ALTERNATIVES TO THE MOTOR FUEL TAX

Final Report

SR 561

ALTERNATIVES TO THE MOTOR FUEL TAX

FINAL REPORT

SR 561

by

Anthony M. Rufolo
Robert L. Bertini
Thomas Kimpel
Transportation Research Group
Center for Urban Studies
Portland State University

for

Oregon Department of Transportation
Research Group
200 Hawthorne Avenue SE, Suite B-240
Salem, OR 97301-5192

December 2001

Technical Report Documentation Page

1. Report No. OR-RD-02-06	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Alternatives to the Motor Fuel Tax Final Report		5. Report Date December 2001 6. Performing Organization Code
7. Author(s) Anthony M. Rufolo, School of Urban Studies and Planning Robert L. Bertini, Department of Civil Engineering Thomas Kimpel, Center for Urban Studies Portland State University		8. Performing Organization Report No.
9. Performing Organization Name and Address Oregon Department of Transportation Research Group 200 Hawthorne Ave. SE, Suite B-240 Salem, OR 97301-5192		10. Work Unit No. (TRAIS) 11. Contract or Grant No. SR 561
12. Sponsoring Agency Name and Address Oregon Department of Transportation Research Group 200 Hawthorne Ave. SE, Suite B-240 Salem, OR 97301-5192		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The National Highway Cooperative Research Program (NCHRP) published its Report 377, Alternatives to Motor Fuel Taxes for Financing Surface Transportation Improvements, in 1995. Increased fuel efficiency and the use of alternative fuels were seen as potential threats to future road finance due to the heavy reliance on fuel taxes. Much has happened since 1995. Technological progress in vehicle fuel-efficiency, alternative fuel vehicles, and methods of collecting alternative types of revenue, has been substantial. This research project focused on updating the work of NCHRP Report 377 to better evaluate the potential for alternatives to motor fuel taxes. The project maintained a primary focus on passenger vehicles and on the issues that must be addressed in designing an alternative. The project consisted of a literature review, an analysis of the economic issues related to fuel tax alternatives, and an analysis of the technological issues related to fuel tax alternatives. Several conclusions and recommendations for further research are offered. In addition, the report outlines several issues that policy makers will have to address as they explore alternatives to dependency on fuel tax revenue.

17. Key Words fuel tax alternatives, road user charges, VMT fee, telematics, automatic vehicle identification, automatic vehicle location, fuel tax, vehicle fuel tax, motor fuel tax, value pricing, congestion pricing, tolls, transportation finance	18. Distribution Statement Available from NTIS and Oregon Department of Transportation (http://www.odot.state.or.us/tddresearch)

19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 69 + appendix	22. Price

Technical Report Form DOT F 1700.7 (8-72) Reproduction of completed page authorized ♻ Printed on recycled paper

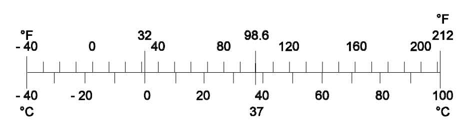
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8C + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

(4-7-94 jbp)

ACKNOWLEDGEMENTS

This project has been made possible by the efforts of many individuals. The research team is grateful to the project manager, Alan Kirk, and the Technical Advisory Committee: Victor Dodier of ODOT Communications, Jack Svadlenak and Mark Joerger of the ODOT Policy Section, Barnie Jones of the ODOT Research Group, Galen McGill of the ODOT ITS Unit and Fred Patron, Federal Highway Administration.

Robert L. Bertini and Tony Rufolo served as co-principal investigators. Thomas Kimpel assisted with the literature review. Shazia Malik, Sutti Tantiyanugulchai and Monica Leal assisted with the technology analysis. Kenneth Dueker and Jim Strathman provided valuable reviews and input during the project.

DISCLAIMER

ALTERNATIVES TO THE MOTOR FUEL TAX

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This report summarizes the efforts of the Alternatives to the Motor Fuel Tax research project and focuses on updating the work of NCHRP Report 377 to better evaluate the potential for alternatives to motor fuel taxes. The project consisted of a literature review, an analysis of the economic issues related to fuel tax alternatives, and an analysis of the technological issues related to fuel tax alternatives.

Literature Review

The literature review showed that there have been many new developments since the publication of NCHRP Report 377 in 1995, both in the realm of technology and in the range of experience with alternative road pricing systems:

- In the near term, the impact on gas tax revenue due to alternative fuel vehicles is likely to be small, due to the small number of such vehicles and the fact that many of the alternative fuels could be subject to taxes similar to the gas tax. There is a much greater potential impact of an increase in fuel economy, either through further improvements for standard vehicles or the much higher fuel efficiency of hybrid vehicles.

- Improved technology has made tolling relatively more attractive as a road finance option; however, there is substantial resistance to the introduction of tolls on previously "free" roads. The FHWA Value Pricing program has promoted a number of projects that demonstrate acceptance of pricing to access higher levels of service.

- While the Value Pricing program has demonstrated the feasibility of selective pricing, it has also raised a number of issues: a) the extent of the pricing; b) the degree of price variation and whether it should be fixed or dynamic; and c) the extent of price and service variation.

- People appear to be more accepting of alternative pricing systems if they receive reductions in other taxes; thus any large scale mandatory system would probably have to address the gas tax. There is currently no experience with such a system, however, and none of the existing projects adjust gas taxes. However, other countries have successfully implemented a variety of pricing systems to raise revenue, and several more are under active consideration.

- While all toll systems seem to be relatively more expensive to operate than the gas tax system, the costs are declining over time and appear to be within the range of costs of other tax systems. The scope of the system and its complexity affect the administrative and compliance costs.

- Value pricing projects that are fairly simple in design and involve either a single facility or a single cordon are much more likely to be successful than elaborately designed projects. Small-scale projects lend themselves to the use of proven electronic toll collection, administration and enforcement technologies. Small-scale projects can also provide valuable demonstrations to the public that can be valuable for assessing user perceptions.

- Post-implementation surveys have shown that people are generally supportive of road pricing, with users of the priced lanes showing somewhat greater support than users of the un-priced lanes.

- Suggestions for congestion pricing or toll roads typically include concerns about the equity of using direct charges. These concerns are much less important when priced options are added to existing “free” roads. There have been no comprehensive analyses, however, of the impact of alternative finance systems on the overall incidence of the finance burden.

- A VMT fee may have medium- to long-term potential as a revenue source for transportation financing, though it is thought to be presently inadequate as an alternative to the fuel tax because of the significant administrative burdens it imposes.

Economic Issues

In the analysis of the economic issues related to fuel tax alternatives, the research project yielded the following major findings:

- Changes in automotive technology, leading to both wide variations in fuel efficiency and alternative-fuel vehicles, raise questions about the viability and equity of the gas tax. Mechanisms such as higher registration fees for fuel-efficient vehicles could be used to equalize the revenue raised for road purposes from different types of vehicles; however, some form of road use pricing appears to be more viable as a method to address the need for road finance.

- Current pricing systems in use in the U.S. are almost exclusively some form of tolls. Tolls have the advantage of being proven under a variety of circumstances and being relatively simple to collect, with recent advances in technology reducing the cost and inconvenience of collection. New technologies have also meant that more sophisticated types of road pricing are also becoming technically feasible.

- Major issues with the more advanced systems are cost and privacy. The cost is likely to decrease over time and with more widespread applications, and cost becomes much less of an issue if the technology is already in place for some other reason.

- Revenue estimates should be relatively easy for a system to completely replace the gas tax; however, revenue estimates for partial replacement or for funding specific objectives would be more problematic. The feasibility of an accurate forecast depends on the type of project, the reliability of data, and accurate representation of people’s likely behavioral changes in response to the incentives created.

- Changes in road finance systems create equity concerns between vehicle classes, between income groups, and among geographic areas. Each system will raise some such concerns and will require analysis based on the specific proposal.

- Most proposed changes are not likely to have much effect on economic efficiency. The major exception is that some form of broadly applied congestion pricing would likely generate substantial benefits associated with more efficient use of road capacity.

- Administration and compliance costs for any alternative are likely to be higher than those for the gas tax and may be substantially higher. Some alternative finance measures are feasible at modest cost, but the more sophisticated ones can become quite costly. The costs of various forms of technology are expected to continue to decline over time, and the use of systems installed for other purposes would reduce the net cost.

- Any system that completely replaced the fuel tax would create substantial coordination problems relative to neighboring states. There would be an incentive for vehicles from other states to buy fuel in Oregon and there would be difficulty in separating travel by state for both residents and non-residents for tax purposes. Many of the partial or voluntary alternatives can be designed to avoid these issues.

- Transition from the gas tax to an alternative revenue source would almost certainly require the use of incentives for a voluntary adoption of the new system. In particular, a rapid change to a system requiring substantial retrofitting of vehicles would likely meet great resistance.

Technological Issues

In the analysis of the technological issues related to fuel tax alternatives, the research project yielded the following major findings:

- In the past five years, there have been many important technology advancements in the areas of telecommunications, toll collection systems, data processing and storage systems, automotive safety and security, as well as some important advancements in automobile propulsion systems.

- Cellular telephone use has increased tremendously in the U.S., and analog cellular technology provides the communications backbone for auto companies' expanding telematics/mayday systems now available in across the country.

- Drivers have adopted automatic vehicle identification (AVI) toll tag technology at a surprisingly rapid rate as toll authorities have replaced or augmented traditional tollbooths with automatic toll collection for bridges, tunnels and toll roads. AVI technology has also been used for several value pricing facilities. The rapid technology adoption has been surprising, particularly in view of substantial privacy concerns.

- Changes in the automobile industry have led to a contraction in the availability of purely electric vehicles and a surge in interest in hybrid vehicles. Further, more computing, location and communications capabilities are available as standard equipment in increasing numbers of new cars, as part of navigation and telematics systems.

- A vendor-neutral review of technologies for possible road pricing systems can range from simple systems targeting only the highly efficient and alternative fuel vehicles to complex systems in which the current fuel tax system would be completely replaced.

- Pricing systems could be administered in partnership with a multitude of possible public agencies and private entities. Systems could be voluntary or mandatory, cover part of the fleet or all of it, include the entire state or merely a region. Administration could be in the form of simple reporting, inspection, or a technology-based solution requiring varying degrees of vehicle monitoring. For example, gas stations could collect VMT information and tax vehicles accordingly as part of the fuel purchase transaction. VMT taxes could be paid as part of a vehicle insurance payment. The state could partner with auto manufacturers and/or mayday service providers (OnStar or ATX Technologies) to charge vehicle owners for VMT fees as part of another service.

- The vehicle odometer or an after-market hubodometer could be starting points for reporting vehicle miles traveled (VMT). Data from hubodometers could be manually read or automatically transmitted to special receivers or by cellular telephone to a central processing center or vendor.

- Global positioning systems (GPS) are likely to remain the basic means of locating a vehicle over a wide area and over various periods of time. Recent improvements in GPS accuracy, along with possible future enhancements, further suggest the continuing importance of GPS.

- AVI systems could be developed to identify vehicles at specific points for the purposes of charging for the use of a particular road or cordon area, for estimating a vehicle's VMT or for monitoring vehicles entering or leaving the state.

- Automatic vehicle location (AVL) systems similar to those used for fleet management could be used for part or all of the fleet in order to monitor road use. Data could be stored in a special on-board processing unit to be read or transmitted for processing.

- A hubodometer used with AVI could facilitate mileage-based pricing that accounted for state border crossings, with the added flexibility of phasing in variable charges for corridors or cordons. VMT data could also be transmitted periodically at AVI receiver locations (public or private).

- A hubodometer may be combined with AVL as an alternative to AVI.

- It is very important to keep in mind that the average driver is paying less than $150 in state fuel taxes, a small amount compared to the cost of a technology-based solution for payment of road user fees. Thus it makes sense to conceive of either a system that is very simple and inexpensive to implement or one that leverages technology used for another purpose.

Issues for Future Policy Making

As policy makers proceed with exploring alternatives to dependency on fuel tax revenue, several general issues will need to be addressed. Some of these issues include the following:

- **Whether an alternative pricing system should include continuing or ending the fuel tax.** While the fuel tax will almost certainly remain in place in the near term, some systems could completely replace it over time. Alternatively, one could look at systems that charge alternative fuel or very high-efficiency vehicles for road use; or the finance supplements could be targeted at funding for specific facilities or geographic areas.

- **Whether an alternative pricing system should tax out-of-state mileage.** Registration fees for passenger vehicles are levied by the home state but gas taxes are paid where fuel is purchased. In effect, the gas tax roughly taxes vehicles based on where they are used. Many of the systems to charge for use of specific facilities or for accessing specific areas would also charge on the basis of use. However, more general systems, such as VMT systems, could be based on usage or on registration status.

- **Whether to charge for social costs.** Automobile use imposes costs that are not paid by the driver, such as the costs created by automobile pollution. Many people have suggested that systems to charge for vehicle use also include charges for these external costs so as to promote more efficient vehicle use. For example, a policy could be implemented that would encourage use of alternative fuel vehicles.

- **The time horizon for implementation of an alternative pricing system.** While a wide range of options exist for alternative pricing systems, the cost of the technology needed to implement them continues to decline. A system that is needed in the near term would likely have to be focused on simpler methods using lower cost technology than for a system expected for widespread use further in the future.

- **Whether to charge more during peak hours in selected locations.** There are likely to be substantial efficiency gains from the use of higher road prices during congested periods, but this may generate increased public opposition and would likely raise the administrative and compliance cost for a pricing system.

- **Tolerable level of administrative costs.** Each of the alternatives under consideration is likely to result in higher administrative costs than the gas tax. Some consideration of what level of cost would be acceptable in both the near term and after full implementation may affect the choice of system.

- **Type of technology and the implications for privacy.** An array of technology options has been presented along with some of the possible ways they can be combined as part of a new road pricing system. Once key decisions are made relating to how a system would be phased in and administered, specific system designs can be sketched and costs and impacts can be estimated. As part of a sketch design for a system, each alternative will exhibit different implications for privacy concerns. These concerns will play a substantial role in determining which systems to consider for testing and implementation.

Once policy makers have addressed these general issues and have identified one or more road use pricing alternatives to consider in depth, each alternative will have specific design issues and data issues to address.

1.0 GENERAL INTRODUCTION

The National Highway Cooperative Research Program (NCHRP) published its Report 377, *Alternatives to Motor Fuel Taxes for Financing Surface Transportation Improvements*, in 1995. Increased fuel efficiency and the use of alternative fuels were seen as potential threats to future road finance due to the heavy reliance on fuel taxes. The project set out to evaluate "alternatives to motor fuel taxation and recommend an innovative approach to financing surface transportation" (*NCHRP 1995*). Among the major conclusions of the report were:

1. Motor fuel taxes will remain important components of state and federal surface transportation revenues for at least the next three decades.
2. Fees or taxes based on vehicle miles traveled (VMT), including congestion pricing, have desirable attributes, but their implementation depends on political and technological development.
3. Rather then seek to replace motor fuel taxes precipitously, agencies should seek a smooth transition to alternative sources by phasing in promising new sources as elements of revenue programs.
4. The development of monitoring technologies for VMT fees, emissions-based fees or congestion pricing can be fostered by transportation agencies; and Intelligent Vehicle Highway System (IVHS) and research programs should address revenue collection issues. (*NCHRP 1995*)

Much has happened since 1995. Technological progress in vehicle fuel-efficiency, alternative fuel vehicles, and methods of collecting alternative types of revenue, has been substantial. This report focuses on updating the work of NCHRP Report 377 to better evaluate the potential for alternatives to motor fuel taxes. While NCHRP Report 377 addresses broad issues of motor vehicle taxation, it states that "there is no a priori reason taxation of heavier vehicles should parallel taxation of lighter vehicles" (p. 24), and much of the report is oriented toward alternatives to fuel taxes for passenger vehicles. This report also maintains a primary focus on passenger vehicles and on the issues that must be addressed in designing an alternative. The next section is a review of recent literature on the topic. This is followed by preliminary analyses of economic and technological issues that must be addressed in designing alternative revenue sources. Finally, some conclusions and recommendations for further research are offered.

2.0 LITERATURE REVIEW

by Anthony M. Rufolo and Thomas Kimpel

2.1 INTRODUCTION

A significant objective of this literature review is to determine whether the conclusions of NCHRP Report 377 should be altered because of faster advancements in technology than were envisioned when the report was written. There are two aspects of technology that must be addressed in answering such a question. The first is the technology of transportation, where greater fuel economy or alternative power sources may erode the revenue-generating capacity of the gasoline tax. The second is the ability to monitor road usage in an efficient and cost-effective manner. The response to both questions appears to be affirmative. In addition, a variety of pricing experiments, conducted under the ongoing Federal Highway Administration (FHWA) Value-Pricing program, provide much-needed information on the practical issues of pricing implementation. Finally, experience in other countries also indicates that alternatives to the gasoline tax are more viable than it may have appeared when NCHRP Report 377 was written.

The tax on gasoline has many benefits as a source of revenue. In particular, it can be levied at a relatively high level in the distribution chain, thus reducing the administrative and compliance cost of the system. While it is often discussed as a tax on individual drivers, neither drivers nor retail distributors typically have any direct involvement in the collection or administration of the tax. Gasoline taxes are typically levied at the wholesale level. The key difference with most of the alternatives to gasoline taxes is the shifting of the tax collection to the individual vehicle. This involves a substantial increase in the number of transactions associated with funding the road system and commensurate increases in administrative and compliance costs. While there is a tendency to focus on the technology associated with such a change, it should be recognized that various types of user finance, such as tolls, have been around longer than the gas tax. The advances in technology enable some pricing systems that were not previously feasible and allow for more efficient collection and for a wider range of options, but low technology options exist as well.

