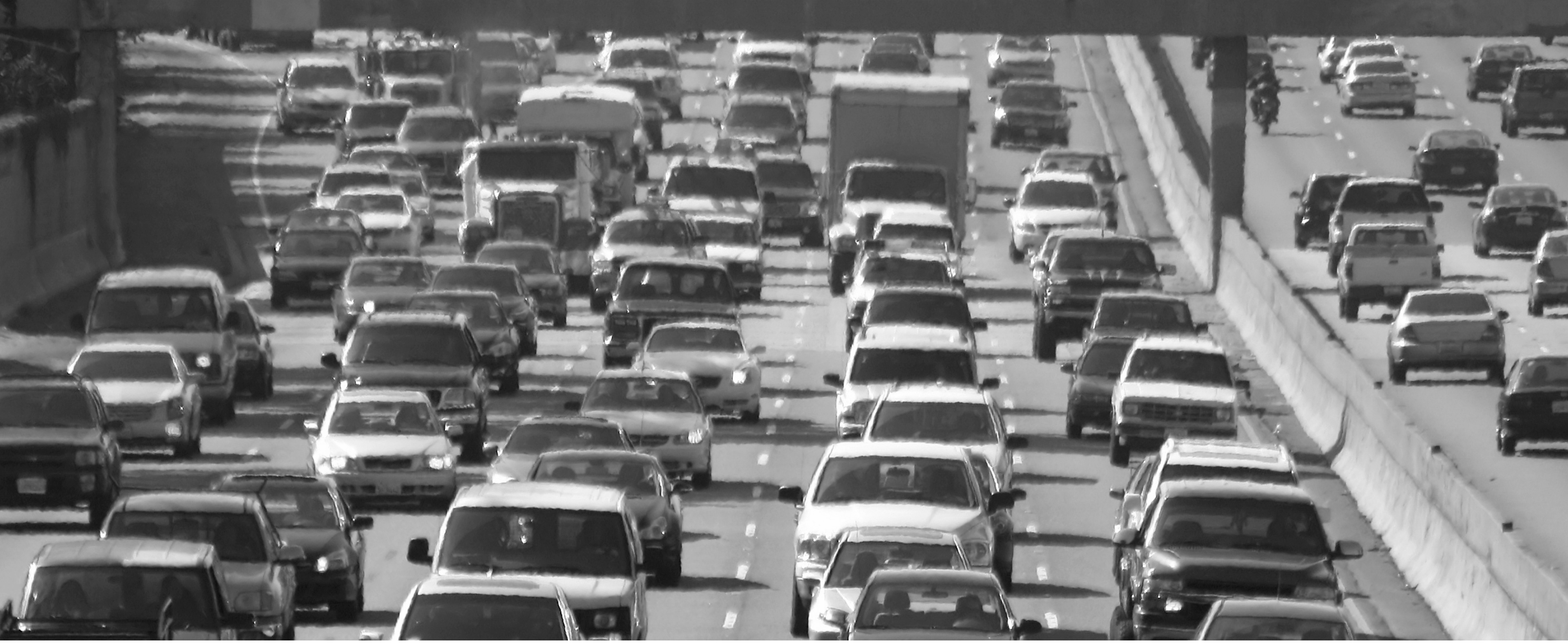

2015 Oregon Highway Cost Allocation Study

An Efficient Fee Demonstration Project White Paper

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ECONorthwest specializes in economics, planning, and finance. Established in 1974, ECONorthwest has over three decades of experience helping clients make sound decisions based on rigorous economic, planning and financial analysis.

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DISCLAIMER

ECONorthwest completed this project under contract to the state of Oregon. The State's purpose in commissioning this study was to outline how an efficient fee for road usage could be demonstrated, and why such a demonstration might be undertaken.

Throughout the report we have identified our sources of information and assumptions used in the analysis. Within the limitations imposed by uncertainty and the project budget, ECONorthwest has made every effort to check the reasonableness of the data and assumptions and to test the sensitivity of the results of our analysis to changes in key assumptions. The fact that we evaluate assumptions as reasonable does not guarantee that those assumptions will prevail.

The contents of this document do not necessarily reflect views or policies of the State of Oregon.

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1. SUMMARY

1.1 BACKGROUND

In the 2001 Oregon Highway Cost Allocation Study, the concept of efficient fee-based cost allocation was introduced. Instead of estimating costs imposed by forecasting highway-agency expenditures and then allocating those expected expenditures to vehicle weight classes, the efficient fee approach forecasts the revenues that vehicles in each weight class would pay if a set of revenue instruments were to charge each vehicle for the costs it imposes for each mile it travels, given the time and place of travel and the weight and other characteristics of the vehicle.

As is emphasized in the previous work on efficient fees for the Oregon Highway Cost Allocation Study, an efficient vehicle fee is about more than just paying for new infrastructure. An efficient fee recovers costs from users directly. Those costs relate to the maintenance and operation of existing infrastructure and services, new infrastructure needs that result from growing transportation demand, and even the costs of pollution.

This issue paper addresses how Oregon might go about demonstrating a program to convert its Highway Fund revenue instruments to efficient fee instruments. The state of Oregon has considerable history with the implementation of road use charging demonstration programs. The current status of the Road Usage Charge Pilot Program, and the history of related efforts are summarized in the ODOT report *Road Usage Charge Pilot Program 2013 & Per-Mile Charge Policy in Oregon.* Another important effort with which the authors are deeply familiar is the *Traffic Choices Study* (a variable rate road charging trial) conducted in Seattle, WA in 2006. Together these two efforts constitute significant "local" knowledge regarding how to effectively design and implement road charging pilot projects.

1.2 WHY CONSIDER AN EFFICIENT (VARIABLE) FEE

Variable pricing, based on peak periods of use, is a common form of pricing in other industries. It is used when capacity is fixed in the short-run, and demand fluctuates significantly between the peak and off-peak periods. Before cell phones, phone companies used peak-period pricing to encourage consumers to shift their use of the fixed capacity of the phone system to off-peak hours (e.g., by charging lower rates evenings and weekends). Some energy utilities use peak pricing. So do theaters. Economists recommend congestion pricing of roads for the same reason private firms use peak-period pricing: to use available resources more efficiently.

How would such pricing work for roads? Imagine that the vehicle you drive could tell a computer what road it is on, and at what time.[1] Location and time correlate to the amount of congestion and delay you are experiencing. Higher (variable) prices during peak periods would encourage you, or travelers with less pressing needs, to shift to other routes or times. That system has many advantages. By charging selectively at certain locations and times, one can influence the amount of congestion during peak periods. Variable tolling could reduce the immediate need for building new highway capacity. By knowing where people are willing to pay tolls, planners would have a direct measure of where to build more capacity: namely, where drivers are willing to pay high tolls because the travel is so important to them. When those signals suggested that new capacity would be beneficial, the accumulated toll revenues would provide money to pay for those improvements. Fairness could also be improved, as revenue is collected from those who burden capacity directly.

The current transportation system is financed through a combination of use-related taxes and fees, and broad taxing instruments that have little relationship with transportation system use. Most existing use-fees are scaled to recover some set of costs by applying an average charge to all similar users. The fuel tax is an example where the cost to the consumer of fuel is an average cost tax on fuel by volume.

But in reality, the costs imposed by users vary considerably over time and space. The premise of congestion-based tolling (also called peak-period or variable pricing or tolling) is that this incorrect pricing leads to an over-consumption of certain types of transportation services (i.e., congestion) and an under-consumption of other transportation services. Correct pricing can reduce this problem. Conventional road finance exacerbates rather than ameliorates the problem. A low charge on all mileage allows excessive congestion during peak periods.

[1] It should be noted that variable pricing does not necessarily involve tolls that dynamically respond to road conditions within very short time intervals. Variable toll rates can be time varying according to a set schedule so that road users have certainty about the costs they will encounter.

While the congestion prompts road authorities to build new capacity, the low charges cannot cover the costs.

If financing of highways through road use charges is to become a more generally usable approach it would need to be responsive to a dynamic set of performance and investment conditions:

- Tolls are levied on existing capacity based on the costs the user imposes. As vehicle use in a corridor increases so do the toll rates; which manages growth in congestion.
- Revenues accrue over time and capacity is added where and when revenues are sufficient to justify investments.
- Cost-based toll rates can be lower after capacity is added since the tolls are not designed to meet a revenue target.
- Alternative routes also have cost-based tolls and so diversion is minimized and revenue yield is easier to predict.
- The entire enterprise is a sound platform for long-term investment and growth.

1.3 OPPORTUNITY FOR GAINS, BUT QUESTIONS REMAIN

The promise of an efficient road use fee is that many of the most difficult aspects of surface transportation management are improved considerably. These management challenges relate to cost recovery, fairness, and pollution and congestion externalities. Each of these can be improved upon through the implementation of road usage fees that 1) more closely reflect the costs that users impose and 2) facilitate better asset management practices amongst road authorities.

The potential for gains is considerable. An estimate was developed of the benefits from implementation based on generalization of results from the Traffic Choices Study in Seattle. The direct benefits to transportation system users that result from a network application of road pricing are sizable, and dominated by the value of travel time-savings benefits. These are an estimate of the social welfare, or "efficiency", benefits associated with the correct pricing of congested roads.

The estimate for the present value of the time-savings benefits is well over $36 billion, with total implementation and operating costs of approximately $5.5 billion. The net present value (benefits less costs) of the benefits to society from implementation of this network wide scenario of road pricing is estimated in the range of $28 billion. Over the implementation period for this scenario the present value of toll revenues is estimated at $87 billion.

Even as long-term benefits from an efficient fee program are clear and large in scale the challenges in implementing such a program are many. Such a fee program represents a large-scale change from existing policy and would involve disruptive transformation for many aspects of surface transportation management and operations.

1.3.1 How will driving behavior change

One of the most important questions a variable fee demonstration project can address is how drivers will respond to the fee structure. The many efficiency arguments in favor of variable road charges depend upon driver's abilities to substitute lower cost (in terms of social costs of congestion and otherwise burdening the road system) behavior for higher cost behavior. The theory is strong and supported by considerable empirical results but understanding details of driver response is important for designing systems that best meet consumer and road operator needs.

1.3.2 What about the technology?

Other questions relate to the technology that would be needed to support the program. Choosing a technology that must endure into the future is a challenging exercise. Many efforts to procure technical systems for demanding enterprises focus on functional requirements rather than technical specifications. This allows managing organizations to be clear about their needs without dictating specific technical details to the market for technical solutions. This was the general approach taken the Traffic Choices Study in Seattle (a smaller-scale pilot effort) and was also generally employed in the case of the Oregon Road Usage Charge Program (a larger-scale early voluntary opt-in implementation). Some specific technical aspects of a fee system operation are discussed in more detail later in this paper.

1.3.3 How might privacy be addressed?

Information systems are becoming increasingly complex. As information is collected, stored and used in more and more beneficial ways, there are also increasing concerns over how information that might be considered "private" is managed and protected against malicious use. Road tolling systems with automated tolling transactions that associate the use of roads with an account holder are just one aspect of life that raise issues of privacy protection in the minds of consumers. A road tolling system that collects and stores detailed information about a large extent of the roads visited by all road users is by extension a larger source of the same kinds of concerns.

The fact is that a road tolling system, like the one that might be used in the operation of this demonstration, collects extensive and detailed information about individual users and their travel behavior. It is impossible to imagine such a system being put into operation without significant safeguards in place to secure personal information. There are many ways to protect the privacy of individuals and to inform them of what data are collected and how the tolling agency and its contractors will use them. With proper planning, education, and technology, the protection of privacy need not be a major roadblock to the successful implementation of congestion pricing systems.

1.3.4 What about fairness?

The primary arguments for road pricing are about improving efficiency and investment policy. Yet many people will wonder if improvements in efficiency will come at the expense of compromises in fairness. Whenever policies change, it creates potential winners and losers, and this would be no less true of congestion pricing of a region's roadways. Transportation services are central features of a regional economy. Consequently, a change in the pricing of highway services will have a mixture of good and bad impacts on certain types of travelers, and on businesses and residents in subareas of the region.

Prospectively judging the fairness of a policy is complex at best, is subjective, and involves considerable uncertainty. Yet potential issues around the distribution of costs and benefits cannot simply be ignored.

Implementing congestion pricing means travelers using congested facilities during the peak period will face greater out-of-pocket costs than they currently pay through the gasoline tax alone. Off peak and night charges, on the other hand likely could be less than they are without congestion pricing if pricing were implemented broadly enough to permit average gasoline taxes to be reduced or eliminated.

1.4 BUILDING ON CURRENT EFFORTS

Oregon is currently implementing a Road Usage Charge Pilot Program; which will provide essential insights into many important topics relevant to the design and implementation of a variable rate pilot project. The implementation of a variable rate pilot project needs to be distinct from the Road Usage Charge Pilot Program but also take advantage of opportunities to build on the systems and practice put in place to support that program. The goal should be to build on success but not interfere with, or complicate, the ongoing implementation of an operational program. The primary differences between variable fees and their flat rate cousins are the need to retain sufficient spatial and temporal details about vehicle use in order to structure a revenue collection program that implements the variable fee. Although early work on mileage fees attempted to design options that would not require the use of vehicle positioning technology, it turns out that spatial details are needed in order to efficiently and accurately administer a simple flat rate fee program.

1.4.1 Road Usage Charge Pilot

An examination of the operating requirements for the Oregon Road Usage Charge Pilot Program reinforces this basic understanding. Both the System Requirements Specifications (2012) and the Open System Architecture Model (2012) clearly provide for a set of technical and administrative systems that support an evolution in charging policy that includes the potential for fees that vary by time of day, location, and vehicle characteristics.

The significant advantage of this compatibility between the variable fees of an efficient fee system and the systems that are to be used for flat rate mileage fees are fairly obvious. A single back office and technical platform offers considerable cost savings with respect to both eventual revenue operations and for the implementation of pilot studies and trials.

Road management and surface transportation policy do not exist in isolation from other aspects of urban systems management. It is therefor important to consider an efficient road usage fee program in light of a range of other policy interests and objectives. Some of these are discussed in this paper, but all of these can be evaluated further as a result of a pilot project implementation.

1.4.2 State Land Use Objectives

Computer simulations of comprehensive congestion pricing policy have demonstrated that a comprehensively-applied congestion pricing system can favor the CBD and major centers, and discourages diffused suburbanization of economic activity. However, such simulations are necessarily very abstract, and may or may not faithfully capture the real-world response to congestion pricing.

1.4.3 Oregon Sustainable Transportation Initiative and GHG goals

An efficient road use fee is uniquely suited to support the major goals of the Oregon Sustainable Transportation Initiative. The reason is that an efficient fee for road use will have broad effects on how urban systems interact with each other. As a starting point an efficient fee addresses reoccurring congestion on major roadways. Less congestion results in travel time-savings that get capitalized in the broader economy. The production possibilities for the Oregon economy are thus improved. The improved performance of the urban road network also reduces greenhouse gas emissions as moderate speeds are maintained even during peak travel periods. In addition, as discussed above, an efficient transportation fee will influence the spatial pattern of the economy and naturally support more compact use of desirable urban land without resorting to regulatory approaches that can be overly prescriptive or crudely applied.

1.5 DEMONSTRATING AN EFFICIENT ROAD USE FEE

To demonstrate the operation of an efficient road use fee it is envisioned that a group of participants will be recruited from the population of Oregon residents. These participants will have their vehicles equipped with mileage fee metering devices for the duration of the demonstration. Participants will drive normally during a baseline data collection period. This baseline period will establish the driving patterns for each household. During the experimental period of the demonstration project the participants will be exposed to the efficient fee. All the major operations aspects of an actual mileage fee will be implemented and tested including, the back office functions, payment processing, and customer services. Many of these functions are already in operation to support the Oregon Road Usage Charge program. Participating households will not be asked to pay the fee out of their own pockets, but they must also face an actual incentive to align their driving behavior with the hypothetical mileage fee charges. To accomplish this objective the project will provide participating households with a travel budget account out of which mileage fees will be deducted. The incentive is realized because participating households are allowed to keep whatever balance remains in their account at the end of the experimental period.

Such a demonstration allows for a rich evaluation of driver behavior, support the estimation of revenue yields from alternate mileage fee policies, tests the operations of the set of systems design to support implementation, permits the examination of how local option taxes could get included in a mileage fee, and tests are range of important topics (e.g. privacy, equity) that relate to policy. A successful implementation of a demonstration project such as this adds considerably to the inventory of knowledge about mileage fee viability and design and should be of interest to a broad set of stakeholders and levels of governmental management. The technology being deployed for the Oregon Road Usage Charge Program meets all the basic requirements for a variable fee pilot program. Building on the implementation of the Road Use Charge Program represents a prudent approach to planning for the technical systems of a variable rate fee program as these technical systems will be proven and improved as a result of an extensive trial implementation period.

1.5.1 Technology and Experimental Design

Standard practice in electronic tolling involves the use of relatively simple in-vehicle radio tags, or transponders (e.g., FasTrak or E-Z Pass). The radio tags contain a unique electronic signature that is communicated to roadside equipment as the equipped vehicle drives by. This electronic toll collection approach has been used successfully since it was first introduced in the late 1980s. An efficient road use fee program would require that vehicles be located in space and time so the fee can also very across these dimensions. The technical implications of these requirements are discussed in the body of the paper.

The dominant feature of the proposed demonstration project is that it will make use of volunteer participants in order to test a full range of important aspects of an actual efficient road use fee implementation. This is in contrast to some kinds of technical demonstration that are intended to prove out new technical system, often involving test facilities and technicians and test professionals.

Demonstration projects that aim to understand consumer behavior must also adhere to scientific standards (experimental designs) that allow for useful analysis to be performed at the conclusion of the study operation.

