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NCHRP

Web-Only Document 161:

System Trials to Demonstrate Mileage-Based Road Use Charges

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Under subcontract to:

ICF International

Contractor's Final Task Report for NCHRP Project 20-24(69)A
Submitted October 2010

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ACKNOWLEDGMENT OF SPONSORSHIP AND DISCLAIMER

ACKNOWLEDGMENTS

This study was requested by the American Association of State Highway and Transportation Officials (AASHTO), and conducted as part of National Cooperative Highway Research Program (NCHRP) Project 20-24. The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation (DOTs). Project 20-24 is intended to fund studies of interest to the leadership of AASHTO and its member DOTs.

The report was prepared by lead author Paul Sorensen and research team members Liisa Ecola and Martin Wachs of the RAND Corporation. The RAND team worked as a subconsultant to ICF International. The work was guided by an NCHRP project panel composed of Neil Schuster and Cian Cashin (co-chairs), American Association of Motor Vehicle Administrators; Stuart P. Anderson, P.E., Iowa DOT; Roberta Broeker, Missouri DOT; Lowell R. Clary, CPA, P3 Development Company, LLC; Karen Chappell and Patrick Harrison, Virginia Department of Motor Vehicles; Cindy McKim, California DOT; Mark Muriello, Port Authority of New York and New Jersey; Lynn Weiskopf, New York State DOT; James Whitty, Oregon DOT; and Jack Basso, Anthony R. Kane, Ph.D., and Joung H. Lee (AASHTO liaisons). The project was managed by Andrew C. Lemer, Ph.D., NCHRP Senior Program Officer.

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FOREWORD

By Andrew C. Lemer
Staff Officer
Transportation Research Board

For a number of reasons, direct charges to road users are being considered to supplement or replace fuel taxes as a primary source of revenue to fund development, operation, and maintenance of the nation's road system. This report presents an analysis of factors to be considered in designing and implementing large-scale trials of mechanisms for collecting such road-user charges, based on vehicle-miles of travel (VMT). A previous report—*NCHRP Web-Only Document 143: Implementable Strategies for Shifting to Direct Usage-Based Charges for Transportation Funding*—that described how currently available technology and administrative structures might be used to implement direct usage-based charges in the near future identified trials as an important element for devising viable systems. The objectives of trials would be to demonstrate the functional feasibility of technologies for recording road usage, assessing charges, and collecting fees; to gauge and possibly encourage public acceptance of direct-usage fees; and to provide insights on cost and organizational matters helpful to designing and implementing direct usage-based charges. This document describes criteria for designing trials; principal uncertainties regarding VMT fees that trails may help to reduce; and possible options for funding, organizing, structuring, managing, and conducting trials. The analysis is informed by recent trials conducted in the United States and elsewhere. The information will be useful to national- and state-level policy makers and to government officials and others who may be engaged in evaluating, designing, and implementing direct usage-based charges.

Faced with steady improvements in vehicle fuel economy, prospects of increasing reliance on alternative energy sources, and widespread reluctance to increase taxes to keep pace with inflation, direct charges for road usage are being considered as a viable alternative to motor-vehicle fuel taxes as a primary source of funds to support construction and operation of the nation's highways. New electronics and communication technologies are making such charges, based on VMT or other indicators of system usage and long familiar to travelers on toll roads, appear increasingly viable in system-wide application.

National Cooperative Highway Research Program (NCHRP) Project 20-24(69) was undertaken to explore proposals that might be implemented quickly, possibly enabling nationwide adoption of direct usage-based charges by 2015. The project, requested by the American Association of State Highway and Transportation Officials (AASHTO), is one of a series of research studies intended to address the specific needs of chief executive officers (CEOs) and other top managers of state departments of transportation (DOTs).

A first phase of the project defined and evaluated a number of options for measuring and reporting road usage and assessing appropriate charges. Options based on fuel-consumption, use of a device combining cellular service and a connection to the vehicle's onboard diagnostics port, and use of a device featuring a Global Positioning System (GPS) receiver were judged in this first phase to be particularly promising. *NCHRP WOD 143*, produced in 2009, described the advantages and disadvantages of these options and important issues to be resolved if usage-based charges are to be successfully implemented.

Some agencies in the United States and abroad have conducted trials or implemented limited direct road-usage charges. Trials can be both a way to test the revenue-collection system's viability and an element of strategy for implementing the system, for example by educating road users and providing opportunities to refine the system. A second phase of NCHRP Project 20-24(69) was undertaken to consider how trials might be most effectively undertaken to inform consideration of a shift to direct usage-based charges in this country.

A team led by the RAND Corporation, Santa Monica, California, working under the auspices of ICF International, conducted both phases of the research. This second phase entailed refining descriptions of direct-charge options suitable for trial, describing criteria to be used in designing trials and the implementation uncertainties that a trial should be designed to resolve, and then describing how trials might be effectively conducted. The research team relied substantially on the informed judgments of subject matter experts and individuals selected to represent key stakeholder perspectives such a road users, motor-vehicle administrators, and road-system operators. An extensive series of individual interviews and a 1-day workshop in Washington, DC, provided the means for collecting these judgments.

While the project's first phase focused on direct-charge options that could be deployed in the 2010 to 2015 timeframe, a decision to conduct trials would likely delay deployment until at least the 2015 to 2020 timeframe. The project's first phase focused on options for developing a national system of VMT fees, but trials could be implemented by individual states or jointly by groups of states. This second-phase work is therefore somewhat broader in scope than the first phase, in terms of the options considered for metering of road usage, fee collection, enforcement and evasion prevention, and protection of road-user privacy. In addition, the research team relied substantially on the recommendations presented in the 2009 report of the National Surface Transportation Infrastructure Financing Commission (NSTIFC) for judging among these options.

The Transportation Research Board's (TRB) intent throughout NCHRP Project 20-24(69) has been to provide timely, fact-based, and balanced analysis of readily implementable means for collecting usage-based charges. Publication of this report and its predecessor as web-based documents reflects this intent by making the project results quickly and widely available to the public. Both reports were reviewed in draft form by individuals not involved in the project, chosen for their expertise and perspective on the issues involved, to assist the authors and NCHRP to make the report as sound as possible. TRB thanks the following individuals for their review of this second report: Randell H. Iwasaki, Contra Costa Transportation Authority, Walnut Creek, CA; Philip J. Tarnoff, Rockville, MD; and Scott E. Stewart, IBI Group, Toronto, Ontario, Canada.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAMVA	American Association of Motor Vehicle Administrators
AASHTO	American Association of State Highway and Transportation Officials
AMPO	Association of Metropolitan Planning Organizations
ANPR	automated number plate (license plate) recognition system
API	application programming interface
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
AVI	automatic vehicle identification
CAFE	corporate average fuel economy standards
CBD	central business district
CEN	European Committee for Standardization
Commerce	U.S. Department of Commerce
DMV	department of motor vehicles
DOT	department of transportation
DSRC	dedicated short-range communications
ECMT	European Conference of Ministers of Transport
EIA	U.S. Energy Information Administration
EPA	Environmental Protection Agency
ERP	Singapore Electronic Road Pricing program
ETC	electronic toll collection
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FTA	Federal Transit Administration
GO	Austrian truck tolling program
GNSS	global navigation satellite systems
GPS	Global Positioning System
HVF	Swiss Heavy Goods Vehicle Fee
IBTTA	International Bridge, Tunnel and Turnpike Association
ID	identification
IFTA	International Fuel Tax Agreement
IRP	International Registration Plan
ISO	International Standards Organization

ITS	intelligent transportation systems
MPO	metropolitan planning organization
MVA	motor vehicle administration
NCHRP	National Cooperative Highway Research Program
NHTS	National Household Travel Survey
NHTSA	National Highway Transportation Safety Administration
NSTIFC	National Surface Transportation Infrastructure Financing Commission
NSTPRSC	National Surface Transportation Policy and Revenue Study Commission
OBD II	on-board diagnostics port (2nd generation)
OBU	on-board unit
ODOT	Oregon Department of Transportation
OIPAF	ODOT Office of Innovative Partnerships and Alternative Funding
PAYD	pay as you drive (insurance or leasing)
PSRC	Puget Sound Regional Council
R&D	research and development
RFP	request for proposal
SHRP2	Strategic Highway Research Program
TIGER	Transportation Investment Generating Economic Recovery grants
TRB	Transportation Research Board
Treasury	U.S. Department of the Treasury
TRUE	Oregon Truck Road Use Electronics pilot program
USDOT	U.S. Department of Transportation
VKT	vehicle kilometers of travel
VMT	vehicle miles of travel

AUTHOR ACKNOWLEDGMENTS

The authors would first like to thank members of the project panel, along with Andy Lemer of TRB, for their thoughtful input and guidance in the research.

The authors would also like to thank the many officials and experts who participated in the project interviews and/or attended and contributed to the May 2010 workshop. At the U.S. Department of Transportation, these include Jack Wells of the Office of Economic and Strategic Analysis; Jim March, Patrick DeCorla-Souza, Allen Greenberg, Ben Hawkinson, and Mary Lynn Tischer of the Federal Highway Administration; and Rob Bertini of the Research and Innovative Technology Administration. From the U.S. Department of the Treasury, we thank Jason DeBaker and Richard Prisinzano of the Office of Tax Policy and John Imhoff, Darren Lefebvre, Richard Little, Holly McCann, Larry Porter, and Michael Solomon of the Internal Revenue Service.

We received valuable input on legislative issues from Susan Binder, formerly of the Senate Environment and Public Works Committee and now at Cambridge Systematics, Alex Herrgott of the Senate Environment and Public Works Committee, Paul Schmid of the Office of Senator Tom Carper (D-Delaware), and Perry Beider of the Congressional Budget Office. At the state level, we thank Steven Polunsky of the State Transportation & Homeland Security Committee of the Texas Legislature and Jim Reed of the National Conference of State Legislatures.

We also spoke to many helpful officials at state DOTs and DMVs. These included Randall Iwasaki, former director of Caltrans, Debra Miller, the Secretary of Transportation for Kansas, Ray Starr of Minnesota DOT, Nathan Earlbaum of New York State DOT, Gregg Dal Ponte of Oregon DOT, Jim Ritzman of Pennsylvania DOT, and Mary Meyland and John Sabala of Texas DOT. We also thank Kurt Myers of Pennsylvania DMV, Michael Harrell of Delaware DMV, and Rena Hussey and Ellen Marie Hess of Virginia DMV.

Steve Heminger of the Metropolitan Transportation Commission, Ashby Johnson at the Houston-Galveston Area Council, and DeLania Hardy of AMPO provided valuable information from the MPO perspective. Additional stakeholder views were thoughtfully provided by Jill Ingrassia of AAA, Darrin Roth and Bob Pitcher of ATA, George Schoener of the I-95 Coalition, Patrick Jones and Neil Gray of IBTTA, Kathryn Phillips of the Environmental Defense Fund, and John Holtzclaw of the Sierra Club.

For insights into the potential linkages between pay-as-you-drive insurance and VMT fees, we were aided by the participation of Tom Warden of Allstate Insurance, Colin Wright of Aviva Canada, David Huber of California AAA, Bill Martin of Farmers Insurance, and Chris Gay of MileMeter Insurance. Perspectives on current and future technology options and back office support functions were offered by Parker Williams and Ken Philmus of ACS, Lukas van der Kroft, a consultant to Alcatel-Lucent, Steve Morello of Egis Projects; Roy Russell of Meadow Networks, and Bern Grush of SkyMeter Corporation.

For their thoughtful discussion of planning processes and previous trials, we are grateful to Monique van Wortel of the Dutch Ministry of Transport, Public Works, and Water Management, Matthew Kitchen of the Puget Sound Regional Council, and Paul Hanley and Jon Kuhl of the University of Iowa. Finally, many long-time observers and experts in the field contributed their

time to this study; these included Emil Frankel of the Bipartisan Policy Commission, Jack Opiola and Scott Wilson of D'Artagnan Consulting, Dick Mudge of the Delcan Corporation, Robert Atkinson of the Information Technology and Innovation Foundation, Mort Downey of Parsons Brinkerhoff, Adrian Moore of the Reason Foundation, Ginger Goodin and Trey Baker of the Texas Transportation Institute, Bob Skinner of the Transportation Research Board, Lee Munnich of the University of Minnesota, Larry Frank of the University of British Columbia, and Ed Regan of Wilbur Smith Associates.

ABSTRACT

Increasing vehicle fuel economy and the likely adoption of alternative fuel vehicles in the coming decades dim prospects for continued reliance on gasoline and diesel excise taxes to fund highway and bridge maintenance, expansion, and completion. Road use charges based on vehicle miles of travel (VMT fees) are viewed by many as a promising replacement for fuel taxes; their revenue yield would be unaffected by fuel economy or fuel type, the fees could be structured to help address additional transportation goals (e.g., reducing recurrent traffic congestion, harmful emissions, and excessive road wear), the system could provide detailed travel data to support improved transportation planning and operations, and the in-vehicle metering equipment could serve as a platform for additional driver services. Yet transitioning from fuel taxes to VMT fees would be a complex undertaking, with many technical, institutional, and political uncertainties to be resolved. To prepare for such a transition, it could be helpful to conduct an extensive set of system trials. The goal in this study is to explore options for scoping and organizing such trials. Policymakers interested in staging trials with the aim of examining and refining concepts for implementing a VMT-fee system would need to consider such questions as: how large the trials should be and how long they should last; how much it would cost to conduct the trials; whether the trials should be conducted in all states or just a few; whether the trials should involve trucks, passenger cars, or both; what types of pricing policies the trials should examine; what technical, institutional, and user acceptance issues should be probed; and who should oversee, manage, and conduct the trials. To gain insight into such questions and identify the factors likely to influence the success of trials, the research team solicited the thoughts and perspectives of representative stakeholders and subject matter experts through an extensive set of guided interviews followed by a one-day workshop. Based on participant responses and supporting research, it is possible to outline several approaches for funding, organizing, structuring, managing, and conducting a set of VMT-fee system trials. The trials could be complemented by parallel efforts in the areas of planning and policy guidance, analytic studies, technical research and development, and public education and outreach.

EXECUTIVE SUMMARY

This summary provides an overview of work conducted under the National Cooperative Highway Research Program (NCHRP) Project 20-24 (69A), *System Trials to Demonstrate Mileage-Based Road Use Fees*. The goal of the study is to develop promising suggestions for scoping, funding, organizing, managing, and conducting a set of system trials to prepare for the possible implementation of road use fees based on vehicle miles of travel (VMT fees) within the United States.

S.1. MOTIVATION FOR STUDY

For nearly a century the United States has relied on motor fuel excise taxes, levied at the federal and state level, as the main source of funding for maintaining and expanding highways. Fuel taxes have performed admirably in this role. They are inexpensive to administer and difficult to evade, and they promote equity in transportation finance by aligning the costs of funding the highways with those who benefit from using them. From an environmental and energy security perspective, fuel taxes also provide a modest incentive for the adoption of more fuel-efficient vehicles.

Despite their advantages, fuel taxes face structural and political liabilities that threaten their ability to provide sufficient highway funding in the coming years. Typically levied on a cents-per-gallon basis, fuel taxes must be raised periodically to keep pace—in terms of real revenue per mile of travel—with inflation and improved fuel economy. Over the past several decades, with the rise in anti-tax sentiment, elected officials have grown increasingly reluctant to take on this politically difficult task. As a result, the federal Highway Trust Fund (or HTF, the repository for federal fuel taxes) and comparable highway accounts in many states face growing funding shortfalls. To keep the HTF solvent, the Congress found it necessary to transfer $8 billion from the general fund in October 2008 and another $7 billion in November 2009 (with additional expenditures embedded in the recent stimulus bills, the Congress allocated in excess of $70 billion from the general fund to surface transportation between 2008 and 2010). Looking forward, the anticipated increase in fuel economy for conventional vehicles, along with the introduction and adoption of alternative fuel vehicles, is likely to further undermine the ability of current motor fuel taxes to raise sufficient highway revenue.

Against this backdrop, many in the transportation field have argued that the federal government and states should either replace or augment current fuel taxes with a system of road use charges levied on the basis of vehicle miles of travel (VMT fees). Because VMT fees would not depend on fuel consumption, the revenue stream would be unaffected by changes in fuel economy or fuel type (VMT fees would still need to be indexed or periodically raised to account for inflation, but the increases would not need to be as frequent or as large as those for fuel taxes). In addition to providing a more stable revenue stream, VMT fees could offer several additional advantages. To begin with, VMT fees could be structured to vary with relevant travel characteristics to help reduce recurrent traffic congestion, harmful emissions, and excessive road wear (for example, charging a higher per-mile fee for peak-hour travel in congested corridors would encourage drivers to shift some of their trips to other times, other routes, or other modes, thereby alleviating congestion). Additionally, the in-vehicle equipment used to meter mileage could also support many other offerings and services that drivers might value, such as pay-as-you-drive (PAYD)

insurance, automated payment of parking fees, real-time routing assistance based on the location of travel and current traffic conditions, safety alerts, and the like. Finally, a system of VMT fees could provide a rich set of detailed travel data to support improved planning and operational management of the road network (to protect privacy, such data would not be linked to specific vehicles; rather, it would be collected and stored anonymously).

Such advantages, combined with recent advances in enabling telecommunications technology, have stimulated growing interest in the concept of distance-based road use charges. The past decade witnessed the introduction of automated truck tolls based on travel distance and vehicle size or weight (referred to as weight-distance tolls) in Switzerland, Austria, Germany, the Czech Republic, and Slovakia. The Netherlands has conducted advanced planning for a national system of distance-based road use charges that would apply to all vehicles, and New Zealand has introduced a system that applies to trucks as well as diesel-fueled cars. Here in the United States, the Puget Sound Regional Council and the University of Iowa have conducted trials of distance-based road use charges that would be applicable for passenger vehicles, the State of Oregon has conducted separate trials for both passenger cars and trucks, and Minnesota is planning to conduct its own trial in the near future.

Several key observations emerge from these initial efforts. First, the technology to support the metering of mileage, potentially by time and location, is viable in practice. Second, though such systems are more expensive to implement and operate than the fuel tax, they are also capable of providing a stable revenue stream. Third, evidence indicates that drivers do in fact respond to price signals embedded in the fee structure. To illustrate this point, the German truck toll levies much higher per-kilometer fees for heavily polluting trucks, and this price structure has accelerated the adoption of less polluting trucks.

Based on this positive initial experience, and in the context of growing transportation funding shortfalls, an increasing number of elected officials in the United States have concluded that it would be valuable to initiate a shift from fuel taxes to VMT fees as rapidly as possible. This perspective served as motivation for the preceding NCHRP 20-24(69) project, *Implementable Strategies for Shifting to Direct Usage-Based Charges for Transportation Funding* (Sorensen et al., 2009). Within the study, the authors were asked to identify and evaluate potential options for implementing a national system of VMT fees within the next five years. The report highlighted several promising approaches, but it also observed that the substantial public policy issues and uncertainties associated with VMT fees would make it difficult to design a cost-effective and politically acceptable system at this time. Examples of such issues and uncertainties include the policy goals that a system of VMT fees should be able to support, the appropriate institutional configuration for collecting and apportioning VMT fees among jurisdictions, the likely cost of enabling technologies produced at scale, and the public acceptance of alternate fee-collection methods. The report then outlined a set of activities that might be funded, perhaps in the next surface transportation bill, to resolve such questions and prepare for possible implementation in the 2015 to 2020 timeframe. These included planning and policy guidance, analytic studies, technical research and development (R&D), expanded system trials, and education and outreach.