The other major difference between the gas tax and alternative finance mechanisms is that the alternatives typically allow options for managing the use of the road system. While this is not a requirement for the alternatives, it opens a whole new range of issues to be considered in evaluating the system. The best-known example would be to use some form of time and distance varying price to manage congestion. These additional objectives can substantially complicate the administration of the tax system.

2.2 TECHNOLOGY

Gas tax collections are sensitive to the average fuel economy for gasoline-powered vehicles and to the use of alternative fuels. Alternative fuels may be subject to taxes to offset the loss of gas tax revenue, but higher efficiency vehicles are more problematic in terms of the impact on tax revenue and the equity of road use charges among vehicles.

A variety of alternative fuel vehicles (AFVs) exist. However, only a limited number appear to have high potential to achieve significant market share in the foreseeable future. Hybrid electric vehicles (HEVs) are the most likely to achieve significant market penetration in the near term, and those currently in production rely on small gasoline engines. Hence, their impact on gas tax revenue is actually through higher fuel economy. The two hybrids currently available in the U.S., the Honda Insight and the Toyota Prius, achieve significantly higher fuel economy than conventional vehicles. Major U.S. automobile manufacturers plan to introduce hybrid-electric pickup trucks and sport utility vehicles in the next few years (*TRB 2001*).

Nevertheless, Orski (*2001*) argues that U.S. auto makers see fuel cell technology as the ultimate solution and are reluctant to invest significant resources in hybrid technology, which they view as an interim solution. He also believes that the fuel cost savings for most users in the U.S. (estimated as $800 over the first 50,000 miles) is not high enough to justify the $3,000 that a hybrid engine adds to a vehicle's cost. Higher fuel prices in other countries are likely to make the hybrids more attractive, and an increase in fuel price in the U.S. or reduced cost for the hybrid engines would make the hybrids more attractive here. However, this does not seem likely in the near term. In addition, Orski reports that the National Research Council has recommended scrapping the program to develop a highly fuel efficient "supercar" since the goal does not seem attainable.

Alternative vehicles that use other energy sources fall into two categories. There are those that burn a different fuel and those operated purely by electricity. While alternative fuels create problems for the gas tax, those that are consumed could be subject to taxation in most cases, with some such tax systems already in place. Mintz (*2000*) reports that federal taxes for motor vehicle use of liquefied petroleum gas (LPG) and liquefied natural gas (LNG) are higher than the energy equivalent tax on gasoline while the taxes on compressed natural gas (CNG) and ethanol are lower. Further, some states have similar tax structures in place, demonstrating their feasibility. However, most analysts do not see much market penetration for such vehicles outside of specialized fleets. A significant issue is that AFVs using CNG, ethanol, and methanol are disadvantaged because of limited fuel availability. Many are configured as flexible fuel vehicles (FFVs) and can often run on traditional fuels.

Bemis (*2000*) does not foresee much impact on gas tax revenue due to alternative fuel vehicles by 2020 due to the small number of such vehicles, but he does see the federal subsidy of ethanol reducing federal road funds. He expects that there is a much greater potential impact of an increase in corporate average fuel economy (CAFE) requirements, but does not foresee much of an impact before 2007. Mintz (*2000*) concludes, "even dramatic increases in fuel economy have little effect on fuel tax revenues in the first ten years or so. After that, however, consumption flattens and then begins to fall."

Electric vehicles would create a much more substantial concern from the perspective of road taxation. It would be difficult to track electricity for road usage and difficult to tax only such uses. However, the electric car does not seem likely to generate large market share. Most electric vehicles (EVs) on the road today are currently being leased from auto manufacturers and exist largely in fleet applications. Markets for "city cars" and neighborhood electric vehicles (NEVs) are starting to emerge (*California Energy Commission 2000*), but the limited range, low speeds and related problems make them unlikely to achieve large market share other than in specialized applications. Fuel cell technology is advancing rapidly, and a significant advance could make an electric alternative more feasible, but production vehicles are still many years away (*TRB 2001*). Fuel cell vehicles also necessitate a new fueling infrastructure that would take time to develop once the vehicles became viable.

2.3 EXPERIENCE

There has been a wide range of experience with alternatives to the gasoline tax. Toll roads have been the most widely used alternative, with many major systems in the U.S. and other countries financed by direct charges for using roads, bridges or tunnels. Tolls are typically levied either for entrance into a limited access facility or are levied at various points along the road. More recently several countries have experimented with a cordon system, whereby an area is encircled by toll stations and a fee must be paid to enter the area; or with toll systems levied throughout the road system. For example, it would be possible to charge a vehicle each time it passed a toll point on the road system.

With current technology, there are several variants that are feasible. State Route (SR) 91 in California uses a single toll point with a variable price for toll lanes in the median of a freeway, based on the general congestion level. Many roads on the East Coast have long collected tolls at on-ramps and various points along the road. They are now allowing the option of electronic toll collection, with substantially reduced cost of administration and compliance at the many toll points.

In general, improved technology has made tolling relatively more attractive as a road finance option; however, there is substantial resistance to the introduction of tolls on previously "free" roads, especially in the U.S. Most tolls in the U.S. have been instituted at the time of construction, and there appears to be substantially less resistance to tolls on new roads than to tolls on existing ones. However, several countries have successfully imposed toll schemes. It appears that most of the toll systems imposed in Europe were used to finance additional road supply even when imposed on an area rather than a specific road. Acceptance of this alternative to higher gas taxes might also be due to the much higher gas taxes already levied. Singapore is still the major example of the imposition of new tolls to control congestion. A variety of other plans have been proposed to either raise revenue or control congestion but were never adopted.

The FHWA Value Pricing program has provided funds to promote experience in more directly pricing road usage. The following summary of projects and experience comes largely from FHWA (*2001*). FHWA classifies the projects as falling into one of four categories: higher peak-period tolls on existing toll facilities; conversions of high occupancy vehicle (HOV or carpool) lanes to high-occupancy toll (HOT) lanes; variable pricing of new capacity; and conversion of fixed costs of driving to variable costs. The first three categories provide direct information that is relevant to using pricing as an alternative to fuel taxes.

The only project with substantial experience under the first category, higher peak period tolls, is the Lee County, Florida project. In this project, existing toll bridges had their tolls reduced during the off-peak (shoulder) periods to induce traffic out of the peak. To take advantage of the discount, drivers had to use an electronic toll system. Experience with the system has been positive despite the fact that the monetary savings are small ($0.25 per crossing for most users).

This project helps demonstrate the feasibility of time-varying tolls on existing toll facilities, and projects are underway to implement some time-varying tolls on existing facilities in New Jersey and New York. Since the Lee County toll was a reduction for off-peak usage, much of the controversy involving equity was avoided. Estimates of the shift in usage indicate some smoothing of the peak, and public acceptance has been high. There are now proposals to look at more extensive use of pricing, such as allowing queue jumping, i.e., allowing vehicles to bypass lines at toll booths, for a higher fee.

In the second category, conversion to HOT lanes, there is more experience; but the most discussed project is the Interstate 15 (I-15) conversion in San Diego. This facility is a two-lane reversible barrier separated HOV facility that was under-utilized. The project allows single occupant vehicle (SOV) users to pay a fee to use the facility while it remains free for HOV users. The most significant difference for this project is the use of dynamic congestion pricing. The HOV rules for California require that a specific level of service be maintained on the HOV lanes. Hence, the fee for access is adjusted every six minutes to maintain the required service level. The fee is posted on variable message signs prior to the entrance to the facility. The fee can typically go as high as $4.00 under normal traffic conditions and as high as $8.00 when there are accidents on the adjacent freeway.

Acceptance has been high and there are plans to extend the facility. This is particularly noteworthy, since most previous studies found strong resistance to the concept of dynamic pricing. The key difference appears to be that in previous discussion, the fee would vary after the driver had made a commitment to a facility. Hence, the driver faced uncertainty over the price and often could not change behavior in response to price changes. This facility provides pricing information to the driver in real time before a decision is required. Thus, dynamic pricing appears feasible if the driver knows the price before a decision is made.

The SR 91 express lanes illustrate the use of fixed rates that nevertheless vary by time of day and day of week. Initially there was a fixed fee during the four-hour peak period. This rate structure was adjusted to a fee that changed every hour, and the fee could be different for the same hour on different days. This case illustrates that it is possible to set fees that vary by time of day but to have those fees change at specific times set in advance. With this system, drivers know in advance what it will cost to use the facility if they arrive at a specific time. The major disadvantage of such systems is setting the fee appropriately to maintain flow. If the fee is too high, the facility is under-utilized while a fee that is too low promotes congestion. The fee on SR 91 has varied to induce some smoothing of the peak, but the evidence indicates that the price differentials have not had much effect on the pattern of usage within each rush-hour period.

SR 91 is the major example of congestion pricing on new capacity. The facility initially allowed free use by carpools but changed this to a 50% discount. There has been extensive analysis of this project. In particular, usage patterns have demonstrated that many lower-income people are willing to pay the toll for faster trips, although not as frequently as higher-income people. It also appears that people use the facility selectively, with relatively few users using it every day.

While the Value Pricing program has demonstrated the feasibility of selective pricing, it has also raised a number of issues that must be addressed in any pricing system. The first is the extent of the pricing. Most of the projects that impose new pricing do so for new capacity that is a small percentage of the total. The second is the degree of price variation and whether it should be fixed or dynamic. Constantly changing prices are most effective in maintaining smooth flow, but they create problems for drivers, especially when unpriced alternatives are not available. The third is the extent of price and service variation. Small (*2001*) has observed that part of the value of the Value Pricing projects is that they allow users to choose from two different service levels for two different prices; however, there may be additional benefits from further varying the prices and service levels.

Small and Gomez-Ibanez (*1997*) provide an excellent summary of various pricing programs in other countries and offer insight into the lessons that can be learned from these examples. Pricing programs based upon toll rings surrounding city centers have been implemented in the Norwegian cities of Bergen, Oslo, and Trondheim. All three Norwegian programs aim to generate revenues to finance major road improvements in their respective regions rather than reduce congestion per se. The Trondheim case is noteworthy in that a discount is given for off-peak travel and charges for frequent users have been capped by ceilings.

In Stockholm, Sweden, a regional transportation package designed to alleviate traffic congestion was proposed. It involved a combination of pricing and the construction of new facilities. The project faced strong opposition from environmental groups over the planned road improvements and was eventually tabled.

A proposed program for Cambridge, England designed as a single-cordon system, attempted to carry the idea of congestion pricing closer to the theoretical ideal. Prices were to vary in real-time depending upon the amount of congestion experienced by each vehicle. A number of problems were identified with this system. In particular, traffic problems would cause a driver's congestion charge to increase at the same time that he or she was experiencing time delays. Further, with an unanticipated set of delays, such as those caused by an accident, the driver would have no way to predict the price nor to avoid the payment while stuck in traffic. The proposed design was eventually modified to be more in line with conventional value pricing systems after questions were raised about the political feasibility of implementing a system that had unpredictable tolls.

Autoroute A1 connecting the cities of Paris and Lille, France is a single-facility congestion-pricing program. In an effort to manage traffic more effectively, a revenue neutral pricing program was implemented using fees that vary by both time and distance. The program shows that pricing can be an effective tool for eliciting the behavioral responses necessary for congestion management.

Cities considering area-wide congestion pricing programs include the Randstad region of the Netherlands and London, England. Both systems were proposed as multiple-cordon systems with the London plan also charging tolls for crossing internal screenlines that would divide central London into six cells. Neither project was implemented because their overall size and complexity raised a number of public concerns. A new proposal for London aimed at reducing congestion in the central area with proceeds used to finance public transportation improvements appears to be gaining popular support (*FHWA 2001*).

2.4 REVENUE

The basic objective of the road finance system is to raise revenue for the construction and maintenance of the system. All alternatives to the fuel tax currently in operation have been in addition to gasoline taxes rather than as a replacement for gasoline taxes. While substantial revenue has been generated in specific applications, there has been relatively little analysis of the ability of the alternative systems to raise as much revenue as the gas tax. In particular, the gas tax is levied at all times and all locations while many of the alternatives look at a limited set of locations or variation by time of day.

Even with roads such as SR 91, that use tolls to pay off construction bonds, there is some question as to whether the toll revenue would be sufficiently high if applied to the entire road system. For example, Sullivan (2000) notes, "it is rare for a new urban highway project to have the SR 91's unusual combination of relatively low capital costs (less than $3.5 million per lane-mile), large demand, and a favorable institutional environment for quick implementation." (p. 6)

In looking at alternatives, serious consideration should be addressed to whether the new option would be an addition to the gas tax or a replacement. Many of the studies of public acceptance for alternative finance schemes find that people are more accepting of alternatives if they would get reductions in other taxes, and any large scale mandatory system would almost certainly have to address the gas tax. However, there is currently no experience with such a system and none of the existing projects adjust gas taxes.

Revenue estimates for complete replacement of the gas tax as the major source of taxation for light vehicles are likely to be relatively easy to generate. The complex part of the question is to generate revenue estimates when there is only partial replacement and to identify mechanisms to compensate for gas taxes paid in addition to the alternative. However, any system to phase in a replacement would have to address such concerns.

2.5 EFFICIENCY

The ability of alternative finance schemes to improve the efficiency of road system usage has generated the most attention from economists. Yet public resistance appears to be greatest where the tolls are intended to accomplish more efficient usage. Recent experience confirms that people do change their behavior in response to tolls, and that this could substantially improve the use of the road system. However, there are serious questions raised when one part of the system is subject to charges and other parts are not. For example, Small and Yan (*2001*) raised the issue of whether tolled lanes in parallel with free lanes, such as SR 91, actually generate a welfare improvement over the same number of lanes, with all free. While there seems to be a general conclusion that the toll lanes improve efficiency, it does raise questions about the overall efficiency effect and how sensitive it is to the price and other characteristics. While most studies still conclude that the existing pricing experiments have improved efficiency, any system that is selective or phased in over time would have to be evaluated for its impact on the rest of the road system.

2.6 ADMINISTRATIVE AND COMPLIANCE COST

While all toll systems seem to be relatively more expensive to operate than the gas tax system, the costs are declining over time and appear to be within the range of cost of other tax systems. The scope of the system and its complexity affect the administrative and compliance costs.

Value pricing projects that are fairly simple in design and involve either a single facility or a single cordon are much more likely to be successful than elaborately designed projects that often never make it out of the planning stages (*Small & Gomez-Ibanez 1997*). Small-scale projects lend themselves to the use of proven electronic toll collection and enforcement technologies. Besides low collection costs, electronic toll collection allows for variable pricing, produces a stable revenue stream, and has low evasion rates (*Forkenbrock 1997*). Electronic toll collection is typically based upon either automatic vehicle identification (AVI) technology in the form of transponders and receivers or vehicle recording devices using smart card technology. Enforcement is commonly undertaken through a combination of video license plate recognition technology and law enforcement patrols. Evasion rates for AVI-based enforcement systems are estimated to be approximately 3-5% (*Supernak, et al. 2001*).

2.7 PUBLIC ACCEPTANCE

As noted earlier, there is substantial public resistance to pricing roads that were previously "free." This is particularly true where the price is seen as a clear increase in cost for the motorist. Many motorists see an added toll as a form of double taxation. Thus replacement of the gasoline tax with a VMT charge may be more acceptable than selectively adding charges with no reduction in other taxes and fees.

Perhaps the biggest change to promote public acceptance has been the change in focus from pricing options as a means to raise revenue to pricing options as a means to offer travelers alternatives, hence the term "value pricing." In particular, the projects in the U.S. that have been successful have almost exclusively focused on providing additional choices rather than reducing the options available.

The value pricing projects for I-15 in San Diego and the Katy Freeway in Houston involved the conversion of HOV lanes to HOT lanes. The I-15 project sought to utilize excess capacity in the HOV lanes and to finance express bus service in the corridor. The aim of the Katy Freeway project was to make use of excess HOV capacity following an increase in the minimum vehicle occupancy from 2 to 3 persons.

SR 91 differs from the above two projects in that pricing is used as a mechanism to generate sufficient revenues to pay for the financing of the facility. Persons who value their time highly can buy into the tolled lanes and be assured of shorter travel times and greater reliability. Users of unpriced lanes also benefit because overall freeway capacity is increased.

Analyses of the I-15 and SR 91 projects show that the majority of users do not use the priced lanes regularly but are instead more discriminate in their use of the pricing option (*Sullivan 1998; Golob, et al. 2001*). Post-implementation surveys for each of the projects have shown that people are generally supportive of road pricing, with users of the priced lanes showing somewhat greater support than users of the unpriced lanes. Of note is that public acceptance levels were shown to decrease following sudden price increases on SR 91 and with the introduction of dynamic (real-time) pricing on I-15, although they have since increased (*Golob, et al. 2001; Sullivan 2001*)

Studies involving I-15 and SR 91 state that the pricing programs do not appear to draw patrons from bus service operating in the same corridor (*Sullivan 2000; Golob, et al. 2001*). Determining the actual impacts on bus ridership has proven more difficult. Early concerns that improved traffic conditions would shift riders from transit onto the toll roads have proven to be unfounded. The impacts of the pricing programs on the rates of carpooling have been shown to be slightly positive or neutral (*Sullivan 2000; Supernak, et al. 2000*).