1.5.2 Geography

The geographic locus of an efficient fee pilot program would follow from the fee structure that is employed. As variable fees for road use by time of day and location will be a large component of the efficient fee, its demonstration will require a location that currently experiences some considerable congestion of the road system. Other factors that might influence the location of a demonstration include the budget available to cover a larger or smaller extent of the road network and its users. Budget for such a demonstration will be driven by participant costs (recruitment, management, equipment, and endowment) and will be somewhat linear with the number of participants. To the extent that sub categories of participants are to be examined independently the sample size requirements will increase which may limit the geographic extent of the experiment. Three aspects of geography are covered in the paper, mileage fee coverage, road network details, and the geography of participant recruitment.

1.5.3 Management and Budget

A variable rate road fee pilot project will be a complex undertaking and require a strong operational partnership from key stakeholders. These key stakeholders include Metropolitan Planning Organizations, various departments of the State of Oregon (at a minimum ODOT but possibly including other departments responsible for revenue collection, vehicle licensing, and enforcement), and the Federal Highway Administration. It is also true that the operation of a variable fee demonstration will require the partnership to be extended to private vendors in order to get the best value from the program operation. The key to the effective management of vendor participation is a clear division of responsibilities that is guided by the particular strengths of each party.

The largest costs for an efficient fee pilot project are likely the costs to implement the technical systems that levy charges and collect behavioral data. Once again it is worth pointing out that building on the approaches taken for the Oregon Road Usage Charge Program can yield significant cost advantages over designing a system from the ground up. Other costs associated with a behavior experiment might include higher costs for participant management, funding travel endowment accounts (should this be included in the experimental design), and the costs of behavioral analysis at the conclusion of the pilot operations. When the Oregon Road Usage Charge Program is significantly underway it will be feasible to develop a more detailed estimate of the costs to implement a variable rate pilot.

Based on the implementation of the Traffic Choices Study in the central Puget Sound region, and other related projects (ODOT, Netherlands) it is possible to develop a preliminary sense of the implementation costs. A pilot project with a two-year duration and involving around 1000 participants might cost between $3 million and $4 million. There may be possibilities for cost savings, but it is unlikely that the project, as specified, could be done for as little as $2 million. Similarly, these estimates are based on an actual study that is similar: they are unlikely to be more than 50% too low, so it is unlikely that the project would cost more than $5 million.

1.6 NEXT STEPS

A well-designed demonstration of variable fee is major undertaking technically, politically, and financially. This kind of effort progresses incrementally. This paper is one first step. The next step would be to build upon the success of current efforts to implement road usage charges in Oregon. Additional steps toward a practical implementation of a pilot project involve developing clear objectives, coordination with other entities and interests and securing the appropriate authorization and funding. These include:

1. Demonstrate variable rates by building on the success and technical implementation of the current mileage fee program
2. Develop a clear message that explains why a pilot project is useful
3. Include local governments and MPOs in planning

4. Secure authorization and funding
5. Ensure accountability with clear expectations about results

2. HIGHWAY FINANCE INNOVATION IN OREGON

In the 2001 Oregon Highway Cost Allocation Study, the concept of efficient fee-based cost allocation was introduced. Instead of estimating costs imposed by forecasting highway-agency expenditures and then allocating those expected expenditures to vehicle weight classes, the efficient fee approach forecasts the revenues that vehicles in each weight class would pay if a set of revenue instruments were to charge each vehicle for the costs it imposes for each mile it travels, given the time and place of travel and the weight and other characteristics of the vehicle. In 2011, an efficient fee study was conducted in parallel with the traditional study and the efficient fee approach was carried through in as much detail as possible, given the availability of relevant data.

This issue paper addresses how Oregon might go about demonstrating a program to convert its Highway Fund revenue instruments to efficient fee instruments. The state of Oregon has considerable history with the implementation of road use charging demonstration programs. The current status of the Road Usage Charge Pilot Program, and the history of related efforts is summarized in the ODOT report Road Usage Charge Pilot Program 2013 & Per-Mile Charge Policy in Oregon. Another important effort with which the authors are deeply familiar is the Traffic Choices Study (a variable rate road charging trial) conducted in Seattle, WA in 2006. Together these two efforts constitute significant "local" knowledge regarding how to effectively design and implement road charging pilot projects.

2.1 SB 801

Senate Bill 810, passed by the 2013 Legislature, creates a program whereby up to 5,000 motor vehicles may volunteer to pay a per-mile road usage charge of 1.5 cents per mile and receive a refund of Oregon fuel taxes paid. The program will begin in July 2015.

Participants would break even if their vehicles averaged 20 miles per gallon (MPG), which is close to the light-vehicle fleet average in Oregon. Of the up to 5,000 participants, no more than 1,500 may be expected to average less than 17 MPG and no more than an additional 1,500 may be expected to average between 17 and 22 MPG. In other words, if there were 5,000 participants, at least 2,000 must be vehicles that would be expected to pay more under the per-mile charge.

Revenues from the per-mile road charge would be deposited in the Highway Fund and 30 percent would be distributed to counties and 20 percent to cities. These are the same proportions currently used to distribute fuel tax and other Highway Fund revenues to local governments.

The legislation does not specify the details of how the fee would be administered. ODOT and the Road User Fee Task Force establish methods for recording and reporting numbers of miles traveled on highways. At least one method must not use vehicle location technology. Participants would be allowed to select a method from the approved list. ODOT also will establish reporting periods.

The legislation does require that participants' privacy be protected. ODOT, its service providers, and their subcontractors will be prohibited from disclosing personally identifiable information except as required by valid court order. Location and daily metered use information must be destroyed within 30 days after payment processing or dispute resolution is completed unless the participant consents to longer retention. There also will provisions for dispute resolution and refunds.

2.2 2006 ODOT ROAD USE FEE EXPERIMENT

The program authorized by Senate Bill 810 will not be Oregon's first. In April 2006, a smaller pilot program was launched. It included 285 vehicles, 299 drivers from 221 households, and two service stations in Portland and lasted for 12 months.

The pilot study used in-vehicle devices that used location data to determine whether the vehicle was in the Portland metropolitan area, which had a higher per-mile rate during peak periods. Location information wasn't stored or reported. The devices interacted with equipment at the participating service stations to add the per-mile charges to the fuel bill and allow the removal of Oregon fuel taxes from the bill.

The study concluded that implementing a similar fee statewide would require $32.8 million of startup capital expenditure for infrastructure, not including the devices in taxpayers' vehicles. The devices used in the pilot cost $547 each, but a mass-produced device would cost far less. Annual operating costs for communication, administration, and enforcement were estimated at $1.6 million.

The 2006 study concluded that:

- Paying at the pump works. Liquid-fuel vehicles need to visit the pump anyway, the pump is equipped to collect payment, the pump knows how much fuel tax to credit, and the on-board device and communicate the amount of the mileage fee to the pump. Other arrangements might work better for all-electric vehicles.
- A mileage fee could be phased in. It could be required for new vehicles and older vehicles could continue to pay the fuel tax.
- A mileage fee could integrate with the point-of-sale systems in place at gas stations and with the State's fuel tax collection system.
- Variable pricing options are viable. The pilot tested a very coarse two-zone system, which proved that geographic location can be used to determine the appropriate fee level without telling the State where the vehicle is traveling.
- Privacy can be protected. The only transmitted and centrally-stored data needed to assess mileage fees are vehicle identifier, miles by rate, and gallons purchased.
- The system would place minimum burden on businesses.
- The potential for evasion is minimal. Tampering with an on-board device would result in payment of the fuel tax.
- The cost to the State of implementation and administration could be low and the ongoing administrative cost would be comparable to the ongoing cost of administering the fuel tax.

2.3 FUTURE OF ROAD TOLLING PAPERS

ODOT commissioned a number of important papers on topics relating to the future of road tolling in the state of Oregon. These papers were developed over a number of months beginning in 2009 and also include a report on pricing proposals for the Portland region. The reports address such topics as the role of pricing to support greenhouse gas reductions, the geographic and situational constraint on tolling, the sufficiency of travel models to support tolling analysis, the evaluation of reliability benefits from tolling, the general economic appraisal approaches and methods for analyzing toll projects, and specific guidance on conduction benefit-cost analysis. These white papers and reports together address a broad range of issues relevant to the design and implementation of a variable rate road use pilot project. Specific references to select findings from these reports are included in other sections of this paper.

2.4 TRAFFIC CHOICES STUDY

Other related work has been conducted just north of Oregon in Washington State. In 2006, the Puget Sound Regional Council, the designated metropolitan planning organization for the Seattle, Washington area, conducted a pilot project to determine how travelers would change their behavior in response to variable charges for road use. The Traffic Choices pilot project placed GPS-based tolling meters in approximately 500 cars belonging to 275 participating households. It observed detailed driving behavior before, during, and after tolls were charged for the use of major freeways and arterials in the Seattle area. Tolls were charged between mid-2005 and mid-2006. Participants were given account balances that would leave them with $75 at the end of the study if they did not change their behavior. If they did change their behavior in response to the tolls, they would be as better off as if the tolls were paid from their own money, in addition to the $75. Due to the significant overlap between the Traffic Choices Study and the characteristics of an efficient fee for road usage, the design of this study and its results are referenced and summarized throughout this paper.

3. WHY CONSIDER A VARIABLE FEE

3.1 LIMITATIONS OF A FLAT FEE

Most of the public revenue sources that help pay for the transportation system do not increase with increased system use. Signals about the cost of transportation at the time it is consumed given by the prices charged at the time of consumption are misleading. They do not give a message that decreases driving when roadway capacity is most compromised, and revenues to increase capacity are not forthcoming. As a result, vehicles exceed the capacity of many miles of roadways for several hours each day; in other words, the result is that use exceeds free-flow capacity, that demand exceeds supply, and that roads are congested.

The current transportation system is financed through a combination of use-related taxes and fees, and broad taxing instruments that have little relationship with transportation system use. Most existing use-fees are scaled to recover some set of costs by applying an average charge to all similar users. The fuel tax is an example where the cost to the consumer of fuel is an average cost tax on fuel by volume.

But in reality, the costs imposed by users vary considerably over time and space. Most important, the costs each new vehicle entering a crowded road during rush hour imposes on the existing stream of vehicles may be very high. The costs that same vehicle imposes on the operation of the system, and the other users on that same road at 11 o'clock at night, may be very low. The premise of congestion-based tolling (also called peak-period or variable pricing or tolling) is that this incorrect pricing leads to an over-consumption of certain types of transportation services (i.e., congestion) and an under-consumption of other transportation services. Correct pricing can reduce this problem.

Conventional road finance exacerbates rather than ameliorates the problem. A low charge on all mileage allows excessive congestion during peak periods. While the congestion prompts road authorities to build new capacity, the low charges cannot cover the costs.

Building a political coalition to raise the tax on fuels, or to increase a flat rate fee structure more generally, is difficult. Since congestion in urban areas prompts expensive capacity enhancing projects the low average fee for road use rarely generates sufficient revenue to cover these costs at a local level. Likewise maintenance costs for low use rural roads may need supplemental funding other than what might be raised from a tax on fuels. This raises concerns over taxpayers in one jurisdiction playing for projects in other settings. Even when these concerns are unfounded the perception of this issue can be enough to thwart a political effort to increase road funding.

Currently there is considerable interest in replacing the tax on motor fuels with a flat rate mileage fee. Such a fee would address the problems of declining revenues associated with improvements in the fuel efficiency of the vehicle fleet but would still suffer from the many other limitations of a flat rate fee structure.

3.2 VARIABLE MILEAGE FEE CAN RAISE THE RIGHT AMOUNT OF REVENUE

Variable pricing, based on peak periods of use, is a common form of pricing in other industries. It is used when capacity is fixed in the short-run, and demand fluctuates significantly between the peak and off-peak periods. Before cell phones, phone companies used peak-period pricing to encourage consumers to shift their use of the fixed capacity of the phone system to off-peak hours (e.g., by charging lower rates evenings and weekends). Some energy utilities use peak pricing. So do theaters. Economists recommend congestion pricing of roads for the same reason private firms use peak-period pricing: to use available resources more efficiently.

How would such pricing work for roads? Imagine that the vehicle you drive could tell a computer what road it is on, and at what time. Location and time correlate to the amount of congestion and delay you are experiencing. Higher (variable) prices during peak periods would encourage you, or travelers with less pressing needs, to shift to other routes or times.

That system has many advantages. By charging selectively at certain locations and times, one can influence the amount of congestion during peak periods. Variable tolling could reduce the immediate need for building new highway capacity. By knowing where people are willing to pay tolls, planners would have a direct measure of where to build more capacity: namely, where drivers are willing to pay high tolls because the travel is so important to them. When those signals suggested that new capacity would be beneficial, the accumulated toll revenues would provide money to pay for those improvements.

Fairness could also be improved, as revenue is collected from those who burden capacity directly.

Ideally, variable tolling would apply to all roads in a region, and efficient tolling would be based on costs that vary by volumes on the roadways, vehicle type, facility, and distance. Less comprehensively, it could be applied selectively to certain facilities or vehicle types (e.g., heavy vehicles). Either would be more efficient than current approaches to finance, which are a combination of semi-efficient pricing (fuel taxes, parking charges, mileage fees) and indirect charges (registration fee, general taxes, ramp metering).

Why would such a practice be more efficient? Within regions with relatively mature transportation systems, peak-period demand also drives the need for new investments in roadway infrastructure. Urban transportation systems are sized and built primarily in response to peak-period use. If consumers (travelers) do not perceive the full costs their travel imposes on the system (reasons to be provided shortly), they will consume too many trips. Peak trips are incorrectly (non-optimally) priced, and the price distortions lead to increased cost to the region in the form of congestion delay and wasted resources. Where traffic conditions are unstable (high vehicle densities) the delay imposed on subsequent vehicles from added vehicles can be quite high and can continue to be experienced long after the vehicle in question has exited the congested segment of roadway.

If individual drivers were to be made responsible for the actual costs that their travel decision imposes on society some drivers might not make the same travel decision as when they experience only the average variable costs of travel (their own travel time). The essence of congestion pricing of roads is that drivers should pay for the aggregate delay they impose on other drivers. If they are not asked to pay these costs, they will each make travel decisions that collectively result in a lot of lost time for all travelers.

The benefits of road pricing are the reduction in social costs in the form of higher speeds/less travel time. The toll revenues are a transfer from road users to the system operator. It is generally the case that the toll revenues are larger than the user benefits, implying that road users (as a general class) will be made worse off under road pricing unless the revenues are used wisely and in a manner that benefits those who pay the tolls.

To understand why peak-period tolling can yield savings, it is necessary to understand the role of pricing in rationing capacity costs. Consider the case, for example, of a movie theater operator deciding how much seating capacity to build in his theaters. The market for theater tickets exhibits wide swings in demand (not unlike a freeway); if the theater owner builds to fully accommodate the peak demand, he runs the risk that he will have a glut of capacity most of the time: capacity he often cannot sell to recover costs. Conversely, if he builds only to accommodate the off-peak demand, then he will have problems of too little capacity in the peak, leading to queuing by customers ("congestion") and lost revenues. In either case, the company's resources or the customers' resources (or both) are wasted.

The solution is to allocate the costs of the capacity to those customers who require it (and are willing to pay for it) by charging more during peak periods than off-peak periods. This strategy rations the expensive, peak capacity, making sure it is not overwhelmed by users who are unwilling to pay, while generating the extra revenue needed to defray the costs of the extra capacity that the company has built to accommodate these customers. In addition, charging peak prices makes it easier for the company to determine how much capacity to build over time based on whatever the peak-period customers are willing to pay.

3.3 VARIABLE FEES REDUCE CONGESTION, WHILE RAISING NEEDED REVENUE

Highway authorities may worry that the short run pricing perspective will not address the issue of how to pay for the investment in the roadway itself. In fact, however, if road pricing and investment policies are managed correctly, congestion charges will generate enough revenue to finance capacity throughout time. The logic of this conclusion is important, and worth elaborating upon. The key point is that pricing and investment are both focused on balancing user costs and benefits. The congestion and wear-and-tear increments of short-run prices actually do indicate the value of new or improved capacity:

If the congestion component of short-run prices is high, it is because traffic delays are great and added capacity (which would relieve the congestion) is more likely to be cost-beneficial. Similarly, if the wear-and-tear costs are high, it is because the roadway is vulnerable to traffic loads and, hence, a project to improve the road's durability would be more likely to be cost-beneficial.

Investment policy itself balances these benefits against the cost of developing the facility. In this manner, congestion tolls and road building costs are related when tolling is properly integrated with decisions to build new roads. Roadways should be improved as long as the cost of serving additional vehicles with the improved road is less than the cost involved in serving them on the existing roads (indicated by the congestion price). Congestion tolling dovetails with a benefit-cost based approach to highway investment decision-making.

Tolling existing roads with appropriate efficient fees makes it easier to identify the road segments that are candidates for improvement: those on which the congestion prices are high, relative to the cost of defraying roadway improvements in that corridor. And congestion prices help moderate congestion in the first instance, and reduce the "false" signals sent by unpriced, congested roads.

The Traffic Choices Study in Seattle offers an opportunity to better understand these phenomena. With 275 households paying road tolls every time they used individual roads in the central Puget Sound region, it was possible to gain some insight into which roads users are willing to pay to use. Since the Traffic Choices Study offered the participants the opportunity to retain funds for avoiding the highest demand facilities that were their preferred choices, those facilities that generated the most revenues represent a truly high value service. The 275 households paid over $275,000 in road tolls during the 10 months of toll operations. Just over 5 percent of the tolled road network (centerline miles) generated 50 percent of the toll system revenues (Exhibit 1.1)

During peak driving times it is no surprise that key multi-lane limited access facilities carried the largest volumes of traffic, and as a result generate sizable revenues when operated as toll roads. These same facilities, designed for high speeds under less than capacity loadings, are notably congestible when demand is high. While a few roads generated half of the toll revenues during the course of the study, the other half of the revenues were generated on a larger number of secondary roads distributed throughout the core urban network. This has at least two important implications for any system of toll roads that focus on the limited-access facilities; 1) failing to include secondary roads in the tolling network represents a sizable loss of revenue opportunity, and 2) of arguably greater importance, failing to appropriately toll the secondary roads will result in traffic diversion onto those roads and result in a loss of revenue and significant degradation of service quality. Traffic diversion may be a particularly onerous problem in environments (such as the greater Portland region) where bus transit systems move large numbers of people during peak travel hours using the secondary road network.