For this study, which represents the second phase of the earlier NCHRP 20-24(69) project, the goal is to further explore the types of system trials that could be helpful to conduct. Should the decision be made to fund expanded system trials to explore and refine VMT-fee implementation concepts, policymakers would need to consider such questions as: How large should the trials be, and how long should they last? How much funding would be needed to support the trials? Should

the trials be conducted in all states or just a few? Should the trials include passenger cars, trucks, or both? What pricing structures should be examined in the trials? What technical, institutional, and public acceptance issues should the trials probe? Who should oversee and manage the trials, and who should be eligible to conduct them? On what basis should funding for the trials be allocated or awarded? This project seeks to address such questions, aiming to provide credible analytical bases for making decisions about the scope, organization, funding, and management of trials to inform public policy discussion of VMT fees to replace or augment fuel taxes.

In terms of the objectives of the initial NCHRP 20-24(69) project—to (a) identify and evaluate potentially viable mechanisms for assessing and collecting VMT fees and (b) propose a practical strategy for implementing a national system of VMT fees with a high likelihood of sustainable success—trials can be viewed as a means for testing and enhancing viability as well as an element of the implementation strategy. Yet this study departs from the base assumptions of the initial research in two regards. First, while the initial NCHRP 20-24(69) project considered mechanisms for implementing VMT fees that could be deployed in the 2010 to 2015 timeframe, a decision to conduct system trials would likely delay such deployment until at least the 2015 to 2020 timeframe. Second, the initial study focused on options for developing a national system of VMT fees. One possible outcome of trials, however, would be for certain states to implement their own VMT-fee systems should the federal government choose not to develop a national system. Based on these two shifts—the longer timeframe and the possibility of state-level deployment—this study does not focus solely on the potential VMT-fee mechanisms identified as promising in the prior report; rather, as indicated in the discussion of methodology below, it reexamines the various implementation options and considers which of these might be helpful to examine in the context of expanded system trials.

S.2. METHODOLOGY FOR CONSIDERING TRIALS

The methodological approach in this study can be summarized as follows:

- Review the results of prior distance-based road use charging studies, trials, and program implementation efforts in the United States and abroad
- Enumerate and characterize potential VMT-fee implementation options (i.e., approaches to metering mileage, collecting fees, protecting privacy, and the like)
- Determine and apply criteria for identifying the most promising VMT-fee implementation options to evaluate in the trials
- Identify uncertainties that would need to be resolved in order to develop a technically feasible, politically viable, and cost-effective system of VMT fees
- Determine which of these issues could be resolved or informed through suitably structured trials
- Solicit input from stakeholder and subject matter experts, through a series of interviews followed by a one-day workshop, regarding:
    - Which of the uncertainties would be most crucial to examine through trials
    - How the trials might be structured to examine these issues
- Conduct additional research, where helpful and feasible, to augment the input received from stakeholders and subject matter experts

- Synthesize findings to outline possible options for funding, organizing, structuring, managing and conducting the trials

The results of the study, largely reliant on the informed input of stakeholders and subject matter experts, might best be viewed as an initial assessment of the many questions that would need to be considered in designing and implementing an expanded set of VMT-fee trials. Though the study included thorough background research and some supporting analysis, the scope did not allow for highly detailed evaluation of each individual topic. The work reported here provides useful insight but also makes clear that additional research on certain issues would be valuable—most notably to provide adequate information on the number of participants to include in the trials and in turn the estimated cost of the trials.

S.3. IMPLEMENTATION OPTIONS TO EXAMINE IN TRIALS

The first three elements of the methodological approach, as outlined above, are aimed at identifying implementation options that would be valuable to explore and refine within the context of trials. Toward this end, the team began by reviewing the results of prior and ongoing trials and programs involving distance-based road use charges, including the aforementioned trials in the United States, the planned program in the Netherlands, and the operational programs in Switzerland, Austria, Germany, the Czech Republic, Slovakia, and New Zealand. Additional, the team examined the implementation of PAYD insurance programs reliant on similar metering technology. These programs and trials are discussed in some depth in Appendix A.

S.3.1. Technical Mechanisms for Implementing VMT Fees

Based on these trials and programs, along with related studies, the next step was to enumerate and characterize the range of potential mechanisms for implementing VMT fees. To frame the review, the study focused separately on options for metering mileage, collecting fees, preventing evasion, and protecting privacy. The first three of these represent the core required elements of system functionality, while the last would be important from the perspective of user acceptance.

The four columns in Table S.1 list different implementation options that were identified and characterized in the study. Note that the options for metering, collecting fees, preventing evasion, and protecting privacy can be combined in multiple ways; there are thus numerous potential technical configurations for a system of VMT fees. The strengths and weaknesses of these options are briefly summarized later in this section; Chapter 2 in this report defines, describes, and characterizes the options in much greater detail.

Table S.1. Potential VMT-Fee Implementation Options

Metering Options	Collecting Fees	Preventing Evasion	Protecting Privacy

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

S.3.2. System Design and Deployment Approaches

Beyond specific technical mechanisms for levying VMT fees, a review of relevant trials, programs, and studies reveals several broader strategies and concepts that might be pursued in designing, deploying, and transitioning to a fully-articulated system of VMT fees. These include:

- **Interoperability (or "open systems").** The basic idea in this concept would be to create a set of technical requirements and standards related to data collection, storage, processing, and communication within the context of distance-based road use fees. This would enable multiple vendors to compete for the provision of in-vehicle metering equipment and billing services, thus helping to drive down cost and promote continued innovation. The pace of technical innovation in this field is quite rapid, and focusing on interoperability standards rather than a specific technical configuration would allow multiple approaches to be employed as they are developed, thus helping to avoid "technical lock-in." As an added advantage, the approach might enable states to develop their own systems that would be able to operate with one another (e.g., to charge out-of-state drivers) in the event that the federal government does not choose to deploy a national system. To support interoperability standards, some form of government-approved certification process would also be needed.
- **Required retrofits.** In transitioning to a system of VMT fees, one possibility would be require that all vehicles be retrofitted with the necessary metering equipment as of a certain date and then begin levying VMT fees from that point forward. This has been the typical approach for the recently implemented weight-distance truck tolls in Europe, and it might be considered for VMT fees for commercial vehicles in the United States as well. Based on cost concerns as well as public acceptance challenges, however, it is not clear that decision makers would choose to apply this approach for passenger vehicles.
- **Installation with new vehicles.** As an alternative to mandatory retrofits, another option would be to require that auto manufacturers, as of a certain model year, begin to install the required metering devices on all new vehicles. Drivers would then begin to pay VMT fees,

rather than fuel taxes, with the purchase of a new vehicle. A key motivation for this strategy would be to reduce the cost of equipping passenger vehicles. Produced at volume (i.e., for all new vehicles), the cost of the equipment itself could be much lower, and factory installation would eliminate the potentially considerable cost of installing retrofitted devices. The cost of the equipment would also be paid by the owner as part of the vehicle purchase price, unless the government chose (possibly for political acceptance reasons) to subsidize the cost. Yet this approach would also face several drawbacks. First, the vehicle fleet is replaced relatively slowly, potentially resulting in a 15 to 20 year transition period. Second, the decision to require that auto manufacturers begin installing metering equipment with new vehicles, given the cost, would only be possible with a clear and unambiguous policy decision to initiate the transition to VMT fees. It would likely take time to build sufficient public support to reach such a decision, further prolonging the overall timeframe for planning and transitioning to a system VMT fees. Third, the cost and capabilities of metering equipment and related services continues to evolve, and it might be premature to settle on a standardized configuration for all vehicles within the near term.

- **Voluntary opt-in.** This concept is intended to overcome anticipated public acceptance concerns associated with transition strategies that would rely solely on mandatory adoption. The basic idea would be to establish a period during which drivers could choose to adopt metering equipment and pay VMT fees (and receive fuel tax rebates) on a voluntary basis. Such early adopters would help to demonstrate, for example, that the methodologies for protecting privacy and preventing evasion work as intended, thus paving the way for full-scale mandatory adoption at a later date. To entice voluntary adoption, in-vehicle metering equipment would be designed to support a range of value-added features, such as PAYD insurance, automated payment of parking fees, real-time routing assistance, safety alerts, and the like. Indeed, if coupled with the interoperability concept outlined above, firms might strive to provide as many value-added services as possible to increase their market share. Note that the voluntary opt-in approach need not preclude a parallel decision to require that auto manufacturers begin, as of a specified model year, to install equipment capable of metering VMT fees on new vehicles; even if the pre-installed equipment were not initially used by all drivers during the voluntary opt-in period, it would ultimately reduce the cost of mandating VMT fees at a later date because fewer vehicles would then need to be retrofitted with the necessary equipment.
- **User choice.** As an extension to the preceding concept, designing the system to provide drivers with as many choices as possible could help build greater support for, or at least reduce resistance to, the implementation of VMT fees. For example, some drivers might prefer to pay more for a device providing many additional services; others might prefer to pay less for a simple device that only levies VMT fees (conceptually similar to current electronic toll collection, or ETC, devices). Some might prefer to pay the same flat rate for all miles of travel, while others might prefer the option to pay lower rates for off-peak mileage and higher rates for peak mileage. Some might wish to pay at the pump, while others might prefer monthly billing. Some might be willing to share their detailed travel data in return for slightly reduced fees, while others might insist on absolute privacy protection. It should be noted that some of these potential choices—such as multiple payment options—could lead to higher implementation and operation costs. Yet with careful planning and foresight, it might prove possible to provide drivers with many of these choices at low cost.

S.3.3. Capabilities and Limitations of Implementation Mechanisms

An important consideration in designing a system of VMT fees is understanding the metering capabilities offered by each implementation option, which would in turn influence the policy goals that the system could potentially address. Relevant metering capabilities include the following:

- **Measuring or estimating all miles of travel.** This would be a pre-requisite for a VMT fee system, and would also be needed for simple forms of PAYD insurance (this capability is supported by all but one of the metering options listed above; RFID tolling on a partial network was introduced as a potential alternative to VMT fees rather than as a means of implementing VMT fees).
- **Accounting for vehicle characteristics.** This might include vehicle emissions class, weight, or axle weight, and would be needed for structuring fees to encourage reduced emissions or for implementing simple forms of weight-distance truck tolls.
- **Determining area of travel.** This would be needed to adequately meter and apportion fees by jurisdiction, to differentiate fees by jurisdiction (e.g., allowing states to levy their own VMT fees), or to implement area-based forms of congestion tolls (e.g., cordon congestion tolls, as implemented in London, Singapore, and Stockholm, or higher per-mile charges in congested areas during peak hours). It might also be used to implement advanced forms of PAYD insurance in which per-mile rates vary by the area in which travel occurs.
- **Determining location or route of travel.** This would be needed to implement route-specific forms of congestion tolling (e.g., facility-specific congestion tolls or network-wide tolls that vary by route) as well as truck tolls that might vary by route. It would also be needed for certain value-added features that rely on specific vehicle location information—for example, the automated payment of parking fees or real-time routing assistance—as well as to provide detailed travel data (appropriately aggregated and protected; that is, not attributable to a specific driver or vehicle) for improved system planning.
- **Time of travel.** This final metering characteristic would be needed in any implementation of congestion tolls as well as for collecting detailed, anonymous travel data for improved system planning.

Table S.2 indicates the metering capabilities, shown as black dots, that would be supported by the various metering options listed in Table S.1. Note that the metering capabilities of several of the options could be extended through the addition of electronic readers (potentially mounted on gantries, signs, overpasses, tunnel entrances, and the like) along heavily traveled routes that would register the passage of a vehicle at a specific location and time (to enable, for example, facility-specific congestion tolls); such extensions are shown as hollow dots.

Table S.2. Capabilities of VMT-Fee Metering Options

Metering Option	Metering Capabilities				
	Meters Entire Road Network	Vehicle Emissions Class or Weight	Mileage by Area or Jurisdiction	Route or Specific Location of Travel	Time of Travel
Self-reported odometer readings	●	●			
Required odometer checks	●	●			
Optional odometer checks	●	●			
Fuel consumption-based estimates	●	●		○	○
RFID tolling on a partial road network		●		○	○
OBU with OBD II	●	●		○	●
OBU with OBD II / cellular	●	●	●	○	●
OBU with GPS	●	●	●	●	●

As indicated by the entries in Table S.2, the odometer options would offer the least flexibility, while the GPS-based OBU would support any of the potential goals that a system of VMT fees might be intended to address. The other options fall between these two end points.

If metering capabilities were the only consideration of interest, then the obvious choice would be to implement VMT fees with GPS equipment. But there are many additional factors that could influence the suitability and desirability of a particular implementation option. These include:

- **Implementation cost.** Relevant considerations include the costs of in-vehicle technology, supporting infrastructure, administration, and enforcement.
- **Functional considerations.** Relevant considerations include technical reliability, ease of enforcement, flexibility and extensibility, integration with other systems, accounting for all vehicle types or classes, accounting for foreign vehicles, ability to manage the transition, and overall system risk.
- **Institutional considerations.** Relevant considerations include administrative complexity, degree of required state support, and legal barriers.
- **User acceptability.** Relevant considerations include burden on individual drivers, burden on the private sector, the ability to audit charges, and privacy concerns.

When evaluated against these factors, a fuller picture of the relative capabilities and limitations of the various implementation alternatives emerges. Each of the metering options (combined with the mechanisms for collecting fees and preventing evasion with which they might be coupled) presents one or more significant drawbacks—for example, being difficult to enforce, requiring significant administrative support from states (potentially a problem if developing a system of federal VMT fees in which state participation would be optional), raising privacy concerns, or entailing high implementation or operating costs. These are summarized in Table S.3: a black dot indicates a known limitation, a hollow dot indicates a potential limitation, and gray shading within a cell indicates that further research would be beneficial to quantify the magnitude of the issue.

Table S.3. Key Limitations of VMT-Fee Implementation Options

Metering Approach	Tough to Enforce	Extensive Required State Support	Burden on Users	Privacy Concerns	Vehicle Equipment Cost	Other Capital & Operating Costs
Self-reported odometer readings	●	●				
Required odometer checks		●	●			●
Optional odometer checks		●				●
Fuel consumption-based estimates				○		●
RFID tolling on partial road network				●		●
OBU with OBD II	○				●	●
OBU with OBD II / cellular	○			○	●	●
OBU with GPS	○			●	●	●

The ratings in Table S.3 were arrived at from the perspective of implementing a national system of VMT fees, and many of the limitations of the odometer options are based on the fact that not all states currently conduct routine vehicle inspections. If VMT fees were implemented within a single state that already conducts annual vehicle inspections, the odometer options could be relatively inexpensive to implement and administer.

S.3.4. Criteria for Identifying Promising Implementation Options

While the above analysis is helpful in understanding the strengths and limitations of alternate implementation approaches, it is not sufficient for distinguishing the most promising options that merit further exploration in trials. Given that each option faces one or more limitations, selecting an implementation approach would inevitably require policy tradeoffs. Would it be viewed as more important, for example, to reduce implementation costs or to support a broader range of functionality? Though such questions can be informed by careful analysis, the decisions must ultimately rest on the judgment of policymakers.

Agreement among policymakers as to the requirements that a system of VMT fees should satisfy has yet to emerge, making it difficult to distinguish the most promising options to include within the trials. The approach taken in this study was to consider recommendations from the recent report of the National Surface Transportation Infrastructure Financing Commission (NSTIFC 2009), which outlined a set of required and desirable attributes for a national system of VMT fees. The NSTIFC recommendations are organized as follows:

- **Pricing capabilities.** The Commission recommended that VMT fees should be able to serve as a single mechanism to support all transportation taxation and pricing. This would require the ability to collect and properly apportion revenue for: (a) federal, state, and local VMT fees; (b) public and private toll road charges; (c) congestion pricing and managed lanes applications at the state and local levels as desired; (d) emissions charges, if not handled through other means; (e) charges on heavy vehicles, possibly based on axle weight; and (f) transit fares via "mobile commerce" technology (e.g., smart cards and mobile phones) that could be integrated with in-vehicle VMT-fee technology.
- **General attributes.** Additionally, the Commission recommended that a national VMT-fee system should: (a) be reliable, secure, and enforceable, and protect against identity theft; (b) permit efficient transfer of revenue among the federal government, states, local jurisdictions, and private service providers; (c) provide travelers and commercial vehicle operators with

information on applicable rates through various modalities; (d) provide adequate privacy protection and allow for anonymous operations for motorists desiring such protection; (e) limit annual net operating costs to less than 10 percent of revenue within a few years of implementation and less than 5 percent over the longer run; and (f) ensure that users, during the phase-in period, are not required to simultaneously pay both VMT fees and fuel taxes.

- **Technical characteristics.** Finally, the Commission recommended that the technical design of the system should: (a) accommodate multiple forms of payment; (b) facilitate integration with future ITS-related applications, including traveler information systems and vehicle-infrastructure integration programs such as IntelliDrive; (c) allow for (and eventually require) the metering equipment to be pre-installed with new vehicles and to be retrofitted for existing vehicles; and (d) rely on federal technical standards that would govern the design of any metering equipment provided by states, localities, or private operators or firms

S.3.5. Implementation Options to Explore in Trials

Considering the relative capabilities, strengths, and limitations of the various implementation approaches in light of the NSTIFC recommendations, the following emerge as promising options to explore in the trials:

- **Metering options.** The only metering option that would fully satisfy the recommendations of the NSTIFC report is the OBU with GPS configuration. That said, it might be beneficial to examine several additional options within the trials for other reasons. The OBU configuration with OBD II and cellular location, for example, would still provide considerable metering flexibility, but likely at lower cost than the GPS option. If pay-at-the-pump were considered as a potential payment mechanism, then the fuel consumption-based estimates might be examined as a potential interim option as part of a longer-term transition to VMT fees. If policymakers considered RFID tolling on a partial road network as a viable alternative to network-wide VMT fees, then the metering devices for a subset of trial participants could be configured to emulate that form of payment. If the trials were intended to support exploration of state-level VMT fees, then a state that already conducts vehicle inspections might choose to evaluate annual odometer readings as a low cost implementation option. As a final note, it might also be helpful for the trials to focus more on general metering capabilities than on pre-specified metering configurations. If, for example, a particular vendor proposed to develop a metering device that would reside on a smart phone and be capable of determining the location of travel, that could be acceptable (subject to other criteria, such as the ability to verify payment for all miles of travel) as well.
- **Options for collecting fees.** The NSTIFC recommendations suggest that it would be helpful to examine at least three of the four options for collecting fees (specifically, those that would complement OBU-based metering): pay-at-the-pump, transmission of billing data to a collection authority, and debit cards. The cost of collecting VMT fees is of considerable concern, and there is significant uncertainty regarding the cost of these alternatives at scale; trials could help reduce this uncertainty. If the trials were intended to support state-level implementation, then payment with registration might also be considered.
- **Options for preventing evasion.** While preventing fee evasion would be crucial, as stressed by the NSTIFC recommendations, little is known regarding the cost and effectiveness of the different potential approaches. This argues for examining as many of the options as possible within the trials. To help reduce the cost of operating a VMT-fee system, the trials might focus in particular on those options that limit the degree of required manual support—

specifically, fuel consumption redundancy checks, external wireless probes for functioning metering equipment, device heartbeat signals, and device distress signals.

- **Options for protecting privacy.** From a technical perspective, protecting privacy is viewed as feasible; any of the privacy protection options could work as intended. The key issue to overcome, then, would be the public perception that VMT fees would violate privacy concerns. This argues for examining within the trials as many privacy protection options as possible—not so much to examine their effectiveness, but rather to better understand public perceptions of the various alternatives.
- **Broader implementation strategies.** Directly or indirectly, the NSTIFC report stresses the importance of interoperability standards and user choice. It also suggests the installation of metering equipment with new vehicles as well as the possibility of retrofitting existing vehicles. It does not, on the other hand, mention the voluntary adoption concept specifically, but it does highlight the importance of supporting value-added ITS-related services that would be a key element of voluntary adoption. It might therefore be beneficial to examine some of these concepts, as appropriate, within the trials as well.