2.8 EQUITY

Suggestions for congestion pricing or toll roads typically bring concerns about the equity of using direct charges. In many cases, people talk of "Lexus Lanes" or use other pejorative terms to discuss the impact of pricing. While higher-income people are more likely to make the payments, there are several relevant perspectives. The first is that a tax that is primarily paid by higher-income individuals might be considered desirable in many ways, and there is substantial evidence that higher-income families are more likely to be driving in congested traffic than lower-income families (*Svadlenak and Jones 1998*). The second is that experience with pricing indicates that many lower-income families are willing to pay the price even when free (but congested) alternatives are available, indicating that the benefits of the time savings outweigh their costs (*Sullivan 1998; Sullivan 2000*). Nevertheless, there have not been comprehensive analyses of the impact of alternative finance systems on the overall incidence of the finance burden.

2.9 BORDER ISSUES

NCHRP Report 377 appears to have been aimed at changes in the federal tax system. There is no discussion of the elimination of the gas tax for part of the system. While states typically do not think about the direct relationship of their actions on neighboring states, experience in the taxation of trucks has proven that some form of inter-state cooperation and coordination is important to make the system work effectively. Thus, interstate trucks report their mileage in each state under the International Fuel Tax Agreement (IFTA), and fuel taxes are adjusted and redistributed to reflect where the fuel was used rather than where it was purchased.

Coordination of tax policy has not seemed to be a particular problem with gasoline taxes, since most states tax gasoline within a relatively small range. Rhode Island had the highest state gas tax in 2001 at 29 cents per gallon and Georgia had the lowest at 7.5 cents per gallon. However, forty of the contiguous forty-eight states had tax rates in the relatively narrow range of 17 to 26 cents per gallon. Further, tax differentials for gasoline are not likely to matter much unless there is a substantial population at the border of two states with a large differential.

Of the seven contiguous states with rates below 17 cents per gallon, New Jersey's 10.5-cent rate as compared with New York's 22-cent rate and Pennsylvania's 26-cent rate, would appear most likely to create border problems. These differentials may be somewhat mitigated by the tolls required to cross between these states at the major population centers, but they do indicate that it is possible to have fairly large differentials without any specific policy. Complete adoption of an alternative mechanism, however, would create a border differential between Oregon and Washington of 23 cents per gallon, thus producing a substantial incentive for border residents to purchase fuel in Oregon. This scenario might require some reporting method similar to IFTA for personal vehicles or some mechanism to tax fuel purchased by out-of-state vehicles.

Similarly, a state with a system different from the gasoline tax would need to have a mechanism for collecting charges from out-of-state cars and for crediting in-state drivers for travel out of state. This is not a problem for certain types of charges, but becomes more of a problem as the new system becomes an extensive replacement for the gas tax. The literature appears to offer little guidance on how to deal with this issue, and it has not been a factor in the existing trials.

2.10 VMT FEE

NCHRP Report 377 concluded that VMT fees offer substantial promise as a financing alternative to the motor vehicle fuel tax. Financing road use through a VMT fee has a number of strengths and weaknesses. Similar to the fuel tax, a VMT fee is directly related to vehicle use; provides a stable and predictable revenue stream; and is subject to similar problems regarding inflation. Revenues from a VMT fee are not adversely affected by the proliferation of alternative fuel vehicles or improvements in fuel economy.

A VMT fee could be implemented as a supplement to existing fuel taxes or in place of them. It is estimated that a 1-cent fee per mile in the state of California would generate approximately $2.8 billion in annual revenue, nearly as much as the current fuel tax (*Adams, et al. 2000*). One of the main benefits of the fuel tax is that rates do not vary much from state to state. An important issue with respect to a VMT fee concerns the development of an appropriate method for charging out-of-state drivers and how to control for in-state drivers that travel out-of-state.

A VMT fee could be set either as a flat rate or a variable rate fee, though a number of tradeoffs exist. The effect of a flat rate VMT fee on congestion levels is indirect. A flat rate fee fails to address inefficiencies associated with road use because it does not differentiate travel by time or location. On the other hand, a variable rate fee has a number of desirable properties. Not only can the fee be varied by time and location, it can also be structured to take into account costs associated with vehicle weight, energy use, and vehicle emissions. From an economic efficiency standpoint, a variable rate VMT fee is appealing because it can closely approximate the true costs of travel on a per vehicle basis imposed on society. With regard to equity considerations, because lower income persons tend to drive fewer miles, a fee schedule could be designed allowing a base (or lifeline) number of miles to remain untaxed until a certain threshold is reached.

The main impediments to implementing a VMT fee relate to political feasibility and administrative costs. The rate structure of a VMT fee program and the actual method used to record and collect information on distance traveled have a large bearing on costs. The simplest collection method could involve reporting of VMT either through voluntary reporting on a predetermined date, or in conjunction with a biennial vehicle inspection program. A major criticism regarding annual reporting of VMT fees is that the fee is far removed from daily travel costs and is therefore not likely to result in significant behavioral changes on the part of drivers.

A VMT fee program using advanced technologies such as electronic odometers, AVI/automatic vehicle location (AVL), and smart card technology would allow for other types of payment such as pay at the pump or quarterly billing. Although the costs of advanced technology systems are currently prohibitive, they should decrease substantially over the next several years. In light of these shortcomings, it has been suggested that a VMT fee has medium- to long-term potential as a revenue source for transportation financing, though it is presently inadequate as an alternative to the fuel tax because of the significant administrative burdens it imposes (*Adams, et al. 2000*).

2.11 LITERATURE REVIEW SUMMARY

The literature review has shown that there have been many new developments since the publication of NCHRP Report 377 in 1995, both in the realm of technology and in the range of experience with alternative road pricing systems:

- In the near term, the impact on gas tax revenue due to alternative fuel vehicles is likely to be small, due to the small number of such vehicles and the fact that many of the alternative fuels could be subject to taxes similar to the gas tax. There is a much greater potential impact of an increase in fuel economy, either through further improvements for standard vehicles or the much higher fuel efficiency of hybrid vehicles.

- Improved technology has made tolling relatively more attractive as a road finance option; however, there is substantial resistance to the introduction of tolls on previously “free” roads. The FHWA Value Pricing program has promoted a number of projects that demonstrate acceptance of pricing to access higher levels of service.

- While the Value Pricing program has demonstrated the feasibility of selective pricing, it has also raised a number of issues: a) the extent of the pricing; b) the degree of price variation and whether it should be fixed or dynamic; and c) the extent of price and service variation.

- People appear to be more accepting of alternative pricing systems if they receive reductions in other taxes; thus any large scale mandatory system would probably have to address the gas tax. There is currently no experience with such a system, however, and none of the existing projects adjust gas taxes. However, other countries have successfully implemented a variety of pricing systems to raise revenue, and several more are under active consideration.

- While all toll systems seem to be relatively more expensive to operate than the gas tax system, the costs are declining over time and appear to be within the range of costs of other tax systems. The scope of the system and its complexity affect the administrative and compliance costs.

- Value pricing projects that are fairly simple in design and involve either a single facility or a single cordon are much more likely to be successful than elaborately designed projects. Small-scale projects lend themselves to the use of proven electronic toll collection, administration and enforcement technologies. Small-scale projects can also provide valuable demonstrations to the public that can be valuable for assessing user perceptions.

- Post-implementation surveys have shown that people are generally supportive of road pricing, with users of the priced lanes showing somewhat greater support than users of the un-priced lanes.

- Suggestions for congestion pricing or toll roads typically include concerns about the equity of using direct charges. These concerns are much less important when priced options are added to existing "free" roads. There have been no comprehensive analyses, however, of the impact of alternative finance systems on the overall incidence of the finance burden.

- A VMT fee may have medium- to long-term potential as a revenue source for transportation financing, though it is thought to be presently inadequate as an alternative to the fuel tax because of the significant administrative burdens it imposes.

3.0 ECONOMIC ISSUES RELATED TO FUEL TAX ALTERNATIVES

by Anthony M. Rufolo

3.1 INTRODUCTION

Road finance is generated from a variety of sources. These include registration fees, title fees, fuel taxes, tolls, and distance-based charges. Fuel taxes for automobiles and other light vehicles have historically provided a clear link between the use of roads and the financing of their construction and maintenance. However, changes in technology, leading to both wide variations in fuel efficiency and alternative-fuel vehicles, raise questions about the viability and equity of this revenue source.

There are several mechanisms that could be used to address the revenue and equity concerns. For example, the initial title fee could be varied by fuel efficiency of the vehicle, with higher-efficiency vehicles paying the discounted present value of their expected fuel tax savings when the vehicle is registered. Alternatively, the annual registration fee could be based on fuel efficiency. While such approaches would address the revenue needed for road finance, the tendency has been for incentives in the opposite direction. For example, the federal government once levied a gas-guzzler surcharge on low-efficiency vehicles; and there are a variety of incentives offered for alternative fuels and more fuel-efficient vehicles, particularly in air quality non-attainment areas. Hence, the concerns for road finance tend to be in conflict with the desire for incentives to improve fuel efficiency and to develop vehicles that use alternative fuels.

In addition, charges that do not vary with vehicle use tend to create equity issues between vehicles that are used intensively and those that receive little use. Further, vehicles that travel through the state but are registered in another state would not be subject to the charges. Thus, while such alternatives should not be dismissed, more direct pricing of road use appears to be a more viable approach to road finance; and this report will focus on the various approaches to road pricing for automobiles and other light vehicles.

As noted in the literature review, road pricing for automobiles and light vehicles is almost exclusively some form of toll pricing at present. Tolls have the advantage of being tested under a variety of circumstances and being relatively simple to collect, with recent advances in technology reducing the cost and inconvenience of collection. New technologies have also meant that more sophisticated types of road pricing are also becoming technically feasible.

Major issues with the more advanced systems are cost and privacy. The cost is likely to decrease over time and with more widespread applications, and cost becomes much less of an issue if the technology is already in place for some other reason. For example, a stand-alone global positioning system (GPS) for an automobile may cost hundreds of dollars, and this expense would be high relative to existing levels of state fuel taxation. Systems currently used for other purposes, however, could be adapted for tax use at much lower cost.

A system currently being demonstrated by Progressive Insurance in Texas monitors vehicle use for insurance purposes. The information from this system could also be used for many road-pricing systems. This experience with monitoring vehicle use also indicates that privacy may not be as much of a concern when people have an option of using the system or not and when there is a perceived benefit. The Progressive Insurance system provides information on vehicle use by location and time that many people would consider to be a violation of privacy; however, the system is voluntary, so anyone concerned about such issues could choose the standard type of insurance coverage. Proponents of wider use of such systems argue that encryption of data would be necessary and feasible for privacy (*Forkenbrock 2000*). Other systems, such as prepaid debit cards that could record and save data that could be deleted by the user, have been proposed as well.

3.2 ISSUES

Any price or tax system will have distributional and efficiency effects. Tax systems are typically evaluated based on revenue potential, stability, equity, efficiency, and administrative and compliance costs. In addition, changes in tax systems typically create transition issues. Further, changes in the tax system in one state will affect its relationship to tax systems in other states. Finally, the technology needed to implement any tax system will affect cost and reliability. In particular, the possibility to use a technology that is in place for some other purpose could substantially reduce the compliance cost of a new system, but it may increase the administrative costs.

Current pricing systems largely use permits and tolls, while more advanced systems seek to monitor vehicle usage by location and time of day. Permits are relatively primitive and typically allow unlimited access for a specific fee. The permit system is most useful to limit travel within a specific area. Those wishing to drive within the designated area must display a permit, but there are no restrictions on the amount of travel and no variation in cost with distance.

Tolls are levied at specific points and can vary by time of day or vehicle class. Simple tolls require a cash payment at a specific point, but current technology allows for automatic collection.

More advanced systems can more accurately monitor vehicle usage, with some capable of providing information on road usage by location and time of day. The latter could be used for more sophisticated pricing systems than are feasible under permits or tolls.

Typically, permits are the least costly option, tolls next most costly, and vehicle monitoring the most expensive. Full discussion of these issues is left for the technical discussion, and there is clearly the potential for overlap of the technologies in specific applications.

This section will provide an overview of the issues in a broad context. Then each of the major alternatives will be discussed and evaluated. The Appendix provides a list of issues that would have to be addressed in defining specific applications of the alternatives as well as some of the data issues that would arise. Determination of the exact type of road user fee application and evaluation of the data available would establish whether more specific evaluations and forecasts could be generated.

3.2.1 Revenue

The most basic revenue question in looking at alternatives to the fuel tax is whether the alternative is expected to supplement the fuel tax or to replace it. Supplements must be evaluated relative to their objectives. For example, a supplement may be intended to generate the equivalent to gas tax revenue for an alternative fueled vehicle or it may be intended to finance a new construction project. Revenue replacement for the fuel tax on alternative fuel vehicles is likely to be relatively simple in terms of revenue forecasts, and the source is likely to be as stable as the gas tax. Similarly, mandatory alternatives that completely replace the gas tax should generate relatively simple analyses for revenue potential and stability.

The big question will be the revenue potential for most other alternatives. In particular, tolls that are intended to fund specific improvements are likely to be problematic. For voluntary participation there is likely to be self-selection, with higher probabilities of participation for those who are most likely to save money under the alternative system and lower participation likely for those expected to pay more. The data for many of these calculations are problematic, and the feasibility of an accurate forecast will depend on the type of project, the reliability of data related to the activity being taxed, and the estimates of people's responses to such taxes in terms of behavior changes. For example, there are a variety of estimates of people’s likely response to a price increase for using a road, but the response will vary tremendously depending on whether one or all lanes are priced and on the non-priced alternatives available.

3.2.2 Equity

Equity issues are raised in a variety of contexts when discussing road finance. The most important such issues are equity between vehicle classes, equity between income groups, and geographic equity. When considering new systems that may only partially replace the fuel tax or that may be phased in over time, concerns about double taxation are also raised.

Oregon addresses the equity between major vehicle classes by separating light (less than 8,001 lbs), medium (8,001 to 26,000 lbs) and heavy vehicles (over 26,000 lbs). Light vehicles almost exclusively pay the gas tax. The general reasoning has been that among light vehicles, the heavier ones impose greater cost on the road system and also tend to get lower gas mileage, thus paying a larger tax. With the wide variation in fuel efficiency and potential for alternative fueled vehicles, this assumption is no longer valid. Hence, from the perspective of equity within the light-vehicle classes, the current gas tax will create a greater and greater distortion over time.

In addition, the relationship between fuel usage and road cost is by no means exact, so alternative pricing schemes offer the potential to more closely tie taxes to the cost imposed on the road system. Finally, congestion also enters into the equity discussion, since those traveling at congested times create a demand for additional capacity that implies greater cost than for those traveling at uncongested times. While the equity issue is not typically discussed with respect to differential pricing during congested periods, it is relevant from this perspective.

Equity among income groups is typically the most sensitive issue in evaluating changes in tax systems. While the gas tax appears regressive when viewed from an ability-to-pay basis, it is generally judged as a user fee for the road system. Changes in the system, particularly ones that allow for optional fee-based use, are often seen as providing benefits disproportionately to those with higher incomes. Thus, toll lanes or HOT lanes are often derided as "Lexus Lanes" for the rich.

There are several problems with this perspective. First, the evidence from SR 91 in California and other pricing systems indicates that usage is not that different by income category from the usage of the free lanes. In particular, substantial numbers of lower-income drivers use the system at various times. Second, the issue really revolves around the overall financing of the lanes. If toll users are paying the full cost of the lanes and also contributing gas tax funds for other road use, it is hard to see how this disadvantages the non-users. However, if the toll roads are not self-financed and there is a substantial differential in usage by income category, then the issue becomes more relevant. A variety of methods exist to address such equity concerns, such as "lifeline" rates or other low-income price breaks.

Toll roads in Oregon do not appear to be good candidates for self-financing, since most studies conclude that demand must be quite high and existing congestion conditions severe to allow a priced road to sufficiently compete with un-priced lanes. Hence, the equity impact of proposed toll roads that also require general road fund support may warrant further analysis.

The other issue with respect to equity among income groups arises when looking at major changes in the methods of financing roads. As will be discussed in the VMT analysis, the Oregon Tax Incidence Model (OTIM) can be used to gain some insight into both the distributional and overall effects of changes in finance. However, it requires careful manipulation to get meaningful results, and it does not appear that the model could be used for discussions of geographic equity. Thus, OTIM is only likely to be useful in evaluating changes that completely replace the gas tax. While many of the policies being considered would be phased in over time, OTIM can be used to get some idea of how the distribution of tax burden would be changed by the time the policy was fully implemented.

Geographic equity implies that road funds should be spent roughly in proportion to their collections by geographic area. Each of the alternatives to the gas tax discussed later in this chapter would alter the geographic distribution of taxes. For example, cordon pricing around urban areas would generate additional funds from these areas. Similarly, toll roads would generate revenue from the specific roads, again more likely to be urban roads. On the other hand, replacement of the fuel tax with a VMT fee might tend to shift the tax burden toward rural areas since city fuel efficiency is typically expected to be lower than fuel efficiency in rural areas. Hence, for an equivalent amount of revenue, city drivers would tend to see lower costs under a VMT fee while rural drivers would tend to see higher ones.

3.2.3 Efficiency

Taxes typically distort decision-making and lead to costs to the economy that are greater than the revenue generated for government. By comparison, prices for goods or services tend to lead to more efficient use of resources by making people evaluate the benefits that they receive versus the cost of provision. Many people argue that the gas tax promotes efficiency in road use because the gas tax is essentially a price for using the system. While this argument has merit, it ignores the differential cost of providing road capacity at different times of day or in different locations. In particular, many economists argue that failing to directly charge higher rates for road usage during congested periods creates substantial efficiency costs for the economy.