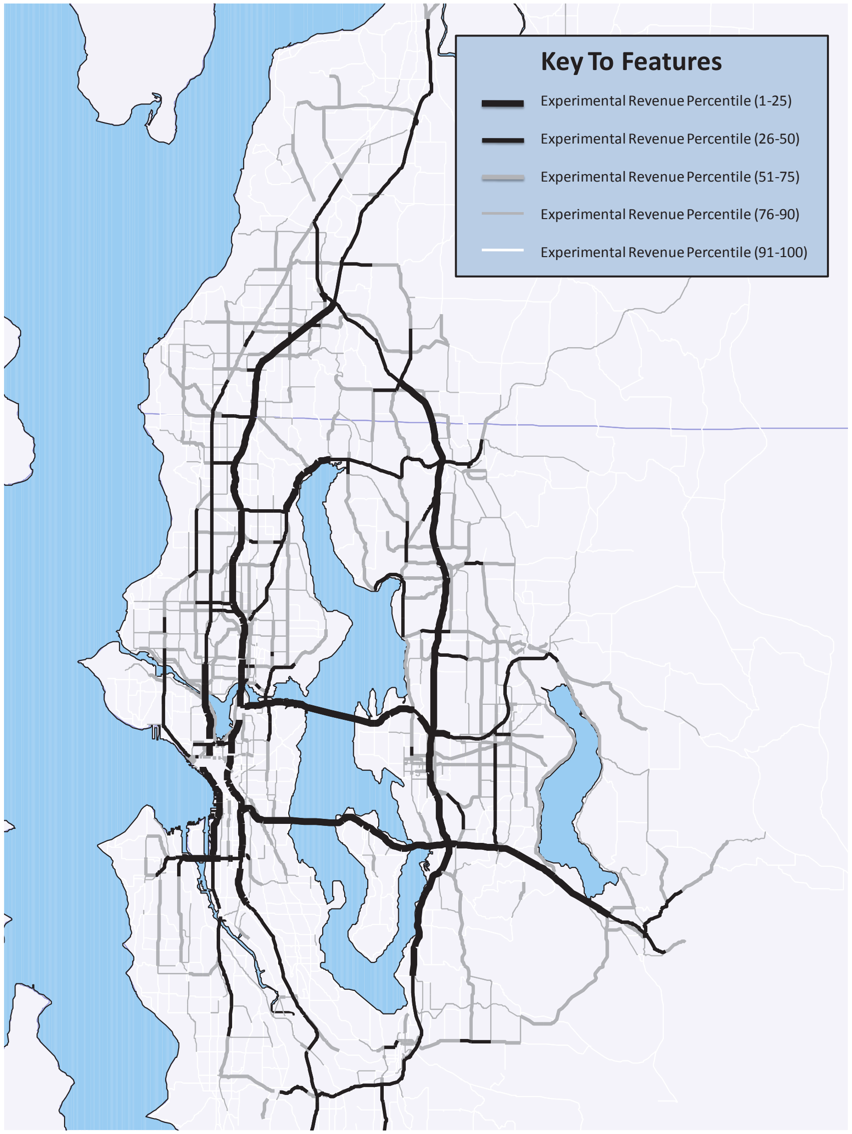
At some point, of course, as new capacity is added to an under-built roadway, the spillover costs (and thus the appropriate congestion price) are reduced, so it becomes cheaper to serve travelers without additional improvements. Thus, the theoretical decision rule is that roadways should be improved until the congestion price is equal to the incremental improvement costs. On a roadway that is neither under-built nor overbuilt, the price calculated from the construction and operating cost of new capacity or from the congestion penalty are the same.

Batten and Pozdena demonstrated this empirically for the state of Oregon in 2000 as part of the Oregon Highway Cost AllocaRon Study (HCAS) process. They emulated efficient tolling statewide, using available data on roadway utilization to project loads and associated tolls for the entire, State system. For the State system as a whole, total revenues collected were not vastly larger under efficient tolling. This suggests that (a) the system, as a whole, is not significantly underbuilt and (b) reform of tolling could occur without imposing toll costs that are, in the aggregate, very different from the current fuel tax, weight mile and registration fees levied today.

In the absence of road pricing, the use-based revenues to road authorities are generally not sufficient to support the kind of infrastructure investment agendas that are a product of the political process. As such, infrastructure investments are underwritten by general taxes. Under these circumstances, travel delay due to congestion becomes the limiting factor that brings the market into some kind of balance. The consequences of this inefficient equilibrium in terms of lost resources are significant.

If financing of highways through road use charges is to become a more generally usable approach it would need to be responsive to a dynamic set of performance and investment conditions:

Exhibit 3.1. Toll Revenues From Traffic Choices Study by Facility



Source: Puget Sound Regional Council, ECONorthwest

- Tolls are levied on existing capacity based on the costs the user imposes. As vehicle use in a corridor increases so do the toll rates; which manages growth in congestion.
- Revenues accrue over time and capacity is added where and when revenues are sufficient to justify investments.
- Cost-based toll rates can be lower after capacity is added since the tolls are not designed to meet a revenue target.
- Alternative routes also have cost-based tolls and so diversion is minimized and revenue yield is easier to predict.
- The entire enterprise is a sound platform for long-term investment and growth.

3.4 VARIABLE FEES REDUCE THE "NEED" FOR EXPENSIVE CAPACITY IN URBAN AREAS

In the absence of road pricing, the incremental revenues to road authorities (government) are not sufficient to support the kind of infrastructure investment agendas that are a product of the political process. As such, infrastructure investments are subsidized by general taxes, reinforcing inappropriate pricing, which signals leading to user demand exceeding supply (congestion). Under these circumstances, travel delay due to congestion becomes the limiting factor that brings the market into some kind of equilibrium. The consequences of this inefficient equilibrium are significant. The European Conference of Ministers of Transport published a research report entitled *Assessing the Benefits of Transport*[2] in 2001. An excerpt from the executive summary of this report reads as follows:

Depending on the circumstances, there can be a net extra benefit from the wider economic effects, which therefore will strengthen the case for an infrastructure investment (road, rail or other, according to local conditions), provided it actually delivers its promised improvements in costs, speeds etc. In other conditions, however, wider economic benefits may be more effectively achieved by transport initiatives other than infrastructure investment (for example traffic management, infrastructure pricing, etc.). In general, where there are distortions in pricing, it is better to correct the prices than to develop investment projects based on the existing prices.

[2]http://internationaltransportforum.org/europe/ecmt/pubpdf/01Benefits.pdf

In short, optimal investment procedures involve benefit-cost assessments in which all appropriate marginal costs and benefits of an investment are counted. A properly specified benefit cost analysis provides useful information about the potential societal gains associated with undertaking the transportation investment. Ideally, all cost-beneficial investments are implemented that are affordable, within some reasonable budget constraint. Investments that are not established to be cost beneficial would not be implemented unless some other overriding policy objective, not accounted for in the benefits analysis, is realized. In which case, the reason for making an otherwise low benefit investment would be explicitly understood by everyone involved in the decision process.

If congestion under unpriced conditions is the wrong signal for investment then implementing variable fees for road use must by definition reduce this costly congestion even in the absence of new road investments. Experiments and real world application of congestion-based fees have demonstrated this to be true. As is stated above, the new revenue will be a much better investment signal than congestion levels on the roadways – and investments will be justified. What is likely is that the investments in new road capacity that are justified will be in smaller increments and at later points in time than would otherwise be the case absent variable road use charges. Smaller increments of investment and the ability to implement these investments later represent real resource cost savings for the state of Oregon.

3.5 LONG-RUN: BENEFITS OF VARIABLE COST-BASED FEES ARE HIGH

The promise of an efficient road use fee is that many of the most difficult aspects of surface transportation management are improved considerably. These management challenges relate to cost recovery, fairness, and pollution and congestion externalities. Each of these can be improved upon through the implementation of road usage fees that 1) more closely reflect the costs that users impose and 2) facilitate better asset management practices amongst road authorities.

The potential for gains is considerable. An estimate was developed of the benefits from implementation based on generalization of results from the Traffic Choices Study in Seattle. The direct benefits to transportation system users that result from a network application of road pricing are sizable, and dominated by the value of travel time savings benefits. These are an estimate of the social welfare, or “efficiency”, benefits associated with the correct pricing of congested roads.

Exhibit 3.2 displays the benefit and cost findings from this analysis as well as the value of the toll transfer. The present value of the time savings benefits is well over $36 billion, with total implementation and operating costs of approximately $5.5 billion. The net present value (benefits less costs) of the benefits to society from implementation of this network wide scenario of road pricing is estimated in the range of $28 billion. Over the implementation period for this scenario the present value of toll revenues is estimated at $87 billion.

The direct benefits to transportation system users are sizable, and dominated by the value of travel time benefits. These are an estimate of the welfare, or “efficiency”, benefits associated with the correct pricing of congested roads. While the experiment was an approximation of optimal pricing policy, a number of important observations can still be made.

First, those who benefit most from network tolling are users with high values of time (higher income motorists and trucks). Transit users and occupants of high occupancy vehicles all realize benefits from tolling as well. Second, the toll revenues that result are considerably larger than the direct user benefits. This is to be expected, but emphasizes the importance of using those revenues to provide further benefits to the road system users. The third point follows from the second: this analysis makes no assumptions about the use of those revenues; which might be used to make improvements to the transportation system (leading to further user benefits) or to offset other taxes and fees (a transfer directly back to the users that also eliminates welfare losses associated with the taxes and fees).

The revenues from network road tolling, in this analysis, are in excess of $13 million (year 2008 dollars) per average weekday. Once again, these may not be optimal toll rates, where the rates that result in the greatest net benefits to society may generate either higher or lower revenues than those analyzed here. Based on 260 weekdays of tolling; the scenario results in more than $3.4 billion in gross annual revenues. As a comparison, all the transportation agencies in the central Puget Sound region collected

Exhibit 3.2. Benefits and Costs of Network Road Pricing

Present Value Benefits/Costs	Millions of 2008 Dollars
Benefits	
Time Savings	$36,600
Reliability Benefits	$4,500
Operating Cost Savings	$2,500
Toll Effects on Consumer Surplus	-$97,100
System Operator Benefits (Tolls)	$87,000
Present Value of Benefits	$33,600
Costs	
OBU Costs	$1,500
Enforcement	$100
Central System	$500
Data Communication	$3,300
Other	$100
Present Value of Costs	$5,500
Present Value of Benefits less Costs	$28,200
Benefit-to-Cost Ratio	6.1

Source: Puget Sound Regional Council, ECONorthwest

approximately $3.1 billion in transportation related revenues (revenues used for transportation expenditures) in 2005.

Absent the rationing of supply based on willingness-to-pay (tolling), it is very difficult to gauge the ideal level of investment in transportation supply. But it appears that network tolling revenues are sufficient to replace all non-use fee forms of transportation revenues currently used to invest in the road system, and would still leave considerable revenues left over for road improvements, and the support of transit or other service operations on the road network.

The user benefits are large, but the toll revenues that result are considerably larger. This is to be expected, but emphasizes the importance of using those revenues to provide further benefits to the road system users through reinvestment, or rebating other taxes and fees.

Congestion-based tolling generates revenues for investment but also limits the wasted time resources associated with overconsumption of scarce peak period roadway capacity. So, a full accounting of the costs and benefits of road tolling compares the implementation and operating costs of the program with the full benefits of more efficiently allocating road space resources. The tolling revenues themselves are treated as an economic transfer since the revenues represent a cost to road users and a benefit to the toll system operator. In the case of public sector management of a tolling system, the revenues could be expected to be reinvested in the transportation system or used to offset other taxes and fees that support public investments.

Under the implementation scenario outlined above, the tolls paid by users and collected by the operator exceed the value of the user benefits. This is expected under all but the most congested pre-tolling road network conditions. If toll revenues are somehow squandered, the effects on society from road tolling will be negative. This finding reinforces the general conclusion that it is not productive to discuss road tolling without simultaneously addressing the issue of how toll revenues will be used.

4. STILL MANY QUESTIONS TO ADDRESS

Even as long-term benefits from an efficient fee program are clear and large in scale the challenges in implementing such a program are many. Such a fee program represents a large-scale change from existing policy and would involve disruptive transformation for many aspects of surface transportation management and operations. Some of these topics are discussed below.

4.1 HOW DRIVERS WILL RESPOND TO ALTERNATIVE FEE STRUCTURES

One of the most important questions a variable fee demonstration project can address is how drivers will respond to the fee structure. The many efficiency arguments in favor of variable road charges depend upon driver's abilities to substitute lower cost (in terms of social costs of congestion and otherwise burdening the road system) behavior for higher cost behavior. The theory is strong and supported by considerable empirical results but understanding details of driver response is important for designing systems that best meet consumer and road operator needs.

4.1.1 Price Elasticities

The literature on how tolls influence driver behavior is quite large, and estimates of price elasticities (percent change in a measure of demand as a ratio of percent change in price or toll costs) vary based on specific circumstances and the timeframe over which behavior is observed.

The Traffic Choices Study in Seattle was possibly the largest scale controlled experiment of tolls being applied to an entire regional network. Elasticities from this study are a useful starting point for understanding the behavioral response of drivers.

The Traffic Choices Study provides the best currently available measures of actual consumer behavior change in response to region-wide variable congestion pricing. Across all households and all trip purposes, the following changes were observed:

- 7 percent reduction in all vehicle tours (tours per week)
- 12 percent reduction in vehicle miles traveled (miles per week)
- 8 percent reduction in tour drive time (minutes of driving per week)
- 6 percent reduction in tour segments (segments of tours per week)
- 13 percent reduction in miles driven on tolled roads (tolled miles per week)

Household elasticities of demand with respect to vehicle operating costs were in the range of -0.05 to -0.15 and are consistent with other empirical estimates. In the economics this range of response is termed inelastic meaning the change in demand is less in percentage terms than the change in prices. And while travel demand is generally understood to be inelastic this should not be interpreted as there being only a modest opportunity to improve the efficiency of the system. To the contrary, the behavioral response to prices for road use are consistently observed and the magnitude of changes in traffic conditions can often mean the difference between a breakdown in the performance of high use roads and free flowing traffic. A more detailed discussion of the analysis and findings from the Traffic Choices Study data can be found in Appendix 1.

4.1.2 Traffic Diversion

A potential concern with road tolls involves the amount if traffic that avoids paying tolls by driving on secondary facilities, or diversion. These concerns were evident in the analysis of toll road projects (NW Cornelius Pass Road and Oregon Highway 217) that were part of ODOT's congestion pricing study resulting from HB 2001. In these cases the projects being evaluated even performed poorly in terms of financial viability due to the toll policies and prevalence of attractive diversion routes. Technically diversion can involve traffic on secondary roads but also can involve trips diverted off the tolled road and made by another mode, or even time of day in the case of time varying toll rates. An important feature of an efficient road fee is that the fee applies to secondary roads as well. One aspect of a demonstration project is to better understand how fees could get structured and managed over time in order to minimize diverted traffic. For example in Germany the heavy vehicle fee program has added roads to their charging network over time as these roads experience increased in traffic and congestion. And since an efficient fee is one that mirrors peak traffic flows the worst kind of traffic diversion, diversion from overpriced and underutilized toll roads during off peak driving periods, is avoided altogether.

4.1.3 Response Surface Over Time

Most estimates of driver response to tolls (including those developed from the Traffic Choices Study) are short-run in nature. In the short-run the opportunities for drivers to avoid tolls may be limited while in the long-run substituting toward lower cost behavior is often more feasible. For example in the short-run past decisions regarding home and work locations will be fixed and in the long-run these decisions can take an efficient road use fee structure into account. As a result it is generally agreed that long-run elasticities of demand are higher in magnitude than are short-run estimates.

4.1.4 Compliance/Evasion

Avoidance behavior is a factor in any program that recovers fees for use of an asset or service. There is an extensive literature on avoidance behavior in general and toll evasion in particular. Generally evasion (trying to evade paying the charge when the service has been rendered) will be a function to some dominant factors 1) the opportunity to engage in evasive behavior, 2) the cost of being caught engaged in evasive behavior, and 3) the probability of being caught. An additional factor is the risk tolerance of any given person with respect to being caught and having to pay the penalty. The implication for an efficient road use fee program is that the general systems for ensuring compliance and enforcement must be carefully designed. Individual approaches to compliance and enforcement have various different cost associated with their implementation and operation, so a careful accounting of cost and revenue effects is needed in order to select an appropriate approach.

4.2 WHICH TECHNOLOGIES WILL MEET THE REQUIREMENTS NOW AND IN THE FUTURE?

Choosing a technology that must endure into the future is a challenging exercise. Many efforts to procure technical systems for demanding enterprises focus on functional requirements rather than technical specifications. This allows managing organizations to be clear about their needs without dictating specific technical details to the market for technical solutions. This was the general approach taken the Traffic Choices Study in Seattle (a smaller-scale pilot effort) and was also generally employed in the case of the Oregon Road Usage Charge Program (a larger-scale early voluntary opt-in implementation).