While the options above emerge as worthy of further exploration in trials, it is unclear whether the trials should seek to examine all of these. A comprehensive set of trials would certainly be costly and complex and might require years to execute. A competing objective could be to keep the trials relatively simple to facilitate greater public understanding, and this might argue for examining a smaller subset of implementation options.

S.4. ADDITIONAL ISSUES TO EXAMINE IN THE TRIALS

While the preceding analysis is helpful in identifying implementation mechanisms and concepts that would be valuable to examine in trials, it does not address a much broader set of questions pertaining to the appropriate scope and organization of the trials. In terms of scope, for example, how many participants should be involved, and how long should the trials last? Should they be conducted in all states or in just a select few? Should the trials focus on passenger cars, trucks, or both? What pricing policies should be examined? What additional technical, institutional, and user acceptance issues should be probed, and in what manner? In terms of organization, who should oversee and manage the trials, and who should be involved in conducting the trials?

To address such questions, as outlined earlier in Section S.2, the first task was to enumerate a comprehensive list of issues and uncertainties that would need to be addressed or resolved to inform policy debate and prepare for implementing and transitioning to a system of VMT fees. We next solicited input from stakeholders and subject matter experts regarding (a) which of the uncertainties would be most important to examine in the trials, and (b) how the trials might be organized and structured to help resolve the most important uncertainties. This was achieved through an extensive set of guided interviews followed by a one-day expert workshop to present, discuss, and refine preliminary findings. Where helpful and feasible within time and budget constraints, additional research was conducted to supplement the interview and workshop results.

S.4.1. Remaining Uncertainties

Based on the review of prior trials and program implementation efforts, along with related studies and discussions, we identified a long list of issues that would need to be resolved in order to design and transition to a system of VMT fees. Broadly, these can be grouped as follows:

- General system requirements
- Technical implementation approaches
- Public and private institutional arrangements
- System deployment and transition issues
- System cost
- User acceptance

As noted in the opening section of this summary, the preceding NCHRP 20-24(69) identified five related sets of activities to help resolve remaining uncertainties and prepare for VMT-fee implementation: planning and policy guidance, analytic studies, technical R&D, system trials, and education and outreach. The research team next considered which of the uncertainties might be resolved or illuminated through system trials and which would need to be addressed through other channels. In short, while trials could be helpful in examining almost all of the uncertainties, additional efforts in the areas of planning, analysis, development, and education and outreach would be needed to fully resolve many of the issues. This underscores the utility of conducting trials within the context of a broader effort to assess and plan for the possible implementation of VMT fees.

S.4.2. Questions for Stakeholders and Experts

The next step, then, was to solicit the input of stakeholders and subject matter experts regarding the appropriate design for the trials. To guide the input, we prepared a lengthy set of detailed questions, presented in Appendix B. The questions were grouped in the following categories:

- Policies to examine in the trials
- Scale, geographic coverage, and duration of the trials
- Technical, institutional, transitional, and user acceptance issues to examine in the trials
- Federal leadership and stakeholder participation in the trials
- Organization and management of the trials
- Allocating funding for the trials
- State and local involvement in the trials
- Private sector involvement in the trials
- Trial participants
- Cost estimates for conducting the trials
- Detailed structure of the trials

S.5. STRATEGIC CONSIDERATIONS FOR THE TRIALS

To solicit diverse perspectives, the interviews and workshop included participants with the following affiliations or areas of expertise: project panel members, U.S. Congressional staff, U.S. Department of Transportation (U.S. DOT), U.S. Department of the Treasury (Treasury), state departments of transportation (DOTs), state departments of motor vehicles or motor vehicle

administrations (DMVs/MVAs), state legislative staff, metropolitan planning organizations (MPOs), stakeholder advocacy organizations, technology providers and tolling system developers and operators, automobile insurance companies, managers of previous pilot tests and program implementation efforts involving distance-based road use charges, and subject matter experts from private practice and academia. A total of 69 individuals participated in the interviews, and 32 participated in the workshop. The full list of participants is provided in Appendix C.

S.5.1. Recurrent Themes from the Interviews and Workshop

While a few interview and workshop participants remained doubtful regarding the political prospects for VMT fees, most were optimistic and focused their commentary on how to structure the trials to be as effective as possible. Among the many comments received, there were several frequently expressed opinions and perspectives that might directly or indirectly influence the design of the trials:

- The lack of clear policy direction is holding back implementation efforts.
- Federal leadership on VMT fees is needed.
- Trials should be structured to prepare for implementation.
- The federal government should be prepared to invest considerably in the trials.
- A VMT-fee system should be designed to address additional goals beyond revenue.
- Principal obstacles to VMT fees include cost and user acceptance.
- Building greater trust in the government is another key challenge.
- Trial development should draw on lessons learned from prior transportation programs.
- Authorizing legislation for the trials should not be overly prescriptive.

S.5.2. Divergent Views on the Path to Implementation

In developing the methodological approach for this study, the initial hope was that a strong degree of consistency on the appropriate size, scope, and structure for the trials would emerge from the interviews and workshop. In fact, while there was general agreement on many issues, other questions generated wildly divergent responses. Opinions about the number of drivers that should participate in the trials, for example, varied from a few thousand to more than a million.

As the divergence in opinions became apparent, the research team asked follow-up questions to gain insight into the reasoning behind different responses. Based on the ensuing discussions, it became clear that variations in answers about how the trials should be structured often stemmed from disparate views regarding the manner in which a transition to VMT fees would likely (or should ideally) unfold. In particular, experts and stakeholders expressed differing perspectives for such questions as:

- Would it be more desirable (or, alternatively, more likely given political considerations), for the initial implementation of VMT fees to occur within states or at the federal level?
- Could VMT fees be implemented in just a few years, or would it take a decade or more?

- Should the transition begin with a mandatory phase-in process (e.g., with the purchase of new automobiles) or should it instead rely on voluntary opt-in strategies for several years prior to the initiation of mandatory adoption? (Here again note that a period of voluntary adoption would not preclude the possibility of requiring that auto manufacturers begin to provide metering equipment with new vehicles as of a certain model year to reduce the number of vehicles that would need to be retrofitted at a later date.)

S.5.3. Frameworks for Scoping and Organizing the Trials

Different views on these questions suggest different pathways to implementation, and these in turn imply alternate goals and structures for the trials. Building on this insight, the research team outlined three conceptual "frameworks," or visions, about how the transition to VMT fees might be pursued, and in turn how the trials could be scoped and organized in support of that vision. The three frameworks, along with their strengths and potential limitations or risks, can be summarized as follows:

Help states help themselves (state framework). In this framework, the trials would be aimed at helping interested states (or groups of adjacent states, such as the I-95 Corridor Coalition) develop their own systems. The federal government might then develop a national system at a later date based on the lessons learned in state programs. In addition to funding, a key federal role in this framework would be to foster the development of interoperability standards and a certifications process to ensure that systems developed in different states could interact with one another. The federal government might also encourage states to examine options that might later be extended to implement a national system. While some states would likely structure the trials to provide information to support subsequent planning and public debate, it is conceivable that others might intend for the trials to evolve directly to implementation.

- **Strengths.** It could be easier to gain public acceptance for VMT fees within an individual state than at the national level, thus increasing the odds of actual implementation. States have more opportunities to create financial incentives for adopting VMT fees—for example, states might allow drivers to pay registration fees by the mile, allow auto insurers to offer PAYD policies, or encourage cities to allow automated payment of parking fees—making it possible to plan a transition strategy involving an initial period of voluntary adoption. States that conduct routine vehicle inspections could implement an odometer-based system at relatively low cost. States control the law enforcement resources to prevent evasion. States could serve as a laboratory for examining innovative VMT-fee concepts.
- **Limitations and risks.** This would not, in the near term, help address federal transportation funding shortfalls. Absent careful planning, there would be a risk that the systems developed in different states would not be interoperable. If one or more states intended that the trials would evolve directly to implementation, then it would be important to establish an initial set of interoperability standards in advance of the trials; though possible, it would be challenging to accomplish this task within just one or two years. The intent for trials to evolve directly to implementation would also imply the need to make certain system design decisions (e.g., the channels for collecting fees) in advance of the trials, without the benefit of experience that might be gained during the trials. The opportunity to drive down costs through economies of scale would be reduced given that there are fewer drivers in any given state than in the nation as a whole.

Carefully plan a national system (federal framework). In this vision, the federal government would take the necessary steps to plan and develop a national system of VMT fees to replace or augment current federal fuel taxes. By design, the system would be sufficiently flexible to enable states to implement their own VMT fees as well, though states would not be required to do so. While the trials would still be conducted in states interested in adopting their own VMT fees, the effort would be more carefully coordinated to examine issues involved in setting up a national system. Following the trials, and subject to political debate, efforts to plan and implement the national system would commence.

- **Strengths.** This option would directly address the need to augment federal transportation revenue, and it would also maximize the opportunity to reduce costs through economies of scale. A national system would enable interested states to implement their own VMT fees without needing to develop a system from scratch; by extension, it would also circumvent the potential for developing incompatible systems in different states.
- **Limitations and risks.** Implementing national VMT fees, from a political perspective, would require some degree of national consensus, an elusive goal. Short of increasing gas taxes, the federal government would have fewer opportunities to encourage voluntary adoption: it does not levy registration fees (for passenger cars, at least) that could be converted to per-mile charges, it does not govern auto insurers, and it has limited influence with municipal parking policies. As a result, the transition plan would likely involve mandatory adoption of VMT fees, compounding the difficulty of achieving public acceptance. To enforce the payment of VMT fees, the federal government would need to either expand the staffing and capabilities of its law enforcement resources (e.g., IRS agents that currently enforce fuel taxes) or rely on significant state support.

Foster a market for in-vehicle travel services (market framework). This last framework represents the greatest departure from earlier thinking about how to accomplish a transition to VMT fees, seeking to achieve several goals in parallel: to overcome current public acceptance challenges through an initial period of voluntary adoption, to implement a fully operational (if initially voluntary) national system of VMT fees as quickly as possible, and to reduce the cost to government of collecting VMT fees. The framework envisions, and would seek to foster, the emergence of a market for in-vehicle metering devices capable of levying federal, state, and potentially local VMT fees and supporting additional value-added services such as automated payment of parking fees, PAYD insurance, real-time traffic alerts, routing assistance, and the like. Firms would compete to provide these devices and services, thereby stimulating innovation and driving down system costs. Additionally, because firms would be able to collect payment for some of the additional services, the amount that they would need to charge the government for collecting VMT fees would be reduced. The main goal of the trials in this framework would be to support the emergence of this market, which would involve a broad range of public and private participation. To do so, the federal government would separately contract with, fund, or subsidize technology providers, states, cities, and auto insurers for their respective roles in the trials, and the intent would be for the trials to evolve directly to system implementation. Trial participants that valued the additional services would become the initial adopters, and additional drivers would be able to adopt the in-vehicle equipment on a voluntary basis as well. After several more years, once it has been demonstrated that the system provides appropriate privacy protection and can be enforced effectively, the government might mandate the adoption of VMT fees for all vehicles.

- **Strengths.** Through its focus on market competition as well as the provision of additional services for which drivers would pay, this approach would reduce the cost to the government for collecting VMT fees. The provision of value-added services would also maximize the social value of the investment in metering devices. The voluntary opt-in period could also make this approach more politically viable, as the proper functioning of privacy protection and fee payment mechanisms could be demonstrated through the experience of early participants before the system would become mandatory. In short, this framework is explicitly designed to address the two greatest barriers to VMT fees: cost and public acceptance.
- **Limitations and risks.** Unless the federal government created incentives for paying VMT fees (for example, raising fuel taxes even higher than VMT fees or instituting a national registration fee that could either be paid in lump sum or by the mile), it is possible that drivers would choose to adopt the metering equipment for its value-added features but choose *not* to pay VMT fees. Under this framework it would be necessary to develop an initial set of interoperability standards and corresponding certification process in advance of the trials, a challenging task. It would also be necessary to make certain system design decisions (e.g., the channels for collecting fees) in advance of the trials, without the benefit of experience that might be gained during the trials. The market for value-added services, though conceptually appealing, is not proven. Managing the trials under this framework, with separately funded service vendors, states, cities, and auto insurers, could prove more challenging. Here again, the federal government would need to either expand its current law enforcement resources or rely on states to detect and prevent the evasion of VMT fees.

The three frameworks are offered as alternate conceptual visions of the pathway to implementing VMT fees, which in turn can be used to help develop a coherent strategy for the VMT-fee trials. The frameworks, however, should not be viewed as absolute; that is, they do not capture all possible pathways to implementation, and they need not be mutually exclusive. For example, decision makers might choose to pursue the market framework for passenger vehicles and the federal framework for commercial vehicles. Or, they might choose a hybrid of the state and federal frameworks, funding some states to participate in trials for a national system and other states to conduct their own separate trials.

Still, it could be helpful to choose among the frameworks in order to clarify the goals that the trials would be intended to support. Each framework, as described above, offers its own distinct set of advantages, limitations, and potential risks, and there is no inherently "right" answer. Rather, it is a matter for policy judgment. Distilled to the simplest level, the selection of a framework for the trials rests on two key questions. First, should the federal government aim to support state-level implementation of VMT fees, with a national system to be developed at a later date based on lessons from state systems, or should the effort be made to develop a national system from the outset? If the former, the state framework would be the appropriate choice. If the latter, then the second question to consider is whether the VMT trials for a national system would be intended to provide insights to inform subsequent public debate and system planning or instead to evolve directly to full-scale implementation (featuring an initial period of voluntary adoption). If the goal were to serve further planning and debate, then the federal framework would be the appropriate choice. If the goal were to evolve directly to implementation, then the market framework would be appropriate. Once an explicit framework decision has been made, questions about how to scope and structure the trials would become much clearer.

S.6. SUMMARY OF OPTIONS FOR THE TRIALS

The preceding analysis, along with the answers offered by interview and workshop participants for more detailed questions, made it possible to outline several options for funding, organizing, structuring, and conducting an expanded set of system trials to facilitate informed policy debate and prepare for the potential implementation of VMT fees. Though alternate designs for the trials would also be possible, the options presented here represent the research team's effort to:

- Comprehensively address the broad range of issues and uncertainties associated with VMT fees to inform the policy debate and explore and refine implementation options
- Reflect frequently expressed perspectives and well-reasoned insights offered by stakeholders and subject matter experts during the interviews and workshops, augmented by additional analysis where helpful
- Support alternative potential pathways for implementing and transitioning to VMT fees, as embodied in the three conceptual frameworks for the trials

The options for the trials are summarized in Table S.4. Within this table, the rows correspond to various questions that were posed to the interview and workshop participants about how to scope and organize the trials—for example, who should oversee the trials, how many participants the trials should include, and what pricing policies the trials should examine. The columns within the table, in turn, correspond to the three conceptual frameworks for the trials. For many of the rows, the identified characteristics of the trials would be similar regardless of the framework in question. For certain issues, however, the details vary from one framework to the next. Note again that the results of the study, as reflected in Table S.4, represent an initial inquiry into the broad array of issues relevant to designing and conducting expanded system trials. If the decision were made to pursue such trials, further analysis on certain issues—most notably the number of participants to include in the trials and the estimated cost of the trials—would be very helpful.

Table S.4. Summary of Options for Comprehensive System Trials

Issues	Frameworks		
	State	Federal	Market
Overseeing, Managing, and Conducting the Trials			
Overseeing the trials	Decision makers designate an oversight panel to provide guidance on the trials and related activities. The panel includes, at minimum, representation from Treasury, U.S. DOT, Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO), and individual states.		
Managing the trials	Decision makers designate the Transportation Research Board (TRB) to manage the overall effort in a program similar to the Strategic Highway Research Program (SHRP II). Alternatively decision makers assign this role to FHWA, Research and Innovative Technology Administration (RITA), or Volpe, or delegate the choice to the Secretary of Transportation.		
Conducting the trials	States assemble teams to bid for trial funding, including technology vendors (to provide metering and billing services) and possibly cities or counties (to test local VMT fees and/or automated payment of parking fees), auto insurers (to test PAYD insurance), and MPOs or research organizations (for education, outreach, and/or analysis).		Technology vendors, states, auto insurers, local jurisdictions, and research institutions are separately funded for their distinct roles in conducting the trials.
Organizing, Funding, and Coordinating the Trials			
Number and location of trials	Trials are conducted in 3 to 6 states or groups of adjacent states. Ideally the selected trial locations span different geographic regions of the country, include predominantly urban and predominantly rural states, include several large urban regions, include "red" and "blue" states, and include one or more multi-state trial configurations.		
Awarding trials	Trial funding is awarded on a competitive basis. Subject to meeting certain proposal requirements, criteria for judging bids could include cost, number of participants, capacity of the proposing entity, provision of value-added services with the in-vehicle equipment, intent to explore more advanced forms of pricing, intent to collect actual revenue, and intent to explore the use of travel data from the system to support improved planning. Additionally, a modest amount of funding might be set aside for any state that wishes to conduct a preliminary investigation of VMT fees (i.e., studies, not trials).		
Coordinating multiple trials	Trials are loosely coordinated. Main unifying theme is the examination of interoperability standards.	Trials are more carefully coordinated to address all issues relevant to developing a national system.	
Size, Duration, and Cost of the Trials			
Size (number of participants)	10K – 20K per trial 50K – 100K total		100K – 200K per trial 500K – 1M total
Duration of the trials	4-6 years total, including 1-2 years for initial preparation, 2-3 years for conducting the trials, and 1 year for evaluation		
Cost of the trials	$100M – $400M		$1B – $4B
Federal share of funding	Federal government either fully funds trials or requires a modest state match of ten to twenty percent. The latter would help ensure that states that apply are committed to the concept, but it might prevent the participation of otherwise interested states given current economic conditions.		

Table S.4. Summary of Options for Comprehensive System Trials (cont)

Issues	Frameworks		
	State	Federal	Market
Metering and Pricing Policies to Examine in the Trials			
Metering VMT on all public roads	Yes (by definition)		
Tolling on a partial road network	Only if viewed by policymakers as a potential alternative to VMT fees		
VMT fees for passenger cars	Yes		
VMT fees for trucks	Yes		
Fees that vary by jurisdiction	Yes		
Congestion tolls	Optional (desirable but potentially too controversial)		
Emissions-based fees	Optional (desirable but potentially too controversial)		
Weight-distance truck tolls	Optional (desirable but potentially too controversial)		
Technical Issues to Examine in the Trials			
Metering options	Optional (acceptable if GPS is only option evaluated)		
Fee collection options	Yes (evaluate multiple options)		
Options for preventing evasion	Yes (evaluate multiple options)		
Options for protecting privacy	Yes (evaluate multiple options)		
Interoperability standards	Yes if envisioned that trials might evolve directly to state implementation, otherwise optional	Optional	Yes
Use of travel data from system	Optional		Yes
Institutional Issues to Examine in Trials			
Actual revenue collection	Yes if envisioned that trails might evolve directly to state implementation, otherwise optional	Optional	Yes
Collect federal and state fees	Optional	Yes	
Parallel auto / truck systems	Optional		
Alternate billing arrangements	Yes		
Competition among firms	Optional		Yes

Table S.4. Summary of Options for Comprehensive System Trials (cont)

Issues	Frameworks		
	State	Federal	Market
Implementation and Phase-In Issues to Examine in Trials			
Integration with toll systems	Yes		
Different vehicle classes	If envisioned that retrofits would someday be mandated		
Charging foreign vehicles	Optional		
Rebating fuel taxes	If envisioned that VMT fees would replace rather than augment fuel taxes		
Voluntary adoption incentives	Yes		
User Acceptance Issues to Examine in Trials			
Concept of VMT fees	Yes		
Alternate fee structures	Optional		
Alternate privacy protection	Yes		
Privacy vs. auditability	Optional		
Value-added services	Optional		
Detailed Strategies for Implementing the Trials			
Interoperability standards	Standards encompass accuracy requirements, privacy protection, support for preventing evasion, data storage and communication protocols, data security, and related functionality. Standards development involves device manufacturers and service providers, related industry consortia, the International Bridge, Tunnel, and Turnpike Association (IBBTA), ITS America, IntelliDrive program representatives, and academic institutions. Effort references ISO/CEN 17575 and related efforts as initial starting point.		
Privacy protection	Privacy advocacy organization enrolled to verify privacy protection methods.		
Preventing evasion	Firm with telecommunications and security expertise enrolled to probe for vulnerabilities related to fee evasion or system security.		