Most changes in the tax system are not expected to have significant effects on economic efficiency, with one major exception. Most transportation economists expect that there would be substantial efficiency improvements if any pricing scheme included differentials by time of day and location to reflect the level of congestion. While congestion related pricing is expected to improve efficiency in general, much would depend on the specific method of implementation. For example, a general pricing scheme based on GPS monitoring of all vehicles would almost certainly improve efficiency. However, a system of imposing congestion prices only on freeways at specific times could reduce efficiency by creating incentives for drivers to switch to un-priced alternate routes.

3.2.4 Administrative and Compliance Costs

Some examples of administrative and compliance cost for the selective pricing of roads or lanes are available, and there are estimates of the costs for a national system of VMT taxation. There do not appear to be any good estimates, however, of the cost for a single state shifting to a general VMT basis.

Annual costs of operating the San Diego I-15 Express Lanes are estimated to be approximately $500,000 for the eight-mile, two-reversible-lane facility (*Kawada, K. as cited in Ward 1998*). The estimate includes administrative, maintenance, enforcement, and electronic tolling equipment costs. The facility has one entry point and a series of variable message signs to inform drivers of the current toll.

Financial information for SR 91 shows that operating expenses ranged from $6.3 million in 1996 to $9.1 million in 1999 (*Hulsizer, G. as cited in Adams, et al. 2000*). Operating expenses remained fairly constant over the period 1997-1999. SR 91 is a ten-mile facility, with two non-reversible lanes in each direction (four total). It also has one entry point in each direction. No definition of operating expenses was given, so it is not clear why this facility faces much higher costs than the San Diego one.

Dr. Ed Sullivan of California Polytechnic State University has supervised most of the analysis of SR 91, and he postulates that the difference is due to several factors:

- I-15 receives various services from the San Diego Council of Governments (SANDAG) and the California Department of Transportation (Caltrans), while SR 91 is fully self-contained and operates its own Freeway Service Patrol, among other items;

- I-15 operates only during weekday peaks while SR 91 is operated continuously; and
- SR 91 has investors to keep happy and lawsuits to deal with, which requires significantly more financial and legal help (*Sullivan 2001*).

NCHRP Report 377 provides several broad figures with respect to administrative and compliance costs for both congestion fees and VMT fees. The VMT scenario that is presented is the full replacement of the motor vehicle fuel tax with a VMT fee. The actual design of the program will have a significant bearing on costs. For example, a VMT fee can be based around a vehicle inspection program, annual self-reporting, or electronic monitoring of the vehicle. The cost of annual self-reporting would be the lowest in terms of administrative and compliance cost, but it would also create the highest potential for evasion. The use of special equipment such as hubodometers, in-vehicle meters, and transponders will add to compliance and administrative costs.

The cost estimates presented in NCHRP Report 377 were based on the technology and prices at the time of the study (1995); thus adjustments for inflation and technological change would be necessary for current estimates. The NCHRP estimates, however, provide for some comparison across programs and give some idea of the range of costs. For programs involving the self-reporting of VMT, annual filing fees were estimated to be approximately $1.70 per vehicle (p. 77), with enforcement costs based upon random inspections of $0.67 per vehicle. The estimated administrative costs for VMT programs for all states combined were $290 million (p. 73) or $11.4 to $14.6 million per year for California alone (p. 83). This represented a $90 million dollar increase over the costs of administering the existing motor vehicle fuel tax for the country as a whole (about a 45% increase). The use of different technologies would also affect the compliance cost for the individual. For example, the estimated cost per vehicle for a hubodometer was $30 for purchase and installation.

Compliance costs for a congestion fee program in which all vehicles are charged a fee for using certain congested roadway was estimated to be annual filing fees of $11.00 per vehicle and transaction costs of $78 per vehicle in addition to the one-time cost of a vehicle transponder (p. 87). The transponder cost was estimated to be $20-$50 per vehicle at that time, but technological improvements have lowered this cost. Additional enforcement costs include the necessary roadside equipment needed to determine fees. Administrative costs related to billing, enforcement, and fee collection were expected to range between $20-$40 per vehicle per year.

Another set of estimates for administrative and compliance costs of a mileage-based tax was generated in a Minnesota study (*Wilbur Smith Associates 1997*). This study concluded that systems based on existing odometer readings would lead to unacceptable levels of evasion. Three options were evaluated. The lowest technology option would be a tamper-proof chip to store vehicle information and the highest would be an electronic odometer coupled with devices at the state border to allow for differentiation of in-state and out-of-state travel (p. 43). Estimates of cost ranged form $20 to $100 per vehicle for equipment and installation of the appropriate technology.

The study estimated that the cost of equipping the state's 3,500 gas stations and 35,000 fuel pumps with equipment to monitor fuel-tax exemptions at about $56 million at that time.

Antenna reader devices at major border crossing locations were estimated to cost $17 million. Additional annual operating and maintenance costs were estimated to be $19 million to $55 million (pp. 53-54).

The study concluded that "the concept of a mileage-based tax is technically feasible, but does not appear to be cost-effective *at this time, particularly if implemented by a single state.*" (p. 56). While the single-state comment reflects issues that arise in tracking residents and non-residents, it also appears to reflect potential benefits of coordination with federal vehicle taxes. Adoption of a VMT based system by the federal government would substantially reduce the cost for adding such a tax at the state level.

All of these cost estimates are subject to substantial variation. They indicate that a variety of alternative finance measures are feasible at modest cost levels but that the more sophisticated ones can become quite costly. Some of the costs could be expected to decline over time.

3.2.5 State Borders and Coordination

Permits and tolls do not create state border or coordination issues (except if the facility or area crosses state lines). Both state residents and travelers from other states would face similar issues. These would include availability and convenience of temporary permits or ability to pay tolls without pre-registration. The latter is typically handled by either having a free option (such as adjacent free lanes on a freeway) or by having an opportunity to make cash payment (such as many toll roads). NCHRP Report 377 discusses the possibility of having convenience points or of using video technology to identify vehicles that have not pre-registered and charging them a higher fee on a per use basis. The latter is likely to create substantial enforcement problems, especially for vehicles registered in another state.

If a VMT system were used to completely replace the fuel tax, there would be substantial issues associated with travel across state lines. Oregon would likely have difficulty in monitoring the VMT of cars registered outside of Oregon, and Oregon drivers would probably expect to not pay the VMT fee for travel outside of the state. Gas tax issues would also become more complicated. The price differential between Oregon and neighboring states would encourage people to purchase their gas in Oregon and avoid the tax imposed by the neighboring states.

Similar issues arise with respect to heavy vehicle taxation, but there are interstate agreements to help prevent this type of tax evasion. However, these agreements rely on reports of mileage traveled by state for trucks involved in interstate commerce. It would be difficult to collect this information for automobiles.

Wilbur Smith Associates (*1997*) evaluated several methods to address such concerns, including equipping gas stations with the technology to detect which cars should pay fuel taxes and which were exempt. They concluded that the expense was too great to warrant the adoption of a mileage-based system. However, they did not evaluate other possibilities to address such concerns, such as a system of self-reporting or a credit system for fuel taxes based on actual receipts.

3.2.6 Transition

Transition from the current tax system to an alternative would create both administrative costs and equity issues. One of the major conclusions from the Value-Pricing experiments sponsored by FHWA is that voluntary systems that offer people an option avoid many of the equity concerns and resistance to alternative revenue sources. Even if the ultimate goal is to completely replace the fuel tax, consideration should be given to a voluntary option as a transition for implementation of any new revenue source. This is particularly true if the new source relies on expensive technology. The cost of retrofitting existing vehicles would be a significant deterrent to adoption.

Voluntary systems must offer users an incentive to change, and they also create potential for evasion. The incentive to use the alternative could be either lower overall cost or better services. In the Value-Pricing experiments both types of incentives have been used. New toll lanes or HOT lanes offer better service for the fee paid, while the Lee County bridge tolls offer a discount to people who adopt the new technology and travel outside the peak. In both cases, many users have not adopted the new technology, and substantial resistance would be expected if there were a general mandate to do so.

In looking at alternatives to the fuel tax, some consideration must be given to the intent of the new system. If it were intended to be a supplement to the fuel tax, then the alternative would most likely be no reduction in service for those who choose not to use the new system. This is the situation seen with most of the value-pricing projects. If the intent is to replace the fuel tax, the alternative must allow for the avoidance or rebate of fuel taxes. The avoidance or rebate of fuel taxes is likely to create substantial administrative and compliance costs.

Oregon has experience with a system whereby some heavy vehicles pay fuel taxes and others do not. With heavy vehicles, the tax is typically much higher than it is for light vehicles, and there is more need to differentiate by weight, since the road costs are much more affected by weight differences for heavy vehicles than for light vehicles. Hence, the cost of similar systems for light vehicles would be larger as a percentage of tax collected. Currently, in Oregon heavy vehicles that pay the weight-mile tax are exempted from the state's diesel fuel tax; but the methods of monitoring the tax exemption are not highly sophisticated, since the tax difference is almost exclusively based on vehicle weight. A more complex system would almost certainly be needed for light vehicles, and the cost would be commensurately higher.

3.3 VMT FEES

A VMT fee was the preferred alternative in NCHRP Report 377. VMT fees have the advantage of being directly related to road usage. There also are a variety of methods that could potentially be used to track and collect the tax. The simplest version of the VMT fee would be for registered owners to be required to note their odometer reading each year and file a paper return, with taxes based on the number of miles driven. The most complex would require a GPS system that monitored the movement of the vehicle, potentially differentiating in-state versus out-of-state travel, type of road, and time of day. A substantial issue with VMT fees would be the method of charging for in-state and out-of-state travel. One solution would be for the state to tax all travel, whether in or out of the state, although this might seem unfair to those who travel extensively out of state.

The cost of administering a VMT fee will depend on the method of implementation chosen. It is estimated that a fee could be collected for about ten percent of the revenue generated (*NCHRP Report 377*). This estimate appears to be based on the use of hubodometers and some form of verification. Simpler systems would have lower administrative costs but would have more problems with enforcement and compliance. A VMT fee could be levied at a rate to completely replace the fuel tax. A fee of somewhat more than one cent per mile would generate revenue roughly equivalent to the current state gas tax.

For any proposed alternatives to the fuel tax, several questions must be addressed. The first is whether the alternative is intended to supplement the fuel tax or replace it. For automobiles and other light vehicles, there appear to be no current examples that completely replace the fuel tax. While complete replacement may be an ultimate objective, the issues of cost and privacy become important considerations. Many people object to the close monitoring of vehicles for privacy reasons, and certain systems would be costly to use simply for tax purposes. Hence, voluntary options for such a system may be desirable.

For example, vehicles with high fuel efficiency or alternative fueled vehicles could be given the option of paying a high annual registration fee or making payments based on VMT. There might be a lower fee to supplement the gas tax for fuel-efficient vehicles and a higher fee for alternative-fuel vehicles. Alternatively, there may be methods to allow for payment of a VMT fee instead of gasoline taxes. For example, gasoline taxes might be raised and the VMT option offered as a lower-cost alternative.

Oregon relies on the weight-mile tax for heavy vehicles, so there is a comparison basis for one alternative to fuel taxes. In addition, Minnesota has undertaken a demonstration project to evaluate the feasibility of monitoring automobile usage using GPS systems. Each of these sources should provide substantial information on the feasibility and cost of these systems. In particular, it appears that the administrative cost of the weight-mile tax is not a large percentage of revenue, but the tax collected per vehicle is much higher than would be expected for automobiles. Hence, the percentage going to administrative costs is likely to be much higher for automobiles unless a greatly simplified system is used. Over time, however, more and more vehicles are expected to have GPS systems for other reasons. Many new vehicles are equipped with GPS systems, and there is a Texas insurance program that uses a GPS system to calculate vehicle insurance payments. Thus, it may be possible to start with either a very simple paper system or to have an optional VMT tax and transition to a more sophisticated system.

The VMT option was used to test the applicability of the Oregon Tax Incidence Model (OTIM) for evaluating the equity and economic effects of different tax systems. The Legislative Revenue Office performed several runs of the model to determine the impact of a VMT fee on the Oregon economy and on the distribution of tax burden by income class. The major run of the model was to eliminate the gas tax and replace it with a VMT fee. The VMT fee was estimated by income class based on national data. The test of the model is illustrative of both its uses and the potential pitfalls in using it.

Most studies conclude that a VMT fee would have roughly the same incidence as the fuel tax and would probably have similar economic effects, since it is roughly equivalent to the gas tax. The major difference is that people with efficient cars would pay slightly more under the VMT fee while people with low mileage per gallon of gas would pay slightly lower fees. National data indicate that within broad income categories there is little difference in average miles per gallon of gas. Nevertheless OTIM finds some differences in the tax incidence.

Net household income is OTIM's most comprehensive measure of expected impact on Oregon households. This measure includes reductions for taxes paid directly and any indirect effects of the taxes through higher commodity prices or other effects. The replacement of the gas tax with an equivalent VMT appears to cause a net reduction of $87 million per year in net household income. Further, OTIM finds that eliminating the fuel tax would generate the largest gain as a percentage of income for the lowest income groups. This indicates that the fuel tax tends to be a relatively regressive tax even though low-income groups tend to drive less. This is consistent with other analyses of the gas tax.

On the other hand, the OTIM simulation finds that the VMT fee is even more regressive in its ultimate incidence, with the shift causing an increase in the net tax burden on lower income groups while the net tax burden on the highest income groups actually declines. This is not consistent with other analyses. This result would not be expected if the taxes were roughly equivalent in revenue and distribution, and the evidence is that they are. For example, Environmental Protection Agency (EPA) data show that there is relatively little divergence in average miles per gallon among income groups. Hence, the impact of a gasoline tax or an equivalent VMT tax should be approximately the same.

The difference appears to be due to the method in which the two taxes are entered into the model. The current gas tax is treated as an excise tax on the purchase of a good. Excise taxes in the model are partly paid by consumers but partly paid by sellers. The tax that is paid by sellers will affect personal income through wages and a variety of other methods, but part of the tax on sellers is exported to people in other parts of the country. However, the VMT fee was modeled as a lump-sum charge imposed on consumers. Hence, the entire burden of the fee would be reflected as reduced household income, and none would be exported through sellers to other parts of the country. This difference does not seem to reflect actual differences in tax incidence but rather the method by which the taxes were entered into the model.

The most important lesson from this exercise seems to be that one must be very careful in how changes in taxes are modeled if one wants to determine the distributional impact. The model also provides other economic data for comparison. For example, under the model, total employment would be higher with a VMT fee than with the gas tax because the gas tax is seen as a distortion within the model while the VMT fee is treated as a lump-sum transfer with no efficiency distortion. The results illustrate the potential power of the model as well as the need for care in using it.

3.4 CORDON PRICING

Cordon pricing is the charging of a fee either for being in a particular area or for entering the area. The charge for being in the area can be accomplished by a variety of methods. The simplest, and the one used in Singapore, the first major city to adopt such pricing, is a permit for driving within the area. In Singapore, the permit is needed for any driving during rush hour within the appropriate area.

A number of European cities are now using the type of cordon pricing where a fee is charged for crossing into the restricted area. Persons already in the restricted area when the price is imposed can continue to drive with no charges, but someone entering the area pays a fixed fee no matter how much driving is done. Having several cordon lines, with fees imposed as each is crossed, can further differentiate this charge.

This system has the potential to charge different rates during congested periods, but most users do not seem to rely on this feature. Rather, it is treated as a general revenue system. Where used as a general revenue system, cordon pricing raises questions of geographic distribution. In areas where it is currently in use, the revenue appears to be used for regional road construction and maintenance. This might be attractive as a revenue source for congested urban areas, but if the revenue were dedicated to such areas it might create questions about the financing of rural roads.

Cordon pricing does not seem to be a viable replacement for the entire gas tax, but would rather work either to help control congestion or as a region-specific revenue source. The method of pricing would create some issues for any cordon pricing system. A system based on GPS would raise all of the issues previously discussed, and one of the benefits of the cordon system is that it can be accomplished with much less sophisticated technology.

The most widely used method is to charge at key access points. The system works better where few access points exist than where there are many access points. The system also differentiates between those crossing the cordon and those not crossing. This can create both equity and efficiency concerns. The equity concern deals with people who reside inside the boundary and thus do not pay access charges versus those residing outside of the boundary who do pay access charges. The efficiency concern occurs because the boundary may actually create spatial distortions by discouraging people from crossing the boundary. This concern can be partially offset by having several cordons, but doing so substantially increases the cost and complexity of the system.

3.5 TOLL AND HOT LANES

As indicated in the literature review, most current pricing activities in the U.S. are associated with toll or HOT lanes. Tolls may be imposed on entire roads or only on specific lanes. The revenue from the tolls is often targeted toward financing the facility. Some older toll roads in other states generate revenue far in excess of their current cost, but it is unlikely that toll roads in Oregon could generate enough revenue to cover their full costs. Hence, any consideration of new toll roads would have to address the issues of the remainder of funding and the equity concerns of having some users pay both the general gas tax and a specific fee for use of the facility.

The Value-Pricing experiments sponsored by FHWA make new capacity available for a fee. In the toll lanes, all vehicles pay the fee, although there may be discounts for HOV vehicles, but there are adjacent free lanes available. In HOT lanes, excess capacity in HOV lanes is made available for SOVs at a price.

3.6 CONGESTION PRICING

Congestion pricing is simply the use of time-varying prices to reflect the greater demand for road capacity during peak periods. This is a relatively simple extension of the price for most pricing systems. Congestion pricing can be implemented on part of a facility (such as SR 91 in California), on an entire facility (such as Autoroute A1 in France), or over an entire area (such as Singapore). The key to congestion pricing is to vary the price by time of day to reflect the level of congestion. Typically, existing static tolls do not vary by time of day and hence do not differentiate between travel at times when there is excess capacity and times when there is not.

