secondary incidents on highways 40% between 1993 and 1997.
		Delay Savings	The I-95 Traffic and Incident Management System (TIMS) in Pennsylvania cut highway incident closure time 55%.
		Throughput	
		Customer Satisfaction	The Virginia DOT has received hundreds of "thank you" letters from customers satisfied with service patrols.
			In Minnesota, a $600K/yr Highway Helper Program reduced the average duration of stall incidents by 8 minutes, saving $1.4 million/yr in delay costs.
		Environmental	Based on calculations of incident delay reduction, models of the Maryland CHART system showed a fuel savings of 4.1 million gallons/year in 2000.
Oregon Example			
Closed Circuit Television Use	Surveillance and Detection	**Delay Savings**	Reduced delays due to incidents by 10 to 45%.
Corridor Management Teams (COMET)	Surveillance and Detection & Mobilization and Response	**Safety Improvements**	1700 responses per week. Reduction in response time.
Region 2 (Central Willamette Valley) Incident Response	Mobilization and Response	**Delay Savings**	Decrease in average delay per incident of 66% on State Highway 18 and 36% on Interstate 5.
		Cost Savings/ Environmental	Net savings in delay and fuel and reductions in maintenance costs estimated to be annual return in 2000 dollars of $250,000 on State Highway 18 and nearly $280,000 on Interstate 5.
ODOT Incident Response Program (I-5)	Mobilization and Response	**Delay Savings**	15% reduction in incident duration on I-5.
			35% reduction in incident related delay on I-5.

Note: Benefits are actual measured numbers unless noted otherwise.

Maximum Operations Benefits Summary, Table 5. Emergency Management Systems

Program Area	Components	Benefit Measure	Example/Benefit Summary
Emergency Management Systems	*Hazardous Materials Management* *Emergency Medical Services* - Advanced ACN - Telemedicine *Response & Recovery* - Evacuation Operations - Response Management	**Safety Improvements**	In Erie, New York, dispatch center notification time was about 1 min. for vehicles equipped with automated collision notification, and 3 to 46 minutes without.
		Delay Savings	
		Throughput	
		Customer Satisfaction	In Puget Sound, Washington, 95% of drivers equipped with Mayday voice communications felt more secure. 70% with text messaging felt more secure.
		Cost Savings	In New Mexico, a private ambulance company used CAD/AVL to guide ambulances to exact locations. The company increased efficiency 10-15%.
		Environmental	
Oregon Example			
National Emergency Messaging System (NEMS)	Response Management	**Cost Savings**	Communication and cooperation between agencies
Four transportation operations centers (TOCs)	Response Management	**Cost Savings**	Work with management and field personnel to minimize incident response time and maximize safety for the traveling public

Note: Benefits are actual measured numbers unless noted otherwise.

Maximum Operations Benefits Summary, Table 6. Traveler Information

Program Area	Components	Benefit Measure	Example/Benefit Summary
Traveler Information	*Pre-trip Information* - Internet - 511 - Other Telephone - TV/Radio - Kiosks *En Route Information* - 511 - Other Telephone - Radio *In-Vehicle Systems (IVS)* - Tourism & Events - Travel Services - Advanced Parking - Electronic Payment	**Safety Improvements**	IDAS models of "ARTIMIS" (Advanced Regional Traffic Interactive Management and Information System) in Cincinnati and Northern Kentucky estimated traveler information reduced fatalities 3.2%.
		Delay Savings	In the DC metro area, a simulation model estimated that commuters who used traveler information improve their on-time reliability 5-16%.
		Throughput	A simulated traffic network in Seattle showed that supplementing freeway Advanced Traveler Information Systems (ATIS) with arterial ATIS may not significantly improve throughput.
		Customer Satisfaction	In Philadelphia, 66% of surveyed commuters changed their departure time, and 86% changed their route after receiving traveler information.
		Cost Savings	In the DC area, models showed pre-trip departure notification can reduce early/late arrivals and save 40% of users $60 or more each year in lost time.
		Environmental	Models of vehicle emissions in Boston showed users of Smart Traveler generated 1.5% less NOx, and 25% less VOCs.
Oregon Example			
Trip Check	Pre-trip Information	**Customer Satisfaction**	60% of the commuters responding have used the World Wide Web to access road and weather information.
			Nearly 40% of respondents considered traffic and weather related information very important, while another 43% considered this information somewhat important.
			95% of survey respondents that have visited Tripcheck found all the information they were looking for.