S.7. CONCLUSION

While the trials envisioned in this study would require considerable investment, they would also play a critical role in helping to prepare for the potential implementation of VMT fees by states or at the federal level within the next five to ten years. The prospect of designing, implementing, and transitioning to a system of VMT fees poses numerous technical, institutional, and political challenges and there are many remaining uncertainties. The trials described in this study are explicitly intended to reduce or resolve such uncertainties in order to inform the policy debate and prepare for the possibility of subsequent implementation.

1. INTRODUCTION

Current federal and state motor fuel excise taxes are beset with structural and political liabilities that have undermined their ability to raise sufficient transportation revenue over recent decades. In the coming years, expected increases in the fuel economy of conventional vehicles along with the adoption of alternative fuel vehicles are likely to further exacerbate this problem (TRB 2005).

Against this backdrop, many analysts and decision makers have argued that the nation should transition from reliance on fuel taxes to a transportation finance system in which road use fees are charged on the basis of vehicle miles of travel, also known as VMT fees (see, for example, NSTIFC 2009, NSTPRSC 2007). In addition to providing a more sustainable revenue source, such a system could, through appropriately structured fees, help to reduce recurrent traffic congestion, harmful emissions, and excessive road wear. The system could also be designed to provide a range of in-vehicle services for the driver, including real-time traffic and incident alerts, alternate routing suggestions, pay-as-you-drive (PAYD) insurance, automated payment of parking fees, and the like. Finally, a VMT-fee system could provide a rich dataset of detailed travel data (stripped of specific driver or vehicle identification to protect privacy) to facilitate improved system planning and operations.

Despite these advantages, implementing a system of VMT fees would be a complex undertaking, involving a daunting array of technical, institutional, and political challenges. Many observers thus assume that a transition to VMT fees would require at least ten to twenty years. Growing funding shortfalls in the federal Highway Trust Fund (HTF) and comparable state accounts, however, have prompted the question of whether it might be possible to implement VMT fees more quickly. In the recent National Cooperative Highway Research Program (NCHRP) 20-24(69) study, *Implementable Strategies for Shifting to Direct Usage-Based Charges for Transportation Funding* (Sorensen et al. 2009), the authors were asked to identify and evaluate potential options for implementing a national system of VMT fees within the next five years. The specific objectives outlined in the project statement were "to: (1) identify and evaluate possibly viable alternative mechanisms for assessing and collecting VMT fees that can be developed and implemented within the near term, 2010 through 2015; (2) propose a practical strategy—for example, considering political and institutional as well as economic and financial issues to be resolved—for implementing a mechanism that will have a high likelihood of sustainable success nationwide; (3) describe the immediate actions necessary to achieve implementation, and (4) identify a longer-term strategy for making a smooth and effective transition from the proposed immediately-implementable mechanism to a robust and sustainable system of VMT-based user fees and an approach to monitoring progress."

While the NCHRP 20-24(69) study identified several implementation mechanisms as promising in the near term, it also observed that remaining uncertainties related to system requirements, cost, institutional structure, and user acceptance would make it difficult to select a cost-effective and politically viable implementation option at this juncture. The report then outlined a set of

activities that might be funded, possibly in the next surface transportation bill, to resolve uncertainties and prepare for possible deployment in the 2015 to 2020 timeframe. The identified activities included planning and policy guidance, analytic studies, technical research and development (R&D), expanded system trials, and education and outreach efforts.

This report presents findings from a follow-on study to the earlier NCHRP 20-24(69) effort. The specific goal in this study is to examine the types of system trials that would be helpful to conduct in order to inform the public policy debate and further explore and refine the potential options for implementing VMT fees. Several underlying assumptions within the study merit brief discussion.

- **Federal leadership and support.** The envisioned magnitude of the trials would almost certainly require federal support. The study therefore assesses options for funding and scoping the trials within a context of substantial federal-government involvement.
- **Federal or state implementation.** It would certainly be possible to implement a national system of VMT fees to replace or augment current federal fuel taxes; states that were interested could use such a system to levy their own VMT fees as well. Another possibility would be for states interested in VMT fees to develop their own systems, in which case it would be beneficial to develop national standards to ensure interoperability among different state systems. The preceding NCHRP 20-24(69) focused specifically on the development of a national system. This study, in contrast, accommodates either possibility; that is, the trials might be structured to help develop a national VMT-fee system, or they might be structured to help states develop their own systems that would be interoperable with one another and would set the groundwork for the potential development of a national system at a later date.
- **Comprehensive trials.** Several pilot tests of distance-based road use charging have already been conducted in the United States, including efforts in Oregon (Whitty 2007, ODOT 2010), in Puget Sound (PSRC 2008), and at the University of Iowa (Kuhl 2007). These prior efforts have focused on demonstrating the technical feasibility of certain implementation options, examining driver perceptions of distance-based road use charges, and evaluating driver response to alternate fee structures. They have not, in contrast, examined many of the detailed implementation issues that would be required in a fully operational system, such as actual revenue collection, enforcement, and system security. The assumption in this study is that the intent of an expanded set of system trials, in addition to informing the public policy debate, would be to set the stage for potential implementation by addressing all critical issues associated with designing, deploying, and operating a system of VMT fees. This would necessitate careful attention to a much broader range of questions; in short, the trials would likely need to be larger in scale, more comprehensive in scope, and longer that previous U.S. pilot tests.
- **Coordinated effort.** As a corollary to the preceding point, the study also assumes that the trials, if funded, might be conducted within the context of a broader, coordinated effort to assess and prepare for the potential implementation of VMT fees. The report therefore considers how the trials might complement related activities in the areas of planning and policy development, analytic studies, technical R&D, and education and outreach.

Before proceeding further, it is also worth adding a brief comment on terminology. Specifically, this report uses the term "trials" to describe a set of activities that involves (a) setting up alternate technical and institutional configurations for implementing a system of VMT fees; (b) enrolling participants to test out the different options; (c) gathering data to characterize the advantages and limitations of the different configurations, including information related to technical feasibility, cost, administrative complexity, driver response, and public perceptions; and (d) synthesizing the results to inform policy debate and support the planning and implementation of a feasible and cost-effective system of VMT fees. Various experts contacted during the course of the research have suggested alternate terms, such as "pilots," "experiments," "test deployments," or "initial deployments." In the experience of the authors, these terms appear to imply subtle distinctions to different individuals, but there is little consistency in their use or understanding. As a matter of convenience, we have therefore adopted the term "trials" to describe the activities outlined above.

The remaining sections in this introductory chapter summarize the methodological approach employed in the study, highlight some of the identified options for the trials, and describe the organization of this report.

1.1. METHODOLOGY

The approach in this study can be summarized as follows:

- Review the results of prior distance-based road use charging studies, trials, and program implementation efforts in the United States and abroad
- Enumerate and characterize potential VMT-fee implementation concepts (i.e., approaches to metering mileage, collecting fees, preventing evasion, and the like)
- Develop and apply criteria for identifying the most promising VMT-fee implementation concepts to evaluate in the trials
- Identify the set of uncertainties that would need to be resolved in order to develop a technically feasible, politically viable, and cost-effective system of VMT fees
- Determine which of these uncertainties could be resolved or illuminated through suitably structured trials
- Solicit input from stakeholder and subject matter experts, through a series of interviews followed by a one-day workshop, regarding:
    - Which of the uncertainties would be most critical to examine through trials
    - How the trials might be structured to address the critical uncertainties
- Conduct additional research, where helpful and possible, to augment the input received from stakeholders and subject matter experts
- Synthesize findings to suggest potential options for funding, organizing, structuring, managing and conducting the trials

The results of the study, largely reliant on the informed input of stakeholders and subject matter experts, might best be viewed as an initial assessment of the many questions that would need to

be considered in designing and implementing an expanded set of VMT-fee trials. Though the study included thorough background research and some supporting analysis, the scope did not support highly detailed evaluation of each individual topic. It should thus be stressed that certain issues, such as the estimated cost of the trials and the number of participants to include, would benefit from additional research attention.

Note that the first three elements in the outlined methodology involve reviewing potential mechanisms for implementing VMT fees and identifying those that would be helpful to examine further through system trials. A similar assessment of VMT-fee implementation options was conducted in the initial NCHRP 20-24(69) study. In the initial study, however, the goal was to identify potentially promising options from the perspective of implementing a national system of VMT fees in the timeframe of 2010 to 2015. A decision to fund expanded system trials would likely delay any effort to deploy VMT fees until at least 2015 to 2020. Additionally, a possible outcome of the trials is that participating states might choose to develop their own VMT-fee systems if the federal government, on the basis of trial experiences, chooses not to implement a national system. These two shifts—the longer timeframe and the possibility of state-level implementation—make it appropriate to revisit the assessment of implementation options that might be examined in the trials.

1.2. OPTIONS FOR THE TRIALS

Through extensive input from stakeholders and subject matter experts, supplemented with relevant background research, it was possible to outline several options for scoping and structuring the trials. This section briefly previews some of the key elements.

1.2.1. Frameworks for the Trials

For many of the questions posed to interview and workshop participants, there was a fair degree of consistency in the responses. Some questions, however, generated wildly divergent answers. Opinions about the number of drivers that should participate in the trials, for example, varied from a few thousand to more than a million. Through follow-on questions and further discussion during the interviews, it became clear that variations in answers about how to scope and structure the trials often stemmed from disparate views regarding the manner and timeframe in which a transition to VMT might unfold. In particular, experts and stakeholders expressed differing perspectives for such questions as:

- Would it be either more likely or more desirable for the initial implementation of VMT fees to occur at the state level or at the federal level?
- Could VMT fees be implemented in just a few years, or would it take a decade or more?
- Should the plan for transitioning to VMT fees include a period of incentivized voluntary adoption to help overcome public acceptance challenges?

Different views on these questions suggest different pathways to implementation, and these in turn imply alternate goals and structures for the trials. Building on this insight, the research team outlined three conceptual "frameworks," or visions, about how the transition to VMT fees might

be pursued, and in turn how the trials could be scoped and organized to support that vision. The three frameworks can be summarized as follows:

- **Help states help themselves (state framework).** In this framework, the trials would be aimed at helping interested states or groups of adjacent states develop their own systems. The federal government might then develop a national system at a later date based on the lessons learned in state programs. In addition to funding, a key federal role in this framework would be to foster the development of interoperability standards and a certifications process to ensure that systems developed in different states could interact with one another. The federal government might also encourage states to examine specific options that could later be extended to implement a national system.
- **Carefully plan a national system (federal framework).** In this framework, the goal of the trials would be to provide the federal government with sufficient information to plan a cost-effective national system of VMT fees. By design, the system would be flexible enough to allow simultaneous collection and apportionment of federal, state, and even local VMT fees. While the trials would still be conducted in states interested in adopting their own VMT fees, the effort would be more carefully coordinated to examine issues involved in setting up a national system. Following the trials, and subject to political debate, efforts to plan and implement the system would commence.
- **Foster a market for in-vehicle travel services (market framework).** The market framework represents the greatest departure from conventional thinking about implementing and transitioning to VMT fees, seeking in parallel to overcome current public acceptance challenges through voluntary opt-in strategies, to implement a fully operational (if initially voluntary) national system of VMT fees as quickly as possible, and to reduce the cost to government of collecting VMT fees. It envisions, and would seek to foster, the emergence of a market for in-vehicle metering devices capable of levying VMT fees and providing a range of additional value-added services. Firms (e.g., device manufacturers, systems integrators, telecommunications providers, tolling operators, etc.) would compete to provide the devices and services, thereby stimulating innovation and driving down system costs, and their ability to collect fees for other services would reduce the amount that they would need to charge the government for collecting VMT fees. The main goal of the trials in this framework would be to support the emergence of this market, which would require a broad range of public and private participation. To do so, the trials would separately fund or subsidize technology providers, states, cities, and insurers for their respective roles in the trials, and the intent would be for the trials to evolve directly to system implementation. Trial participants that valued the additional services would become the initial adopters, and additional drivers would be able to adopt the in-vehicle equipment on a voluntary basis as well. After several more years, once it had been demonstrated that the system provides appropriate privacy protection and can be enforced effectively, the government might mandate the adoption of VMT fees for all vehicles.

As described later in this study, each of these frameworks offers both advantages and potential limitations, and there is no inherently "right" answer. Rather, the selection of a framework for the trials (or potentially the selection of elements drawn from several frameworks) would be a

matter for policy judgment. Based on the selection of a particular framework, questions on how to scope and structure the trials would then become less ambiguous.

1.2.2. Highlights of the Identified Options for Trials

The following summarizes some of the specific options for overseeing, managing, funding, scoping, structuring, and conducting the trials that emerged from the study. Though alternate designs for the trials might also be possible, the options outlined in the study are intended to: (a) comprehensively address the broad set of issues and uncertainties associated with the prospects for designing and implementing VMT fees; (b) reflect frequently offered perspectives and well-reasoned insights from the interview and workshop participants, supplemented with additional analysis where helpful; and (c) support alternate potential pathways for implementing and transitioning to VMT fees, as embodied in the state, federal, and market frameworks.

- **Strategic guidance for the trials:** Decision makers would designate an oversight panel to provide strategic guidance on the trials and related activities. The panel would ideally include, at minimum, representation from the U.S. Department of Treasury (Treasury), the U.S. Department of Transportation (USDOT), the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and individual states.
- **Managing the trials:** Decision makers would also designate an entity to manage the trials and related activities. The management role, under guidance from the oversight panel, would involve writing and issuing requests for proposals (RFPs), evaluating proposals, awarding funding, managing contracts, and the like. The Transportation Research Board (TRB) was cited by many respondents as a promising candidate for this role, though other options would also be possible.
- **Awarding trial funding:** Funding for the trials would be awarded on a competitive basis. Subject to meeting certain required elements for participation, competitive criteria for evaluating proposals might include cost, number of participants, capacity of the proposing entity, intent to examine the provision of value-added services, intent to explore the use of anonymous travel data to improve system planning, intent to test out more advanced forms of pricing, intent to collect actual revenue, and (for the state framework) a plan for how the trial results would support subsequent efforts to design and implement VMT fees.
- **Number and location of trials:** There would be a small number of trials—perhaps three to six—in different states or groups of states, providing social, demographic, geographic, and regional diversity. The trials would also include at least one multi-state configuration.
- **Participation in the trials:** In the state or federal frameworks, the trials would ideally involve tens of thousands of participants (perhaps 10,000 to 20,000 per trial, and 50,000 to 100,000 in total) to examine system cost and feasibility issues. In the market framework, it would be helpful to include hundreds of thousands of participants (perhaps 100,000 to 200,000 per trial, and 500,000 to 1,000,000 in total). This would motivate the private sector to provide innovative service offerings and create a large base of initial voluntary adopters at the conclusion of the trials. Given the relationship between the number of participants and the cost of the trials, additional research on this issue would be valuable.

- **Duration of the trials:** The trials would last four to six years, including one to two years for initial preparation and planning, two to three years of actual trials, and a final year for evaluation.
- **Cost of the trials:** Preliminary evaluation suggests that the trials would cost roughly $2,000 to $4,000 per vehicle, including about $1,000 for the metering and billing services over a three year period plus an additional $1,000 to $3,000 for additional trial activities (planning, management, analysis, interaction with participants, and the like). Assuming 50,000 to 100,000 total participants (for the state and federal frameworks), the trials might cost $100 million to $400 million. Assuming 500,000 to 1,000,000 total participants (for the market framework), the trials might cost $1 billion to $4 billion. These estimates hinge on several inherent uncertainties; additional research on this issue would be valuable.
- **Pricing policies to examine in the trials:** Pricing policies to examine would include VMT fees across the entire public road network, VMT fees for both cars and trucks, and parallel collection of federal, state, and perhaps local VMT fees. Many interview and workshop participants viewed the inclusion of variable pricing structures (e.g., congestion tolls) as desirable but also highly controversial, and therefore optional within the trials.
- **Technical issues to examine in the trials:** Priority technical issues to examine under any of the frameworks would include alternate means of collecting fees, preventing evasion, and protecting privacy. The set of technical issues might be expanded to include interoperability standards in the state framework, or to include interoperability standards along with additional uses of real-time travel data in the market framework.
- **Institutional issues to examine in the trials:** Priority institutional issues to examine under any of the frameworks would include simultaneous collection and apportionment of VMT fees in different jurisdictions and at different levels of government (e.g., federal, state, and potentially local VMT fees) and alternate institutional configurations for billing and account management. The set of institutional issues might be expanded to include the collection of actual revenue in the state framework, or to include the collection of actual revenue along with multiple technology vendors operating in parallel in the market framework.
- **Other implementation and phase-in issues to examine in the trials:** Other priority implementation and phase-in issues to examine would include integration with existing tolling systems and the exploration of incentives for voluntary adoption. Contingent on certain system design choices, it might also be helpful to examine mechanisms for rebating fuel taxes and to test metering equipment on both older and newer vehicles.
- **User acceptance issues to examine in the trials:** Priority user acceptance issues to examine would include user understanding and support for distance-based road use charges and user perceptions of alternate privacy protection mechanisms.

1.3. ORGANIZATION OF THE REPORT

The remainder of this report is organized as follows. Chapters 2, 3, and 4 present the results of the background research conducted for the study. Chapter 2 sets forth the possible motivations for transitioning to a system of VMT fees and enumerates the policy goals that such a system might be designed to address. The potential benefits are viewed by many as compelling, and as a result the concept of VMT fees has received increasing attention over the past decade. Chapter 3

begins with a brief review of prior and ongoing trials and programs involving distance-based road use charges, both in the United States and abroad. Drawing upon this material, it then identifies a spectrum of VMT-fee implementation concepts—including options for metering mileage, collecting payment, preventing evasion, and protecting privacy—and considers their relative strengths, limitations, and uncertainties. Against that backdrop, Chapter 4 reviews and applies a set of criteria, based on recommendations from the National Surface Transportation Infrastructure Finance Commission report (NSTIFC, 2009), for identifying the potential implementation mechanisms that would be most valuable to evaluate via trials.