The scope of congestion pricing also has important ramifications. Pricing selected facilities or entry points can cause spillover of traffic onto un-priced roads. Where there is a new facility that adds to total capacity, this is not likely to be a concern since there is still a net reduction in traffic on the un-priced roads. However, adding a price to a facility that was not previously priced can create spillover and can worsen traffic conditions on other, adjacent roads. The geographic scope may also be important, since pricing entry to some areas but not others may alter people's willingness to work or shop in the priced areas relative to the un-priced ones. Finally, spatial differentiation of price may be important to reflect varying levels of congestion at different locations.

A key issue when pricing is used is the frequency and method of changing the price. Abrupt price changes tend to cause spillover of traffic into the periods immediately before and after the high-priced periods; but too many changes can be difficult to administer and confusing for users. The majority of existing systems have a pre-determined price that changes at specific times. Typically, the price is changed several times over each peak. However, systems based on permits typically have one price for access and often maintain the permit system even in off-peak periods to avoid the problems associated with change in price.

The I-15 in San Diego is the only example of full dynamic pricing, with the price adjusted every six minutes to maintain the level of service on the priced lanes. The dynamic pricing provides the user with greater certainty about time but less certainty about price. The trade-off between variations in price and variations in average speed is a significant one that would merit careful study in any pricing system. In general, dynamic pricing only seems to be feasible where there is an option to avoid the priced system and people have the price information sufficiently far in advance to be able to make informed decisions.

3.7 ECONOMIC ISSUES SUMMARY

- Changes in automotive technology, leading to both wide variations in fuel efficiency and alternative-fuel vehicles, raise questions about the viability and equity of the gas tax. Mechanisms such as higher registration fees for fuel-efficient vehicles could be used to equalize the revenue raised for road purposes from different types of vehicles; however, some form of road use pricing appears to be more viable as a method to address the need for road finance.

- Current pricing systems in use in the U.S. are almost exclusively some form of tolls. Tolls have the advantage of being proven under a variety of circumstances and being relatively simple to collect, with recent advances in technology reducing the cost and inconvenience of collection. New technologies have also meant that more sophisticated types of road pricing are also becoming technically feasible.

- Major issues with the more advanced systems are cost and privacy. The cost is likely to decrease over time and with more widespread applications, and cost becomes much less of an issue if the technology is already in place for some other reason.

- Revenue estimates should be relatively easy for a system to completely replace the gas tax; however, revenue estimates for partial replacement or for funding specific objectives would be more problematic. The feasibility of an accurate forecast depends on the type of project, the reliability of data, and accurate representation of people's likely behavioral changes in response to the incentives created.

- Changes in road finance systems create equity concerns between vehicle classes, between income groups, and among geographic areas. Each system will raise some such concerns and will require analysis based on the specific proposal.

- Most proposed changes are not likely to have much effect on economic efficiency. The major exception is that some form of broadly applied congestion pricing would likely generate substantial benefits associated with more efficient use of road capacity.

- Administration and compliance costs for any alternative are likely to be higher than those for the gas tax and may be substantially higher. Some alternative finance measures are feasible at modest cost, but the more sophisticated ones can become quite costly. The costs of various forms of technology are expected to continue to decline over time, and the use of systems installed for other purposes would reduce the net cost.

- Any system that completely replaced the fuel tax would create substantial coordination problems relative to neighboring states. There would be an incentive for vehicles from other states to buy fuel in Oregon and there would be difficulty in separating travel by state for both residents and non-residents for tax purposes. Many of the partial or voluntary alternatives can be designed to avoid these issues.

- Transition from the gas tax to an alternative revenue source would almost certainly require the use of incentives for a voluntary adoption of the new system. In particular, a rapid change to a system requiring substantial retrofitting of vehicles would likely meet great resistance.

4.0 TECHNOLOGY ISSUES RELATED TO FUEL TAX ALTERNATIVES

by Robert L. Bertini

4.1 INTRODUCTION AND BACKGROUND

Across the nation it is becoming clear that the current fuel tax system used for financing the highway transportation infrastructure will become less effective as the use of more fuel-efficient vehicles and alternative-fuel vehicles increases. Partially in response to declining real revenues coupled with increasing vehicle miles traveled (VMT), some agencies have begun testing innovative forms of road finance in order to meet their infrastructure needs. For example, agencies have increased fuel taxes, levied additional sales taxes for specific time periods, constructed new toll roads on new rights-of-way, added toll lanes to existing freeways and converted a high occupancy vehicle (HOV) lane facility to a high occupancy toll (HOT) lane facility. Some of these have been made possible by the emergence of new, low cost, reliable toll collection technology.

Further, a federal study (NCHRP Report 377) concluded that a desirable replacement for motor fuel taxes would be a fee or tax based on VMT. However, as with many past road pricing analyses, technology proved to constrain any further demonstration or detailed design of an improved pricing system. Since publication of NCHRP Report 377 in 1995, it is generally agreed that there have been technology advancements in the areas of telecommunications, toll collection systems, data processing and storage systems, automotive safety and security, as well as some important advancements in automobile propulsion systems. Brief comments will be made on each of these advancements.

First, cellular telephones have become nearly ubiquitous in terms of numbers of users and geographical coverage. The most current industry statistics report that there were about 110 million cellular phone users in 2000 (42% of the U.S. population).[1] This represents a 28% growth from the 86 million users in 1999. Industry forecasts predict the presence of about 182 million cellular phones in the U.S. by 2004 (corresponding to about 70% of the population). As a means of comparison, currently 93% of the U.S. population is served by a 911 provider (land line telephones), covering only 50% of the nation's land area.

The wireless industry has developed basic coverage of nearly all of the populated areas of the U.S. by analog technology. Advancements are being made using higher bandwidth digital

[1] Source: Cellular Telecommunications and Internet Association, 2000. These are industry forecasts, and thus caution should be taken in applying them. Given the current economic downturn and the aftermath of the September 11, 2001 terrorist events it is likely that industry forecasts will be revised in the near future. Also, current cellular systems charge users for incoming calls, unlike land line phone calls and unlike cellular systems in Europe and Japan where cellular use is much more widespread. Changes to this policy in the U.S. would likely also influence the penetration rate.

systems, but as of today, analog cellular provides the basic backbone of the cellular, particularly in rural areas. As an example, the General Motors (GM) OnStar telematics/mayday system uses analog cellular communications to provide automatic airbag deployment notification for its vehicles.

Second, drivers are adopting automatic vehicle identification (AVI) technologies ("toll tags") for bridge, tunnel, and highway toll payment at a surprisingly rapid rate, despite privacy concerns. Automatic toll collection systems such as FasTrack and EZPass are expanding rapidly due to user demands, and in Southern California, drivers can even use their toll tags in a fast food drive-through lane. In an AVI system, tag readers must be placed over each lane of traffic at a cost of about $1,000 per reader. Tags are being miniaturized such that their cost is becoming negligible. Tag readers must have electrical power and communications capabilities, and thus there would be costs associated with data transmission. Data also require processing and storage at a central administrative facility.

At the same time, computer-processing capabilities are becoming faster and less expensive, and the use of large databases is becoming commonplace. For example, toll collection systems maintain highly secure payment systems that correctly debit customers' accounts each time they pass the toll collection point. (California's FasTrak system meets 99.99% accuracy specifications.)

The automobile industry has developed a concept called "telematics," which combines embedded cellular communications, location capability using global positioning systems (GPS) and in-vehicle computing to enable drivers to take advantage of services such as airbag deployment notification systems; one button emergency call; roadside assistance call; stolen vehicle tracking; remote door unlock; door-to-door navigation systems; personalized concierge systems; access to consumer information such as news, weather, sports, stocks and traffic conditions; and remote vehicle diagnostics.

For example, if a vehicle is involved in a crash and the airbag deploys, the telematics system will automatically call the service center via the embedded cellular phone, and provide the vehicle's identification and location. An operator will attempt to make voice contact with the occupants. At the same time, the operator will dispatch the appropriate emergency services to the vehicle's exact location. GM has developed its own service entity called OnStar, while most other automakers use a service provider called ATX Technologies. Figure 4.1 illustrates some of the components of a telematics-equipped vehicle.

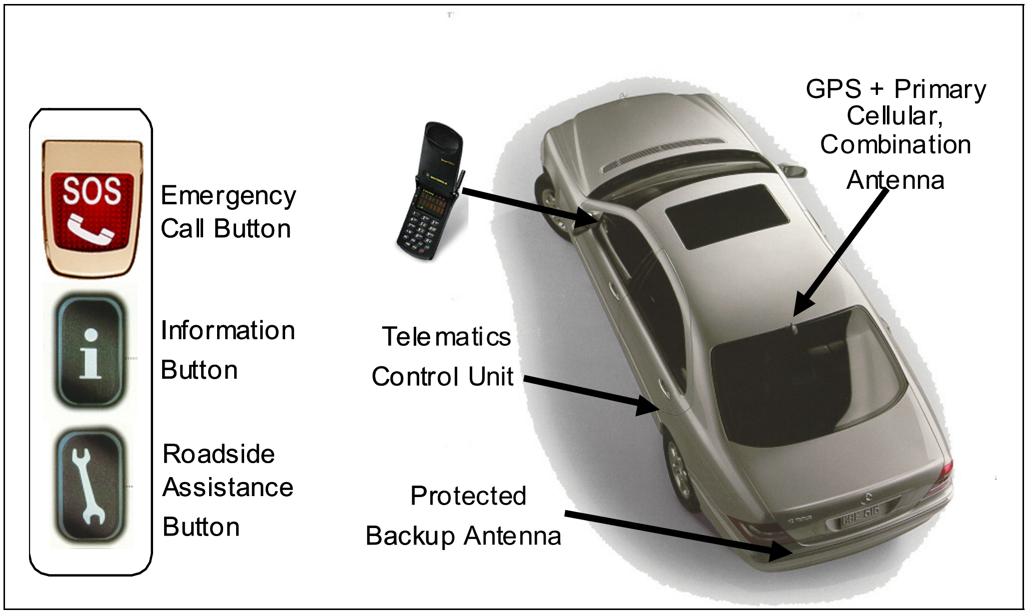


Figure 4.1: Various components of a telematics system

Finally, since the publication of NCHRP Report 377 in 1995, some changes in the vehicle fleet have occurred. The predominance of sport utility vehicles (SUVs) and light trucks has been established. Some auto manufacturers have had trouble meeting the U.S. Corporate Average Fuel Economy (CAFE) standards, and have looked for small vehicle solutions to bring up their averages. Also, there are very few purely electric vehicles left on our roadways. The recall of GM's lease-only EV1s has left only a small number of highway-legal electric vehicles, mainly in the hands of fleet owners. A small number of small, low speed electric vehicles called neighborhood electric vehicles (NEVs) are present in tourist areas.

Fuel-efficient internal combustion vehicles (e.g. the Ford Focus) are sold at high volumes, and gasoline-electric hybrid vehicles have entered the market (Honda Insight and Toyota Prius) and are quite popular, despite their small sizes and higher prices. These vehicles are two- to three-times more fuel-efficient than an average vehicle. Clearly this increased fuel efficiency would represent a corresponding drop in fuel tax revenue for these vehicles. While it is difficult to gauge the accuracy of industry announcements, Honda and Toyota claim to be expanding into full production of their hybrid vehicles, and the other major automakers have announced plans to release hybrid vehicles in the next model year (e.g., Ford Escape will be released in 2003 as will a Dodge SUV hybrid).

Partially in response to California's zero-emission-vehicle mandate, the auto industry has developed a fuel cell partnership, a demonstration project for testing fuel cell cars, trucks and buses. Some of the fuel cell vehicles are based on hydrogen as a primary fuel source, while other vehicles use more traditional fuels, even including gasoline. Clearly, vehicles with high fuel efficiency or those that use alternative fuels are on the horizon.

4.2 OBJECTIVES

The objectives of this introductory technology analysis are:

- to identify several possible technologies for collecting an alternative fee or tax in lieu of the gasoline tax, and
- to introduce some of the issues that must be addressed with these technologies.

The analysis will include a technology taxonomy as well as proposed evaluation criteria for consideration of the different technologies. Given that technology changes at a rapid pace, this analysis can only represent a snapshot in time. Further, this report does not attempt to answer a specific question or design a specific system architecture. The topics covered were developed in close collaboration with the Technical Advisory Committee (TAC) for this project.

4.3 ASSUMPTIONS

The technology discussion that follows considers a continuum of possible road pricing systems. At one end are relatively simple systems targeting only the highly efficient and alternative fuel vehicles. At the other end are systems in which the current fuel tax system would be completely replaced. Capabilities for any sort of variable pricing (such as by location and/or time of day) and distinction between in-state and out-of-state driving are also included in the discussion.

The discussion remains "vendor-neutral," and rather focuses on general categories of technology. Hence, no specific proprietary system is considered, though brand-name systems may use the components described here. A slight preference is given to systems that are based on reliable infrastructures. For example, the GPS satellite network is maintained by the U.S. Department of Defense and as such is perceived to be very reliable.

Also, because a partial or full fuel tax replacement system must be available statewide, in both urban and rural settings, only relatively mature technologies are considered. However, it is probable that all technologies considered will undergo continuing improvements and component/system price reductions. Some technologies that are in a development phase are mentioned briefly for completeness.

4.4 ADMINISTRATION

When considering a range of possible future technologies for the potential collection of a road user fee incorporating variable pricing strategies, it is possible to also envision a wide range of administration options. All administration systems would be more costly than the current system for collecting state fuel tax revenue. Some possible scenarios include:

- **VMT Reporting (low cost)**: Using an honor system with selective enforcement, vehicle owners could simply report their VMT on a periodic basis, using paper forms or electronic filing. As an analogy, many transit systems have shifted to a barrier-free fare payment system using an honor system with fare inspectors. Enforcement would be a critical component of a low cost VMT reporting, particularly since there is no actual requirement that a vehicle have an operating odometer. Instead, Federal Motor Vehicle Safety Standard (FMVSS) No. 580 and Oregon state law require that a seller complete a written disclosure of the odometer reading when selling a motor vehicle. This is required on all motor vehicles up to and including 12,000 lbs. unladen weight, or vehicles less than 10 years old. The federal law also requires all states to have the odometer disclosure statement printed on their vehicle titles and to record that reading on the title issued to new owners.

The National Highway Traffic Safety Administration (NHTSA) actively investigates odometer fraud. A state is prohibited from licensing a vehicle unless the odometer disclosure statement is completed and the buyer submits the seller's title with the application for a new title. The penalty for false statements on the odometer disclosure is a $2,000 fine and/or 3 years imprisonment. Federal regulations also require that the buyer sign the odometer disclosure statement acknowledging the odometer reading. In the future, Oregon could choose to require functional odometers as a condition for registration within the state. A VMT reporting system could be accomplished in partnership with a multitude of possible entities, including the following:

- **Department of Revenue**: taxpayers could report VMT on state tax returns.
- **Department of Transportation, Driver and Motor Vehicle Services**: vehicle owners could report VMT at DMV facilities upon biennial vehicle registration.
- **Department of Environmental Quality**: for vehicle owners residing within DEQ boundaries, VMT reporting could be conducted at DEQ facilities.
- **Service stations or auto dealerships**: private entities such as gas stations or auto dealers could provide VMT reporting facilities.
- **Auto manufacturers:** auto manufacturers maintain current information on their customers for recall and other customer service and brand loyalty purposes. The manufacturers could also collect VMT data from vehicle owners as part of their continuing customer contacts.
- **Insurance companies**: vehicle owners could report VMT to their insurance companies for reporting to the state.
- **Private contractors**: the state could contract with a private company for a statewide VMT reporting system, perhaps giving the public confidence in privacy and security.

- **VMT Inspection (medium cost)**: Similar to the list above, a myriad of entities could provide an inspection-based means of accurately reporting VMT.

  - **DMV/DEQ**: vehicle owners could have VMT inspected at DMV/DEQ facilities.
  - **Service stations/auto dealerships/insurance companies/private contractors**: VMT inspection facilities could be provided for reporting to the state.

- **Technology-based Solution (high cost)**: A system based on more advanced technology for collecting VMT information plus possibly including the capability to apply variable pricing according to time and location could be administered by a variety of entities:

- **State**: a state department (DMV, DEQ, etc.).
- **Insurance company**: the state could partner with insurance companies providing location-based insurance services (a company in Texas is demonstrating such a system using GPS technology).
- **Auto security company**: LoJack is a familiar theft prevention system based on GPS technology. The state could partner with such a company.
- **Private contractors/service stations**: A private partner could be responsible for setting up a technology-based system. Oil companies are currently investigating technology improvements for their service stations so that large data streams can be transmitted to/from vehicles while in a service station. Such a short-range communication system could be used to transfer road usage information for reporting and payment to the state. Service stations could also manage the administrative aspects of a VMT pricing system, and the state could arrange appropriate incentives to cover the costs to the stations.
- **Auto companies/service providers**: Providers of telematics services, including OnStar and ATX Technologies could provide VMT and location information to the state. Telematics systems are capable of directly reading the odometer and transmitting the information via cellular communications to the service center. Also, the service provider could record a vehicle's location periodically or record when a vehicle crosses a state boundary or enters an urban area with a cordon pricing system. Auto companies would be ideal partners for testing a field demonstration of an advanced road pricing strategy. In recognition of the viability of such a system, a pooled-fund study led by the state of Minnesota has begun a demonstration project to evaluate the feasibility of monitoring automobile usage using GPS systems.