Maximum Operations Benefits Summary, Table 6. Traveler Information

511 Number	En Route Information	**Delay Savings**	Road and weather condition information along route resulted in informed choices and reduced delay. Previous studies indicate a 72% increase in call volume when a traveler information telephone system converts from a seven-digit number to a 511-type number.

Note: Benefits are actual measured numbers unless noted otherwise.

Maximum Operations Benefits Summary, Table 7. Commercial Vehicle Operations

Program Area	Components	Benefit Measure	Example/Benefit Summary
Commercial Vehicle Operations	*Credentials Administration* - Electronic Funds - Electronic Registration/Permitting *Safety Assurance* - Safety Information Exchange - Automated Inspection *Electronic Screening* - Safety Screening - Border Clearance - Weight Screening - Credential Checking *Carrier Operations & Fleet Management* - AVL/CAD - On-Board Monitoring - Traveler Information *Security Operations* - Asset Tracking - Remote Disabling Systems	**Safety Improvements**	Infrared brake screening tested in 4 states improved inspection selection for trucks, increasing the percentage placed out-of-service by 250%.
		Delay Savings	Carriers commissioned new vehicles 60% faster by printing their own electronic credential paperwork and not waiting for conventional mail delivery.
		Throughput	
		Customer Satisfaction	A survey of truckers showed operators who carried hazardous materials were very much in favor of hazardous materials incident response programs.
		Cost Savings	Motor carriers surveyed indicated that the Commercial Vehicle Information Systems and Network (CVISN) electronic credentialing reduced paperwork and saved 60-75% on credentialing costs.
Oregon Example			
Weigh in Motion	Weight Screening	**Safety**	Reduced hazards of merging and diverging at weigh station.
		Delay Savings	Decreased delay.
Downhill Speed Warning System	Traveler Information	**Safety**	Reduction in number of truck-related accidents.
Green Light Preclearance Program	Weight Screening	**Delay Savings, Cost Savings**	Reduction in travel time and cost.

Note: Benefits are actual measured numbers unless noted otherwise.

Maximum Operations Benefits Summary, Table 8. Operations and Maintenance

Program Area	Components	Benefit Measure	Example/Benefit Summary
Operations & Maintenance	*Information Dissemination* - Portable DMS - HAR - Internet/Wireless/Phone *Asset Management* - Fleet Management - Infrastructure Management *Work Zone Management* - Temporary Traffic Management - Temporary Incident Management - Lane Control - Variable Speed Limit - Speed Enforcement - Intrusion Detection	**Safety Improvements**	In Iowa, 55% of truckers surveyed said the automated work zone CB-radio warning system first alerted them of painting crews on I-35.
			The Nebraska Department of Roads (NDOR) is using ITS technologies to improve safety and efficiency in a work-zone project along I-80 in the Omaha area. System components include nine electronic traffic detectors, two mobile camera units, 21 variable message signs and a central computer system. The system informs motorists approaching the construction zone of real-time delays, instructs them to slow down, and advises them to take alternate routes if necessary.
		Delay Savings	The New Mexico Department of Transportation used ITS technologies in rebuilding the interchange between Interstates 25 and 40 in Albuquerque. At the so-called "Big-I" interchange, deployment of variable message signs, automated traffic sensors, work zone surveillance, incident response, and other ITS technologies reduced the average clearance time for traffic incidents by 44%.
		Throughput	
		Customer Satisfaction	Most people surveyed about the Minnesota Guidestar program said Smart Work Zone warning signs were accurate and useful.
		Cost Savings	In Montana, WIM scales installed in travel lanes on major truck routes can improve pavement fatigue estimates and save $4.1 M/year in construction costs.
		Environmental	
Oregon Example			

Note: Benefits are actual measured numbers unless noted otherwise.