Next, chapters 5, 6, and 7 describe the structure and intent of the interviews and workshop and summarize their results. Chapter 5 begins by enumerating a comprehensive set of uncertainties that would be helpful to resolve to inform policy and plan for full-scale implementation of VMT fees. It then describes the role of the interviews and workshop in soliciting input from key stakeholders and subject matter experts on: (a) which of the uncertainties would be most important to examine through trials, and (b) how the trials might be funded, structured, and conducted to help resolve these high-priority issues. Chapter 6 describes general themes that emerged from the interviews and workshop. It also discusses the significant degree of variation in the responses for some of the interview questions, which in turn led to the development of the three potential frameworks for structuring the trials and facilitating the transition to VMT fees. Chapter 7 then summarizes the responses of interview and workshop participants, along with any supplementary analysis by the research team, for more specific questions about how to best scope and structure the trials

Chapter 8 synthesizes the study results, outlining several integrated options for funding, organizing, managing, and conducting the trials. It also identifies issues that might be helpful to address in the context of related efforts in the areas of planning, analysis, technical R&D, and education and outreach.

Following the concluding chapter, Appendix A provides a more detailed review of the prior trials and programs introduced in Chapter 2. Appendix B enumerates the set of interview questions, while Appendix C lists those who participated in the interviews and workshop. Finally, Appendix D offers a more detailed presentation of the material summarized in Chapter 7, including discussions during the interviews and workshop along with any supporting analysis conducted by the research team.

2. POTENTIAL POLICY GOALS OF VMT FEES

This chapter outlines the potential policy goals that might be supported by a system of VMT fees. The material provides a helpful backdrop for the discussion in subsequent chapters of implementation mechanisms and policy issues that might be further explored in the context of expanded system trials.

The current consideration of VMT fees as a potential revenue source is motivated, in part, by the recent erosion of fuel tax revenue. Federal and state excise fuel taxes have been the dominant source of highway funding in the United States for much of the past century, and they currently account for almost two thirds of highway user fees and roughly half of all highway expenditures (TRB 2005). Typically levied on a cents-per-gallon basis, however, motor fuel taxes must be raised periodically to offset the effects of inflation and improved fuel economy. Over the past several decades, fuel taxes at the federal level and in many states have not been increased with sufficient frequency or magnitude to keep pace with these factors. The net result has been a decline in real fuel tax revenue per mile of travel. Real highway spending per mile of travel in the United States has declined by about 50 percent since the HTF was established in the late 1950s, for example, and the federal gas tax has experienced a cumulative 33 percent loss in purchasing power since 1993, the year in which it was last increased (NSTIFC 2009).

The reduction in real revenue per mile of travel has led to growing shortfalls in the federal HTF, which serves as the repository for federal excise fuel taxes, and many comparable state highway accounts. To keep the HTF solvent, Congress found it necessary to transfer $8 billion from the general fund in October 2008 and another $7 billion in August 2009. In response to deteriorating economic conditions, Congress subsequently infused the federal surface transportation program with an additional $36.7 billion in the American Recovery and Reinvestment Act, $8 billion in the High Speed Rail program, and $19.5 billion (plus $8.7 billion in restored contract authority) in the Hiring Incentives to Restore Employment Act (Orski 2010). With growing concern over the size of the federal deficit, however, the prospects for continued support from the general fund in future years appear dim.

The anticipated introduction of more fuel-efficient conventional vehicles along with alternative-fuel vehicles in the coming decades threatens to further undermine the viability of gasoline and diesel fuel taxes as a sustainable source of highway revenue. It is of course possible that ways could be found to tax other sources of vehicle fuel or power to help pay for roads—for example, by assessing fees at recharging stations that might be deployed to serve an emerging market for electric vehicles. Yet two challenges would remain. First, all vehicle types (e.g., conventionally-fueled, bio-fueled, electric, hydrogen, etc.) could continue to become more efficient over time, making it necessary to impose politically difficult (and therefore unlikely) tax hikes on a frequent basis in order for the revenue to keep pace with travel. Second, there would likely be certain fuel or power options—for example, charging an electric vehicle at home with photovoltaic panels—that would be difficult to tax.

Against this backdrop, analysts and decision makers have been exploring a broad array of revenue options that might augment or replace federal and state fuel taxes (see, e.g., Whitty 2003, TRB 2005, Cambridge Systematics et al. 2006, NSTPRSC 2007, and NSTIFC 2009). Though such studies have identified a range of instruments might be employed to raise additional transportation revenue, VMT fees have often been characterized as a particularly promising option (or, in the oft-cited words of one of the NSTIFC Commissioners, the "least stinky" alternative). This is because a system of VMT fees, in addition to producing a more stable revenue stream, could be designed to support additional policy goals as well.

The policy objectives that could be addressed through a system of VMT fees, however, would depend on the technical design of the system. At one end of the spectrum, it would be possible to implement a relatively simple system intended solely to provide a more stable source of revenue. At the opposite end, one could design a much more sophisticated system capable of raising revenue, helping to reduce recurrent traffic congestion, harmful emissions, and excessive road wear, and providing a range of value-added services for the driver. In addition to deciding *whether* or not to implement VMT fees, then, decision makers would also need to consider *what type* of system to develop. This choice would have significant implications in terms of the cost of implementing and operating the system as well as the benefits that the system could ultimately provide. A key goal of the trials, in fact, might be to help illuminate such tradeoffs.

In the remainder of this chapter we examine the range of policy objectives that might be addressed through a system of VMT fees. These include the ability to generate a more stable source of highway revenue, to accurately collect and apportion revenue by jurisdiction; to structure fees to reflect the full costs associated with travel, with the practical benefits of reducing recurrent traffic congestion, emissions, and excessive road wear; to collect much richer information about travel patterns and real-time traffic conditions to enhance system planning and operations; and to provide a platform for offering many additional in-vehicle services to benefit drivers. The chapter concludes with a discussion of alternative ways in which decision makers might conceptualize a system of VMT fees.

2.1. SUSTAINABLE REVENUE

As described earlier, federal and state excise fuel taxes, levied on a cents-per-gallon basis, are eroded by both inflation and improved fuel economy. With the anticipated increases in vehicle fuel economy and greater market penetration of alternative fuel vehicles, the latter is expected to become particularly problematic in the coming decades. The Energy Information Administration (EIA 2009) has projected that VMT will grow by about 45 percent by 2030 while the increase in gasoline and diesel consumption will be less than 15 percent. A critical advantage of VMT fees (assuming a flat per-mile charge applied to all vehicles) is that the revenue stream would be keyed to miles of travel rather than fuel consumption and thus unaffected by either fuel economy or fuel type. If, as expected, VMT continues to grow more rapidly than fuel consumption in future years, so too would VMT fee revenue.

To illustrate the potential significance of this benefit, the preceding NCHRP 20-24(69) study (Sorensen et al. 2009) employed EIA's VMT and fuel consumption forecasts to examine the revenue implications of replacing federal fuel taxes with federal VMT fees in the timeframe of 2015 to 2030. To place the two options on equal footing, the analysis assumed that current fuel

tax rates would remain in place until 2015. It then compared the revenue effects of: (a) replacing fuel taxes with VMT fees on an initially revenue-neutral basis in 2015 (with a flat rate of roughly 1.1 cents per mile for all vehicles to raise the same revenue as fuel taxes in 2015) and then keeping the same nominal per-mile rate until 2030, and (b) continuing with fuel taxes at current rates between 2015 and 2030. In 2009 dollars, based on the projections of EIA, VMT fee revenue would grow from $35.7 billion in 2015 to $47.4 billion in 2030, a 33 percent gain. In contrast, revenue from fuel taxes would grow from $35.7 billion to $39.2 billion, a gain of only 10 percent. In other words, VMT fees, even if set to be initially revenue neutral, would grow to exceed fuel taxes by more than 20 percent within just 15 years—a direct reflection of the expectation that growth in VMT will significantly outpace grown in fuel consumption in the coming decades. From this perspective, then, VMT fees offer the prospects for a more "sustainable" source of revenue than fuel taxes.

That said, it should be noted that VMT fees, like per-gallon fuel taxes, would not be immune to the effects of inflation. As such, it would be necessary to either index or periodically increase VMT fees to preserve purchasing power. In comparison to fuel taxes, however, which must simultaneously deal with inflation and improved fuel economy, VMT-fee increases would not need to be as large or as frequent.

It is also worth considering the possibility that VMT would not continue to grow rapidly in the coming decades. With a period of extremely volatile gas prices followed by a severe economic downturn, vehicle travel has been relatively stagnant over the past several years. Additionally, many policymakers have espoused longer-term strategies for reducing VMT in order to mitigate climate change and achieve greater energy independence. Thus significant continued growth in VMT is far from certain. Yet under the assumption that average fuel economy continues to increase (arguably a reasonable assumption given the recent increases in corporate average fuel economy, or CAFE, standards, the availability of electric vehicles and plug-in hybrids now entering the market, ongoing research and development efforts for other types of alternative-fuel vehicles, the prospects for worldwide growth in the demand for oil leading to higher gas and diesel costs in future years, and the possibility of future legislation that would price carbon emissions via taxes or a cap-and-trade system), then stagnant growth in VMT would lead to an even faster decline in fuel tax revenue. Additionally, it should be noted that reduced growth in VMT would also indicate a reduced need for investment in new capacity. In short, even if VMT were not to grow as rapidly as EIA forecasts suggest in the coming years, VMT fees would still likely provide more stable revenue than fuel taxes, and they should in fact track relatively well with road and highway investment needs.

2.2. ACCURATE COLLECTION AND APPORTIONMENT OF FEES

Provided that a VMT-fee system were able to determine the location of travel, it would be possible to accurately collect and apportion fees by jurisdiction. This would enable, for example, a system in which different states could charge their own VMT fees and receive payment for all vehicle travel within their boundaries. It would also enable a single state to charge only for mileage within its borders, as illustrated in the Oregon pilot test, or for cities and counties to levy their own local VMT fees. In a system capable of determining the specific route of travel, even more accurate collection and apportionment would be possible. For travel on a toll road, for example, the system might charge and remit tolls to the toll provider but not charge additional

VMT fees. In a similar vein, the system could be designed to levy VMT fees for travel on public roads but not on private roads.

2.3. STRUCTURING FEES TO REFLECT THE FULL COST OF TRAVEL

VMT fees offer a compelling advantage not possible with most other revenue instruments: the ability to vary fees to reflect the full social costs imposed by each trip—for example, the cost of congestion delays imposed on other travelers, the negative health and environmental effects of harmful pollutant emissions, and any excessive damage to the roadway—in turn promoting more efficient use of the system. In practical terms, it would be possible to structure the fees based on relevant vehicle and travel characteristics (such as vehicle or axle weight, emissions, location of travel, and/or time of travel) to help limit recurrent traffic congestion, improve air quality, and reduce excessive road wear. Such challenges have proven very extremely difficult to address through other policy mechanisms.

2.3.1. Reducing Traffic Congestion

To help reduce recurrent traffic congestion, the per-mile rate would be set higher for peak-hour travel in congested areas or corridors. This would encourage drivers to shift at least some of their trips to other times of day, other routes, or other modes, thus relieving congestion. The concept of charging more for peak-hour travel, often referred to as congestion tolling or congestion pricing, has proven extremely effective where implemented, leading to much faster traffic flow and significantly reduced congestion delays (see, for example, Supernak et al. 2003, Obenberger 2004, and Doan 2010). Depending on metering capabilities and policy goals, VMT fees could be structured to implement several alternate forms of congestion tolls:

- **Facility-based congestion tolls.** In this form, congestion tolls would be applied on heavily traveled facilities (e.g., a bridge, tunnel, or freeway segment), or perhaps within certain lanes on a given facility (e.g., managed lanes or high-occupancy/toll lanes).
- **Cordon congestion tolls.** In this form, implemented in London, Stockholm, and Singapore, vehicles would be assessed a fee for entering, exiting, or driving within a clearly delineated charging zone, but the fee would not depend on distance traveled within the zone.
- **Zone-distance congestion tolls.** In this form, examined in the Oregon trials and likely to be examined in the upcoming Minnesota trials, congestion tolls would be levied on the basis of distance traveled within a particular zone—for example, setting a higher per-mile rate for all peak-period travel within the CBD.
- **Network-wide congestion tolls.** In this form, examined in the Puget Sound trials, distance-based congestion tolls could be applied throughout the network on any routes that suffer routine congestion, and the rates could vary depending on the time and the specific route.

2.3.2. Reducing Emissions

To provide an incentive for reducing emissions, the per-mile fee would be higher for more polluting vehicles and lower for less polluting vehicles. Drivers would thus have an incentive, when purchasing a new vehicle, to select a more environmentally benign option. This approach has been employed in the German truck toll (Doan 2010), where the most polluting vehicles pay

50 percent more per kilometer than the least polluting vehicles. Since the program was launched in 2005, the emissions-based price structure has stimulated a 58 percent shift from dirtier truck models (Euro class 1, 2, and 3) to cleaner trucks (Euro class 4 and 5). One could envision at least two possible approaches to varying per-mile charges based on emissions within a system of VMT fees.

- **General emissions fees.** In this simpler form, the per-mile fee would vary based on vehicle emissions class for all miles of travel, regardless of location.
- **Zone-based emissions fees.** The harm caused by pollutant emissions depends, to some degree, on the location of travel. In some rural areas with generally good air quality, for example, emissions might cause little harm at the margin. In more heavily polluted urban regions (for example, air basins not in compliance with ambient air quality standards under the Clean Air Act), additional emissions would be more problematic. Reflecting this differential, emissions fees might be constructed to vary with both vehicle emissions class and the zone of travel.

2.3.3. Reducing Road Wear

Heavy commercial trucks cause significantly more road damage than lighter passenger vehicles. Key factors in determining the amount of damage include axle weight (i.e., total laden weight divided by number of axles) and the type of road on which the travel occurs (e.g., heavily engineered highways vs. lightly engineered surface streets). To help reduce excessive road wear, truck VMT fees might therefore vary based on axle weight (higher, all else equal, for trucks with fewer axles) and type of route (higher, all else equal, for travel on lightly engineered routes). This would encourage truckers to adopt trailer configurations designed to reduce axle loads and to travel, where possible, on heavily engineered highways or main arterials, thereby reducing overall pavement damage. Despite the potential advantages of this approach (Small et al. 1989), most existing weight-distance truck tolls have only approximated the key features. In the New Zealand truck toll, which relies on a maintenance cost allocation model, truck fees do vary by both weight and axle configuration (New Zealand Ministry of Transport undated). Most other weight-distance truck tolls—in Germany, Switzerland, and Austria, for example—rely on surrogates for vehicle size and weight and do not differentiate tolls by type of route. In practice, then, one might conceive of two possible formulations of weight-distance trucks tolls within a system of VMT fees:

- **General weight-distance truck tolls.** In this form, similar to most existing truck tolls, the fee would depend on the weight (or axle-weight) of the vehicle but would not vary by route (note that while several weight-distance truck tolls only charge for travel on certain facilities, they do not typically differentiate the per-mile or per-kilometer rate by specific route among those roads subject to the charge).
- **Route-specific weight-distance truck tolls.** In this form, the rate would vary by both weight or axle-weight and specific route of travel.

2.3.4. Additional Benefits

In addition to the intrinsic benefits of reducing recurrent traffic congestion, vehicle emissions, and excessive road wear, structuring VMT fees to reflect the social costs associated with travel—particularly the costs associated with congestion—would provide three additional benefits:

- **Raising additional revenue.** The first and most obvious benefit would be to raise additional revenue beyond base VMT fees. Consider that existing cordon tolls in London, Stockholm, and Singapore, which apply congestion pricing in relatively small urban areas, generate annual net revenues in the range of tens to hundreds of millions of dollars (Doan 2010). Applied more broadly through urban and suburban regions of the United States, congestion tolls would likely generate tens of billions of dollars annually. The additional revenue could help fund the initial development and operation of the VMT-fee system and provide further support for much needed system maintenance and investments.
- **Signaling investment priorities.** Second, user response to the variations in pricing would provide a clearer signal about where additional transportation investments would be most beneficial. In the case of congestion tolls, rates are typically allowed to rise as needed to preserve free-flowing vehicle traffic. As demand for travel within a corridor increases, so too will congestion tolls. The level of tolls needed to preserve free-flow travel speeds would therefore offer an unambiguous indicator of the relative priority of investments in additional capacity. As another example, imagine that weight-distance truck tolls were implemented and that numerous trucks continued to use a lightly-engineered route despite the higher per-mile charge for travel on such routes. From this behavioral pattern, one could reasonably infer that alternate routes were simply less efficient for truck travel patterns, suggesting that it would be beneficial to upgrade the engineering standards for the route in question.
- **Reducing investment needs.** Third, varying the per-mile fees to account for the costs of travel, and in turn influencing vehicle and travel choices, would ultimately reduce the amount of funding required for maintaining and expanding the system. With weight-distance truck tolls, for example, owners and drivers would respond to the price structure by adopting vehicle configurations with lighter axle loads and choosing more heavily engineered routes, thus reducing total damages and in turn maintenance requirements. Similarly, broad application of congestion tolling would likely lead to a modest decrease in total vehicle travel, thereby easing the pressure for system expansion. Even more importantly, however, congestion tolls would enable far more productive use of existing lane capacity. This is because steadily flowing lanes—the objective of congestion tolls—can carry far more vehicles per hour than heavily congested lanes. As an illustration of this phenomenon, the congestion-priced Express Lanes on the SR-91 facility, operating at 60 to 65 mph during peak hours, carry roughly double the cars per lane per hour as the adjacent congested free lanes, which operate at just 15 to 20 mph during peak hours (Obenberger 2004). In short, the application of congestion tolls would allow the current road network to carry far more traffic than it currently does. Reflecting this potential, the most recent *Conditions & Performance* report from the Federal Highway Administration (FHWA 2010), in a major methodological advancement, considered the cost of maintaining or improving the system both with and without congestion tolls. The findings were dramatic. In the absence of congestion tolling, for example, the costs of improving the Interstate system for projects with a benefit-cost ratio of at least 1.5 were estimated at $47 billion. With the addition of congestion tolls, and

again using a benefit-cost ratio screen of 1.5, the cost of improving the Interstate system would decrease to just $24 billion (Poole 2010), nearly a 50 percent reduction.

While structuring VMT fees in a manner that would ultimately influence travel behavior and vehicle purchase decisions might be viewed by some as coercive, economic theory provides strong support for this approach. In addition to the benefits of travel, each vehicle trip also imposes a broad range of costs. Some costs, such as those associated with vehicle ownership, fuel, and insurance, are borne by the driver or vehicle owner. Others, such as congestion delays the adverse effects of harmful pollutants, and excessive damage to pavement (damage exceeding the value of fuel taxes collected to maintain the transportation network), are currently shifted to other drivers or to society at large. Economists refer to these categories, respectively, as *private* costs and *external* costs (or externalities). In the presence of the latter, drivers will rationally tend to "over-consume" travel resources—that is, confronted only by private costs, they will often make trips for which the total costs (including both private and external costs) exceed the total benefits. Such trips, by definition, make society worse off as a whole (though they might make the individual driver better off). From this perspective, varying VMT fees to align with the full costs imposed by each trip would have the effect of internalizing (that is pricing, or making private) current externalities. This would lead drivers to forego trips for which total costs exceed total benefits, thereby increasing net social welfare (Downs 2004).

It should be stressed that the pricing of external costs should not curtail economically or socially productive travel; for such trips, the total benefits would continue to outweigh total costs. It would, on the other hand, lead drivers to alter or abort their least-valued trips—for example, shifting a discretionary trip to a shopping mall from peak hours to off-peak hours. To the extent that vehicle travel can be divided into "good VMT" (largely productive) and "bad VMT" (largely wasteful), aligning VMT fees with the full cost of travel would tend to reduce the latter while preserving the former.