The toll industry is a highly dynamic industry with technical systems that mirror those employed by other information and communication intensive industries. The pace of new technology adoption is fast and the costs of locking into an inferior technology model can be high. These risks are low for a small-scale demonstration project but considerable for full operations. Some specific technical aspects of a fee system operation are discussed in more detail later in this paper.

4.3 HOW CAN PRIVACY CONCERNS BE HANDLED?

Information systems are becoming increasingly complex. As information is collected, stored and used in more and more beneficial ways, there are also increasing concerns over how information that might be considered "private" is managed and protected against malicious use. Road tolling systems with automated tolling transactions that associate the use of roads with an account holder are just one aspect of life that raise issues of privacy protection in the minds of consumers. A road tolling system that collects and stores detailed information about a large extent of the roads visited by all road users is by extension a larger source of the same kinds of concerns. The fact is that a road tolling system, like the one used in the operation of this experiment, collects extensive and detailed information about individual users and their travel behavior. It is impossible to imagine such a system being put into operation without significant safeguards in place to secure personal information. Appendix B discusses privacy and road tolling in more detail.

The questions around privacy protections in part change with respect to the circumstances of the individual whose data requires protection. These circumstances include the following:

- Normal Vehicle Operations – what data is available to whom and under what circumstances in the case of users who are assumed to be in compliance with the fee program?
- Suspicion of Fee Evasion - what data is available to whom and under what circumstances in the case of users who are assumed to be out of compliance with the fee program? And furthermore how is out of compliance determined in the first place?
- Suspicion of Other Crimes – what data is available to whom and under what circumstances in the case of users who are suspected of other crimes and where vehicle use data is considered relevant to a criminal investigation?

Privacy is discussed in more detail in Appendix 2, but it is also useful to think of a pilot program as an opportunity to clarify privacy objectives and standards of practice.

Each of the technologies used for electronic tolling will record data on users' personal travel behavior (if they use a toll road or enter a cordoned area), but the level of privacy concerns vary for each of the technologies. For example, while there is a general concern about theft of the in-vehicle devices or hacking of a user's account, there are fewer concerns with the theft of transponders than with in-vehicle GPS devices, because transponders carry no record of where they've been. On the other hand, transponder-based systems need to store information about where the transponder has been read in a back-end data system, whereas GPS-based on-board units can keep all location data inside the unit, which remains in the user's possession unless it needs to be audited.

Many consumers misunderstand how GPS works and believe that in GPS-based systems, satellites can "see" them and track them as they move around. In reality, the GPS satellites only transmit their identifier and the time. GPS receivers use differences in time to calculate their distance to each satellite they can "see," and from those, calculate their position on the surface of the earth. Acceptance of GPS-based technology will require educating consumers.

People also have privacy concerns related to the use of cameras for tolling. Many people are concerned with the use or sale of personal travel data to entities not directly related to tolling, such as law enforcement agencies, private investigators, or firms seeking to use the data for marketing purposes.

In Germany, the Federal Office for Goods Transport (BAG) is responsible for the truck toll system and Toll Collect is a subcontractor. BAG defines the requirements to be implemented and oversees the data protection policy. Permission to process data for the toll system is provided by the Truck Toll Regulation and the Federal Commissioner for Data Protection and Freedom of Information. Data is processed by the operator, "strictly in accordance with data protection guidelines and exclusively for the statutorily prescribed purpose of toll collection." Personal data are transmitted only to the extent necessary to fulfill toll collection and contract obligations and the transmission of data is performed through authenticated encrypted messages. In addition, the bill itself only contains information about the route the truck traveled, at what time, and the toll the user is required to pay. Law enforcement authorities cannot use this information to determine average speed as the on-board unit does not store any information on the speed of the truck. Billing data are not sold to any third parties. The German system relies on photographs of vehicles' license plates for enforcement; drivers cannot be recognized in the photos. Photos are deleted "within a fraction of a second" for vehicles that are determined to be exempt from the toll.

In the U.S., E-Z Pass customers are assured that all information related to their account, including their financial information and vehicle movement records, will only be used for billing, deducting toll charges, enforcing toll collection laws, or other legal uses as ordered by courts. The latter allowed use has caused some concern, however, as E-Z Pass records were released under court order and used in a divorce trial as evidence of infidelity.

There are many ways to protect the privacy of individuals and to inform them of what data are collected and how the tolling agency and its contractors will use them. With proper planning, education, and technology, the protection of privacy need not be a major roadblock to the successful implementation of congestion pricing systems.

Andrew J. Blumberg of Stanford University, along with several coauthors, has published extensively on location privacy in general and location privacy issues related to tolling in particular. Blumberg argues that systems that create and store digital records of people's movements through public space are an inextricable part of the fabric of everyday life and there will be many more such systems in the near future. He cites current examples such as:

- Monthly transit swipe-cards
- Electronic tolling devices (e.g., FasTrak, E-Z Pass)
- Cell phones
- Services telling you when your friends are nearby
- Searches for services and businesses near your current location
- Free Wi-Fi with ads for businesses near the network access point you're using
- Electronic swipe cards for doors
- Credit and debit card transactions at stores, ATMs, vending machines, etc.

He argues that these systems are innovative and promise benefits ranging from increased convenience to transformative new kinds of social interaction. Unfortunately, these systems pose a dramatic threat to location privacy, the ability of an individual to move in public space with the expectation that under normal circumstances there is no record of their having been there. Society is not likely to stop the cascade of new location-based digital services, nor does it appear that it would want to, as the benefits of such services to users are expected to be substantial.

4.4 WINNERS AND LOSERS; EQUITY IN SEVERAL DIMENSIONS

The primary arguments for road pricing are about improving efficiency and investment policy. Yet many people will wonder if improvements in efficiency will come at the expense of compromises in fairness. Whenever policies change, it creates potential winners and losers, and this would be no less true of congestion pricing of a region's roadways. Transportation services are central features of a regional economy. Consequently, a change in the pricing of highway services will have a mixture of good and bad impacts on certain types of travelers, and on businesses and residents in subareas of the region.

Prospectively judging the fairness of a policy is complex at best, is subjective, and involves considerable uncertainty. Yet potential issues around the distribution of costs and benefits cannot simply be ignored. Yet, what does fairness depend on?

- Value of travel time savings (willingness to pay)
- Income effects ability to pay
- Availability of alternatives
- Uses of the revenues

Implementing congestion pricing means travelers using congested facilities during the peak period will face greater out-of-pocket costs than they currently pay through the gasoline tax alone. (Off peak and night charges, on the other hand likely could be less than they are without congestion pricing if pricing were implemented broadly enough to permit average gasoline taxes to be reduced, for example. Realistically, however, this would require a comprehensive tolling system.) This will cause some diversion of trips to different routes, at different times, by different modes, and may induce some travelers not to travel at all.

Because these adjustments in travel behavior relieve traffic levels on the priced roadway, the roadway offers faster and more reliable travel times to all vehicle types, which may benefit even those who are induced to change their travel behavior. Gomez-Ibanez analyzed the application of congestion pricing to existing roads and identified the most important winners and losers.

There are several important things to note about any accounting of winners and losers. First, some travelers will benefit from congestion-based charging only if the HOV response is good. Those who are "tolled out" of their SOVs, for example, can benefit only if this is the case. This underscores the importance of removing the institutional impediments to increased bus, vanpool and carpool services. It may also argue for use of some of the congestion-based charging revenue to assist transit. Second, the pattern of winners and losers does not decompose directly into rich vs. poor, as is sometime alleged by critics of congestion pricing. Although drivers of SOVs with low time values are the ones most likely to be "tolled off" the road, many may be better off despite this if the performance of the highway-based HOV alternatives improves significantly. Those for whom HOV alternatives remain unsatisfactory, however, will be adversely affected.

Gomez-Ibanez identifies three groups that are likely to be winners:

1. Motorists who would drive with or without the toll but who place a high value on travel time savings (for these motorists the gains from improved traffic speeds outweigh the toll cost);

2. Travelers who would use HOV services on the tolled road whether or not tolls are charged (they benefit from improved speeds while paying little or no toll); and

3. Recipients of toll revenues (i.e., taxpayers if tolls reduce the pressure for tax increases or, alternatively, the clients of government programs if tolls are used to finance an expansion of government services).

Four other groups are likely losers.

1. Motorists who would continue to drive on the road despite the toll but who place a relatively low value on travel time. (Even though the time savings does not compensate these motorists for the toll charge, they may have to tolerate this loss because alternate routes or HOV services are too inconvenient for trips they are making.);

2. Motorists who shift from the tolled road to a competing untolled facility. (The untolled facility is less convenient otherwise these motorists would have used it even in the absence of tolls.);

3. Other users of the competing untolled roadway (since congestion will increase on that road); and

4. Motorists who choose not to make the trip at all because of the toll (or who, with congestion pricing, now drive at a less convenient time of day when the tolls are lower).

One final group may benefit or lose depending on specific circumstances —travelers who switch from driving to HOV or bus services on the tolled road. (Some of those who switch may benefit if the HOV or bus speeds are improved greatly by the tolls, but others may lose if the bus or HOV speed improvements are modest or these modes were fairly inconvenient to begin with).

In this regard, a distinctive feature of congestion pricing is it generates revenue that can be used to offset any such negative effects, by financing transit alternatives where appropriate, or other compensatory actions. Indeed, the reason economists recommend road pricing over regulatory and land use approaches to congestion problems is because it is a policy that has the potential to make everyone better off through prudent use of the revenues generated by the policy. In contrast, regulatory and land use policies produce no revenue, and generally require additional taxation to implement.

The current U.S. practice for recovering costs relating to public expenditures on surface transportation is based on fuel taxes, licensing fees, transit service fares or tariffs, general taxing mechanisms such as sales and property taxes, and the limited application of flat rate tolls applied to selected road facilities (often bridges and tunnels). Most of these mechanisms are either unrelated to the transportation market (the environment in which individuals and firms make consumer and producer decisions), or are based on averaging costs over a wide range of separate cost generating categories. These practices are the particular result of many decades of public financing and provision of transportation infrastructure and services, during which transportation investments were considered to be general public goods. As a result, an ongoing area of analysis has to do with understanding the degree to which various users groups, and tax and fee-paying groups are responsible for the costs of maintaining and investing in transportation infrastructure and services. Often these policy concerns are characterized as issues of horizontal equity, documenting the degree to which cost responsibility and cost recovery converge.

Numerous cost recovery and cost responsibility studies attempt to detail the degree to which there is cross subsidization of transportation costs between different classes of roadway users. The Federal Highway *Cost Responsibility Study* is a periodic analysis that equates cost responsibility with the recovery of national highway financing costs. The results of this analysis are used to evaluate the adequacy and "fairness" of existing "user fees", such as national fuel taxes.

Randall Pozdena examined the specific case of California's road financing structure in 1995 in a paper titled *Where the Rubber Hits the Road*. The summary of this report states the following:

> *Overall, the problem with roadway financing in California is not a lack of funds. The problem is that the available funds are not used rationally. The current system of financing leads to a nine fold under-pricing of congested capacity, and a twofold overpricing of uncongested capacity. As things stand, roadway users pay about two cents per vehicle mile traveled on congested roads, instead of the eighteen cents per mile traveled that they should be paying. Users of uncongested roads also pay about two cents per mile traveled while they should only be paying one cent per mile traveled.*

A recent report commissioned by the California Legislature, ***Financing Transportation in California: Strategies for Change***, authored by Martin Wachs and colleagues, evaluates the future of California transportation finance. The report documents the limits of existing financial instruments, which have increasingly shifted cost responsibility away from users or beneficiaries, and which are facing greater uncertainty in the face of growing tax aversion. The report recommends returning to the primary use of user fees, and in particular mentions toll and variable toll financing. The report also highlights the importance of pursuing innovative finance structures and arrangements including various forms of debt financing and the use of public-private partnerships.

4.4.1 Different classes of heavy vehicles

It is generally understood that the existing approach to levying weight fees on heavy vehicles is imprecise with respect to actual cost responsibility. In Oregon this is less true than in other settings but it is still the case that lighter trucks often overpay with respect to the wear and tear costs they impose and the heaviest vehicles typically underpay. An efficient fee system could eliminate this mismatch by including a fee structure that respects the vehicle gross weight, the number axles and the engineering details of the roads that are being used. The question of measuring loaded vehicle weight raises some additional challenges for an efficient fee program as it would likely require on-vehicle scales that are integrated with the fee charging technology.

4.4.2 Rural v. urban v. suburban

Another set of stakeholders affected by congestion pricing are businesses and residences that are already located in certain urban places. Congestion-based charging influences the value and use of land because it changes the cost of access; some landowners will lose from implementation of congestion-based charges, others will gain. Policy makers also need to know how the land-use effects fit into a region's objectives for land conservation and development. These issues were considered earlier in this paper under land use effects.

4.4.3 Peak v. off-peak

Differentiating costs for peak period versus off-peak period road use is a principle feature of an efficient road use fee program. Recovering cost from the users that impose capacity burdening costs on the state of Oregon is a consequence of implementing such a fee program.

4.4.4 Effects on low-income households

An accounting of the benefits that accrue to users of the transportation system is an important first step in understanding the very large potential merits of network scale road pricing. However, many policy-makers and members of the public will also want to know how those benefits (and the toll burden) get distributed throughout society. Once again turning to the results of the Traffic Choices Study is helpful. The regional modeling of benefits from this study does include, as separate vehicle classes, an accounting of travel for four individual income classes, as well as other classes of users (trucks, transit, other high-occupancy vehicles, walk and bike). Accounting of income classes is reserved for only home-based work single occupant vehicle trips. So, if trips switch modes from auto to transit or vanpool between the base and the policy or investment scenarios, tracing the user benefit implications becomes slightly less precise. However, retaining this user class disaggregation in the calculation of user benefits provides a reasonable approximation of the distribution of benefits across these classes of users. Exhibit 4.1 contains data about the portion of travel time user benefits that accrue to each class of users. The table also displays the portion of the toll burden borne by each user class.

Exhibit 4.1. Daily User Benefits Without Accounting of Revenue Dispensation

User Category	Time	Operating Costs	Reliability	Tolls	Total User Benefits
Drive alone home-based work					
Low-income	-$4,237.55	$2,879.95	$77.89	-$111,459.39	-$112,739.10
Low middle-income	$48,664.48	$12,015.81	-$4,020.51	-$391,627.16	-$334,967.38
High middle-income	$299,562.32	$29,797.01	$15,747.74	-$1,054,050.81	-$708,943.73
High-income	$865,158.48	$46,848.85	$68,841.43	-$1,745,207.90	-$764,359.14
Drive alone non-work	$548,909.37	$121,593.05	$68,872.94	-$4,203,786.37	-$3,464,411.01
Carpool and Vanpool	$339,375.37	$65,697.11	$41,550.26	-$1,978,324.12	-$1,531,701.38
Transit	$156,137.49	$0.00	$0.00	$0.00	$156,137.49
Light truck	$1,524,141.85	$131,363.10	$260,178.98	-$2,147,544.47	-$231,860.55
Medium truck	$557,553.38	$65,040.04	$70,483.24	-$707,268.03	-$14,191.37
Heavy truck	$648,423.62	$50,158.92	$71,483.56	-$861,077.58	-$91,011.49
All Users	**$4,983,688.80**	**$525,393.83**	**$593,215.52**	**-$13,200,345.82**	**-$7,098,047.67**

Source: Puget Sound Regional Council, ECONorthwest

Low income drive-alone users experience a loss in travel time benefits, and low-middle income users experience only modest gains. Trucks benefit significantly under this tolling scenario. It should be noted that the toll policy did not attempt to optimize the truck toll rates based on the costs (congestion, accident risks, emissions, and road damage) that trucks impose as a consequence of their size and weight. Transit users and high-occupancy vehicle occupants all realize benefits from tolling. All users pay more in tolls than they realize in user benefits, implying that all classes of users would be worse off under tolling if the revenues were simply disposed of instead of reinvested or rebated to taxpayers in the form of reductions in other taxes and fees.

4.4.5 Effects on transit providers

The primary effect on transit providers from an efficient road use fee is the improved performance for transit vehicles that operate on previously congested roadways. Other effects would include higher patronage and higher cost recovery opportunities that arise when road usage is more costly during peak hours on urban roadways. If transit vehicles are required to pay the road use fees then these would represent a change in vehicle operating cost. However, these higher operating costs would be small in comparison to the gains from improvements in speed and reliability and increased fare revenues.

4.5 FEDERAL CONSTRAINTS ON TOLLING

A central question is whether an efficient road use fee is considered a tax or fee or a toll. Current Federal constraints on tolling the interstate system of highways would need to be addressed in advance of any implementation. It is unlikely that such constraints would impede the implementation of a pilot study as specific provisions for pilot programs have been in place for some time, and Federal support for exploring alternatives to the tax on fuels is ongoing. It is the variable nature of the efficient fee approach that will need to be explored with Federal partners more fully as interest in this topic matures over time.

The handling of revenue generated on federal highways also would involve determining how revenues get remitted to highway authorities and whether the fees would be inclusive of federal taxes.

4.6 HOW WILL THE ENTIRE ENTERPRISE BE MANAGED

For the purposes of a demonstration project many of the important questions of how best to design and manage an operational program can be put aside for the time being. A demonstration project can be managed in any manner such that the results of the research effort will be obtained while minimizing the burden and cost of administration. At an appropriately small scale, questions about what entity in government or the private sector is best positioned to undertake key aspects of operations are secondary to other aspects of experimental design. This will not be the case for full operations. In this light it may be useful to consider the key elements of an operational program in order to begin to think through the process through which a demonstration might eventually transition into full revenue operations.