Maximum Operations Benefits Summary, Table 9. Road Weather Management

Program Area	Components	Benefit Measure	Example/Benefit Summary
Road Weather Management	*Surveillance, Monitoring, & Prediction* - Road Surface - Atmospheric Conditions *Information Dissemination* - Dynamic Message Signs (DMS) - Internet/Wireless/Phone - Highway Advisory Radio (HAR) *Traffic Control* - Variable Speed Limits - Signals - Lane Use *Response & Treatment* - Fixed Winter Maintenance - Mobile Winter Maintenance	**Safety Improvements**	In Idaho, weather-related warnings on freeway dynamic message signs decreased vehicle speeds 35% compared to a 9% decrease without the signs.
		Delay Savings	
		Throughput	
		Customer Satisfaction	30% of highway maintenance staff surveyed in Iowa, Missouri, and Wisconsin used an Internet based weather information network to prepare for winter storms.
		Cost Savings	In Wisconsin, a snow forecasting model (with ice detection) improved DOT work schedules and reduced labor costs 4 hrs/person during significant storms.
		Environmental	
Oregon Example			
Road Weather Information System (RWIS) around the State of Oregon	Response and Treatment	**Cost Savings**	ODOT maintenance crews are currently using RWIS data to make decisions about when and where to send maintenance vehicles in order to be able to use agency resources more efficiently.
Automated Wind Warning Systems (on US Route 101 over the Yaquina Bay Bridge in Newport and on US 101 near Humbug Mountain between Gold Beach and Port Orford)	Information Dissemination	**Safety**	Improved drivers' awareness of hazardous driving conditions and thus helped drivers avoid crashes by driving more cautiously.
Flood Warning System on Highway 101	Information Dissemination	**Cost Savings**	Since April 2000 when the system was installed, no liability claims related to flooded roads have been filed against the City of Seaside.
Remote Snow Zone Signs Activation	Information Dissemination	**Cost Savings, Safety**	In addition to enhancing maintenance efficiency, these new systems (i.e. the retrofitted remotely activated signs and dynamic message signs) will eventually help to provide real-time information to the trucking community on traction tire and chain requirements on ODOT's TripCheck Web site.

Maximum Operations Benefits Summary, Table 9. Road Weather Management

Note: Benefits are actual measured numbers unless noted otherwise.

Maximum Operations Benefits Summary, Table 10. Crash Prevention and Safety

Program Area	Components	Benefit Measure	Example/Benefit Summary
Crash Prevention & Safety	*Road Geometry Warning Systems* - Ramp Rollover Warning - Curve Speed Warning - Downhill Speed Warning - Overheight/Overwidth Warning *Highway-Rail Crossing Systems* *Intersection Collision Warning* *Pedestrian Safety* *Bicycle Warning Systems* *Animal Warning Systems*	**Safety Improvements**	In Colorado, a downhill speed warning system on interstate I-70 decreased truck accidents 13% and reduced runaway ramp usage 24% in 2 years.
			In San Mateo, California, the local transit authority (SamTrans) partnered with the California Department of Transportation (Caltrans) and a private-sector firm, the Gillig Corporation, on a system that warns transit bus drivers of impending collision with vehicles in front of them. The system uses radar and other sensors to detect obstacles, and a sophisticated software program to determine the threat level.
		Delay Savings	Models of increased traffic flow at a San Antonio rail crossing showed dynamic message signs with delay information can reduce system delay 6.7%.
			In Oakland County, Michigan, the number of red-light stops decreased by 33% after officials outfitted more than 350 intersections with an Australian-designed system known as SCATS (officially, the Sydney Coordinated Adaptive Traffic System).
		Throughput	FHWA has opened an “intelligent intersection testing facility” in McLean, Virginia, to develop and test collision prevention technologies.
		Customer Satisfaction	70% of truck drivers and 85% of car drivers surveyed in California felt curve speed warning systems were useful.
		Cost Savings	
		Environmental	An automated horn warning system in Ames, Iowa, reduced elevated noise impact areas 97% adjacent to a highway rail intersection.
Oregon Example			

Maximum Operations Benefits Summary, Table 10. Crash Prevention and Safety

Program Area	Components	Benefit Measure	Example/Benefit Summary
Advanced Curve Warning System (5 locations on I-5 Myrtle Creek curves)	Curve Speed Warning	**Safety**	Results from similar deployments in northern California on I-5 near the Sacramento River Canyon were used to estimate likely benefits in Oregon. Studies of the California projects found that the average speed of trucks through these curves was reduced by an average of 4%.
Downhill Speed Warning System (Emigrant Hill on westbound I-84)	Downhill Speed Warning	**Safety**	Helps inexperienced drivers who do not realize how difficult it is to slow to a safe speed once they get started down this hill.
Dundee Queue Detection System	Collision Warning System (Visibility in hilly area)	**Safety**	Provides drivers with additional time to respond and reduces the likelihood that they will be involved in a rear-end collision. There have been only four crashes in the 10-month period after installation as opposed to nine crashes in the 10-month period before installation of this system (60% decrease).

Note: Benefits are actual measured numbers unless noted otherwise.