2.4. COLLECTING DETAILED TRAVEL DATA

Provided that a system of VMT fees were capable of metering both the time and route of travel, it could be an invaluable source of detailed travel information. Data from the system might be used, for example, to better calibrate regional transportation demand models. The system might also support the collection of real-time information on current traffic conditions throughout the road network (while real time traffic data based on loop detectors and other sensors is already available for many highways, it is not typically available on the arterial road network). Such information could prove extremely helpful for local traffic management operations, and it would also enable automated routing assistance based on current network traffic conditions (in contrast, most existing routing services only consider expected travel times).

The prospect of collecting detailed travel data raises, of course, obvious privacy concerns. It would therefore be appropriate to collect such data on an anonymous basis. Additionally, it would be fair to provide drivers with the choice of whether or not to share their data. As an inducement, drivers willing to share their data might be offered a small break on the per-mile fee, reflecting the social value of the data. It should also be stressed that any effort to collect detailed travel data across the entire road network in real time would likely need to incorporate sampling

strategies to avoid excessive data storage and processing requirements, an issue that merits additional research attention.

2.5. ADDITIONAL DRIVER SERVICES

Finally, a system of VMT fees could offer a platform for providing many additional services that drivers might value. Potential benefits that these services might offer include the opportunity for financial savings, greater convenience, improved safety, and access to additional functionality. Listed below are some of the more commonly discussed options.

- **Pay-as-you-drive insurance.** PAYD insurance offers the potential for lower mileage drivers to save on their insurance premiums, perhaps as much as several hundred dollars each year. (In a similar vein, other fixed fees, such as state vehicle registration fees or the federal heavy use vehicle tax, could also be paid on a per-mile basis.) One could logically envision at least two forms of PAYD insurance:
  - ***General PAYD insurance.*** In this form, applied in most PAYD insurance applications to date (see Appendix A), insurance payments would depend only on total distance traveled.
  - ***Location-dependent PAYD insurance.*** Traditional insurance premiums often vary, among other factors, with residential location, reflecting the fact that collisions, thefts, and the like are more probably in certain areas than in others. Extending this logic, it is conceivable that some auto-insurers might choose to factor the location of travel (and perhaps the time of travel) into the per-mile rates.
- **Automated parking payment.** With the more advanced GPS configurations now being developed, it is possible that the metering device could determine the specific location in which a vehicle is parked, thus enabling the automated payment of parking fees. As a result, drivers would no longer have to insert coins in the meter or visit a multi-space parking machine to pay their fees. Additionally, drivers would only need to pay for the actual time that they occupied the space; gone would be the exasperation of "leaving extra time on the meter." One of the more intriguing variations on this concept is the idea that cities might, rather than issuing parking tickets, allow drivers to remain beyond the posted time limit for the parking space but at a higher rate. For example, in a two-hour limit parking zone, vehicles might be charged at the rate of one dollar per hour for the first two hours and then five dollars per hour thereafter. This would eliminate worries about getting a parking ticket but still provide an incentive to achieve the desired parking turnover rate. Related to this idea, the system could also be designed to generate parking payment summaries for those who need to report parking fees as a business expense.
- **Automated toll payment.** For toll roads that accept both cash and electronic payment, and for users that have not yet acquired a transponder, in-vehicle metering equipment could enable automated payment of the tolls, thus eliminating the need to stop at a tollbooth and pay the correct amount of money.
- **Automated weight-distance truck toll payment.** Within the several states that currently operate weight-distance truck tolls, in-vehicle metering equipment could eliminate the manual paperwork currently required to document and pay the tolls (as in the Oregon TRUE trials described in ODOT 2010). Given that such tolls apply only within particular states, a VMT-fee system would need to be able to determine the jurisdiction of travel for this option.

- **Location-dependent travel services.** If the in-vehicle equipment were able to determine the current location or route of travel, it would also be possible to enable many of the features commonly associated with personal navigation devices—for example, the provision of real-time routing assistance or the identification of nearby points of interest.
- **Media services.** The in-vehicle metering device, if properly equipped, could also provide satellite radio or serve as a Wi-Fi node for passengers (not the driver) in the vehicle. This, incidentally, could open a broad range of potential applications that might be offered over the Internet, such as parking location and reservation services.
- **Improved traveler safety.** The installation of sophisticated telecommunications equipment within a vehicle would also enable numerous potential safety features, many of which have been discussed in the context of FHWA's IntelliDrive program (RITA undated). It is perhaps helpful to distinguish two groups of features in this category:
    - ***Location-dependent safety features.*** Knowledge of the current location and route of travel would make it possible to provide in-vehicle safety warnings—for example, alerting the driver of school zones, construction zones, sharp ramp curves, hazardous patches of roadway, or a downstream traffic incident. It would also allow for the transmission of disabled vehicle alerts.
    - ***DSRC-enabled safety features.*** The addition of dedicated short range communications (DSRC) technology to the metering equipment would enable additional safety features reliant on vehicle-to-vehicle or vehicle-to-infrastructure communications, such as warnings of imminent potential collisions due to merging or suddenly stopping vehicles.

The above represents, perhaps, just a small sampling of traveler services that might emerge in the coming years. Just as it would have been hard to predict, five years ago, the many applications that can now be added to a smart phone, so too is it conceivable that the private sector might develop currently unanticipated traveler services to install with in-vehicle metering equipment.

As suggested in this section, there is a considerable degree of overlap between functionality often discussed in the context of FHWA's IntelliDrive program and the range of value-added features that might be incorporated with the in-vehicle metering equipment in a system of VMT fees, and to date it remains unclear how these parallel efforts might complement one another. It is possible, for example, that retrofitted VMT-fee metering devices might be augmented with an appropriate subset of envisioned IntelliDrive features; alternatively, if equipment to support IntelliDrive features is someday installed in all new vehicles, that equipment might include technical components (e.g., GPS) to support metering VMT fees across the road network as well. Given the overlap in potential functionality, it would certainly be helpful to devote additional effort to explore the possible linkages between IntelliDrive and VMT fees within the context of VMT-fee trials and related research and planning activities. One specific idea discussed later in this report would be to include representation from the IntelliDrive program in the development of technical standards for VMT-fee metering devices and services.

2.6. CONCEPTUALIZING A SYSTEM OF VMT FEES

By definition, any approach for implementing a system of VMT fees should be able to meter or estimate total miles of travel. A relatively simple possibility, for example, would be to inspect a

vehicle's odometer each year and assess VMT fees based on incremental mileage. By basing fees on mileage rather than fuel consumption, such a system would provide more sustainable revenue than fuel taxes.

For a system of VMT fees to support many of the additional features described above, however, the mechanism for implementing VMT fees would need to be more technically sophisticated—able to determine, in various degrees of precision, certain vehicle attributes (weight, axle-weight, or emissions class) and/or travel characteristics (area of travel, route of travel, and/or time of travel). The implication is that in considering alternate approaches for implementing VMT fees, it would be helpful for decision makers to first determine what types of additional functionality the system should be capable of supporting.

Would the sole goal of the system be to create a more stable revenue stream in comparison to fuel taxes? Or would it also be valuable for the system to meter mileage and apportion fees by jurisdiction, to reduce emissions, to reduce recurrent traffic congestion, to reduce excessive road wear, to collect detailed travel data, to provide a platform for additional travel services, or to support some specific combination of these options? If the sole goal were to provide a more stable revenue source, many implementation options might be considered. If additional functionality were desired, there would be fewer options from which to choose.

A related question to consider is how important it would be to design a system that is inherently flexible or extensible. Imagine, for example, that the federal government made the decision to implement a VMT system for which the principal goal was a sustainable revenue source. While in principle this would allow for the development of a relatively simple system, there might still be value in selecting a more sophisticated implementation approach. The federal government might choose, for example, to develop a system that would provide states or local areas with the ability to institute congestion tolls at some future date without needing to totally revise the system.

Following this reasoning, the logical approach would be to implement a VMT-fee system that provides the most flexible metering capabilities. Unfortunately, such a choice might also increase the cost of developing and operating the system and create greater user acceptance challenges. So there are certainly important tradeoffs to consider. The following chapter introduces the various implementation options possible and discusses their relative strengths and limitations along these lines.

3. OPTIONS FOR IMPLEMENTING VMT FEES

The concept of distance-based user fees has received considerable attention over the past decade, with examples spanning the range from preliminary research and pilot projects to planning and full-scale implementation. This chapter begins with a brief introduction of these prior efforts. Additional details about specific trials and programs are provided in Appendix A.

Drawing on lessons from prior studies, trials, and implementation efforts, the chapter next enumerates potential mechanisms for implementing a system of VMT fees and considers their relative strengths and limitations. Included in the discussion are options for metering mileage, for collecting fees, for preventing evasion, and for protecting privacy.

The closing section of the chapter examines several broader concepts for designing and deploying a system of VMT fees. These include interoperability standards, required retrofits, installation with new vehicles, voluntary adoption, and user choice.

3.1. RELEVANT TRIALS AND PROGRAMS

The past decade has witnessed a proliferation of pilot tests and program implementations involving some form of distance-based road use charges. At least three factors have motivated the growing interest in this approach. First, the challenges associated with declining state and federal fuel tax revenue have grown acute, motivating decision makers to consider a range of innovative funding options (note that while transportation funding regimes are different in other countries, many face comparable funding shortfalls). Second, recent technological advances have enabled a broad range of electronic tolling options offering the potential to develop new forms of road pricing not possible in decades past. Third, as the problems associated automobile and truck travel—traffic congestion, harmful air pollutants, dependence on foreign sources of oil, and the threat of climate change—have become more severe, decision makers and analysts have grappled with a wide range of strategies for reducing auto use and promoting less energy-intensive transportation alternatives. There now appears to be a growing recognition that the manner in which transportation is financed can significantly influence such outcomes.

Taking stock of planning efforts, pilot tests, and programs implemented in recent years, one can discern three broad categories of distance-based pricing concepts that might offer insights in the technical and administrative design of a VMT-based system for road use charges. The examples within these categories might also yield important insights into a range of technical, political, administrative, and legal obstacles that would need to be overcome in order to implement distance-based road use fees. The three categories are as follows:

- **General-purpose distance-based road use charges.** This category involves the application of distance-based road-use charges that would apply to all light-duty vehicles (e.g., passenger cars), and potentially apply to trucks as well. Examples include recent trials in Oregon and the Puget Sound region, ongoing trials conducted by the University of Iowa, planned trials in

Minnesota, efforts to develop a system in the Netherlands, and an implemented program in New Zealand that includes diesel-fueled passenger cars and trucks.

- **Weight-distance truck tolls.** Similar to the previous category, the key distinctions here are that (a) the charges only apply to heavy trucks, and (b) the per-mile rate typically varies by some measure of vehicle weight to account for road wear. Examples include a pilot test in Oregon examining the automation of an existing weight-distance truck toll, a study that might lead to a pilot test of truck VMT fees in New York, and implemented programs in Switzerland, Austria, Germany, the Czech Republic, and Slovakia.
- **Pay-as-you-drive (PAYD) insurance/leasing.** Automobile insurance and leasing costs are often fixed, structured as a set price for a fixed period of time (e.g., $1000 per year for insurance). The idea behind PAYD insurance and leasing is to vary these costs on a per-mile basis such that the less one drives, the less one owes. Examples of PAYD insurance include programs in Massachusetts along with mileage-based policies offered by GMAC, MileMeter, Progressive Insurance, Aviva, CoverBox, Hollard Insurance, Nedbank, and Real Insurance.

Appendix A provides additional discussion of the trials and programs listed in each of these categories. Collectively, they offer a wealth of technical, institutional, and political lessons relevant to the design and implementation of VMT fees. High-level observations include:

- Designing and implementing a system of VMT fees represents a complex undertaking, posing a broad range of technical, institutional, and political challenges.
- Numerous implementation options are possible, varying in both cost and capabilities.
- Distance-based road use fees are able to raise significant revenue.
- Drivers do respond to the price signals embedded in road use fees, suggesting that the idea of structuring fees to influence travel choices would be effective.
- While the concept of distance-based road use charges does not usually receive strong initial public support, views become more favorable as the concept is better understood.
- Key barriers to implementation include cost, privacy concerns, and general mistrust in the government.

3.2. TECHNICAL MECHANISMS FOR IMPLEMENTING VMT FEES

From prior programs and trials, concepts discussed in the literature, and suggestions offered by transportation officials and decision makers, one can discern at least eight potential VMT-fee metering concepts (and it is certainly possible that additional options will emerge in the coming years). For several of these, the means of collecting payment and preventing evasion are implicit in the metering approach, and privacy does not emerge as an issue. With others, there are multiple alternatives that might be employed to assess fees and collect bills, to prevent evasion, and to protect user privacy. This section therefore begins by outlining the eight general VMT metering concepts and then describes additional payment, enforcement, and privacy mechanisms that could be coupled with some of these.

To date, metering and payment options have received the most comprehensive consideration among planners and researchers. In describing the options in these categories, we therefore mention prior applications, summarize key strengths and limitations, and identify any significant uncertainties that would benefit from further research. In contrast, while some of the options for preventing evasion and protecting privacy have been studied or implemented in related contexts, others have been discussed in more speculative terms. The description and commentary for the options in these latter categories is therefore more limited. The specific metering, payment, enforcement, and privacy options reviewed in this section are as follows:

Metering concepts:

- Self-reported odometer readings
- Periodic odometer checks
- Assumed annual mileage with optional odometer checks
- Fuel consumption-based mileage estimates
- Radio frequency identification (RFID) tolling on a partial road network
- OBU connected to on-board diagnostics (OBD II) port
- OBU with OBD II connection and cellular location
- OBU with GPS equipment

Payment mechanisms:

- Payment with vehicle registration
- Pay-at-the-pump
- Transmission to collection authority
- Prepaid debit cards

Enforcement mechanisms:

- Odometer inspections
- Odometer redundancy checks
- Metering equipment inspections
- Default fuel tax payment
- Fuel consumption redundancy checks
- External DSRC/automated number plate recognition (ANPR) checks
- Device “heartbeat” signals
- Device “distress” signals

Privacy protection mechanisms:

- On-board data aggregation / fee computation
- Anonymous proxy fee computation
- Trusted third party
- Prepaid debit cards
- Anonymous user accounts
- Data encryption

3.2.1. Metering Concepts

From a technical perspective, the eight metering concepts can be grouped into three categories. The first three all rely on the odometer. The next two involve the installation of relatively inexpensive automatic vehicle identification (AVI) devices (likely in the form of RFID tags or transponders) combined with supporting infrastructure deployed along the roadways and/or at fueling stations to facilitate metering, payment, and enforcement functions. The final three use more sophisticated OBUs within each vehicle to meter travel; here again it might be necessary or helpful to deploy additional equipment at fueling stations or along the roadways, but only to support payment and enforcement, not to support metering.

Note that in addition to the options outlined here, all of which could be implemented for the existing vehicle fleet, it would also be possible to require that auto manufacturers begin to install metering equipment on new vehicles as of a certain model year (discussed in greater detail later in this chapter). While this would likely be less expensive than retrofitting vehicles with OBUs (eliminating, for example, the cost of installing retrofitted equipment, and achieving greater economies of scale), it could also take much longer to phase in the equipment as the existing auto fleet is slowly replaced. Yet it is a viable and potentially attractive strategy and thus merits consideration as a possible pathway for implementing and transitioning to VMT fees.

Odometer-Based Options

Self-reported odometer readings. For this option, drivers would report their current mileage each year as part of the annual registration process. The state department of motor vehicles (DMV) or motor vehicle administration (MVA) would then assess a corresponding mileage fee, which would be added to the base vehicle registration fee (if paying the full amount in a lump sum proved to be burdensome for some drivers, an option of paying the fee in more frequent installments could be provided; this might require, however, significant changes to current DMV or MVA fee collection processes and procedures). In the case of federal VMT fees, the state would then pass along the mileage fee component, minus some administrative charge, to the Treasury Department.

- **Prior applications.** Several auto insurance programs that offer mileage-based discounts (as opposed to more precise pay-as-you-drive rates) rely on self-reported odometer readings.

- **Strengths.** This represents the least expensive implementation option, with no in-vehicle equipment requirements and relatively low collection cost. Another benefit is that this option would not create privacy concerns.
- **Limitations.** The drawbacks to this approach are many. To begin with, it would be very difficult to enforce in the absence of routine odometer inspections (Whitty and Svadlenak 2009). A driver might, for instance, repeatedly underreport mileage over a period of some years and then scrap the vehicle at the end of that period – this would be very difficult to detect or prevent. This option would also require that all states record and store vehicle odometer data in their vehicle registration systems (not all do so at present) and update their billing systems. Based on interviews with state officials for the previous NCHRP 20-24(69) study (Sorensen et al. 2009), many state registration databases can be described as "fragile" legacy systems for which even simple changes to data fields or billing processes might be difficult to achieve. Also, many states allow multi-year registration options, meaning that either they would have to change their processes to incorporate annual readings or drivers would be asked to pay several years' worth of mileage in a lump sum. Finally, this option offers limited metering capabilities; rates might vary by relevant vehicle characteristics, but not by time or location of travel.
- **Uncertainties.** There are no significant uncertainties associated with this option.

Periodic odometer checks. Similar to the prior option, the key distinction here is that drivers would submit to periodic (likely annual) odometer readings at certified stations as the basis for assessing mileage fees. The odometer readings could be conducted either by a public agency, such as a state DMV or MVA, or contracted to authorized private stations. Here again, fees would be added to the base registration charge, and states would remit any federal share of VMT fees to the Treasury Department.

- **Prior applications.** Several PAYD insurance programs rely on annual odometer inspections.
- **Strengths.** Here again, no additional in-vehicle equipment would be required, and this mechanism would not raise privacy concerns. In states that already inspect vehicles on a regular basis, the incremental cost of reading the odometer would be minimal.
- **Limitations.** This option also faces a number of limitations. The most important of these is the capital and operating cost of setting up check stations and recording odometer readings in states that do not currently conduct regular vehicle registrations. Although about two-thirds of the states currently inspect vehicles (e.g., to check emissions equipment), the inspections are often conducted less frequently than once per year, and in many states the inspections are not required of all vehicles (e.g., emissions checks might only be required for vehicle owners in urban areas that do not meet federal air quality standards). Additionally, state vehicle registration databases would again need to be updated to record and bill for mileage. The pricing flexibility under this option (i.e., the ability to account for time or location of travel) would be limited, and it would not be possible to meter mileage and allocate fees by jurisdiction. The need to conduct periodic odometer readings would also increase the burden on road users in states that do not currently require vehicle inspections. Finally, though enforcement would be easier than under the self-reporting model, it is still possible that vehicle owners could find ways to tamper with their odometers (Bomberg et al. 2009).

- **Uncertainties.** Further research on the cost of implementing and operating vehicle odometer inspections, particularly for states that do not currently perform vehicle inspections, would be helpful to more accurately compare the costs and benefits of this approach.

Assumed annual mileage with optional odometer checks. With this approach, road users would be assessed an assumed annual VMT fee based on the average mileage one might expect given the vehicle's age and class (e.g., passenger vehicles vs. commercial trucks). Road users that travel significantly less than the assumed amount would have the option of submitting to annual odometer readings to qualify for a reduced fee based on actual miles of travel, while users that travel more would simply choose to pay the estimated mileage charge. As with the previous option involving odometer inspections, states would still need to provide the infrastructure for road users that choose to have their odometers read, and they would likewise need to modify their vehicle registration and billing systems to accommodate this new form of charging. Once collected, the federal share of VMT fees would be remitted to the Treasury Department.