A technology-based system could be considered as a long-term, desirable system implemented statewide. However, it would likely be more financially feasible and publicly acceptable to phase in such a program. In terms of cost and administrative magnitude, one could compare a statewide VMT pricing system that monitored actual vehicle use on particular facilities with a telephone system. From publicly available records, it appears in 1998 Qwest had about $865 million in revenue, and reported administrative costs of about $188 million, or 21% of the revenue. Since Oregon's fuel tax revenue is approximately $390 million per year, one would expect the administrative costs of a centralized billing system to be substantially higher than the 21% ($82 million). This is substantial when compared to the existing motor fuel tax system with very low administrative costs.

4.5 BASIC TECHNOLOGIES CONSIDERED

Figure 4.2 shows a taxonomy of possible technologies for collection of road user fees and describes the categories of basic technologies considered for this analysis. In the basic VMT reporting/inspection systems, only three pieces of data are critical: vehicle identification number, date/time, and cumulative distance traveled.

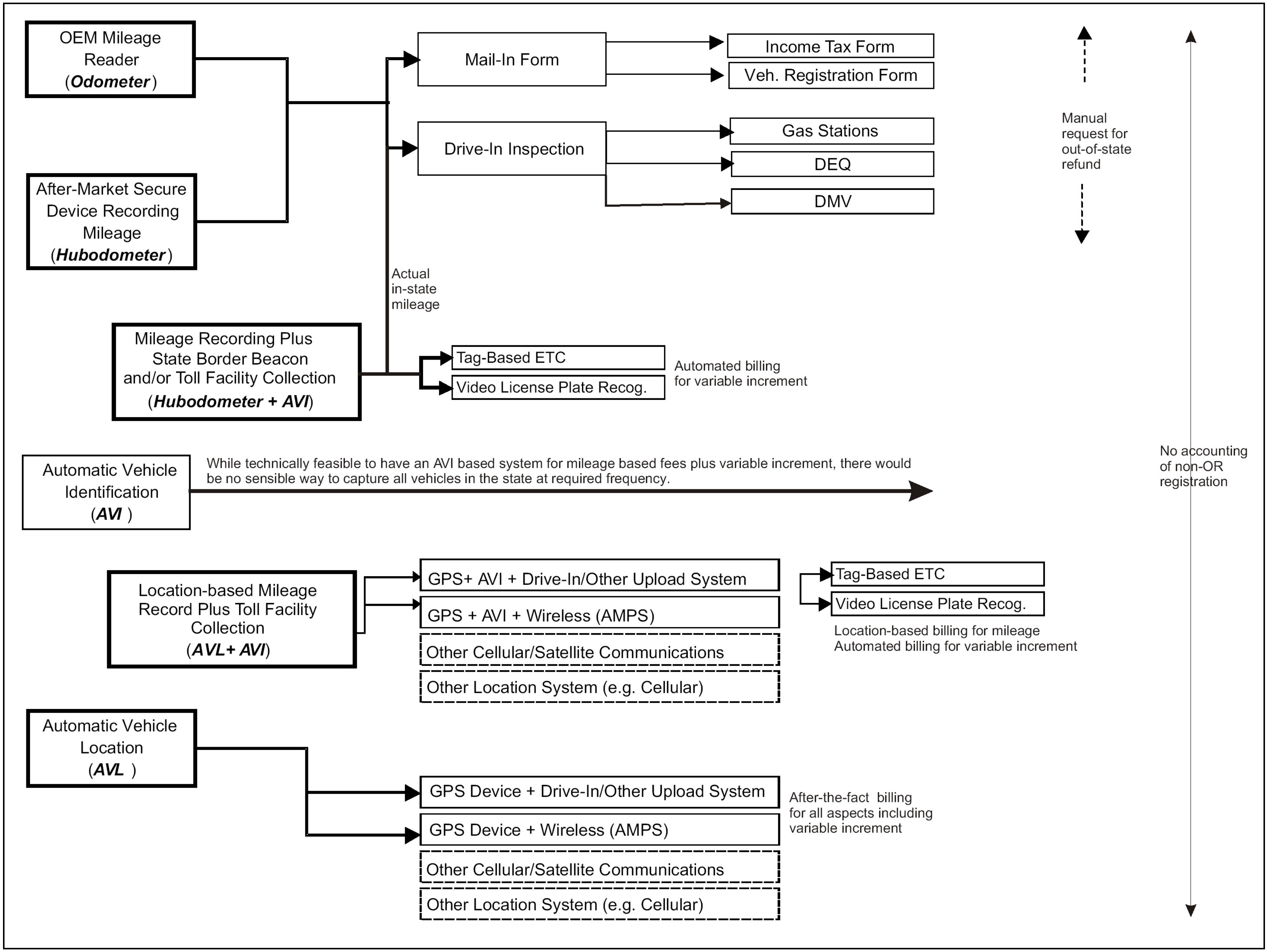


Figure 4.2: Taxonomy of possible technologies for collection of road user fees

4.5.1 Odometer

First, the odometer included as original equipment on every vehicle (referred to on the taxonomy as an original equipment manufacturer (OEM) device) could be used as the basis for a road user fee determination. An odometer registers the cumulative distance a vehicle travels and can be mechanical or computerized in nature depending on the age of the vehicle. Unlike mechanical odometers, the computerized odometers are sealed and are designed to be somewhat tamper proof. They use a toothed wheel mounted to the output of the transmission and a magnetic sensor that counts the pulses as each tooth of the wheel goes by. Knowing the distance the car travels with each pulse, the odometer reading is stored and updated via an electrical/communication bus between the engine control unit (the vehicle's computer) and the dashboard. These readings only provide the distance traveled in the forward direction. If someone tries to roll back the odometer, the value stored in the engine control unit will disagree. This value can be read using a diagnostic computer, generally available at all auto dealership service departments.

Despite the perception that modern computerized odometers are tamper proof, there have been numerous odometer related fraud cases reported. As shown in Figure 4.2, a self-reporting VMT system could be augmented by an audit system where odometers would be checked for data, thereby also checking if any tampering has occurred. Odometer fraud (a federal crime) most often occurs when titling a vehicle in a new state. Also, auto repair shops have been known to roll back odometers of used cars. The National Highway Traffic Safety Administration (NHTSA) estimates that the illegal practice of rolling back odometers is a significant problem, estimated to cost the American consumer between $2 billion and $4 billion annually.

4.5.2 Hubodometer

A hubodometer is a relatively simple after-market device that records mileage with every turn of the wheel, forward and backward, needing no wiring or complicated programming. A hubodometer would be a standardized, more secure device for recording VMT as part of a coordinated statewide road user fee system. Hubodometers are secure devices and come factory sealed. They are often used on fleet vehicles (e.g. buses) to facilitate scheduling and monitoring of regularly scheduled maintenance and safety inspections. Some manufacturers state that their hubodometers are secure, but it is likely that a small potential exists for evasion. There are tamper-evident systems that attempt to overcome evasion tactics.

Traditionally, mechanical hubodometers have dominated the marketplace, but electronic hubodometers have come on the market recently. Mechanical hubodometers are mounted on the axle hub, showing the actual mileage the vehicle traveled. On the other hand, electronic hubodometers record distance using electronic sensors with a light emitting diode (LED) display. Electronic hubodometers can be enhanced with a simple radio frequency (RF) data transmission system that facilitates reporting of mileage to a central system. RF data transmission would be suitable for a drive-in type inspection, where distances are short and little interference is present. Cellular communications would be appropriate and necessary for long range communications and for a system without a drive-in component. As of now, hubodometers used in vehicles serve as a simple gauge to verify important distance related warranties for tires and brakes.

As shown in Figure 4.2, reporting systems for hubodometers could be similar as those for an odometer based system. For future applications in hybrid, electric or fuel cell vehicles, mechanical or electronic hubodometers could be used to record VMT as a requirement for vehicle registration. The primary benefit from specifying a hubodometer to record VMT would be that the state could standardize the equipment and have some sense that the device's security is not violated. The approximate price range of a simple mechanical hubodometer is in the $25-$50 range, while an electronic hubodometer may cost approximately $300 for the hubodometer only. Adding an RF data receiver for an electronic hubodometer would entail an additional cost, ranging between $1,500-2,000.

4.6 ADVANCED TECHNOLOGIES CONSIDERED

With more advanced technologies come more capabilities and more data requirements. For the systems below there are four key variables needed in order to keep track of when and where a vehicle is traveling: vehicle identification, *x*-coordinate, *y*-coordinate and time. Using the changes in *x*- and *y*-coordinates, distance can also be calculated.

4.6.1 Global Positioning Systems

Briefly, global positioning systems (GPS) include a satellite network developed by the U.S. Department of Defense that can be used by consumers equipped with a small receiver to estimate location (*x*- and *y*-coordinates) over time. GPS technology is quite mature and accurate, particularly since May 2000, when an intentional scrambling of the satellite signal – known as selective availability (SA) – was turned off in order to make higher-accuracy signals available to the general public.

Figure 4.3 shows how 300 point estimates represent the location of a fixed point both with and without SA. With SA the rule of thumb was that GPS could locate a point within an area the size of a football field (100 meters with a 95% confidence interval). Without SA, GPS can locate something within an area the size of a tennis court (30 meters with a 95% confidence interval). In areas with minimal ionosphere interference, GPS can provide accurate readings within a few meters. GPS has limitations in urban areas where tall buildings can interfere with satellite signals.

GPS is used for navigation systems, fleet management, emergency location and many other location-based services. If a vehicle's GPS location is reported on some frequent basis (e.g., every 30 seconds or some other frequency), the distance traveled can be calculated. If the location is matched to a map, then the type of facility can be matched with time of day to determine whether a variable price (toll) was applicable. The U.S. Coast Guard has established land-based auxiliary differential GPS (DGPS) stations near coastal waters that provide improved location capabilities. There is a movement to expand DGPS throughout the nation.

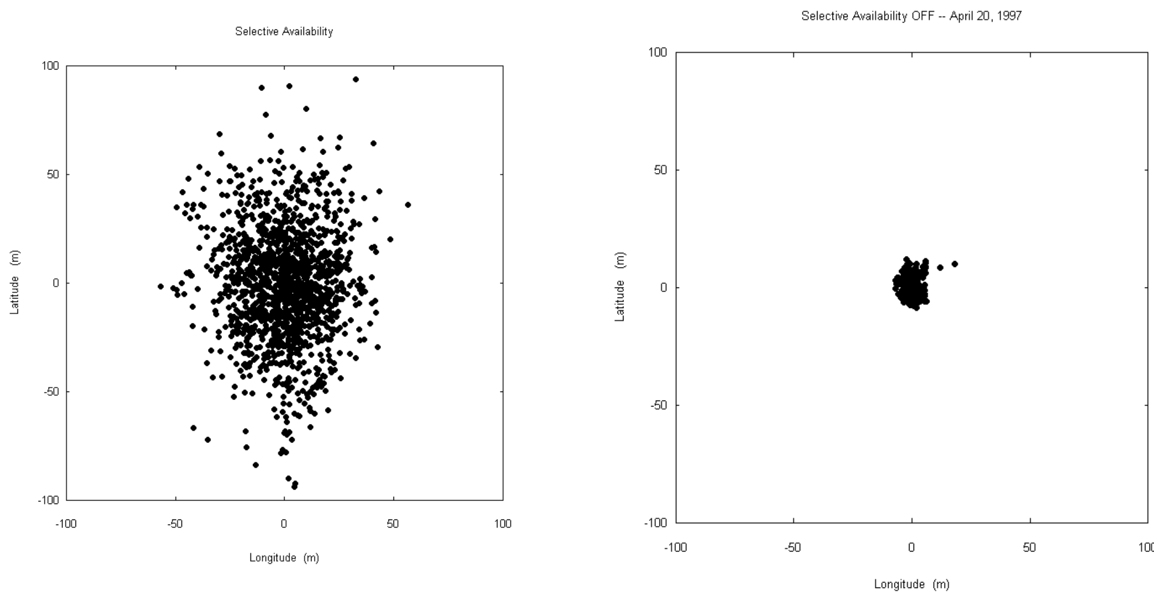


Figure 4.3: Impact of elimination of Selective Availability[2]

4.6.2 Cellular Communications

Cellular communications technology is expanding rapidly, both in the areas of voice and data communications. Analog cellular provides the best geographic coverage of the state of Oregon, while digital cellular is available in many urban areas. Figure 4.4 shows red (dark) zones corresponding with analog system coverage and yellow (light) zones corresponding with digital coverage. Cellular providers are also increasing the bandwidth of their systems to enable Internet-style browsing and transmission of large quantities of data.

Currently, the locations of cellular 911 calls cannot be determined. Some 911 systems can identify the nearest cellular tower. But the Federal Communications Commission has mandated that all cellular 911 calls (referred to as E-911 calls) provide location data to a specified degree of accuracy in the next several years. Some have proposed that cellular location data can be used to provide traffic information, and a demonstration of this is currently underway in Maryland and Virginia.

[2] Source: National Geodetic Survey

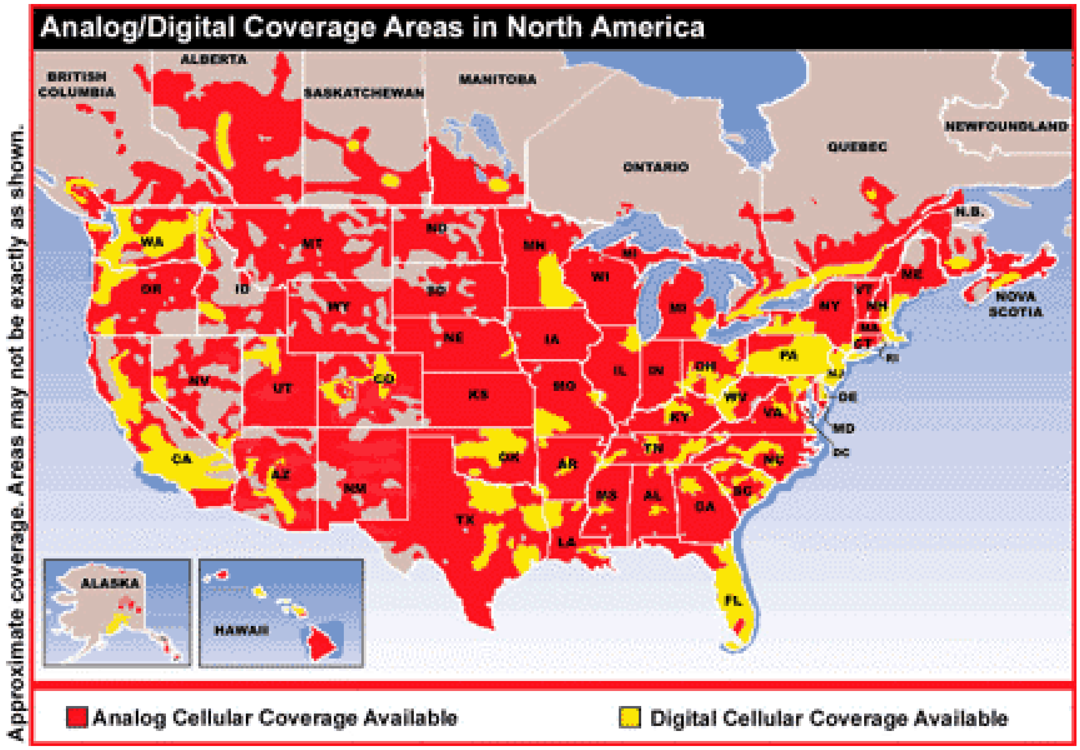


Figure 4.4: Analog/digital coverage areas in North America[3]

4.6.3 Automatic Vehicle Identification (AVI)

Automatic Vehicle Identification (AVI) refers to a family of technology that allows the identification of a particular vehicle at a particular point in space. Typically, a roadside "reader" is placed at a fixed location and is able to read "tags" on passing vehicles. If readers are placed at several locations, the travel time of each vehicle between the readers can be calculated easily. AVI is typically thought of as one of the components of a modern electronic toll collection (ETC) system, having the ability to determine ownership of a passing vehicle for the purpose of charging a toll to the proper customer account. AVI technology is point based, i.e., identifiers are fixed at locations for the purpose of identifying the vehicle, which in turn carries an identification tag/sticker that transmits the information. Application of AVI may be made at cordon lines or state border crossing points where vehicles entering or leaving the state could be identified and recorded.

AVI technology is mature and may be classified under four main categories: Laser, Radio Frequency (RF), Infra-Red (IR) and Video:

- **Laser** systems use a bar-coded sticker attached to the vehicle that is often on the driver side rear window. A laser scanner can read it as the vehicle passes through the lane or the cordon.

[3] Source: The TeleAdapt Group

- **RF** systems use a transponder (tag) that is mounted either on the vehicle bumper, inside windshield or roof and is read by an RF reader/ antenna.
- **IR** systems are very similar to RF systems in that they use an in-vehicle tag, which is read by a reader/transmitter installed in the lane.
- **Video** systems employ stationary video cameras with license plate reading systems that match vehicles at several locations using the license plate image.

Laser technology has several drawbacks, which limit its use in the toll collection environment, especially in an open road system. Chief among these are ease of forgery and sensitivity to weather and dirt. In addition, the laser scanner is limited in the distance it can be placed from the vehicle. RF technology overcomes these limitations and as such is proving to be the most popular AVI technology for new ETC systems. IR systems also overcome many of the same limitations over laser scanner systems. Video systems have some limitations in terms of the ability of cameras to detect license plate images during inclement weather.

For the purpose of auditing or enforcing cordon entry or exit violations, video cameras are typically incorporated at toll facilities. The three main types of video recording systems are:

- **Image capture** of violation vehicle license plate image for disk storage transmission.
- **Videotape** recording of all activity in time-lapse mode, with violations in real-time mode.
- **Line-scan** camera with compressed storage on disk for telephone-line transmission (most notably for visual identification of untagged vehicles).