4.6.1 Policy making

Policy making for an efficient fee program includes the full complement of operational decisions addressing rate setting, revenue objectives and uses, privacy protections, exemptions or special rules, enforcement and revenue collection methods, and ongoing evaluation and refinements to the program. The key is to have the policymaking body, or bodies, in a direct accountability relationship with system operations. This might imply a tiered approach to itemizing and allocating aspects of policy at various levels of oversight. At the highest level is legislative policy-making and oversight, but many operational policies can be more appropriately placed in the hands of entities that face proper incentives to implement policy that is in the customers' interests. As many aspects of policy will interact with each other in ways that may not be initially obvious, a demonstration project is a useful way to explore and better understand the dynamics between policies and how best to structure a policy development framework for an efficient road use fee program.

4.6.2 Implementation

There are many approaches to supporting the implementation of a road use fee program. Due to the complex nature of the enterprise it is true that the implementation will involve many state agencies at a minimum, and likely private sector entities as well. A pilot program is less exacting in terms of cost efficiencies due to its temporary nature and smaller scale. As a result the details of an implementation strategy may not be fully mapped out in advance of operating a demonstration project and, in fact, may be informed by experience gained through the pilot program.

4.6.3 Collection, enforcement

Appropriate governance of the payment processing, collection and enforcement aspects of an operating program will paly a very critical in determining its success. These are the aspects of a program that touch the customers most directly and are also lines of business that government agencies may not have sufficient experience to take on themselves. These are opportunities for partnering with other organizations that specialize in customer service and the unique technical requirements for cost effective payment processing.

4.6.4 Role of local governments

Local authorities will have a keen interest in an efficient fee program design and implementation. Local authorities are recipients of state road use revenues and also experience considerable traffic and road use effects associated with the current system of fuel taxes. Changes in the fee structures will result in changes in traffic patterns, by time, location and vehicle type. The patterns of revenues that are remitted to local authorities would also likely change as cost responsibility is more closely adhered reflected in the fees. For all these reasons local authorities should be included early on in the process of developing a pilot program. Pilot projects afford the opportunity to make advances in implementation without overdue burden of process so long as all interested parties understand clearly what the pilot it intended to accomplish and how they will get to participate in understanding and making use of the results of the effort.

4.6.5 Performance measures and evaluation

Clarity about goals and objectives are also advanced through a program of evaluation that includes discrete measures against which the success of the program can be compared. This is true for both operating programs and for pilot projects. Measures could relate to the operation of the technical systems, the performance of partnering organizations, customer service performance, revenue objectives, research goals, and myriad other aspects of the pilot or the operating program.

4.7 HOW COULD REVENUES BE ALLOCATED

The allocation of revenue from an efficient fee program is possibly the most significant policy question faced by a road authority. As discussed earlier in this paper the benefits of an efficient fee system are largely tied up in the revenues that are generated and allocating these in a useful manner is of the greatest importance.

4.7.1 Overhead, collection, enforcement

The tax on motor fuels has very low administrative costs. No replacement for this tax will be able to achieve similar administrative efficiencies, and any fee system that includes payment processing and communication technologies will have operating costs that are considerably higher. It is not uncommon for electronic toll systems to have toll system operating costs that are 20% of gross revenues. In its infancy, due to inability to take advantage of scale economies, the Oregon Road Use Charge Pilot Program is expected to have operating costs that are higher still. But the expectation is that operating costs in the range of 5% of gross revenue is a reasonable longer-term target. In particular enforcement and payment processing costs can be quite variable across operating programs depending on a wide range of design and policy choices.

4.7.2 Congestion fee revenue associated with specific corridors

The topic If revenue allocation for revenues collected on specific road facilities has been discussed extensively earlier in the paper. This is a policy choice for those involved in designing the fee program. Theory supports the allocation of revenues to those parts of the network, or the owners of those parts of the network, where revenues are generated.

4.7.3 Wear and tear fee revenue associated with facility ownership

With detailed road usage information the appropriate revenues associated with infrastructure wear and tear can be remitted directly to the relevant road authority ex post. After enough usage and revenue information has been gathered for unique pieces of infrastructure expected revenues could even be allocated ex ante if required to meet maintenance schedules, and then trued up later on. The operative point is that the efficient fee system obviates the need for auxiliary data collection to support the budget development process. In this manner intergovernmental transfers also more closely reflect actual cost responsibility objectives. This is particularly important where heavy vehicles make frequent use of lightly engineered road surfaces.

4.7.4 How would it compare to current revenue allocations?

Current allocations of fuel tax revenues reflect a very general understanding of the share of vehicle traffic local systems endure. A revenue share set aside is then distributed to each local entity based on formula that respects the general size of the entities' driving populations. These methods are clearly an approximate tool for allocating funds to local road authorities. It is feasible to remit to local authorities the exact share of road usage revenues that they are due based on the fee structure rules that reflect cost responsibilities. Fee structures that reflect wear and tear as well as congestion, and even localized pollution costs can be unique to each piece of road infrastructure if needed. It is easy to imagine a nearly impossibly complicated set of fee schedules that would quickly become burdensome to customers but a systematic classification of the important dimensions of costs could easily be devised that would significantly enhance the fairness and utility of the revenue allocation process.

5. VARIABLE RATES BUILD ON, AND COMPLEMENT, OTHER POLICIES

5.1 A NATURAL ENHANCEMENT TO A FUEL TAX REPLACEMENT

The primary differences between variable fees and their flat rate cousins are the need to retain sufficient spatial and temporal details about vehicle use in order to structure a revenue collection program that implements the variable fee. Although early work on mileage fees attempted to design options that would not require the use of vehicle positioning technology, it turns out that spatial details are needed in order to efficiently and accurately administer a simple flat rate fee program.

An examination of the operating requirements for the Oregon Road Usage Charge Pilot Program reinforces this basic understanding. Both the System Requirements Specifications (2012) and the Open System Architecture Model (2012) clearly provide for a set of technical and administrative systems that support an evolution in charging policy that includes the potential for fees that vary by time of day, location, and vehicle characteristics.

The significant advantage of this compatibility between the variable fees of an efficient fee system and the systems that are to be used for flat rate mileage fees are fairly obvious. A single back office and technical platform offers considerable cost savings with respect to both eventual revenue operations and for the implementation of pilot studies and trials. There will be significant additional benefits associated with building on the planned technical and administrative infrastructure that will be employed to implement a flat rate mileage fee. These added benefits relate to legal, policy, administrative processes. It is also true that the basic principles involved have a common origin, including:

- Cost recovery
- Fairness
- Adequately finance the system
- Guide investment decisions

It happens that a variable rate structure is superior to a flat rate structure in terms of achieving each of these objectives.

5.1.1 Build on policy and technical infrastructure for mileage fee

A variable fee on vehicle use builds naturally on the underlying logic and technology of a flat rate mileage fee. The efficient fee approach has several advantages over the traditional approach to highway cost allocation:

- It is not affected by year-to-year variations in the mix of project types undertaken by the agencies
- It is not affected by budget constraints that result in under spending by agencies
- It is not affected by the inherently "lumpy" nature of investment in transportation infrastructure

If an efficient fee approach to highway cost allocation were used, the benefits would likely include the following:

- Each vehicle would pay exactly the costs it imposes, which can be much fairer than equity between weight classes, and which aligns each vehicle operator's behavior with what is best for society. A vehicle would travel when the benefits of the trip are greater than the cost to the traveler and to the rest of society.
- Vehicles would make different numbers of trips and some trips would be at different times or on different routes than under the traditional highway user fees, resulting in a more efficient use of existing infrastructure.
- Where carpooling, transit, biking, or walking are viable alternatives to single-occupant auto travel on congested roads, their share of trips would increase, resulting in a more efficient use of existing infrastructure.
- The collected revenues would, by definition, be just sufficient over time to provide the optimal amount of new capacity and the optimal levels of preservation and maintenance for all facilities.
- In the long run, efficient pricing would lead to more efficient land uses and transportation infrastructure investments through voluntary rearrangements that are beneficial to those making the changes.

To achieve these benefits, efficient fees must actually be levied and their levels must be communicated to travelers at the time travelers make relevant decisions.

5.1.2 Wear and tear fees could vary with weight, axles, studded tires, and road type

Wear-and-tear fees recover the future maintenance, preservation, and capital replacement costs a vehicle imposes by wearing out the roadway it drives on. The sum of all wear-and-tear fees represents the optimal level of expenditure on maintenance, preservation, and capital replacement and does not depend on actual expenditures in any particular biennium or the cost-effectiveness of actual maintenance and preservation programs.

Wear-and-tear fee components cover roads and bridges and vary with the weight and configuration of the vehicle, the presence of studded tires, and the proportion of degradation on the particular facility that is due to use (as opposed to decay that would occur over time even in the absence of use). The higher the proportion that is due to use, the higher the cost per user-mile.

Oregon's existing weight-mile tax is an example of a wear-and-tear fee that is much closer to efficient than the revenue instruments used for heavy trucks in other states.

5.1.3 Congestion fee could vary with time and place of travel and vehicle PCEs

A congestion fee recovers the future costs associated with investing in additional capacity or otherwise relieving congestion. It is based on the costs a vehicle imposes on other vehicles by taking up space on a particular facility at a particular time and is a function of the value of other travelers' time and the amount by which the vehicle slows traffic.

Congestion-related costs can vary greatly over the road network and the course of a day. And to promote efficient use of the facility, congestion fees must reflect those costs by varying with actual traffic volumes and roadway capacities. In implementation, the prices are could be recalculated continuously and can change every few minutes if necessary to reflect changing traffic conditions, or can be a fixed schedule of time varying charges.

Efficient congestion fees reflect a facility's capacity and potential for congestion, the current traffic volume, and the characteristics of the vehicle paying the fee. Longer vehicles and vehicles that require additional space because they accelerate and decelerate more slowly each contribute more to congestion than does a single passenger car. Congestion fees are calculated per passenger car equivalent (PCE) mile. While efficient congestion fees can produce significant revenue (estimated at over $200 million per year in Oregon), they will be at or near zero at most times on most roads.

5.1.4 Possible additional per-mile rate for overhead

An administrative fee recovers the cost of highway agency activities not directly covered by the congestion or wear-and-tear fees, such as planning, administration, finance, information services, and collection costs for user fees. The Oregon Highway Cost Allocation Study provides a long history of analysis on cost responsibility in the state of Oregon. This analysis can become the framework for identifying an administrative fee component of a variable rate road-charging program.

5.1.5 Other potential fee components

An emissions fee component could recover the costs imposed on others by the emissions produced by the vehicle. In the case of electric vehicles, it may include the emissions produced in generating the electricity used to charge the vehicle. Charging the emissions fee leads to optimal emissions levels regardless of how the revenue is spent. Emissions fee revenues could then be spent on offsetting administrative costs, reducing the administrative fee needed. Components representing fees for other externalities imposed by vehicles could be included as well. The concept for other fees is the same as with emissions. To be included, the externality must be quantifiable, there must be a defined relationship between the quantity of travel and the quantity of the externality produced, and there must be a defined cost per unit of externality, which may be negative in the case of an external benefit.

5.2 EFFICIENT PRICING WOULD COMPLEMENT OTHER STATE POLICIES

Road management and surface transportation policy do not exist in isolation from other aspects of urban systems management. It is therefor important to consider an efficient road usage fee program in light of a range of other policy interests and objectives. Some of these are discussed briefly below, but all of these can be evaluated further as a result of a pilot project implementation.

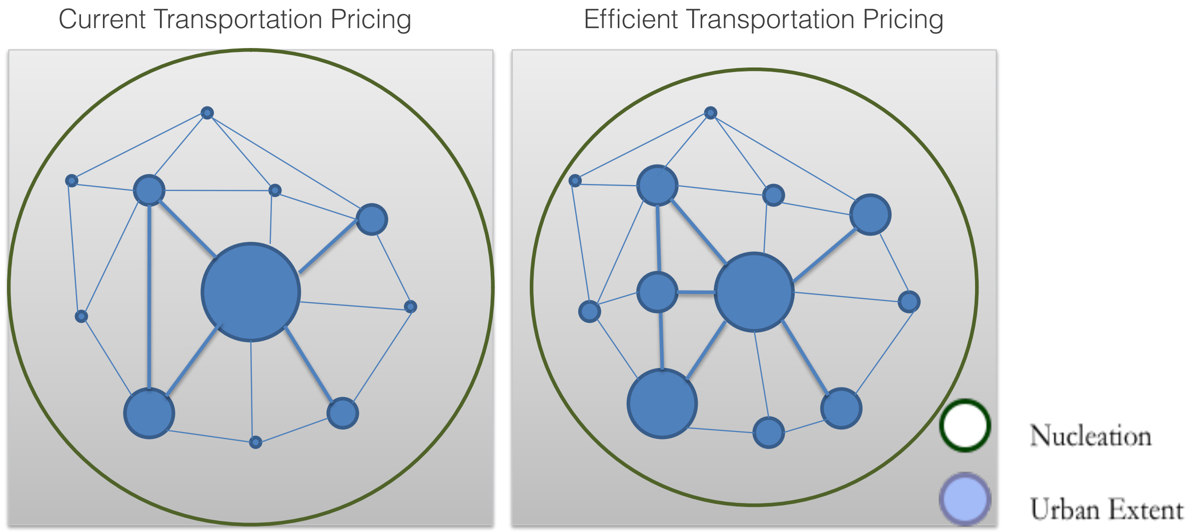
5.2.1 Land use goals and TPR

Generally, the effects on land use depend on the comprehensiveness of coverage of the congestion pricing system. If the coverage of the congestion pricing system is reasonably complete (i.e. comprehensive, mileage-based regional pricing is employed, without major traffic diversion to unpriced facilities), congestion pricing likely will tend to reinforce existing employment centers. (As outlined by Deakin, 1993, the use of the pricing revenues will also impact the potential for affecting urban form.)

This follows despite the fact congestion pricing will raise the out-of-pocket cost of the home-to-work trip. The relevant cost measure to consider for land use analysis purposes, is the full cost of travel (including time), not just the cash cost. Although congestion pricing raises the cash cost of travel in the peak period, it should lower time costs and travel costs overall, especially if HOV services respond appropriately and the congestion pricing revenues are efficiently spent. (Indeed, to the extent that congestion pricing policy fails to lower total travel costs, it has not been properly implemented. After all, the logic of congestion pricing is to improve economic efficiency, which implies, by definition, the use of fewer economic resources, not more.)

Congestion pricing thus should improve formerly-congested access to existing locations, which should improve these locations' competitive viability in the region. In turn, to the extent the rising cost of congestion to and in the CBD is a major contributor to the trend

Exhibit 5.1. Road Pricing and Polycentric Urban Form



of employers moving to suburban locations, it is theoretically possible that congestion pricing may help existing centers.

Thus assuming reasonably comprehensive, regional implementation of congestion pricing, the result could be less development sprawl. This follows from the fact that such a pricing system can introduce a bias in favor of:

- Short over long trips, since vehicles pay by the mile;
- Trips in corridors served well by transit alternatives (or in which carpooling or vanpooling is convenient), since this represents an important way for travelers to avoid the congestion tolls.

Computer simulations of comprehensive congestion pricing policy have demonstrated that a comprehensively-applied congestion pricing system can favor the CBD and major centers, and discourages diffused suburbanization of economic activity. However, such simulations are necessarily very abstract, and may or may not faithfully capture the real-world response to congestion pricing.

We can say with certainty that the decentralization that has occurred in American cities has occurred in the absence of congestion pricing. Whether implementation of congestion pricing will reverse those trends is much less clear. Comprehensive congestion pricing will have centralizing effects on land-use patterns, since the attractiveness of the downtown location is maintained or enhanced by the policy. Whether this is enough to reverse 50 years of decentralization is, frankly, not known.

If congestion pricing coverage is incomplete, with only a few facilities priced properly, its effects are likely to be even more difficult to predict. At best, the effects on land use would be a spotty rendition of the effects described above; at the worst, depending on the policy practiced on the unpriced portion of the roadway network, congestion pricing could exaggerate the tendencies for business activity to dissipate in the region.

The worst case would arise if congestion pricing is implemented only on a selected facility and is implemented in an erroneous fashion. In particular, if the prices are set too high, and/or the revenues collected from the congestion prices are spent in a way that does not improve travel conditions on the affected facilities, congestion pricing would have mostly bad effects on development patterns. In this case, many of the travelers will perceive (properly) that the policy has, in fact, increased their full cost of travel, and may locate their residences or businesses to avoid this impact.

One possibility that appropriately concerns downtown interests, for example, is that congestion pricing is applied selectively to congested, CBD-oriented roads, and then the revenue is dissipated. Mismanaged congestion pricing in this case probably would encourage:

- Diversion of development to the unpriced portions of the region;
- Suburbs-oriented trip-making (if CBD trips are priced and suburban trips are not).

From this discussion it is obvious that it may not be possible to forecast exactly the winners and losers from congestion pricing because the outcome depends on:

- How well, and how completely, congestion pricing is implemented;
- How efficiently the revenues collected via congestion pricing are utilized.

All economists can urge in this regard is that the congestion pricing revenues be used, to the extent possible, in the corridor in which they were generated to redress the income distributional effects of congestion pricing. Most importantly, if the revenues are not used efficiently, congestion pricing may not generate overall net benefits and it would be unfair to ask the public to support it.

5.2.2 Oregon Sustainable Transportation Initiative (OSTI)

The Oregon Sustainable Transportation Initiative (OSTI) is an integrated statewide effort to reduce greenhouse gas (GHG) emissions from transportation while also supporting healthy, livable communities and economic opportunity. The effort is the result of several bills passed by the Oregon Legislature, and it is designed to help the state meet its 2050 goal of reducing GHG emissions by 75 percent below 1990 levels.