- **Prior applications.** In effect, this presents drivers with an option that is similar to choosing between standard auto insurance (based on assumed average mileage) and PAYD insurance (based on actual mileage).
- **Strengths.** As with the previous two odometer-based options, no additional in-vehicle equipment would be required, and this mechanism would not raise privacy concerns. Additionally, the cost of administration would be less than with required odometer checks since many users would choose to pay the estimated mileage charge rather than having their odometer checked each year. Finally, road users would not face any additional burden unless they chose to submit to annual inspections in order to pay reduced mileage fees.
- **Limitations.** This option also faces a range of limitations and concerns. As with the prior odometer option, pricing flexibility would be limited to mileage and vehicle characteristics, and it would not be possible to meter mileage and apportion fees by jurisdiction. States would still need to develop a network of odometer reading stations for those users wishing to qualify for lower fees based on reduced mileage, and they would need to update their vehicle registration databases and billing systems as well. The potential for odometer fraud would still be a concern. It is also worth noting that any drivers wishing to qualify for a reduced rate would need to have their odometers checked both before and after the year in question. Unique to this odometer-based option, there could be equity concerns as well. Specifically, while vehicle owners that traveled less than the assumed amount would likely have their odometers read to qualify for a reduced total fee, they would still end up paying the assumed base rate on a per-mile basis. In contrast, drivers that traveled far in excess of the assumed annual mileage would simply choose to pay the fixed total fee, resulting in a much lower charge on a per-mile basis. In other words, those who drove less would tend to subsidize those who drove more. Given our understanding of the factors that influence travel behavior (Pisarski, 2006), this would tend to benefit wealthier drivers at the expense of poorer drivers, and suburban and rural drivers at the expense of urban drivers.
- **Uncertainties.** To better assess this option, it would be helpful to conduct further research on the number of drivers who would choose to submit to annual readings, and the corresponding implications regarding the cost of developing and operating a system of odometer inspections.

AVI/RFID-Based Options

Fuel consumption-based mileage estimates. Under this approach, described recently by Whitty and Svadlenak (2009) as a potential interim step in the longer-term transition to VMT fees, fuel consumption would be combined with information about a vehicle's fuel economy to serve as the basis for estimating travel distance. All vehicles would be equipped with some form of AVI (likely an RFID tag embedded in the license plate or registration sticker). When purchasing fuel, electronic readers installed at the pump would detect the vehicle ID and use this information to determine the vehicle's fuel-economy rating (and, optionally, other characteristics such as weight or emissions class) based on the make and model. The expected mileage could then be estimated based on the number of gallons purchased. The corresponding charge would be added to the fuel purchase price, while fuel taxes (already paid at the wholesale level and therefore built into the retail price) would be subtracted. Vehicles not yet equipped with an AVI device (including foreign vehicles) would continue to pay the existing fuel taxes rather than mileage charges. The administration for this approach would involve expanding the existing fuel tax collection system to include fuel retailers along with wholesalers. Specifically, it would be necessary to account for the difference between fuel taxes (paid at the wholesale level) and mileage fees (collected at the retail level) and interact with fuel retailers to either collect or refund the difference (this "pay-at-the-pump" model is described in greater detail later in this chapter).

- **Prior applications.** This approach has not been previously implemented, either in trials or full-scale programs.
- **Strengths.** There are several important advantages to this approach. First, the cost of equipping vehicles with electronic identifiers should be quite low (RFID tags can cost on the order of a few cents per unit). Second, because this approach would not meter the location of travel, privacy concerns should not be significant. Third, vehicles not yet equipped with the required identifier would simply continue to pay the existing fuel tax. This means that (a) the system could be phased in over time, (b) foreign vehicles could continue to pay their share of road use costs via the gas tax, and (c) enforcement should not be a major concern—vehicles, when refueling, would either pay mileage charges or gas taxes.
- **Limitations.** There are several limitations for this approach as well. The mileage estimates might be inaccurate depending on travel conditions (e.g., vehicles traveling in heavy traffic congestion experience reduced fuel economy and would therefore end up paying higher fees on a per-mile basis). Additionally, alternative-fuel vehicles (e.g., electric cars) would require a parallel mechanism for assessing VMT fees, and the share of such vehicles is expected to grow in the coming years. Because the approach would provide no information about the location of travel, pricing flexibility would be limited and there would not be possible to accurately apportion revenue among jurisdictions. It would also be necessary to find the right avenue for equipping all vehicles with the AVI device; as discussed in the preceding NCHRP 20-24(69) study (Sorensen et al. 2009), enabling legislation would likely be required in some states to include an RFID tag within a license plate or registration sticker. There might also be some privacy concerns associated with the use of RFID or other AVI options. Finally, there might be issues related to the cost and complexity of implementing pay-at-the-pump; these are discussed later in this chapter.

- **Uncertainties.** The key uncertainty for this approach pertains to the cost and administrative burden of implementing a pay-at-the-pump system for collecting fees.

RFID tolling on a partial road network. With this option, all vehicles would be equipped with some form of AVI—likely an RFID tag or transponder—and gantry-mounted electronic readers would be set up along the most heavily traveled segments of the road network to support facility-based tolls—i.e., a fixed or variable charge for each segment traveled. It should be stressed that this approach would not support tolling across the entire road network, as it would not be practical to install gantries on lightly traveled roads. As a result, it would be inappropriate to view this approach as a true "VMT fee" option, since it would not capture a significant share of VMT. Even so, it is a potential usage-based fee system that merits consideration for replacing or augmenting fuel taxes. Additionally, this tolling concept would make it possible to extend the functionality of several other VMT-fee implementation options. Specifically, any option that involves some form of in-vehicle equipment, but is unable to meter the specific route of travel (i.e., fuel consumption-based estimates or the use of OBU configurations that do not include GPS), could be augmented through the addition of gantry-mounted readers to enable facility-based congestion tolls along select routes. For the RFID tolling approach, at least two payment options would be possible. First, a collection authority (either publicly or privately administered) could be established to manage road use accounts for each driver; each time a vehicle passed a tolling gantry, the user's account would then be charged. Second, the AVI device could be designed to accommodate prepaid debit cards; each time a vehicle passed a tolling gantry, the corresponding toll would then be debited from the card. These two payment options receive additional attention later in the chapter.

- **Prior applications.** This approach is employed in both the Austrian and Czech Republic weight-distance truck tolls, which only apply for travel on major highways.
- **Strengths.** The costs of in-vehicle equipment with this option would be low. Additionally, the technology is similar to that employed in many existing toll roads, and is thus well understood. Finally, this approach would allow congestion tolling on the most heavily traveled corridors, which could both relieve congestion and raise considerable revenue.
- **Limitations.** Within the context of a study aimed at scoping potential trials for a system of VMT fees, the most important limitation for this option is that it would not capture all miles of travel. Additionally, the cost of equipping a significant portion of the road network with gantries to detect vehicles and read their AVI devices would be considerable. Because this approach would need to register the passage of vehicles at specific points on the road network, privacy concerns would likely arise (though these could be overcome through the use of pre-paid debit cards or some form of "anonymous" accounts made available to road users concerned with privacy). There could also be problems caused by traffic diverting from tolled main routes to un-tolled local routes. Finally, this option could introduce geographic equity concerns. Specifically, if this option were implemented by the federal government, if gantries were only installed on heavily traveled corridors, and if the resulting revenue were distributed among the states based on the current HTF allocation formula, then urban states would likely end up subsidizing rural states.
- **Uncertainties.** There are several important uncertainties that would need to be resolved to better assess this option. These include determining the subset of roads that would be subject

to tolls, estimating the cost of installing all of the needed gantries, and estimating the cost of the two potential payment mechanisms implemented at scale.

OBU Options

OBU connected to OBD-II port. For this approach, vehicles would be equipped with an OBU connected to the OBD II port, providing data on vehicle speed that would be used to compute travel distance. The per-mile fee could be modified, if desired, by vehicle characteristics such as weight, fuel economy, or emissions class. Fees could be collected as part of the vehicle registration process, through the pay-at-the-pump model, or via wireless communications to a collection authority (while debit cards would also be possible, this option does not present the same privacy concerns that might motivate some drivers to prefer this option).

- **Prior applications.** This approach is used in several PAYD insurance programs.
- **Strengths.** One advantage of this approach is that the per-vehicle costs, though more expensive than simple RFID tags, should be fairly low, perhaps around $25 or less per unit. In comparison to GPS-based systems, retrofitting existing vehicles with the device would be relatively easy, requiring a simple connection to the OBD II port. With certain PAYD insurance programs already using this approach, the technology can be viewed as "proven" and off-the-shelf devices are available. In comparison to the fuel consumption approach, the mileage estimates, though still the result of a calculation, should be more accurate. Additionally, this device would not meter the location of travel, and so should not create substantive privacy concerns.
- **Limitations.** Because this option would not determine the location of travel, pricing flexibility would be relatively limited, and it would not be possible to meter mileage and apportion fees by jurisdiction. Additionally, the OBD II port is only available on vehicles manufactured after 1996; as such, it would be necessary to establish a parallel charging mechanism for older vehicles (note, though, that the percentage of such vehicles on the road will continue to decline over time). Any of the options for collecting fees would entail at least moderate administrative cost and complexity. It would also be necessary to implement strategies to ensure that drivers do not disable the OBU to avoid mileage charges (a recurrent theme for the options that involve an OBU).
- **Uncertainties.** The main uncertainties for this approach pertain to the cost of the devices produced at scale and the cost and complexity of the alternate payment mechanisms that might be developed.

OBU with OBD II port connection and cellular location. Developed by Max Donath at the University of Minnesota (Donath et al. 2009), this approach would involve an OBU that incorporates an OBD II port connection and an embedded cellular communications device. Speed data from the OBD II port would be used to estimate mileage, while the cellular technology would make it possible to determine the location of travel (based on the spatial relationship to nearby cell towers) with sufficient accuracy to place the vehicle in a specific jurisdiction or zone (but not necessarily on a specific route). This configuration should thus make it possible to vary rates by vehicle characteristics, by jurisdiction, or by smaller geographic area (e.g., to levy zone-distance congestion tolls in a dense urban district). The location data would

also make it possible to allocate mileage fees among multiple jurisdictions. Options for collecting fees would include payment with registration, pay-at-the-pump, wireless transmission to a collection authority, and prepaid debit cards.

- **Prior applications.** This approach has not yet been tested or implemented in practice.
- **Strengths.** Owing to the addition of cellular technology within the OBU, this option would be more expensive than the previous approach. On the other hand, the cellular device would be used to both support any needed communications and determine location. In comparison to the GPS option, this would result in fewer required components on the device and lower overall cost—perhaps on the order of $25 to $50 per unit once produced at scale. It would also require much less power than the GPS configuration, and as a result could potentially draw needed power through the OBD II port rather than requiring a direct connection to the battery. This would result in significantly lower installation costs. Another possible benefit with this configuration is that the use of cellular technology to determine the approximate location of travel would enable flexible pricing options yet might not raise the same degree of privacy concerns that the public associates with GPS (the device would not determine the specific route of travel). Without further study of public opinion, however, it is difficult to know if this option would assuage privacy concerns.
- **Limitations.** The application of cellular technology for providing information about the location of travel in the context of road use fees remains to be demonstrated in practical field trials, so there is some technical risk with this option. The addition of cellular equipment would also require a service contract, and this would add to the ongoing operational cost. Additionally, because the OBD II port is only available on vehicles manufactured after 1996, it would be necessary to establish a parallel charging mechanism for older vehicles. Any of the available options for transmitting and billing for mileage would entail at least moderate cost and complexity. Finally, here again it would be necessary to develop strategies for ensuring that a vehicle owner cannot disable the OBU to evade mileage charges.
- **Uncertainties.** Key uncertainties with this option include the cost of producing the units at scale as well as the cost of implementing and operating any of the potential collection mechanisms. While in theory this approach should provide sufficient spatial accuracy to enable fees levied by county, by city, or even within specific urban areas, this has yet to be demonstrated in practical trials. In particular, it would be helpful to examine how accurate the location functionality works in different geographic settings—for example, in areas known for poor cellular coverage. It also remains to be seen whether this option would help to mitigate the privacy concerns commonly associated with GPS.

OBU equipped with GPS. In this final option, the OBU would be equipped with GPS to meter the location of travel with much greater precision, including the route of travel and perhaps even the specific lane of travel. Travel distance, in turn, could be calculated based either on successive GPS coordinates or via a connection to the OBD II port. Note that in the prior NCHRP 20-24(69) report, the authors distinguished between two GPS options, referred to as "coarse resolution" (able to determine area of travel but unable to reliably determine specific route) and "fine resolution" (able to reliably determine route of travel) under the assumption that the former would be less expensive to the latter. Subsequent to the publication of that report, however, several experts have noted that with recent technology advances it is now possible to develop

GPS units that can reliably determine the route of travel at relatively low cost, likely on the order of $50 to $100 per unit at scale. Accordingly, this report only includes one GPS option and assumes that it would be capable of route-specific metering if desired. With this level of specificity, the approach could accommodate any of the envisioned pricing structures for a system of VMT fees, including area-based congestion tolls, facility-based congestion tolls, and weight-distance truck tolls that vary by road class (i.e., heavily vs. lightly engineered). Or, as an alternative, it would be possible to implement a simpler fee structure not dependent on route, in which case the greater accuracy would mainly support value-added services. As with previous OBU options, potential payment mechanisms include payment with registration, pay-at-the-pump, wireless transmission to a collection authority, and prepaid debit cards.

- **Prior applications.** GPS-based OBUs have been used to meter travel by area or jurisdiction in the New Zealand road use fees, the Swiss truck toll, the Oregon trials, the University of Iowa trials, and several PAYD insurance programs. They have been used to meter travel by specific route in the German truck toll, the Slovakian truck toll, the PSRC trials, and the Georgia Tech trials. Additionally, it was envisioned that the planned Dutch distance-based pricing system would incorporate charging by specific route of travel.
- **Strengths.** As noted above, this option would provide the greatest flexibility in potential pricing schemes. It would also allow the possibility of *not* charging for travel on roads that should not be subject to road use fees—e.g., roads on private property (of the other metering approaches, only RFID tolling could likewise avoid charging for such use). And because GPS—as an alternative to relying on speed data from the OBD II port—could be used to estimate travel distance, GPS-based in-vehicle equipment could work for all vehicles on the road (i.e., including vehicles built before 1996 when OBD II was introduced). Additionally, as auto manufacturers increasingly provide GPS as standard equipment on new vehicles, it might become unnecessary to retrofit vehicles with the necessary metering equipment. A final advantage worth noting is that the inclusion of GPS would make possible a number of potentially attractive "add-on" services such as real-time navigation based on current traffic patterns, location-tagged emergency distress signals, and even automated payment of parking fees (Grush 2010d). Such features would be valuable if pursuing a voluntary opt-in strategy for initial system implementation, as discussed later in this chapter.
- **Limitations.** Though the cost of GPS equipment is coming down, this would still be the most expensive OBU option. Additionally, because GPS equipment requires a battery connection and an antenna mounted with direct line-of-sight to the sky, the installation costs for retrofitting vehicles would likely be higher than with the other OBU options. It would also be necessary to develop more precise digital road network maps to facilitate metering by specific route of travel, likely entailing at least some expense (note, though, that travel data collected from the system could potentially be used to help correct and refine existing digital maps). Privacy concerns would be acute, and considerable outreach would be necessary to ensure the public that their private travel data has been sufficiently protected. As with the other OBU options, any of the payment mechanisms would likely be both costly and administratively complex, and it would be necessary to develop strategies to prevent users from tampering with the OBU.
- **Uncertainties.** Here again, key uncertainties include the cost of producing the units at scale as well as the cost of implementing and operating any of the potential collection mechanisms.

It also remains to be seen whether public concerns regarding the issue of privacy could be overcome through concerted efforts at education and outreach.

Summary of potential payment mechanisms. As indicated in the preceding text, the possible options for metering mileage vary considerably in terms of their metering capabilities. This has important implications for the types of functionality that could be supported within a system of VMT fees, a point that is explored with greater precision in the next chapter. In Table 3.1, the metering capabilities offered by each option are shown as black dots. Note that the metering capabilities of several of the options could be extended through the addition of gantries along heavily traveled routes that would register the passage of a vehicle at a specific location and time (to enable, for example, facility-specific congestion tolls or cordon tolls). Such extensions are illustrated within the table as hollow dots. As indicated within the table, the GPS-based option would provide the most extensive capabilities, followed closely by the OBU equipped with cellular communications and a connection to the OBD II port. At the other end of the spectrum, the odometer options would offer minimal metering capabilities.

Table 3.1. Metering Capabilities of Options for Metering Mileage

Metering Option	Metering Capabilities				
	Meters Entire Road Network	Vehicle Emissions Class or Weight	Mileage by Area or Jurisdiction	Route or Specific Location of Travel	Time of Travel
Self-reported odometer readings	●	●			
Required odometer checks	●	●			
Optional odometer checks	●	●			
Fuel consumption-based estimates	●	●		○	○
RFID tolling on a partial road network		●		○	○
OBU with OBD II	●	●		○	●
OBU with OBD II / cellular	●	●	●	○	●
OBU with GPS	●	●	●	●	●

3.2.2. Payment Mechanisms

As alluded to in the discussion of metering options, there are at least four potential mechanisms through which fees might be assessed and collected, though the specific options available depend on the metering approach. The four options include payment with vehicle registration fees, pay-at-the-pump, wireless transmission to a collection authority, and prepaid debit cards.

Payment with registration fees. This would be the logical payment option for any of the odometer-based metering approaches, and it could in theory be used with any of the OBU options as well (that is, the mileage data from the OBU, rather than the odometer, could be read during a vehicle inspection). Mileage fees would simply be added to the annual registration fee and the state would then remit federal VMT fees, perhaps holding back a small percentage to cover administrative costs, to the Treasury Department. If desired, the fees might be broken up into multiple payments through the year for drivers who would find this helpful, although this would require modifications to existing registration billing processes.

- **Prior applications.** States and local agencies routinely levy registration fees, but these do not currently include charges levied on a per-mile basis.
- **Strengths.** As this approach simply adds on to a well-established revenue collection system, it should be the least costly (not including the potentially significant cost of odometer inspections or OBU readings) and complex of any of the options.
- **Limitations.** This would require all states to modify their vehicle registration and billing systems. Though the necessary changes would seem modest, at least some state DMV/MVA officials interviewed in the prior NCHRP 20-24(69) described their existing registration and billing software as "fragile" legacy systems that would be expensive to modify. Additionally, enabling legislation might be required in many states. Both of these issues are potentially problematic given that not all states appear eager to support federal efforts to implement a mileage-based system of road use charges (Sorensen et al. 2009). Finally, if payment via registration were coupled with mandatory odometer inspections or OBU readings to determine mileage fees, the cost of collection could increase considerably—particularly in those states that do not currently conduct routine vehicle inspections (roughly 15 out of 50).
- **Uncertainties.** There are two main uncertainties with this approach. The first is the cost of implementing odometer inspections or OBU readings in states that do not currently inspect vehicles. The second is whether all states could be encouraged or required to implement payment with vehicle registration to support federal efforts.

Pay-at-the-pump. This would be the logical payment option for mileage estimates based on fuel consumption, and it represents one of several options for any of the OBU-based metering approaches. Whenever a vehicle refueled, the vehicle's metering equipment (AVI or OBU) would wirelessly transmit relevant data (either fees currently owed or data from which to calculate fees) to an electronic reader mounted at the pump; mileage fees would then be added to the purchase price, while fuel taxes would be subtracted. Though this might be viewed as piggybacking off of the existing fuel tax collection system, in fact the fuel tax system would need to be dramatically expanded to accommodate this payment approach. Currently the IRS levies fuel taxes at the *wholesale* level—that is, at approximately 1,400 terminal racks scattered throughout the United States. These taxes are then built-in to the per-gallon price that retailers pay and in turn passed along to the end consumer. Under the pay-at-the-pump, model, in contrast, fuel taxes would be subtracted, and mileage fees added, at the *retail* level. This means that the IRS would need to set up accounts will roughly 160,000 retail fuel stations throughout the country (and potentially with commercial fleet fueling operations, if commercial vehicles were not all required to begin paying VMT fees on the same date) in order to either credit or collect the difference between mileage fees added to and fuel taxes debited from the purchase price.