In addition to toll collection, some types of RF tags are also being used for vehicle-to-roadside (VRC) communications. This technology allows a tag equipped with some form of readout to inform the driver of traffic conditions. There are three main RF technologies, which are either in use today or undergoing extensive trials: RF tags, RF smart tags and smart cards with RF transponders

- **RF/IR** tags are located in or on the vehicle, and are used in conjunction with an in-lane RF/IR antenna/reader to communicate identifying information about the vehicle and customer to the toll system. The information stored on the tag is fixed (read-only) and cannot be changed and the tag does not have any processing capabilities. The read-only type is also called a type-I transponder.

- **RF Smart** tags are RF devices located on the vehicle, used in conjunction with an in-lane RF antenna/reader to communicate identifying information about the vehicle, customer, and account balance information to the toll system. Some portions of the tag information are fixed (such as vehicle and customer data) while others are updateable (such as balance information). The smart tag contains a small microprocessor, which maintains account balance information, and is updated each time the smart tag is used. RF smart tags operate in full duplex mode, meaning that they are able to send and receive data at the same time. They actively generate the signal used to communicate with the antenna/reader via a transmitter. They are also referred to as type-II transponders.

- **Smart Cards** require two components: the smart card itself, and a separate RF/IR transponder (tag). The smart card (such as those being tested for single transit fare payment systems) is an integrated circuit (IC) device, which contains a tiny microprocessor, and memory that stores account balance information. The RF/IR transponder is a device located in or on the vehicle, which interfaces with the smart card and allows the smart card to communicate with the in-lane antenna/reader. In addition, the transponder contains information about the vehicle, which it transmits to the antenna/reader along with the smart card information. Smart cards with RF transponders are currently undergoing extensive trials in Europe. Smart cards with IR transponders are currently in use in Malaysia and Japan.

Therefore, the functioning of the AVI system as a whole involves the deployment of AVI tags, the installation of multiple AVI reader field site systems, and the development of a computer data processing system to collect and process data. As the vehicles pass the AVI reader field sites, the AVI antennas recognize the tags and report the tag reads to the AVI data processing system.

AVI systems in place today must meet stringent security and accuracy specifications. For example, Caltrans required its vendor to achieve and maintain 99.99% vehicle identification accuracy for its FasTrak system before it was deployed. In addition, customer service standards dictate that all billing be conducted accurately and maintain privacy in accordance with accepted credit card industry standards. (Drivers use their credit cards to pay for bridge and highway toll transactions.)

An AVI tag reader costs on the order of $1,000 per installation per lane, plus power and communications costs, while a tag costs no more than about $20 for the most advanced types. However, since an AVI system can only record the passage of a vehicle at a particular point, it could not record the total mileage traveled by all vehicles. Therefore, as shown in Figure 4.2, AVI would not satisfy the requirements for a VMT road user tax system; it would have to be used in combination with other technologies as described below.

4.6.4 Automatic Vehicle Location (AVL)

AVL is a technology that uses GPS to locally or remotely record the location of a vehicle over time (at some specified interval). The location information can be stored on the vehicle for later processing or transmitted in real time or periodically via cellular communications to a central data processing unit. The combination of GPS technology with wireless communications is used to locate and communicate with almost any moving object. For commercial fleet operators, such systems, using an Internet-based user interface, provide an efficient way to locate and monitor vehicle fleets. The mobile units transmit GPS location data at some frequency over wireless communications networks to a base station that uses the GPS data to display vehicles' real-time location on a background map. By providing dispatchers with accurate real-time fleet location, a mobile positioning system can increase the efficiency of commercial businesses such as taxi services and tow truck operations.

AVL systems generally include a network of vehicles that are equipped with a GPS receiver, a simple processor, a cellular modem, and a cellular antenna. This network can connect with a base station consisting of a computer station as well as a GPS receiver and interface. AVL systems also enable companies to structure delivery routes more efficiently by compiling a database of vehicle information, including location of customers in relation to established delivery routes.

AVL systems can also be used to increase the accountability of field personnel and improve the efficiency of a company's dispatching procedure. Dispatchers can get a real-time snapshot of driver adherence to a route, provide customers with an estimated time of arrival, and communicate directly with drivers. AVL systems operate without expensive receivers or other equipment. The GPS unit installed in the vehicle makes use of a minimal amount of power from it and transmits GPS location data, either on a regularly timed basis or in response to a command. This data is then converted into mapping that is instantly available.

As shown in Figure 4.2, AVL may be used as a dynamic, accurate, time stamped means of collecting user charges. Auto companies, their telematics service providers or other contractors could be engaged for collecting location information from vehicles equipped with AVL, either via cellular communications or via short-range (RF) communications or a physical data download at particular drive-in locations such as gas stations or auto service centers. Locations can be matched to a map in real time or via post-processing to determine distances traveled out of state, within variably priced cordons or on variably priced corridors.

Some vehicles come equipped with navigation systems, and they are also available as an after-market device. A navigation system includes a GPS receiver, a computer interface and a map database (typically a CD- or DVD-ROM). To operate the system, the driver enters a location and the computer displays the shortest path route on a screen and provides turn-by-turn directions using computer-generated speech and graphical displays. These navigation systems currently cost about $2,000.

Auto companies offer their telematics systems as standard equipment on many models, with a small service fee required after the first one or two years. There would be an opportunity to leverage from GPS-based systems already being installed in many models on the market today. Fleet users may already be pursuing the purchase of hybrid or other alternative fuel vehicles, many due to available government purchase incentives. Therefore, it would be possible to leverage the installation of a fleet management system that could be integrated with a road user fee system.

A mileage-based system could be extended to differentiate charges by road segment or area and time of day. However, differential charges by exact location and time of day would require vehicle monitoring systems that link to digital road map databases that provide segment charge rates. Spatial accuracy sufficient to "snap" to the correct road segment on a digital map and temporal accuracy to dynamically reflect all roads in use would be needed. The spatial accuracy issue is confounded by two considerations. One is that monitoring depends on following a sequence of positions. When one or more GPS data points are wrong due to errors in positioning from passing under overpasses or past high rise buildings that interrupt signals from satellites, the vehicle appears to leap off one road onto another and back again. Tests of relative distance are needed to determine if a point is too far away from the last position to be possible.

The second problem is that the spatial accuracy requirement is dependent on the geography of the road network. In areas of greater density, with roads close together and many intersections, much greater accuracy is needed to place a vehicle on the correct segment. This is a particular problem on important segments such as freeways, due to the proximity of frontage roads, ramps and over- and under-passing streets. Consequently, where differential charges are imposed, instrumentation of major highways, may be preferable to reliance on vehicle monitoring.

4.6.5 Hubodometer + AVI

As mentioned earlier, AVI alone could not effectively meet the needs of a road user pricing system. As shown in Figure 4.2, when combined with an odometer or hubodometer for charging basic VMT, AVI can detect vehicles at points where transponders or tags or video detection are present such as at state boundaries, cordon lines, toll corridor payment points and at intersections. This can help in detecting the vehicles moving out of Oregon's borders or entering any areas (cordons or corridors) where variable pricing may be applied. AVI receivers could be placed on public rights of way or within private establishments such as gas stations or auto repair facilities. As vehicles pass an AVI receiver, its cumulative mileage could be transmitted and recorded along with the vehicle's identification. These data could be used to calculate a mileage-based charge and the vehicle owner could then be billed by a public or private entity.

4.6.6 Hubodometer + AVL

A vehicle equipped with AVL would not technically need an odometer or hubodometer in order to assess basic VMT pricing. However, for either transition or privacy issues, it may be desirable to consider using the hubodometer for basic pricing and AVL for variable pricing, e.g. in peak periods when the vehicle using the facility at that time could eventually be charged the fee designated for using the facility. This combination also facilitates detecting when and where the vehicle leaves and re-enters the state, by using AVL as an "on-off switch" at state boundaries and cordon areas.

4.6.7 AVL + AVI

It may not be necessary for vehicles to be equipped with both AVL and AVI. However, as shown in Figure 4.2, it may be desirable for a system to use AVL to calculate a basic VMT based fee, while using AVI for the variable component of cordon or corridor based pricing systems. The benefit of using AVI for this purpose is that the driver can receive feedback in the form of a transponder's "beep" when charged a particular price for entering a highway during a peak period. An AVL-only system could be developed to accomplish the same task.

4.6.8 Low Earth Orbit Satellite Systems

Low earth orbit (LEO) satellite systems have been proposed and partially deployed for (apparently) both advanced/worldwide communications coverage plus the potential to provide accurate location information. Because these systems are not particularly mature or financially solvent at present, it appears that the combination of GPS location plus analog cellular communications would provide the necessary services in a more reliable fashion. It may be that in the future new opportunities will evolve from advancements of proposed LEO systems. Such a system – called Certified Wide Area Road Use Monitoring (CWARUM) – has been proposed, using LEO satellites as the communications backbone for road user pricing. A system with nearly identical functionality could be developed using GPS and cellular communications, either administered by a government entity or a private contractor or vendor.

4.7 PERSPECTIVES

One of the important considerations in discussing possible changes in the collection of road use fees is the cost of a new system compared to the existing system. Some simple calculations will help put these costs into perspective. Given that there are approximately 2.9 million registered passenger vehicles in the state of Oregon (*ODOT 2000*), we can obtain an order-of-magnitude estimate of the potential revenue of the current fuel tax system. If the average vehicle travels about 14,000 miles per year with a fuel efficiency of approximately 25 miles per gallon, that translates to a purchase of about 560 gallons of fuel per year. With the $0.24 fuel tax, each vehicle might contribute about $134, so that the state could see annual revenue of about $390 million. If the fuel tax were to be replaced completely by a VMT tax, and given that the total VMT in Oregon in 1998 was about 32.8 billion miles (*ODOT 2000*), a fee of approximately $0.012 per mile would need to be charged in order to remain revenue neutral.

It is worth noting that the average Oregon driver would likely be surprised to learn that he/she is currently paying on average about $134 in state fuel tax, since there is no summary document (analogous to a property tax bill) that provides such a figure to drivers. One should recall this $134 figure when considering the per-vehicle cost of the technology used to collect a road user fee. In addition, this analysis has not included costs of technology, administration and compliance costs. Higher administrative and enforcement costs increase the mileage tax required to provide the same revenue for road construction and maintenance.

Clearly, with a straight VMT based system, drivers of the least fuel-efficient vehicles would be the “winners,” and drivers of more fuel-efficient vehicles would be the “losers.” A VMT pricing system aimed specifically at hybrid, fuel cell and electric vehicles could be structured to prevent revenue loss or to encourage people to purchase these vehicles as a means of reducing air pollution and energy consumption. The latter benefits are quantifiable but would not be seen as actual revenue. There is one international example of creating an incentive for drivers to use alternative fuel vehicles. In London, a congestion charging proposal (using license plate recognition video cameras) would levy a daily charge of £5 for all vehicles entering the central city, with a 100% discount for drivers of electric and alternative fuel vehicles.

It is recognized that there are serious transition issues as well as state border issues. For this analysis it is assumed that it may be possible to manually or automatically subtract out-of-state travel (depending on the technology used). Having the ability to automatically perform this function would also enable automatic cordon pricing, but this capability would come at substantial cost. With regard to vehicles not registered in Oregon, it is assumed that the only way to assess an appropriate fee for these vehicles would be to retain the fuel tax or establish toll facilities at state boundaries.

4.8 COMPARISON OF TECHNOLOGY OPTIONS FOR PRICING ROAD USE

Table 4.1 shows a matrix that compares five technology options in eight evaluation categories, using a scale between 1 and 10 (where 1 represents the lowest level and 10 represents the highest level in a given category). The first category is reliability of the hardware and/or software needed to implement each system. The Hubodometer Only system would have the highest reliability, while the systems relying on GPS (the AVL and AVL+AVI) would likely have the lowest reliability.

In terms of evasion potential, the Odometer Only would have the highest evasion potential, while the other systems would have uniformly lower evasion potential due to the likelihood of a drive-in or other communications-based reporting system.

The Odometer Only would provide the lowest cost solution while the AVL systems would be the most expensive. Once deployed, all systems would be relatively easy to use and convenient to vehicle owners, although all would require more effort and cost than the current gasoline tax system.

The Odometer Only system would be the lowest cost system for the State to deploy, while the AVL systems would be most costly. The relative costs of the system depend on the level of technology, with the AVL based systems being the most costly to operate.

Similarly, the public would likely accept the simpler, less costly systems, while they may object to the more expensive systems and the recording of vehicle location information. None of the potential systems would necessarily require a full deployment involving all vehicles in the fleet. Any of the systems could be partially deployed and/or phased in. However, there would likely be economies of scale, for example, in purchasing in-vehicle or roadside equipment. As shown in Table 4.1, the simpler systems would be easier to phase in for this reason.

Table 4.1: Qualitative comparison of fuel tax technology options

Possible Technologies for Collection of Road User Fees	Reliability of Hardware/Software	Evasion Potential	Costs to Vehicle Owners	Ease and Convenience to Vehicle Owners	Start-up Costs to Agencies	Operating Costs to Agencies	Public Acceptance	Partial Implementation/Phasing		
Odometer	8	8	1	9	2	2	9	8		
Hubodometer	9	5	3	8	4	3	9	8		
Hubodometer + AVI	8	5	4	8	7	5	6	6		
AVL + AVI	7	5	10	8	9	9	4	6		
AVL	7	5	10	8	9	9	3	6		

LEGEND: 1=Low 10=High

4.9 PHASING IN A NEW ROAD PRICING SYSTEM

As indicated by the above discussion, there are many ways that a new road pricing system could be phased in. Here are some examples of issues to be considered:

- As a data collection/research tool, a paper reporting system could be adopted immediately for all vehicle owners while maintaining the fuel tax. Each vehicle owner could report his or her VMT on an annual basis as part of a vehicle registration, county property tax or state income tax payment. A form could be designed to collect vehicle make, model, total mileage, along with other demographic information. If such a database were developed immediately, this would fill in many of the gaps described in this report and inform policy makers about whether and where alternative fuel vehicles are proliferating. The data collected could also help establish VMT fees as well as providing information about urban/rural equity concerns.

- One of the first major administrative issues to be resolved would be the mechanism by which a driver would pay the VMT fee while a gasoline tax was still in place for other drivers. For example, a gas station could handle the administration and add a VMT fee to the total gasoline bill based on an odometer/hubodometer/transponder reading. Alternatively, a VMT vehicle could be exempt from paying gasoline taxes at the gas station and could submit the VMT fees directly to the state or to a service provider. Another option could be that a vehicle owner would need to submit evidence of gasoline tax paid as an offset to their VMT fee, and either receive a refund or pay the difference directly to the state or service provider. Tests of these possibilities could be conducted and feasibility and user reaction could be gauged.

- Based on the information gained from one year of VMT reporting (a relatively inexpensive data collection exercise), a decision could be made to initiate a voluntary pilot program for payment of a VMT fee for only certain types of vehicles and/or for vehicles in certain regions. One sample method would be to partner with a manufacturer of hybrid vehicles and engage in an experiment whereby a secure odometer or hubodometer could be installed for all such vehicles registered in Oregon. A paper-reporting system could be instigated in the near term, while requiring these manufacturers to include a technology-based reporting system in future model years for vehicles registered in Oregon.

- Parallel pilot programs for testing AVL-based systems could be initiated in partnership with a rental car company, an auto insurance company, and/or an auto manufacturer (e.g., DaimlerChrysler, General Motors, BMW) that offers navigation and telematics/mayday systems. Via these partnerships, various reporting mechanisms could be tested, with an eventual requirement that VMT reporting capabilities be included as standard equipment for vehicles registered in Oregon. Most auto manufacturers are developing automatic diagnostic systems that can be accessed remotely; such systems could very easily include reporting of an odometer reading that could be transmitted to the state for billing purposes.

4.10 FURTHER RESEARCH

Additional research steps are necessary to focus this analysis on selected road use pricing scenarios, in order to demonstrate the capabilities of the various systems and estimate actual deployment costs and benefits. Thus far, this analysis has lacked a defined research question and set of deployment objectives. The next steps should identify a small menu of alternatives, timeframes and penetration rates for desired deployment. At that time, it would be possible to provide actual cost estimates and further details relating to possible private partners, administrative and communications costs, evasion rates based on actual experience, and further analysis of user acceptance and privacy concerns.

4.11 TECHNOLOGY ISSUES SUMMARY

- In the past five years, there have been many important technology advancements in the areas of telecommunications, toll collection systems, data processing and storage systems, automotive safety and security, as well as some important advancements in automobile propulsion systems.

- Cellular telephone use has increased tremendously in the U.S., and analog cellular technology provides the communications backbone for auto companies' expanding telematics/mayday systems now available in across the country.

- Drivers have adopted automatic vehicle identification (AVI) toll tag technology at a surprisingly rapid rate as toll authorities have replaced or augmented traditional tollbooths with automatic toll collection for bridges, tunnels and toll roads. AVI technology has also been used for several value pricing facilities. The rapid technology adoption has been surprising, particularly in view of substantial privacy concerns.

- Changes in the automobile industry have led to a contraction in the availability of purely electric vehicles and a surge in interest in hybrid vehicles. Further, more computing, location and communications capabilities are available as standard equipment in increasing numbers of new cars, as part of navigation and telematics systems.

- A vendor-neutral review of technologies for possible road pricing systems can range from simple systems targeting only the highly efficient and alternative fuel vehicles to complex systems in which the current fuel tax system would be completely replaced.