An efficient road use fee is uniquely suited to support the major goals of the OSTI. The reason is that an efficient fee for road use will have broad effects on how urban systems interact with each other. As a starting point an efficient fee addresses reoccurring congestion on major roadways. Less congestion results in travel time savings that get capitalized in the broader economy. The production possibilities for the Oregon economy are thus improved. The improved performance of the urban road network also reduces GHG emissions as moderate speeds are maintained even during peak travel periods. In addition, as discussed above, an efficient transportation fee will influence the spatial pattern of the economy and naturally support more compact use of desirable urban land without resorting to regulatory approaches that can be overly prescriptive or crudely applied.

5.2.3 Greenhouse gas reduction policies

To the extent congestion pricing reduces air and/or noise pollution, as an ancillary effect to VMT reduction, there may be general environmental benefits. An ODOT commissioned paper on road pricing's role in reducing greenhouse gases addresses many relevant issues.

The issue is not as straightforward as it seems, however. One of the effects of congestion pricing, for example, is to cause vehicles remaining on the roadways to travel at higher speeds. Typically, the rate of emissions, per mile, increases at higher speeds (as do motor and tire noise as well). Hence, whether there are pollution benefits, on balance, will depend upon the partially offsetting effects of higher speeds and lower traffic levels.

In addition, congestion pricing does not necessarily reduce travel by the most polluting vehicles or reduce the number of cold starts. It is possible, for example, that when faced with higher out-of-pocket costs from congestion prices, drivers may try to economize by retiring old vehicles more slowly. And if most of the reduction in congestion come from spreading of the peak (rather than reduction in trips), cold starts may not be reduced significantly either.

Detailed studies of congestion pricing in California and Washington suggest that congestion pricing, on balance, does have beneficial air pollution effects. However, because of the uncertainties involved, policies focused directly on vehicle emissions generally are preferred to relying on the ancillary effects of congestion pricing. An ODOT paper from 2009: *Tolling White Paper #1: Potential Effects of Tolling and Pricing Strategies on Greenhouse Gas Emissions* examines greenhouse gas emissions opportunities from road pricing for Oregon. Conclusions from this paper include the observation that road pricing's influence on emissions is largely a function of its ability to improve roadway operating speeds and that overall effect on emissions will be dependent on the scale and extent of a road pricing application.

5.2.4 Numerous other programs and incentives

There are numerous additional objectives, programs and existing incentive systems that are important to the state of Oregon. These include, but are not limited to the following:

- Freight Movement
- Efficient Infrastructure Development
- Infrastructure Condition and Reliability
- Efficient Land Use
- Travel Demand Management
- Active Transportation
- Energy Demand Management
- MPO-level Transportation and Land-use Planning

An efficient road use fee system can advance objectives in each of these areas.

6. HOW TO MOVE FORWARD

6.1 DEMONSTRATION DESIGN

Demonstration project design should begin with clear objectives, then outline what is required to meet those objectives. The objectives of an efficient vehicle fee program include the following:

- Charge vehicles the costs they impose on the transportation system; including the wear and tear cost on infrastructure, the costs of building new capacity as existing capacity is burdened, and cover other external costs such as pollution and noise.
- Improve fairness by recovering these costs from the specific vehicles that impose those costs
- Sustainably fund transportation maintenance and investment programs over the long-run through the revenues generated from the efficient fees.

But the objectives of a pilot study can differ from the program objectives. For example one pilot project objective might be to fully solve how best to structure payment systems, enforcement, or protect privacy while designing a program that is striving to reach the broader policy objectives listed above. Pilot, or demonstration, project objectives are guided by an overall strategy for determining how to advance the broader program of efficient fees.

Demonstrations of new programs or policies tend to fall into one of two categories: general demonstrations and technical demonstrations. General demonstrations focus on proof of concept, building awareness, and identifying policies that need further investigation. Technical demonstrations involve a more formal testing of some specific functional aspect of a new program. The two categories are not entirely exclusive, of course, allowing a combination of objectives to be met with any given demonstration project design. In the case of an efficient fee demonstration in Oregon what is required is to build awareness about the subject, identify policies of importance as these ideas gain momentum, and to prove out the basic structure of an efficient fee program to a broad audience. Much has been done elsewhere (e.g. Seattle, Atlanta and Oregon in the U.S. and Germany, UK and the Netherlands in Europe) to design and test specific technical implementation aspects of mileage fees, or what are often referred to as Road User Charges. And the technology required and the organizational management approaches and practices in this arena will continue to evolve quite rapidly. In summary, a demonstration project in Oregon will likely be a combination of a general and a technical demonstration.

If the intent is to fully design and field-test a comprehensive approach to efficient fee implementation then there is a very long list of issues that need resolution. And as such the decision-making agenda to support that process would be extensive. One approach to moving forward involves a recognizing that the work to be done is too detailed and too broad to undertake everything in one pilot. The only example where there was an attempt to resolve all policy and implementation questions in one field trial was the Dutch road pricing program The Dutch spent tens of millions of dollars over many years, and included significant industry consultation in a design a pilot that would then roll right into implementation if it proved successful. This was a high-risk approach with potential high reward, but in the end changing politics derailed the pilot.

If on the other hand the intent of a pilot is to more fully understand a single aspect of policy (take privacy for example) then the decision-making factors are more limited in scope, but a lot more detailed and specific. It is always beneficial to first know what it is that folks are hoping to discover through the demonstration in advance of adding this additional detail. In truth, a demonstration project can be used to do any number of things, including:

- Explore one single dimension of policy
- Design a single aspect of an operational program
- Test general feasibility of a broader policy program
- Field test technology

The basic order of steps involved in getting through the numerous decisions involved in designing and implementing a demonstration project might include the following.

1. Determine the general objectives of the demonstration (technical trial, broad policy design, detailed programmatic design, etc.)
2. With the above determined, sketch out a decision agenda that ensures the demonstration will produce the desired results.
3. Fit the results of the demonstration into a larger policy agenda for advancing the overall practice around efficient fees.
4. Number 3 above may necessitate further demonstrations of technology, or pilots to design a specific aspect of the program.
5. Communicate the importance of the broader policy agenda and the specific benefits of the well-designed demonstration project that will help everyone involved to refine policy and advance the practice in a manner that will be acceptable to the general public.

The myriad of road charging trials in the U.S., but also substantially in Europe, has resulted in clarity on whether such systems would work technically. It has been demonstrated that even the costs of implementation would be exceeded by the efficiency gains and revenue opportunities an efficient fee system offers. The primary potential objections relate to hoe exactly such a fee system would affect peoples' lives. While it is fairly easy to predict the overall magnitude of fees, revenues and benefits, it is considerably more difficult to be specific about the distribution of these effects across members of the general public without an opportunity to observe behavior that is part of a carefully designed demonstration project. This type of effort has only been undertaken in the Puget Sound region, nearly a decade ago and involving a limited sample of participants.

In addition, the question of how Oregonians will respond to an efficient fee that involves vehicle-positioning technology, and how a system can be designed to safeguard privacy, needs further detailed exploration.

Demonstrations are an expensive undertaking and should be designed carefully. What follows is a list of potential priorities for efficient fee demonstrations in the US market:

1. Pilot systems that will truly address privacy concerns. These concerns necessitate both technical and administrative systems that will need to be designed and tested against "hostile" participants to see if there are weaknesses and if people can break the security.
2. Demonstrate the merits of integrating fee and investments policy. It needs to be demonstrated that the benefits of the efficient fee system will materialize for consumers. Most people think these efforts are about grabbing revenues and they will need to be shown how investment policy can be improved in a manner that meets their needs.
3. Design a pilot that will fully explore the incidence of fee payment. Such an effort would understand efficient fees with respect to alternatives to the efficient fee system and with respect to user income. The effort would strive to fully explore questions around fairness in a manner that sheds real light on this issue.
4. Technical systems that support an efficient fee are available. There is no need for a general technical trial, only trials of very specific technical solutions to specific

problems such as payment processing and enforcement of very specific programs.

If there is clarity on the general objectives of the "next" trial then these pilot project objectives can then get translated into demonstration project operating requirements. Beyond requirements, it is necessary to put additional shape on the skeleton of the design in order to allow for a budget estimate to be developed. The design that follows has benefited from relying on experience in actual demonstration project implementations and as such is rooted in practical knowledge that is key to understanding budget and schedule risks.

6.1.1 Summary of Proposed Efficient Fee Demonstration

A demonstration of an efficient road use fee in Oregon might look something like what is summarized below. The process of developing this description is one that begins with a set of demonstration project objectives and the identification of functional requirements that address those objectives. The description of the demonstration then follows from the functional requirements. Demonstration project objectives and requirements are described in more detail later in this section of the paper.

To demonstrate the operation of an efficient road use fee it is envisioned that a groups of participants will be recruited from the population of Oregon residents. These participants will have their vehicle equipped with mileage fee metering devices for the duration of the demonstration. Participants will drive normally during a baseline data collection period. This baseline period will establish the driving patterns for each household. During the experimental period of the demonstration project the participants will be exposed to the efficient fee. All the major operations aspects of an actual efficient road use fee will be implemented and tested including, the back office functions, payment processing, and customer services. Many of these functions are already in operation to support the Oregon Road Usage Charge program. Participating households will not be asked to pay the fee out of their own pockets, but they must also face an actual incentive to align their driving behavior with the hypothetical mileage fee charges. To accomplish this objective the project will provide participating households with a travel budget account out of which fees will be deducted. The incentive is realized because participating households are allowed to keep whatever balance remains in their account at the end of the experimental period.

Such a demonstration allows for a rich evaluation of driver behavior, support the estimation of revenue yields from alternate mileage fee policies, tests the operations of the set of systems design to support implementation, permits the examination of how local option taxes could get included in an efficient fee, and tests are range of important topics (e.g. privacy, equity) that relate to policy. A successful implementation of a demonstration project such as this adds considerably to the inventory of knowledge about road use fee viability and design and should be of interest to a broad set of stakeholders and levels of governmental management.

6.1.2 Demonstration Project Objectives

Demonstrations of new programs or policies tend to fall into one of two categories: general demonstrations and *technical* demonstrations. General demonstrations focus on proof of concept, building awareness, and identifying policies that need further investigation. Technical demonstrations involve a more formal testing of some specific functional aspect of a new program. This effort has aspects of each of these categories with a combination of objectives to be met through demonstration project design. There have already been a number of demonstration projects implemented within the U.S. (with Oregon leading the way) and so the basic feasibility of doing so in Oregon is clearly established. As a result a demonstration project will be part of a broader body of ongoing research and exploration. An NCHRP report developed by the RAND Corporation outlines some guidelines for the design of additional mileage fee, or road use charging demonstrations. In particular future demonstration projects might beneficially focus on one or more of the following topics:

- Explore a range of technical issues that surround implementation
- Understand driver behavior in response to new fee structures
- Determine the process through which mileage fees are phased in as other highway finance approaches (fuel taxes, tolls) evolve or remain in force
- Identify institutional issues that will present themselves during the design and implementation of a mileage fee system

- Establish pricing and rate setting policies beyond a simple fuel tax replacement
- Explore factors that influence user acceptance of mileage fees
- Design solutions to privacy and evasion problem associated with an implementation of mileage fees

In cases where the mileage fees vary by time and location, travel behavior will be more significantly influenced. As a result a comprehensive demonstration would not be limited to only technical issues but would involve human participants and an attempt to understand the range of potential behavioral responses to the fees. Demonstration projects that recruited volunteer participants and measured behavioral responses have been implemented recently in the U.S., and the design requirements and costs are well understood. A fee structure that is relevant to Oregon might include fees that are higher in urban downtown settings during peak periods of travel. There could be a number of variations on these themes.

An efficient fee affords the opportunity to recover the primary costs of provisioning and operating transportation infrastructure from transportation system users. When the mileage fee is a variable fee, as opposed to a flat fee, then there is also an opportunity to improve the fairness of the cost burden, begin to minimize the large social costs of highway congestion, and even to address other costs of transportation such as vehicle emissions.

Exhibit 6.1 Limited and Comprehensive Demonstration Design Feature Options

Demonstration Design Feature	Limited Demo	Comprehensive Demo
Fee rate structure		
Flat rate fee	●	●
Variable fee by time of day, location, vehicle		●
Local option taxes		○
Demonstration subjects		
Random recruitment		●
Self-selected participants	●	
Targeted group of participants	○	○
Scale of demonstration		
Less than 500 participants	●	
500+ participants		●
Geographic extent		
Entire metropolitan region		●
Subset of metropolitan region	●	○
Demonstration of operational functions		
Payment processing systems	○	○
Vehicle metering technology		●
Enforcement systems design		○
Private operator/vendor involvement		●
Demonstration policy emphasis areas		
Privacy protections	○	○
Gains and losses to subpopulations		○
Out of state vehicle program design	○	●
Transitional strategies		○
User acceptability and education program	○	●
Fee rate setting and disposition of revenues		○
Management of the demonstration		
MetroPlan and State partnership	●	●
Federal support		○
Mileage-Based User Fee Alliance		○

Source: ECONorthwest

6.1.3 Demonstration Project Design Features

Design features for an efficient road use charge might start with the following:

1. A variable rate mileage fee with some opportunity for fee structure modification to accommodate localized variation in the rates to address vehicle type or congestion.
2. A larger-scale demonstration project (500+ participants) allowing for behavioral analysis and generalization of findings to a larger population.
3. A demonstration that includes the implementation and testing of the various aspects of payment processing (account development, data communication, central office support services, financial transactions, etc.).
4. A demonstration project that includes an assessment of the opportunities for efficiency gains in terms of traffic congestion.
5. A demonstration project led by the State with strong coordination and involvement from the local authorities.

Based on the broad set of important objectives it will be important that a demonstration project in Oregon be designed to be a comprehensive pilot project. One important point of discussion involved the scale of the demonstration project implementation. Features of a comprehensive demonstration are summarized in Exhibit 6.1 on the previous page.

The proposed demonstration project design is intended to represent a project that could be implemented in Oregon in order to meet a set of carefully considered demonstration objectives. While the design has been thoughtfully developed it is intended only as a guide to implementation. As the preparations for implementing a demonstration project progress it is certain that project objectives and the resulting technical requirements will be modified. Consistent with this understanding, the design is organized around functionality rather than specifications. The core functionality is what needs to be supported by technical systems and experimental and analytical methods.

6.1.4 Participatory Demonstration and Experimental Design

The dominant feature of the proposed demonstration project is that it will make use of volunteer participants in order to test a full range of important aspects of an actual efficient road use fee implementation. This is in contrast to some kinds of technical demonstration that are intended to prove out new technical system, often involving test facilities and technicians and test professionals.

Other participatory demonstrations involving instrumented vehicles have been implemented elsewhere and as a result this effort will not start from scratch or attempt to re-implement efforts already proven successful. Using actual participants allows for a deep understanding of behaviors, choices, and the consequences for consumer benefits. All important aspects of policy, including revenue incidence, implications for congestion and infrastructure improvements, fairness, and approaches to privacy protection require actual participants to be the core organizing principle of the demonstration design.

Measuring the effects of the program specifically introduce the need for careful experimental design. The primary challenge is preserving a control against which behavior, modified by experimental treatment, can be compared. The proposed demonstration is likely to involve a quasi-experimental design.

6.1.5 Variable Rate Fee Structure

The efficient fee demonstration should support the testing of a variable rate fee applied to miles driven by participating vehicles. In this manner the project will better understand how differences in fee design influences in various outcomes of interest including user behavior, user and economic benefits, revenue opportunities and a wide range of other factors. Applying variable fees for road use provide an opportunity to make road use fees more closely reflect the costs that vehicle use imposes (described more below) in the form of road wear and tear, capacity burdening that engenders capacity improvements, and a range of other factors that may be time and location dependent. The fee structure could include one or all of the following.

Wear and Tear Fee

Wear-and-tear fees recover the future maintenance, preservation, and capital replacement costs a vehicle imposes by wearing out the roadway it drives on. The sum of all wear-and-tear fees represents the optimal level of expenditure on maintenance, preservation, and capital replacement and does not depend on actual expenditures in any particular biennium or the cost-effectiveness of actual maintenance and preservation programs.

Wear-and-tear fee components cover roads and bridges and vary with the weight and configuration of the vehicle, the presence of studded tires, and the proportion of degradation on the particular facility that is due to use (as opposed to decay that would occur over time even in the absence of use). The higher the proportion that is due to use, the higher the cost per user-mile.

Oregon's existing weight-mile tax is an example of a wear-and-tear fee that is much closer to efficient than the revenue instruments used for heavy trucks in other states. Incorporating such a fee structure into an efficient fee program that applies to all vehicles in Oregon is a feasible undertaking.

Congestion Fee

A congestion fee recovers the future costs associated with investing in additional capacity or otherwise relieving congestion. It is based on the costs a vehicle imposes on other vehicles by taking up space on a particular facility at a particular time and is a function of the value of other travelers' time and the amount by which the vehicle slows traffic.

Congestion-related costs can vary greatly over the road network and the course of a day. and to promote efficient use of the facility, congestion fees must reflect those costs by varying with actual traffic volumes and roadway capacities. In implementation, the prices are recalculated continuously and can change every few minutes if necessary to reflect changing traffic conditions.

Efficient congestion fees reflect a facility's capacity and potential for congestion, the current traffic volume, and the characteristics of the vehicle paying the fee. Longer vehicles and vehicles that require additional space because they accelerate and decelerate more slowly each contribute more to congestion than does a single passenger car. Congestion fees are calculated per passenger car equivalent (PCE) mile.

Administrative and Other Fees

An administrative fee recovers the cost of highway agency activities not directly covered by the congestion or wear-and-tear fees, such as planning, administration, finance, information services, and collection costs for user fees. The Oregon Highway Cost Allocation Study provides a long history of analysis on cost responsibility in the state of Oregon. This analysis can become the framework for identifying an administrative fee component of a variable rate road-charging program.

An emissions fee component could recover the costs imposed on others by the emissions produced by the vehicle. In the case of electric vehicles, it may include the emissions produced in generating the electricity used to charge the vehicle. Charging the emissions fee leads to optimal emissions levels regardless of how the revenue is spent. Emissions fee revenues could then be spent on offsetting administrative costs, reducing the administrative fee needed.

6.2 DATA REQUIREMENTS

Ideally an efficient fee pilot project would be designed in a manner that takes advantage of large quantities of high quality information about attributes of the driving population as well as a detailed understanding of their behavior and price sensitivities. Comprehensive data of this kind is never available and is expensive to generate. Luckily one of the key merits of a pilot project is that it is a trial and getting prices exactly "right" up front is not critical. Also, the nature of variable fee structures is that they are designed to respond to changing conditions and demands. And the data that is required that allows for fees to respond to these changing conditions are generated from the fee program itself. It is still true that a starting point for the design of an efficient fee will benefit from some basic data on traffic conditions and costs. And travel models can be a useful means of discovering the underlying parameters for an efficient fee structure.

6.2.1 Detailed traffic data

Detailed traffic data, including counts and speeds by vehicle class by facility by time of day are useful in developing a variable rate fee structure. An example of this kind of data that is collected from loop counters in the freeway network from the Seattle area is displayed below. The following figures illustrate the 24 hour diurnal traffic patterns for a selected freeway location within the Seattle area freeway network. These patterns were used to help identify appropriate times to vary toll rates according to levels of demand for the Traffic Choices study.

6.2.2 Detailed cost data by facility

Traffic data is useful in estimating the congestion fee portion of an efficient fee but information about the costs of maintenance and preservation of road assets is useful in estimating the wear and tear portion of the fee. The long history of the Oregon Highway Cost Allocation Study provides extensive data on the marginal and average maintenance and preservation costs by facility type.

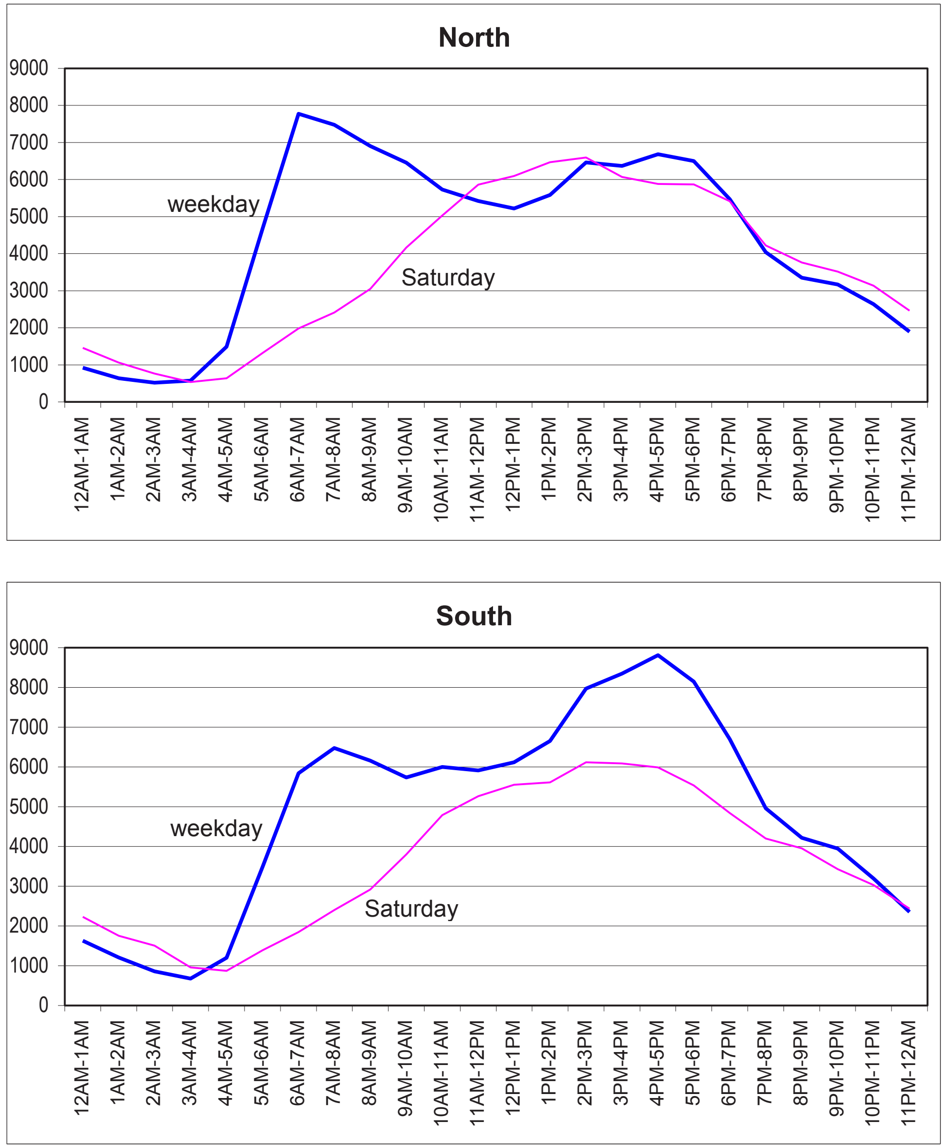
6.2.3 Travel demand models for areas with significant congestion

A travel demand model is a good starting point for understanding the appropriate fee structure that might get applied to any given road network. ODOT's *Tolling White Paper 3: Travel Demand Model Sufficiency* discusses Oregon specific topics in travel demand modeling of tolling. Taking advantage of the approaches to highway assignments under congested conditions that are inherent to these models is a reasonably straightforward exercise the yields first approximations of an efficient fee structure. Such an exercise was done in support for the Traffic Choices Study in Seattle.

The PSRC travel demand model was used to study travel patterns on the toll network. The main purpose of the study was to establish the distribution of toll costs during a typical travel day, paying particular attention to how these costs varied with the facilities used, time-of-day and direction of travel. Link toll costs are assumed to be a function of the link volume-to-capacity ratio, with the specific functional form varying by facility type (see Technical Memorandum PB4). The analysis is based on

Exhibit 6.2. Diurnal Traffic Flow Example

I-5 @ S Holden St / Boeing Field
(south of downtown Seattle)



Source: Puget Sound Regional Council, ECONorthwest network traffic volumes obtained from a 1998 base scenario, estimated using the toll-free (as opposed to the toll-augmented) volume-delay functions, and on travel demand matrices segmented by time of day (AM Peak, PM Peak and Off-Peak).

The model data were examined from two different angles: first to establish average and range of the trip-based toll costs that would be incurred given existing travel patterns, and second to establish link-based toll costs as a function of facility characteristics. The latter measure helps to establish toll rates by facility type (and other network-based characteristics), while the former measure helps understand the cost to travelers implied by the link-based toll rates.

The economic principle underlying the tolling scheme developed recognizes that the social marginal cost of travel exceeds the private marginal cost recognized by the vehicle user (described previously in this paper). The PSRC regional model was used to determine the VMT-weighted average toll rates as well as toll rate variation for all freeway/expressway facilities and all arterials. Not all roads are sufficiently utilized to warrant a toll at all times of the day and/or directions of travel. However, in the interest of keeping the tariff structure reasonably simple to grasp and remember, it was necessary to develop a toll schedule that was logically tied to these average toll rates (based on the weighted average external costs imposed per vehicle). The use of the weighted average external cost toll rates recognizes that some roads will be overpriced, and others underpriced; in fact, some variability of this type is actually desired for the statistical analysis and assessing the confidence intervals around resulting elasticity estimates.

The average arterial road toll rate per mile was almost exactly one-half of the average freeway toll rate during both the three hour AM and PM peak periods. Combined, the two peak periods comprise 25% of the day, but account for 43% of daily VMT. For the model's off-peak period — the remaining 18 hours of the day with highly variable traffic conditions ranging from peak shoulder hours to the middle of the night — the average arterial toll rate was 57% of the same freeway toll rate.

The consistency of the average ratio between the economically efficient toll rates for freeways and arterials led to one of the simplifying assumptions for the study — that the arterial toll rate per mile would always be one-half of the corresponding freeway rate at any given time of day.

The composite measures served as base values for a series of tariff structure and toll schedule options that were considered. Each option examined variation from the average base toll rates in a number of dimensions, including travel direction, proximity to the urban core areas, and additional time of day differentiation. The pros and cons of these options were then considered by the study team, weighing statistical analysis advantages of complexity against participant comprehension.

The final tariff structure shown in represents a compromise that was intended to provide ample opportunities for statistical analysis and price elasticity estimation, while at the same time retaining an aspect of simplicity that will facilitate rational behavior modification by participants.

6.3 TECHNOLOGY THAT SUPPORT AN EFFICIENT FEE PROGRAM

Standard practice in electronic tolling involves the use of relatively simple in-vehicle radio tags, or transponders (e.g., FasTrak or E-Z Pass). The radio tags contain a unique electronic signature that is communicated to roadside equipment as the equipped vehicle drives by. Current systems use various short-range communication technologies and protocols and are typically implemented with proprietary hardware and software elements. Roadside equipment includes the toll tag readers and any equipment necessary for vehicle classification and enforcement, as well as equipment to transfer all necessary transaction information to a central toll operations center. This electronic toll collection approach has been used successfully since it was first introduced in the late 1980s.

Similar technology has been used in the Singapore-area pricing program since 1998. The London Congestion Charging Zone also relies upon roadside equipment for vehicle identification and account processing, although in London video cameras capture the license plates of each vehicle entering the charging zone. Cameras are positioned at all points of access to the zone and also at key locations within the zone.

These approaches require that dedicated roadside tolling equipment be deployed over the full extent of the tolled network and, as a consequence, also require new infrastructure any time the tolled network is expanded or altered. The approach to network tolling that was investigated as part of the Traffic Choices Study in the Seattle area did not rely on roadside equipment, although enforcement would depend upon strategically located video license plate reader equipment. The in-vehicle tolling devices locate the vehicle on the road network and communicate directly with the central tolling operations system, resulting in significantly less civil infrastructure, and enabling flexible extensions or alterations of the tolling network.

To date, there are few true network charging programs in operation. Heavy vehicles are tolled on major roads in a few European countries, and the Netherlands is making progress toward a national kilometer charging program to be implemented by 2016. With few operational systems, and none that rely exclusively on GPS-tolling technology, there have been lingering questions about the complexity and cost of such an approach.

The in-vehicle electronic toll collection system elements implemented for the Traffic Choices Study in Seattle met the base requirements for toll system operations. There remain issues that would need to be addressed in an actual implementation, but the Traffic Choices Study is a strong “proof of principle” from a technological standpoint, especially considering that the on-board units (OBUs) used in that study relied on technology that is now more than ten years old.

An extremely important emerging realization (to which the Traffic Choices Study has contributed) is that the implementation of full network tolling is no longer fundamentally constrained by technological limitations. The toll system elements implemented for the Traffic Choices Study met the base requirements for toll system operations. Indeed, it is technically possible to implement the same pricing policy principles within the highway realm that have, for so long, been in common use in virtually all other markets in the economy. This is not to say that there are no issues that need to be addressed in an actual implementation. But the Traffic Choices Study is a strong “proof of principle” from a technological standpoint. A set of system requirements developed for the Traffic Choices Study is included as Appendix C.

More importantly, the technology being deployed for the Oregon Road Usage Charge Program meets all the basic requirements for a variable fee pilot program. Building on the implementation of the Road Use Charge Program represents a prudent approach to planning for the technical systems of a variable rate fee program as these technical systems will be proven and improved as a result of an extensive trial implementation period. As noted earlier the System Requirements Specifications (2012) and the Open System Architecture Model (2012) for the Oregon Road Usage Charge Pilot Program clearly provide for a set of technical and administrative systems that support an evolution in charging policy that includes the potential for fees that vary by time of day, location, and vehicle characteristics. The ability to support a fee program with vehicle positioning at it operating core is an important step in allowing an efficient fee demonstration to be a follow on to current efforts to transition to mileage-based highway finance.

6.3.1 On-board technologies

Transponders, also referred to as electronic tags, are the most common component of electronic toll collection in use around the world. Transponders are often mounted in the windshield of a vehicle, but may be located elsewhere in the vehicle.

Transponders are part of Automatic Vehicle Identification (AVI) technology that enables tolling facilities to accurately identify a specific vehicle at highway speeds. AVI technology also includes the use of a road-mounted or overhead gantry-mounted reader, which communicates with the transponder to identify the vehicle. As a vehicle passes under a toll-collection gantry, its electronic identification encoded into the transponder is sent to the gantry-mounted reader. The driver does not have to stop to pay the toll and no tollbooths are required. The vehicle identifier is sent on to a back-end toll collection system.

On-board GPS units (OBUs) monitor a vehicle’s travel and calculate tolls from inside the vehicle, eliminating the need for installing expensive sensors on the roadway. This is particularly advantageous when applying tolls throughout a region, where it is not feasible to have ubiquitous, gantry-mounted sensors. The OBU uses signals from GPS satellites to determine the exact vehicle location and communicates with back-end systems through the cellular telephone network to learn of changes to toll rates and to communicate users’ charges and account balances. The vehicles’ locations are not transmitted, but may be temporarily stored within the OBU for verification purposes.

One of the advantages of GPS-based tolling is that this technology allows for more accurate time- and location-based tolls. Recent advances in GPS and related technologies allow for far more accurate identification of a vehicle's movement through a tolled area. GPS-based systems do have limitations, however. GPS systems rely on the vehicle's ability to receive satellite signals, which requires an unobstructed view of the sky. Recent advances in GPS-related technology take advantage of information from cell towers to estimate location, speed, and direction in the absence of satellite signals.

Mobile Enforcement Readers (MERs) are installed in enforcement vehicles. An MER unit allows an officer to read the transponders of passing vehicles or to travel adjacent to a vehicle in the HOT lane and read the transponder. The mobile unit provides the officer with the last date and time the transponder was read and whether the account is valid. This technology is used to ensure that users are not disengaging their vehicle's transponders as they pass under tolling gantries.

Some of the factors of importance when considering an efficient fee system technology will include the following:

- Functionality
- Privacy
- Auditability
- Reliability
- Cost

There are a variety of technical means through which mileage fees could be implemented. Any serious effort to account for vehicle mileage must support independent validation of objective vehicle use information. A Nation Cooperative Highway Research Program report[3] developed by the RAND Corporation itemizes the following technical approaches to metering vehicle use, payment processing, managing enforcement, and protecting privacy:

Exhibit 6.3. Potential VMT-Fee Implementation Options

Metering Options	Collecting Fees	Preventing Evasion	Protecting Privacy
• Odometer options: – Self report – Required check – Assumed mileage with optional check • Mileage estimates based on fuel economy and fuel consumption • Radio-frequency identification (RFID) tolling on a partial road network • On-board unit (OBU) options – On-board diagnostics (OBD II) connection – OBD II / cellular – GPS	• Pay with registration • Pay at the pump • Wireless transmission to billing authority • Debit cards	• Odometer inspections • Odometer redundancy checks • Metering equipment checks • Default fuel tax payment • Fuel consumption redundancy checks • External wireless checks for functioning equipment • Device heartbeat signals • Device distress signals	• On-board data aggregation and fee computation • Anonymous proxy fee computation • Trusted third party • Prepaid debit cards • Anonymous user accounts • Encryption

Source: Rand Corporation

In practical terms, actual revenue operations for efficient fee charging would require some automated system of cataloguing vehicle use either through a connection with the vehicle odometer and diagnostics port, or through exogenous means of vehicle identification and measurement of use such as GPS tolling devices.

Supplemental On-road Devices

Traffic sensor systems may be subsurface, roadside, or overhead. Inductive sensors embedded in the road surface can determine the presence of a vehicle. These sensors may be used to count the number of vehicles crossing a location as well as the number of axles in a vehicle as a vehicle passes over them. A two-loop sensor can also determine the speed of the vehicle passing over it.

Weigh-in-Motion (WIM) systems are capable of estimating the gross vehicle weight of a vehicle as well as the portion of this weight that is carried by each wheel assembly, axle, and axle group. WIM systems provide the date and time

[3]NCHRP Report: System Trials to Demonstrate Mileage-Based Road Use Charges; RAND Corporation; Santa Monica, CA; 2010

of each vehicle passing over it, along with axle weights and spacings, vehicle classification, speed, and transponder ID, if the vehicle has a transponder. WIM systems allow participating trucks with transponders) to bypass weigh stations (e.g., “green light” programs).

License Plate Recognition (LPR) systems use video imaging and optical character recognition to determine a vehicle’s license plate number as it passes by the reader. LPR systems can be used to identify violators, apply tolls to vehicles that do not have transponders, and verify that transponders are in the vehicles they are registered to. LPR is the primary technology in use in the toll cordon area of downtown London.

Vehicle Occupancy Monitoring for managed lanes that allow exceptions to tolling for high-occupancy vehicles use infrared or visible light cameras to detect and count the number of occupants in a car. These systems suffer from both accuracy and privacy issues.

6.3.2 Back-end technologies

Back-end systems and devices

Back-end systems monitor and coordinate the information coming from on-road and on-vehicle systems. They may also archive such information for verification and auditing. In addition, back-end systems perform tolling-related calculations; manage user accounts, identification, tolling accounts, and transponder tag identification; and deduct tolls from users’ accounts. It is especially in the area of back-end systems that an efficient fee demonstration should build on the work undertaken by the Oregon Road Usage Charge Program.

In the U.S., several different companies manage tolling on highways in different states. Most of the northeastern states use E-ZPass, California relies on FasTrak, Minnesota uses MnPass, and Texas has TollTag, EZ TAG, and TxTAG. These last three are interoperable throughout the state. Interoperability among the several different tolling agencies across the country has not yet been achieved. In London and in Germany, a single tolling agency is responsible for operating and managing the tolling systems. In London, the cordon pricing is operated by Transport for London. In Germany, the Toll Collect system is ubiquitous in tolling heavy trucks for use of federal highways. Back office functions that were part of the Traffic Choices study are included as Appendix D.