- Pricing systems could be administered in partnership with a multitude of possible public agencies and private entities. Systems could be voluntary or mandatory, cover part of the fleet or all of it, include the entire state or merely a region. Administration could be in the form of simple reporting, inspection, or a technology-based solution requiring varying degrees of vehicle monitoring. For example, gas stations could collect VMT information and tax vehicles accordingly as part of the fuel purchase transaction. VMT taxes could be paid as part of a vehicle insurance payment. The state could partner with auto manufacturers and/or mayday service providers (OnStar or ATX Technologies) to charge vehicle owners for VMT fees as part of another service.

- The vehicle odometer or an after-market hubodometer could be starting points for reporting vehicle miles traveled (VMT). Data from hubodometers could be manually read or automatically transmitted to special receivers or by cellular telephone to a central processing center or vendor.

- Global positioning systems (GPS) are likely to remain the basic means of locating a vehicle over a wide area and over various periods of time. Recent improvements in GPS accuracy, along with possible future enhancements, further suggest the continuing importance of GPS.

- AVI systems could be developed to identify vehicles at specific points for the purposes of charging for the use of a particular road or cordon area, for estimating a vehicle's VMT or for monitoring vehicles entering or leaving the state.

- Automatic vehicle location (AVL) systems similar to those used for fleet management could be used for part or all of the fleet in order to monitor road use. Data could be stored in a special on-board processing unit to be read or transmitted for processing.

- A hubodometer used with AVI could facilitate mileage-based pricing that accounted for state border crossings, with the added flexibility of phasing in variable charges for corridors or cordons. VMT data could also be transmitted periodically at AVI receiver locations (public or private).

- A hubodometer may be combined with AVL as an alternative to AVI.

- It is very important to keep in mind that the average driver is paying less than $150 in state fuel taxes, a small amount compared to the cost of a technology-based solution for payment of road user fees. Thus it makes sense to conceive of either a system that is very simple and inexpensive to implement or one that leverages technology used for another purpose.

5.0 GENERAL CONCLUSIONS

NCHRP Report 377 concluded that VMT charges should be tested and that some form of mileage charges would be the best alternative to fuel taxes. This conclusion still seems valid, and the improvements in technology make more sophisticated VMT systems less expensive and more reliable than those existing when NCHRP Report 377 was written. The major difference between the conclusions of the report and actual experience since then has been the implementation of various toll facilities under the Value Pricing projects supported by FHWA. Unlike the systems envisioned in NCHRP Report 377, the value-pricing projects have relied on relatively simple toll systems, using relatively new technology that eliminates many of the negative aspects of tolling.

While the basic conclusions of NCHRP Report 377 – that experiments using VMT be tried and that any changes be phased in over time – are still supported, the use of tolls to pay for new facilities and better access has opened a different perspective that is worthy of further consideration. In particular, the use of tolls is an alternative method to phase in some form of pricing that may be more acceptable to the public than full VMT pricing.

On the other hand, the improvements in technology make voluntary use of alternative systems much more feasible than they were just a few years ago. While there are no perfect off-the-shelf solutions, the components necessary for a new road pricing system are largely proven and exist in various forms. The Progressive Insurance program in Texas has demonstrated that it is possible to monitor vehicle use by location and time of day for the purpose of imposing charges; and its acceptance by a large number of voluntary users indicates that the privacy issues may not be as great a barrier as some have thought. In addition, the presence of approximately 2 million vehicles with telematics systems indicates that there may be opportunities for states to collaborate with auto manufacturers in planning new road pricing strategies.

The evidence from existing experiments is that some form of pricing is both feasible and politically acceptable under certain conditions. Pricing has been used to pay for new options in a growing number of places. The key elements to its acceptance appear to be that new options are offered, that existing users are no worse off, and that participation is voluntary. Alternatively, it appears that people may voluntarily choose alternative systems if they provide benefits to the user. Thus, raising existing taxes or fees and offering a lower-cost alternative to those using the new technology may provide an acceptable transition mechanism. Given these conditions, several options exist for implementing the technology. While it has yet to be used in the U.S., a number of countries have also successfully implemented some form of cordon or access pricing on a broader scale, without offering options for those who wish to avoid the payments.

To move forward, it would not be necessary to evaluate all of the trade-offs that exist among the technological, economic, and political issues that are raised by alternative methods to raise revenue for the road system. However, it is necessary to identify some broad categories of promising alternatives and develop more definitive information on the likely cost to users, administrative costs, evasion rates, and so on. The technological improvements and the reduced cost of the new technology have substantially improved the prospects for these alternatives relative to what was available at the time of NCHRP Report 377, but the assertion that more testing is needed still holds.

5.1 NEXT STEPS

As policy makers proceed with exploring alternatives to dependency on fuel tax revenue, several general issues will need to be addressed. Some of these issues include the following:

- **Whether an alternative pricing system should include continuing or ending the fuel tax**. While the fuel tax will almost certainly remain in place in the near term, some systems could completely replace it over time. Alternatively, one could look at systems that charge alternative fuel or very high-efficiency vehicles for road use; or the finance supplements could be targeted at funding for specific facilities or geographic areas.

- **Whether an alternative pricing system should tax out-of-state mileage**. Registration fees for passenger vehicles are levied by the home state, but gas taxes are paid where fuel is purchased. In effect, the gas tax roughly taxes vehicles based on where they are used. Many of the systems to charge for use of specific facilities or for accessing specific areas would also charge on the basis of use. However, more general systems, such as VMT systems, could be based on usage or on registration status.

- **Whether to charge for social costs.** Automobile use imposes costs that are not paid by the driver, such as the costs created by automobile pollution. Many people have suggested that systems to charge for vehicle use also include charges for these external costs so as to promote more efficient vehicle use. For example, a policy could be implemented that would encourage use of alternative fuel vehicles.

- **The time horizon for implementation of an alternative pricing system.** While a wide range of options exist for alternative pricing systems, the cost of the technology needed to implement them continues to decline. A system that is needed in the near term would likely have to be focused on simpler methods using lower cost technology than for a system expected for widespread use further in the future.

- **Whether to charge more during peak hours in selected locations.** There are likely to be substantial efficiency gains from the use of higher road prices during congested periods, but this may generate increased public opposition and would likely raise the administrative and compliance cost for a pricing system.

- **Tolerable level of administrative costs.** Each of the alternatives under consideration is likely to result in higher administrative costs than the gas tax. Some consideration of what level of cost would be acceptable in both the near term and after full implementation may affect the choice of system.

- **Type of technology and the implications for privacy.** An array of technology options has been presented along with some of the possible ways they can be combined as part of a new road pricing system. Once key decisions are made relating to how a system would be phased in and administered, specific system designs can be sketched and costs and impacts can be estimated. As part of a sketch design for a system, each alternative will exhibit different implications for privacy concerns. These concerns will play a substantial role in determining which systems to consider for testing and implementation.

Once policy makers have addressed these general issues and have identified one or more road use pricing alternatives to consider in depth, each alternative will have specific design issues and data issues to address. These are outlined in Appendix A.

6.0 REFERENCES

A New Approach to Assessing Road User Charges, Institute for Intelligent Transportation Systems Programs, University of Minnesota, 2000.

Adams, M., Hiatt, R., Hill, M., Russo, R. Wachs, M., & Weinstein, A. (2000). Financing transportation in California: Strategies for Change (Final Draft). [Report No. UCB-ITS-RR-2001-2]. Berkeley, CA: Institute of Transportation Studies.

Adams, M., Hiatt, R., Hill, M., Russo, R. Wachs, M., & Weinstein, A. (2000). Financing transportation in California: Strategies for change (Final Draft). [Report No. UCB-ITS-RR-2001-2]. Berkeley, CA: Institute of Transportation Studies.

An Introduction to Congestion Pricing for Oregon Policymakers, ECO Northwest, 1995.

Bemis, Gary (2000). "Forecast Availability and Cost of Petroleum-Based Fuels," Second National Conference on Transportation Finance (Transportation Research Board Conference Proceedings 24: Washington, DC): 110-112.

Benefits Assessment of Advanced Public Transportation System Technologies, Federal Transit Administration, 2000.

California Energy Commission (2000, August). California Energy Outlook 2000: Volume II-Transportation Energy Systems [Report No. P200-00-001v2]. Author.

Cellular Telecommunications and Internet Association (CTIA) Semi-Annual Wireless Industry Survey, December, 2000.

DeCorla-Souza, P. Making Value Pricing on Currently Free Lanes Acceptable to the Public with "Credit" Lanes, 2000.

Federal Highway Administration (2001). Value Pricing Notes 6. Washington, DC: Author

Forkenbrock, D. J., & Schweitzer, L. A. (1997, April). Intelligent transportation systems and highway finance in the 21st century. Paper presented at the meeting of Transportation Finance in the 21st Century, Dallas, TX.

Forkenbrock, David (2000). "Advanced-Technology Approach to Assessing User Charges: Research Progress," Second National Conference on Transportation Finance (Transportation Research Board Conference Proceedings 24: Washington, DC): 114-116.

Golob, J, Golob, T., & Supernak, J. (2001). Phase II Year 3 Attitudinal Panel Study. San Diego State University, Department of Civil and Environmental Engineering.

Intelligent Transportation Systems Benefits, Federal Highway Administration, 2001.

Introduction to Electronic Payment Systems and Transportation, ITS America Electronic Payment Systems Task Force, 2001

Litman, T. Distance-Based Charges: A Practical Strategy for More Optimal Vehicle Pricing, Transportation Research Board, 1999.

Mintz, Marianne (2000). "Alternative Fuel and Hybrid Vehicles: Timing and Market Share," Second National Conference on Transportation Finance (Transportation Research Board Conference Proceedings 24: Washington, DC): 112-113.

NCHRP Report 377, *Alternatives to Motor Fuel Taxes for Financing Surface Transportation Improvements* (1995),

Oregon Department of Transportation (ODOT) Key Facts, 2000.

Orski, C. Kenneth (2001). "The Hybrid Car," Innovation Briefs Vol.12, No. 6.

Reno, A. T., & Stowers, J. R. (1995). Alternatives to motor vehicle fuel taxes for financing surface transportation improvements. NCHRP Report 377. Washington, DC: Transportation Research Board.

Reno, A. T., & Stowers, J. R. (1995). Alternatives to motor vehicle fuel taxes for financing surface transportation improvements. NCHRP Report 377. Washington, DC: Transportation Research Board.

Report on the Value Pricing Pilot Program, Federal Highway Administration, 2000., Tolltrans, Traffic Technology International, August/September, 2000.

Small, K. A., & Gomez-Ibanez, J. A. (1997). Road pricing for congestion management: The transition from theory to policy. In T. H. Oum, J. S. Dodgson, D. A. Hensher, S. A. Morrision, C. A. Nash, K. A. Small, & W. G. Waters II (Eds.), Transport Economics (pp. 373-403). The Netherlands: Harwood Academic Publishers.

Small, K. A., & Yan, J. (2001). The value of "value pricing" of roads: Second-best pricing and product differentiation. Journal of Urban Economics, 49 (2), 310-336.

Small, Kenneth A., "The Value of Value Pricing," Access number 18 (Spring 2001): 23-27.

Sullivan, E. (1998). Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes: Final Report. San Luis Obispo: Cal Poly State University, Department of Civil and Environmental Engineering.

Sullivan, E. (2000). Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes: Final Report. San Luis Obispo: Cal Poly State University, Department of Civil and Environmental Engineering.

Sullivan, E. (2001). Personal correspondence, 11/1/01. San Luis Obispo: Cal Poly State University, Department of Civil and Environmental Engineering.

Supernak, J., Golob, J., Golob, T., Kaschade, C., Kazimi, C., Schreffler, E., & Steffey, D. (2000). Phase II Year 2 Final Report. San Diego State University, Department of Civil and Environmental Engineering.

Supernak, J., Steffey, D., Kaschade, C., Arieneri, B. (2001). Phase II Year 3 Enforcement Effectiveness and Violation Assessment. San Diego, CA: San Diego State University, Department of Civil and Environmental Engineering.

Svadlenak, J. & Jones, B. (1998). Congestion pricing and ability to pay: income levels and poverty rates of peak-hour, single occupancy vehicle commuters in Portland Oregon. Northwest Journal of Business and Economics, 1-15.

Transportation Research Board (2001). Review of the Research Program of the Partnership for a New Generation of Vehicles: Seventh Report. Washington, DC: National Academy Press.

Walton, J. and Crabtree, J. A Needs Assessment and Technology Evaluation for Roadside Evaluation of Commercial Vehicles, ITS America, 2000.

Ward, J. L. (1998) Value pricing: A synthesis of lessons learned. Minneapolis: MN, University of Minnesota, Hubert H. Humphrey Institute of Public Affairs.

What Have We Learned About Intelligent Transportation Systems, Federal Highway Administration, 2000.

Wilbur Smith Associates (1997). “Road Pricing Study: Final Report,” prepared for Minnesota Department of Transportation under sponsorship of Federal Highway Administration.

APPENDIX: ISSUES IN REVENUE ESTIMATION

ISSUES IN REVENUE ESTIMATION

1. VMT Fee: All in-state drivers pay a per mile fee for use of state roadways.
    a. Design Issues:
        i. Does fee vary by vehicle class?
        ii. Does fee vary by emission levels?
        iii. Is fee assessed on an annual basis or at select times?
        iv. How to differentiate VMT attributed to in-state and out-of-state vehicles?
    b. Data Issues:
        i. Need mileage information attributed to in-state and out-of-state vehicles.
        ii. Depending upon design, in-state VMT may need to be further stratified by vehicle class, emissions.
        iii. Need information on revenues attributed to in-state and out-of-state vehicles from traditional methods such as gasoline tax.
        iv. Concerning incidence of fee, information on VMT by income class is required. Note that there is a paucity of information on this subject.
        v. Administration and compliance costs based upon annual reporting readily obtainable. Costs based upon frequent charges at fueling stations or other means more difficult to obtain.

2. Congestion Pricing: All drivers in a metropolitan region pay a time varying fee to travel in any lane of traffic on select facilities.
    a. Design Issues:
        i. One or several metropolitan areas?
        ii. Is fee based on spot, facility, or corridor pricing?
        iii. Is fee based on set schedule or allowed to vary according to real-time traffic volumes?
        iv. Does fee vary by vehicle occupancy?
    b. Data Issues:
        i. Revenues related to number of vehicles traveling each priced facility. Requires traffic count data by time of day.
        ii. Need estimates on number of vehicles likely to be diverted from priced facilities as well as number of vehicles that time shift to lower priced periods.
        iii. If fee varies by vehicle occupancy, then need estimates on number SOVs on each priced facility.
        iv. Concerning incidence of fee, survey information pertaining to behavioral responses by income group to pricing more difficult to obtain.
        v. Estimates of administration and compliance costs are readily obtainable from existing congestion pricing programs.

3. Cordon Access: Certain drivers pay a fee to enter a cordon area within a metropolitan region.
    a. Design Issues:
        i. One or several metropolitan areas?

    ii. Single or multiple cordon system?
    iii. Are fees charged at major entrance points only or all entrance points?
    iv. Are there internal zones (screenlines)? If so, are persons living in central zones charged same rate?
    v. Does fee vary by time of day (e.g., peak and off-peak period rates)?
    vi. Does fee vary by vehicle occupancy?
  b. Data Issues:
    i. If single or multiple cordon system, then traffic count data at entrance points is needed.
    ii. If cordons further divided by internal zones, then O-D information is needed.
    iii. Need estimates on number of vehicles likely to be diverted from priced areas as well as number of vehicles that time shift to lower priced periods.
    iv. If fee varies by time of day, then above data sources must be stratified by time period.
    v. If fee varies by vehicle occupancy, then need estimates on number SOVs.
    vi. Concerning incidence of fee, income information on persons who change travel behavior in response to pricing is necessary.
    vii. Administration and compliance costs will vary by complexity of program design. If single or multiple cordon system, costs are readily obtainable. If cordons further divided by internal zones, then costs more difficult to obtain.

4. Toll Roads: All drivers pay fee to use select roadways throughout state
  a. Design Issues:
    i. Which roadways will be tolled (e.g., interstates, state highways, major arterials)?
    ii. Will tolls roads consist of new facilities or will existing capacity be priced?
    iii. Does fee vary by time of day?
    iv. Does fee vary by vehicle occupancy?
  b. Data Issues:
    i. Revenues related to number vehicles traveling each tolled segment of road. Requires traffic count data.
    ii. If fee varies by vehicle occupancy, then need estimates on number SOVs on each segment.
    iii. If fee varies by time of day, then above data sources must be stratified by time period.
    iv. Need estimates on number of vehicles likely to be diverted from priced facilities as well as number of vehicles that time shift to lower priced periods.
    v. Concerning incidence of fee, income information on persons who change travel behavior in response to pricing is necessary.
    vi. Estimates of administration and compliance costs are readily obtainable.

5. HOT Lanes: Certain drivers elect to pay time varying fee to travel in HOV lanes on select roadways.
    a. Design Issues:
        i. Which roadways will have HOT lanes?
        ii. Is fee based on set schedule or allowed to vary according to real-time traffic volumes?
        iii. Does fee vary by vehicle occupancy?
    b. Data Issues:
        i. For set fee schedule, need estimate of number of vehicles likely to take advantage of priced lanes by time of day (prices) for each facility.
        ii. For variable fee schedule, need estimate of number of vehicles likely to take advantage of priced lanes according to traffic volumes (prices) for each facility.
        iii. If fee varies by vehicle occupancy, then information on number of vehicles by occupancy status also needed.
        iv. Concerning incidence of fee, survey information pertaining to behavioral responses by income group to pricing is readily available.
        v. Estimates of administration and compliance costs are readily obtainable.