Enforcement

There are three common types of tolling-related violations: 1) failure to meet required vehicle-occupancy levels, 2) failure to pay a toll, and 3) crossing into or out of priced lanes where not allowed. The enforcement of vehicle-occupancy restrictions, such as in high-occupancy vehicle (HOV) lanes, can be difficult. Manual enforcement (wherein patrol officers are required to observe the violation, pursue the violating vehicle, pull the vehicle over to the roadside, and manually issue a ticket) can be labor-intensive, costly, and dangerous.

Tolled facilities, including tolled lanes and high-occupancy toll (HOT) lanes, have different options for enforcing toll collection. Toll lanes often enforce toll payment by detecting a transponder in the user’s vehicle. Violators may lack a working transponder, have an invalid account, or have inadequate funds for the toll. Violations are captured by a video or photograph of the violator’s license plate.

6.3.3 Communication technologies and protocols

The most obvious approach to the data communication requirements of an efficient fee program is to employ standard cellular communication services. Due to the potentially high cost of these types of services there may also be opportunities to partner directly with data communication service providers. A discussion of communication requirement for the Traffic Choices Study is included in Appendix D.

6.4 GEOGRAPHY

The geographic locus of an efficient fee pilot program would follow from the fee structure that is employed. As variable fees for road use by time of day and location will be a large component of the efficient fee, its demonstration will require a location that currently experiences some considerable congestion of the road system. Other factors that might influence the location of a demonstration include the budget available to cover a larger or smaller extent of the road network and its users. Budget for such a demonstration will be driven by participant costs (recruitment, management, equipment, and endowment) and will be somewhat linear with the number of participants. To the extent that sub categories of participants are to be examined independently the sample size requirements will increase which may limit the geographic extent of the experiment.

The geography covered in a road use fee demonstration has implications for project design and budget. The following discussion of project geography is intended to provide sufficient understanding to allow for project planning and budgeting but final specifications about the geographic extent must be reserved for pre-implementation design. Three aspects of geography are covered below, fee coverage, road network details, and the geography of participant recruitment.

6.4.1 Geographic Coverage of the Efficient Fee

If participating vehicles are equipped with GPS enabled metering devices then there is essentially an unlimited geographic extent of the efficient road use fee demonstration within the state of Oregon. In other words wherever a participating vehicle is driven there is a corresponding record of mileage. The design question for the project will which taxing jurisdictions to represent within the tariff model functions of the back office. As a practical matter it should be a fairly simple process of establishing geographic entities to include in a tariff model, and not prohibitively difficult to support the accounting of road use fee revenues for additional taxing jurisdictions, should this be desirable. Taken together these considerations support a geographic coverage that represents independent taxing jurisdictions that include the state as a whole and potentially counties should local option taxes be envisioned.

6.4.2 Road Network Detail

There are at least two independent means of measuring vehicle mileage with GPS enabled metering devices. The first is a simple Euclidean measure of distance covered between GPS waypoints. Any arbitrary set of waypoints can be summed to provide a total distance between points of interest. The second approach takes the raw GPS waypoints and employs a method for matching those points to a digital map representation of a road network. Once GPS records are matched to the road network it is the attributes of that road network that provide a measure of the distances that are covered. It is likely that for any mileage fee program both methods will be employed in some form. For example, vehicle mileage might be totaled as a product of simple Euclidean distance between GPS waypoints but a geo-gate (a cut point on a digital map) would signal the traverse between two counties. In the case of a fee that varies by facility (e.g. urban freeways during peak travel periods) each road segment would be have a corresponding digital representation as a component of a charged network. Since measuring the Euclidean distance between GPS waypoints introduces no particular design constraint on the project it is useful to consider more closely the requirement to develop a digital map of the parts of the road network that have unique charges associated with them.

A variable mileage fee is likely to involve fees that vary by facility and time of day, but only in cases where there is some significant congestion present on the road. Rural roads and local collectors are unlikely to fit this definition. As a result the extent of the road network that needs to be part of a digital network is fairly modest. Many forms of digital maps or road networks currently exist, and many are open source. The form of digital map that is best for this project will depend on the approach to map matching that is employed. All of these details are best left open until a technology vendor is involved in the final design effort. If digital maps, and map matching algorithms, are only required for use in the back office then there are likely no constraints on the size of the road network that can be used. If map matching must occur in the in-vehicle metering device then storage limitations of these devices may present some upper bound on the size of the road network. For all the above reasons it is useful to consider limiting the network of uniquely prices facilities to urban freeways and arterials.

6.4.3 Participant Recruitment Geography

The design requirements that the sample protocol introduces are discussed more in the next section, but the geography of the sample is one important consideration. The participants in the demonstration project should generally reside and work in the geography in which the fee is being implemented. Since participant management is a potentially costly exercise the sampling geography should be as centralized as is feasible given other project design objectives. Minimizing the costs of communicating and coordinating with participants is a very important part of managing overall project costs for this type of demonstration. Other aspects of the sample design, such as sample enrichment discussed below, also argue for an oversampling of the urban population.

6.5 EXPERIMENTAL DESIGN

6.5.1 The design of a demonstration follows from its objectives

A brief examination of the approach to experimental design employed during the Traffic Choices Study is Seattle help to illustrate how important it is to have clarity on study objectives. A similar example is the recent design of the Oregon Road Usage Charge Program; which is well documented and understood by authorities in Oregon.

In the spring of 2003, the Traffic Choices study team began designing an experiment that would require a highly technical simulation of a toll system. The project had a limited budget to create the technical system, yet it needed to support the highly detailed behavioral experiment. The technical system needed to meet a variety of requirements, including:

- Represent a high degree of roadway network detail
- Provide a highly flexible toll schedule
- Assign road users to roads used accurately
- Handle all transactions in a verifiable manner
- Provide direct feedback to the road user about facility use and tolls
- Support behavioral analysis with flexible system for storing participant data
- Provide toll system billing functions
- Equip all participating vehicles with meters, and uniquely identify all those vehicles
- Function without permanently altering participant vehicles
- Support operations with little or no testing
- Meet the project budget

The project team selected the GPS tolling approach because it offered a ubiquitous and cost-effective method of tolling on all roads. By relying on “in-vehicle meters,” the team avoided the need for expensive wayside antennae. GPS allowed for cost-effective tolling of arterial roads, important in the Puget Sound region where the extensive highway network makes selective tolling pilots difficult to implement. GPS technology also has valuable future implications: as vehicle technology changes, it could become a replacement for the existing tolling of roads using fuel taxes.

The toll system needed to handle complex trip characteristics and tolling strategies. In short, it had to be very accurate about where and when vehicles traveled (high precision waypoint locational capability and high frequency waypoint capture capability). In addition, the OBUs needed to be able to communicate user fees to participants as they were incurred, including total trip costs as well as toll rates per mile. They needed to include the capacity to communicate eight to ten different price levels (for different time periods or facility characteristics) and reliably price the over 7,000 road links in the regional network.

The measurement of trips, vehicle miles traveled (VMT), trip purpose, route, origin and destination locations, and so on would be determined, in part, by analyzing the data once the trips were completed. Because daily travel behavior naturally has a large variance, the quality of the data had to be high so as to not introduce spurious variation with missing or imputed data. Because behavior changes measured in this study would be subtle or marginal, losing or misinterpreting data had high costs, so reliability was a critical requirement for the selection of the system for the data retrieval and processing.

While the project team was defining the technical requirements of the system and acquiring a vendor to provide such a system, it was also refining all other aspects of the experiment. The team created requirements for the sample to ensure the findings could be generalized to a broader population of road users, and determined toll rates to closely approximate the short-run marginal costs associated with the use of various elements of the road network. It developed a participant recruitment and management plan, and established a basic methodology for creating household travel budgets (endowment accounts). In summary, the study went through the following steps before implementation:

Exhibit 6.4 Design and Implementation Steps

5/1/2003	Developed approach to toll system vendor procurement
9/1/2003	Issued request for qualifications from System Integrators (toll technology)
10/20/2003	Received System Integrator submittals
11/15/2003	Selected of Siemens as System Integrator
2/5/2004	Held initial design workshop with Siemens
4/1/2004	Signed Siemens contract
4/1/2004	Finished sample design and participant recruitment planning
5/1/2004	Started tolling road network development (geography and road classes)
7/1/2004	Started road digital map file (geo-data) development process
7/1/2004	Started project communications material development
9/21/2004	Started participant recruitment
9/30/2004	Completed back office functionality
10/20/2004	Completed initial participant recruitment
10/20/2004	Completed tolling network geo-data
10/28/2004	Achieved passage of the system Acceptance Test (Siemens)
11/8/2004	Began installation of On-Board Unit (OBU)
11/30/2004	Began second participant recruitment phase
1/1/2005	Finished tariff model - toll rates
2/10/2005	Completed second phase participant recruitment
2/20/2005	Completed OBU installation
3/1/2005	Began baseline data collection

Source: Puget Sound Regional Council, ECONorthwest

6.5.2 Must also meet scientific standards for validity of results

Pilot projects that aim to understand consumer behavior must also adhere to scientific standards that allow for useful analysis to be performed at the conclusion of the study operation. Sample size is a key issue for any experiment. The sample for a study of road users should be grouped by households, as many households have multiple vehicles. A large sample is always preferred (everything else being equal) to a smaller sample. As a practical matter, however, the advantages of sample size must be balanced against the disadvantages of measurement error if sample size is gained by using a primitive data collection technology.

Holding the methods and precision of data collection constant, a larger sample means larger costs due to the requirements of equipping all household vehicles with charging meters and funding their travel budgets. For all of these reasons, it is generally better to have high-quality data from a smaller sample than lower-quality data from a larger sample. But each pilot project is unique and will introduce its own sample and analysis requirements. Behavioral experiments must consider experimental protocol, control for self-selection bias, and may require an enriched sample approach. All of these factors interact with the sample requirements. The approach taken for the Traffic Choices Study is outlined in Appendix E.

6.6 MANAGEMENT OF THE DEMONSTRATION

A variable rate road fee pilot project will be a complex undertaking and require a strong operational partnership from key stakeholders. These key stakeholders include Metropolitan Planning Organizations, various departments of the State of Oregon (at a minimum ODOT but possibly including other departments responsible for revenue collection, vehicle licensing, and enforcement), and the Federal Highway Administration.

Regional planning bodies are locally based and have direct access to other local taxing jurisdictions. The State of Oregon should provide oversight and guidance related to statewide interests and policies as well as address coordination across the various state agencies. The Federal Highway Administration has a particular interest in road fee programs and addressing some degree of standardization across various states involved in testing these programs. The funding of a significant demonstration project will also require funding contributions from a broad array of partners. There are many ways to structure a partnership and this paper does not attempt to posit what approach will best meet agency and stakeholder needs in Oregon.

The recent organization of various parties interested in mileage fee programs under the Mileage Based User Fee Alliance offers another opportunity to learn from related efforts, clarify design and demonstration project objectives and identify common areas of practice that need attention. The Alliance represents a coming together of a number of States as well as vendors and researchers in the market.

It is also true that the operation of a variable fee demonstration will require the partnership to be extended to private vendors in order to get the best value from the program operation. The key to the effective management of vendor participation is a clear division of responsibilities that is guided by the particular strengths of each party. A variable fee demonstration involves developing and deploying a system of systems with functional dimensions that include in-vehicle hardware for positional locating, telecommunications, back office and data management, account management and bill processing. It is probably clear that private vendors will take a lead role in some aspects of the project, for example the mileage fee recording devices installed in the participant vehicles and telecommunication services. But private vendors may be required in other aspects of operations. The current concept-level planning of a demonstration is not the right time to determine roles and responsibilities but early design work on the implementation of the demonstration project must get detailed enough to provide clarity on which parties as best positioned to take on what roles. It is necessary to do this work in advance of going out into the market to secure private vendor products and services.

There are many approaches to securing and managing vendors, and generally managing the risks associated with project implementation. One approach is to contract for services with performance targets rather than products that meet specifications. Another approach is to develop open standards around how technical aspects of the project will operate and then invite any vendor that can meet those standards to participate in the project. Invitations to participate can be extended to any vendor with off-the-shelf technology as a means of keeping costs down and minimizing the risks associated with technology development efforts.

6.6.1 Budget is a function of the design details and approach to partnering with potential vendors

The largest costs for an efficient fee pilot project are likely the costs to implement the technical systems that levy charges and collect behavioral data. Once again it is worth pointing out that building on the approaches taken for the Oregon Road Usage Charge Program can yield significant cost advantages over designing a system from the ground up. Other costs associated with a behavior experiment might include higher costs for participant management, funding travel endowment accounts (should this be included in the experimental design), and the costs of behavioral analysis at the conclusion of the pilot operations. When the Oregon Road Usage Charge Program is significantly underway it will be feasible to develop a more detailed estimate of the costs to implement a variable rate pilot.

Based on the implementation of the Traffic Choices Study in the central Puget Sound region, and other related projects (ODOT, Netherlands) it is possible to develop a preliminary sense of the implementation costs. Pricing for hardware, software, and the telecommunication services required for a mileage fee demonstration changes quickly. A more comprehensive review of recent efforts at implementing mileage-based user fees should be undertaken during the pre-design phase of the project and used to refine budget details in advance of contracting for any required services.

One important goal of demonstration projects is to minimize risk associated with the full implementation of complex programs. But any large-scale demonstration project will itself include risks. The primary risks in such programs are to the budget and schedule. Early design work on the implementation of the project should involve an identification of specific risk factors, and strategies to minimize and manage those risks.

A planning budget should incorporate some risk management even at this early stage in planning. Key aspects of the budget about which there is uncertainty can be estimated using information on cost probabilities. A budget rollup can then use Monte-Carlo simulation techniques to develop expectations about total project cost. A pilot project with a two-year duration and involving around 1000 participants might cost between $3 million and $4 million. There may be possibilities for cost savings, but it is unlikely that the project, as specified, could be done for as little as $2 million. Similarly, the estimates are based on an actual study that is similar: they are unlikely to be more than 50% too low, so it is unlikely that the project would cost more than $5 million.

7. NEXT STEPS

A well-designed demonstration of variable fee is major undertaking technically, politically, and financially. This kind of effort progresses incrementally. This paper is one first step. The next step would be to build upon the success of current efforts to implement road usage charges in Oregon. Additional steps toward a practical implementation of a pilot project involve developing clear objectives, coordination with other entities and interests and securing the appropriate authorization and funding.

1. Demonstrate variable rates by building on the success and technical implementation of the current mileage fee program

The implementation of a variable rate pilot project needs to be distinct from the mileage fee program but also take advantage of opportunities to build on the systems and practice put in place to support that program, especially back office systems, enforcement and payment processing. The goal should be to build on success but not interfere with, or complicate, the ongoing implementation of an operational program.

2. Develop a clear message that explains why a pilot project is useful

ODOT's report on the outreach involved in their Tolling and Pricing stakeholder process (*Tolling and Pricing Stakeholder Involvement Summary and Recommendations*) was clear on the importance of developing an understandable message about where policy is heading and why. The report states: "ODOT should prepare to deliver messages that thread these various technical and methodological issues together into a more comprehensive story as part of a broader public education and involvement process." Developing a message begins by agreeing on, and finalizing, a set of objectives for the pilot project. Potential objectives are discussed in section 6.1.2. With a project of this complexity and potential sensitivity it will be necessary to develop a strategic communications plan that identifies core messages and tactics for forming expectations and presenting information about the project to stakeholders and the public. The message should be about an efficient operation of an overall road management and investment program, not just about the need for revenues.

3. Include local governments and MPOs in planning

Many of the cost associated with road use such as congestion and road wear and tear occur on infrastructure managed by local government agencies. Congestion, in particular, is largely an urban phenomenon. Close coordination with local entities involved in road system management will be critical to the success of a variable rate road use fee pilot project. Regional planning organizations are locally based and have direct access to other local taxing jurisdictions and as such are one effective means for coordinating with a large number of individual jurisdictional interests.

4. Secure authorization and funding

Appropriate authorizations and funding will need to be secured before a pilot project can be initiated. Authorization should include specific directives to state agencies and provide general guidance on pilot project objectives and desired outcomes. Since there is an opportunity to build on, but not interfere with, the work of the Oregon Road Use Charge Program authorization and funding should be secured in a time frame that will allow the pilot to begin operations by around 2017.

5. Ensure accountability with clear expectations about results

Conducting pilot projects is a prudent means of testing potentially complex and costly changes in policy. To get the most out of a pilot test it is important to specifying the results that are desired. Expected results should tie clearly back to the objectives of the project. Pilot project authorization should clearly state the desired results of the program while providing sufficient flexibility in program operations. The promise of a variable mileage fee is that many of the most difficult aspects of surface transportation management are improved considerably. These management challenges relate to cost recovery (revenue), fairness, pollution, and congestion externalities. Each of these can be improved upon through the implementation of road usage fees that 1) more closely reflect the costs that users impose and 2) facilitate better asset management practices amongst road authorities. Even as long-term benefits from an efficient fee program are clear and large in scale the challenges for implementing such a program are many. Such a fee represents a large-scale change from existing policy and would involve disruptive transformation in many aspects of surface transportation management and operations. Demonstration projects offer an opportunity to gain insights into how to design a program and how to respond to challenges without making the commitment of a full-scale implementation. The pilot project proposed here should be expected to generate significant contributions to the knowledge about mileage-based user fees across a broad range of important topics, including:

- Accounting for Driver Behavior
- Testing the technical and operational systems
- Safeguarding Privacy
- Understanding Fairness