- **Prior applications.** This payment option was successfully demonstrated in the Oregon VMT-fee trials, but has not been implemented in any full-scale programs.
- **Strengths.** This payment mechanism presents several compelling advantages. To begin with, vehicles lacking the necessary metering equipment would still need to pay fuel taxes. This means that (a) the system could more easily be phased in over time, with some drivers paying VMT fees and others paying fuel taxes, (b) foreign vehicles could continue to pay their share

of road use costs via the gas tax, even after all domestic vehicles had been equipped with an AVI or OBU, and (c) enforcement should be less of a concern, as any vehicle with a non-functioning AVI or OBU would default to paying fuel taxes (though in the case of OBU-based systems, it would still be necessary to ensure that drivers had not temporarily disabled their metering devices between fueling stops). Additionally, once all fueling stations had been equipped with the necessary supporting infrastructure (e.g., readers at each pump), ongoing administrative costs *might* be relatively low. In their investigation of this concept for the State of Oregon, Whitty and Svadlenak (2009) estimated that this system would cost roughly $1.8 million per year to operate, roughly double what the state currently pays to administer fuel taxes. That said, some of the experts that we spoke with during the preceding NCHRP 20-24(69) study were skeptical that the administrative costs for this option could be so low (Sorensen et al. 2009), so the issue clearly merits additional research attention.

- **Limitations.** On the negative side, this option would require considerable initial capital costs. In the same study for Oregon, Whitty and Svadlenak (2009) estimated that the required electronic readers, software, and computing equipment would cost on the order of $15,000 per station. With roughly 160,000 stations across the country, this would total around $2.4 billion. Not all station owners would be eager to adopt this new equipment (a federal mandate would almost certainly be required), and the period required to retrofit all stations might take a number of years. Another issue, one that would become increasingly important in future years, is that this approach would only work for vehicles that visit stations to purchase fuel. Electric vehicles, and possibly other vehicle/fuel configurations (e.g., compressed natural gas with home fueling stations), would not be covered. Though pay-at-the-pump should be sufficient for the majority of vehicles for the foreseeable future, one or more additional options would need to be provided to accommodate other classes of vehicles.
- **Uncertainties.** The main uncertainties with this payment approach that merit more rigorous evaluation include the cost of equipping fueling stations to interact with vehicle metering devices, the cost of modifying the current fuel tax collection system to interact with retail stations, the cost of training station operators how to use the tax collection equipment and interact with the IRS and/or state revenue agencies, the cost of system administration, and the appropriate payment options to include for vehicles that do not rely on gas or diesel.

Transmission to collection authority. This option would be possible with RFID tolling or any of the OBU alternatives (for RFID tolling, telecommunications equipment coupled with the RFID readers would send information about vehicles that passed specific charging points; for OBU options, the OBU would wirelessly transmit either current charges owed, if calculated on the OBU, or travel data from which the collection authority would calculate charges owed). Each user would have an account with the collection authority covering one or more vehicles, and these accounts could be either pre-paid (as with many current electronic tolling operations) or billed as charges accrue. From an institutional perspective, there are several possible structures that might be considered for the collection authority. There could be just a single collection authority, which might be administered by the federal government, by some type of non-profit or joint powers entity governed by federal and state representatives (analogous to the International Registration Plan and International Fuel Tax Agreement), or by a private firm or consortium under contract. Alternately, there could be multiple firms engaged to collect road use fees on behalf of the federal government and states. In this vein, one might envision a system in which

vehicle owners select a particular metering device that complies with federal requirements and at the same time select a vendor to handle collection services, much as one currently chooses a cell phone and cellular service carrier (this idea is discussed further in the section on interoperability later in this chapter).

- **Prior applications.** Most of the operational distance-based road use charging programs employ this payment approach, though they vary in the particulars. In the Swiss truck toll, for example, the collection system is publicly administered, whereas in the German program the function has been contracted to a private consortium. In New Zealand, drivers that opt for electronic road use charging can choose among multiple competing vendors (New Zealand Ministry of Transport undated). In the United States, both the PSRC and University of Iowa trials have emulated wireless transmission to a central collection authority.
- **Strengths.** A compelling advantage for this payment option is that it could handle all vehicle classes, not just vehicles that visit fueling stations. Additionally, in comparison to pay-at-the pump, it would not require the significant capital investment to equip all fueling stations with electronic readers to communicate with in-vehicle devices.
- **Limitations.** One likely drawback for this approach is high operational and administration costs—including such functions as data transmission, account maintenance, and billing—though more research on this issue is needed. As part of the initial Oregon VMT fee study, Bertini et al. (2002) considered the option of setting up a central collection agency to support Oregon's three million drivers. By their estimates, such a system would require roughly $1 million in initial capital costs plus an additional $50 million per year in operating costs (roughly 50 times what the state pays to administer fuel taxes), although much of this expense was based on the assumption of sending out paper bills in the mail each month. One would expect—particularly with continued advances in telecommunications and online billing—that a more efficient system could now be developed. Yet none of the road pricing programs developed to date that rely on this payment approach appear to have achieved low administrative costs, especially in comparison to fuel tax collection. In a review of recent weight-distance truck tolls and cordon tolls, annual operating costs for the Swiss, Austrian, and German truck tolls were reported to be 4 percent, 9 percent, and 16 percent of annual revenues, respectively (ECMT 2006). For the system being developed in the Netherlands, planners had set a target that administrative costs not exceed five percent of revenue (Dutch Ministry of Transport, Public Works, and Water Management undated).
- **Uncertainties.** The cost of administering this payment option is the most significant uncertainty. Further investigation to characterize the benefits and drawbacks of alternate administrative structures (e.g., single vs. multiple collection authorities and public vs. non-profit vs. private administration) and search for strategies to lower administrative costs would also be helpful. Another uncertainty relates to the issue of how to rebate fuel taxes. Assuming that a transition to VMT fees would span multiple years, there would be a period—possibly a prolonged period—during which some drivers had installed metering equipment and others had not. During this transition, those that had begun to pay VMT fees should, in fairness, receive a rebate for any fuel taxes paid. This could be accomplished by requiring that drivers save fuel purchase receipts to qualify for the rebate, but this would constitute a burden for drivers and likely prove cumbersome from an administrative standpoint. An alternate and potentially promising approach suggested by Donath et al. (2009) would be to issue fuel

purchase cards that would be swiped as part of the fuel purchase process to automatically record the amount of fuel taxes that should be debited from a driver's mileage fees. Further attention to this issue, however, would be helpful.

Prepaid Debit Cards. With this payment mechanism, potentially attractive as a means of protecting privacy for any of the metering approaches that determine location of travel, in-vehicle equipment would be configured to accept prepaid debit cards that would be charged as mileage fees accrue. Users might be able to purchase or replenish the debit cards at banks, fueling stations, convenience stores, and the like. Note that it might still be viewed as necessary to collect some travel data from the device (through wireless communications) or from the smart card itself (perhaps when it is replenished) in order to facilitate accurate apportionment of fees by jurisdiction. Yet that information could be provided on an anonymous basis; there would be no need to link driver or vehicle information with the mileage data to facilitate the payment of fees, since the fees would already have been debited from the card. Thus privacy could be maintained even if some anonymous travel information were shared.

- **Prior applications.** This approach has not been employed in any of the distance-based road use fee systems discussed thus far, but it is used in the Singapore ERP program, a system that combines facility congestion tolls on the major thoroughfares approaching the central business district (CBD) and cordon tolls at the CBD perimeter (Goh 2002).
- **Strengths.** The principal motivation for this approach would be to provide an anonymous payment mechanism for those concerned with privacy issues. Because the fees would be debited directly within the metering device, there would be no need to transmit travel or billing data to any outside party.
- **Limitations.** Similar to the collection authority approach, the administrative costs for this option would likely be relatively high. In the Singapore case, for example, annual operating costs (including collection, enforcement, and other related functions) represent about 7 percent of revenue (ECMT 2006).
- **Uncertainties.** Further research would be needed to plan how a system of debit cards for road use fees could be deployed in the United States, and how much such a system would cost to administer at scale.

Summary of potential payment mechanisms. Table 3.2 summarizes the potential payment mechanisms that might be coupled with the various metering options. Hollow dots in the cells indicate feasible pairings; black dots indicate the most logical potential pairings.

Table 3.2. Applicability of Potential Payment Mechanisms

Metering Option	Vehicle Registration	Pay-at-the-Pump	Transmission to Collection Authority	Prepaid Debit Cards
Self-reported odometer readings	●			
Required odometer checks	●			
Optional odometer checks	●			
Fuel consumption-based estimates		●		
RFID tolling on a partial road network			●	●
OBU with OBD II	○	●	●	○
OBU with OBD II / cellular	○	●	●	●
OBU with GPS	○	●	●	●

3.2.3. Preventing Evasion

Just as there are multiple potential mechanisms for collecting payment, so too are there a range of possible options for detecting and/or preventing evasion (and it is reasonable to expect that continued research and development efforts will yield additional approaches in the coming years). The applicability of these options often depends, in turn, on the specific form of both metering and payment. While some of the options have been applied in practice, others have only been discussed in conceptual terms or evaluated in research contexts.

It is important to highlight that several of the current options for preventing evasion would require a significant degree of manual intervention (e.g., periodically inspecting a vehicle's odometer to ensure that it aligns, at least roughly, with mileage as recorded by an OBU), while others are intended to automate the enforcement process. From the perspective of reducing administrative costs, it would be highly desirable to identify one or more automated mechanisms capable of ensuring a high degree of system compliance. If this is not possible, the approaches requiring manual intervention on a routine basis could be substituted, but this would obviously increase system administration costs. In the following list of options, the first three would require substantial manual intervention; the latter five are aimed at preventing or detecting evasion in a more automated fashion, though they might still require some degree of manual support.

Odometer inspections. In this option, applicable for the two odometer-based metering options that involve official inspections (as opposed to self reporting), the odometer would be used to meter mileage, and there would be no independent check to verify that the user had not tampered with the odometer. This could prove highly problematic, and is one of the reasons that the odometer-based options scored poorly with respect to enforcement in the preceding NCHRP 20-24(69) report (Sorensen et al. 2009).

Odometer redundancy checks. In this option, applicable for any of the OBU options, the current odometer reading would be compared with mileage recorded by an OBU to ascertain whether the device might have been tampered with. If there were a gross mismatch between the two (specifically, between mileage recorded on the device and the change in the odometer reading since the time when the device was installed), further inspection to determine whether the driver had tampered with the metering device would be merited. One might envision that all vehicles with metering equipment would be required to submit to annual odometer redundancy

checks, but this would significantly increase the costs of administration and place a greater burden on drivers as well. As a less costly and less intrusive alternative, such checks might be performed in a more random fashion, such as when vehicles were stopped for other violations.

Metering equipment inspections. Conceptually similar to the previous example, this option would involve visual inspection of the in-vehicle metering device to confirm that it had not been subject to tampering. For example, the device could be affixed with a seal on installation, and a quick inspection could determine whether the seal had been broken. Here again such inspections could be required on a routine basis or, to reduce costs, could be performed in more of a random, ad hoc fashion.

Default fuel tax payment. This option would only be applicable for fuel consumption-based estimates (Whitty and Svadelank 2009). Drivers who had not had the AVI device installed, or had disabled the AVI device, would still pay fuel taxes instead of mileage fees. Though drivers might, depending on the fuel efficiency of their vehicles, save money by paying fuel taxes, the relative savings would be small, thus deterring deliberate evasion attempts. Note that in the case of an OBU metering option combined with pay-at-the-pump, the default fuel tax payment approach would help ensure payment in the case of a disabled OBU. It would not, on the other hand, detect if a driver had temporarily disabled the OBU and then re-enabled it prior to visiting the fueling station.

Fuel consumption redundancy checks. This approach, also described by Whitty and Svadlenak (2009), would only be suitable for OBU metering devices, and only under the pay-at-the-pump model. To help ensure that drivers did not disable the OBU between fueling stops, both mileage fees and the quantity of fuel purchased would be recorded with each transaction. Software would then be employed to compare fuel purchase quantities with recorded mileage for each vehicle over time. If, considering the vehicle's fuel economy, gross discrepancies were to emerge, the vehicle could be flagged for manual inspection to determine whether the driver had tampered with the OBU.

External DSRC/ANPR checks. This is perhaps the most commonly described enforcement strategy for electronic road pricing, and has been implemented in both distance-based pricing programs (e.g., many of the European truck tolls) and more conventional electronic tolling operations. The basic concept would be to set up automated check points with a DSRC/RFID reader to query passing vehicles and verify the proper functioning of their metering equipment. Each checkpoint would also include a camera, linked to an ANPR system, to photograph potential violators and determine their license plate numbers for follow-up enforcement activities (one possibility would be to set up check points at intersections that have already been equipped with cameras and communications devices for other applications, such as traffic management or traffic light enforcement). This enforcement approach would be suitable either for RFID tolling or for any of the OBU options. In the case of RFID tolling, the approach could be implemented by adding cameras to the charging gantries along the tolled routes. For any of the OBU options, which would meter mileage across the entire road network, some check points might be located at fixed points, but it could also be helpful to include mobile check points that could be randomly located throughout the road network. This would help to deter drivers from disabling the OBU by creating uncertainty about where a check point might be located, though it would also

increase staffing support requirements (i.e., to periodically move the mobile check points). An additional issue to consider for this approach is whether and how it could be implemented during a prolonged transition period when only a subset of vehicles had been equipped with metering devices.

Device "heartbeat" signals. This strategy would be suitable for any of the OBU options under the payment mechanism involving periodic transmission of usage or fee data to a collection authority. In essence, the device—either on its own or in response to a query from the billing system—would periodically send a signal indicating that it was functioning properly. If the device failed to send one or more signals over some period of time, the vehicle would be flagged for investigation to determine whether any tampering had occurred (Grush and Roth 2009).

Device "distress" signals. Conceptually similar to the previous option, this would also be applicable for any of the OBU options involving transmission of billing data to a collection authority. In this case, the OBU would be configured to send out a distress signal if the driver attempted to disconnect, shut down, or otherwise disable the equipment. This would in turn trigger investigation of the vehicle in question (Grush and Roth 2009).

Summary of mechanisms for preventing evasion. As suggested in the preceding descriptions, the suitability of alternate enforcement strategies would depend on the metering approach and in some cases on the selected payment mechanism as well. This is summarized in Table 3.3. Within the table, the black dots indicate that a particular mechanism could be employed for a particular metering option or, in the case of the OBU options, for a particular combination of metering and payment.

Table 3.3. Applicability of Potential Enforcement Mechanisms

Metering Option / Payment Mechanism	Odometer Inspections	Odometer Redundancy Checks	Metering Equipment Checks	Default Fuel Tax Payment	Fuel Consumption Redundancy Checks	External DSRC / ANPR Checks	Device Heartbeat Signals	Device Distress Signals
Self-reported odometer readings								
Required odometer checks	●							
Optional odometer checks	●							
Fuel consumption-based estimates				●				
RFID tolling on a partial road network						●		
OBU with OBD II								
Pay-at-the-pump		●	●		●	●		●
Transmission to collection authority		●	●			●	●	●
OBU with OBD II / cellular								
Pay-at-the-pump		●	●		●	●		●
Transmission to collection authority		●	●			●	●	●
Prepaid debit cards		●	●			●		●
OBU with GPS								
Pay-at-the-pump		●	●		●	●		●
Transmission to collection authority		●	●			●	●	●
Prepaid debit cards		●	●			●		●

3.2.4. Protecting Privacy

The prior three categories of implementation options—metering, payment, and enforcement—would be necessary to construct a functioning VMT-fee system. Protecting privacy, in contrast, would not be strictly necessary from a functional perspective. Privacy has, however, emerged as a key public concern, suggesting that strong privacy protection would likely prove necessary to gain public acceptance (Goodin et al. 2009).

Accordingly, the issue of privacy has been addressed in most VMT-fee concepts and trials to date, and a number of privacy protection strategies have been explored or discussed. Before turning to the specifics, however, it is useful to comment on several broader tradeoffs that arise in discussions of privacy.

The first tradeoff pertains to the issue of being able to audit mileage bills (Goodin et al. 2009). In broad strokes, privacy advocates see value in ensuring that the government—or, by proxy, the collection authority—would not have access to the detailed travel information (e.g., specific areas, routes, and/or times of travel) upon which a mileage fee might be based. To support this goal, an OBU might be designed to aggregate travel data and compute relevant fees within the device; it would then only need to transmit the total amount owed (and potentially, how the amount should be divided among jurisdictions) to the collection authority. Yet it is also the case that many users would like the opportunity to audit their bill to dispute any fees that they believe to be incorrect. If the collection authority did not have access to the raw travel data, however, it would be unable to provide a detailed accounting of how the fee was computed. There is thus an inherent tension between privacy and auditability. One possible workaround would be to provide a mechanism through which users could download their travel data from the OBU and print out their own detailed report of mileage fees. More generally, however, it is clear that there should be a way for individuals to access their own data and a process for rectifying any mistakes that an individual identifies in the mileage fees.

A second tradeoff pertains to the potential value of detailed travel data in supporting other transportation systems and analyses—either to benefit the specific driver or, more broadly, all travelers. Examples, many of which are also discussed in the context of IntelliDrive, include in-vehicle alerts of downstream traffic incidents, real-time routing assistance, real-time traffic data collection, household travel surveys, speed and throughput studies for specific facilities, and additional intelligent transportation system (ITS) applications (for a more comprehensive list, see Bomberg et al. 2009). If time and location data were not allowed to leave the OBU, many of these additional functions could not be supported.

In the face of such tradeoffs, one could envision a system in which drivers would be presented with several options in terms of privacy vs. data sharing. For example, some devices might be configured to provide maximum privacy, while others might transmit detailed travel data so that the collection authority could regularly provide users with a detailed breakdown of the mileage fees. Additionally, recognizing that detailed travel data provides social value in the context of the applications listed above, a system might be structured such that users willing to share their data—even if only on an anonymous basis—would receive a slight reduction in the per-mile rate in compensation.

In contemplating approaches to privacy protection, it might be helpful to reference several principles for privacy protection set forth in the *Sofia Memorandum*, a set of guidelines on electronic road use pricing produced by the International Working Group on Data Protection in Telecommunications (Grush 2010b, p. 47). These can be summarized as:

- The anonymity of the driver can and should be preserved by using the so-called smart client or anonymous proxy approaches (discussed below) that keep personal data of the drivers under their sole control and do not require off-board location record-keeping.
- Road pricing systems can and should be designed so that the detailed trip data are fully and permanently deleted from the system after the charges have been settled in order to prevent the creation of movement profiles or the potential for function-creep.
- Processing of personal data for other purposes (e.g. pay-as you drive insurance or behavioral-based marketing) should only be possible with clear and unambiguous consent from the individual.
- In terms of enforcement, the system should not ascertain the identity of the driver or owner of a vehicle unless there is evidence that the driver has committed something which is defined as a violation of the road pricing system.

One can interpret the principles in the *Sofia Memorandum* as ensuring the ability to fully protect private travel data for drivers that prefer total anonymity. Yet as suggested in the third bullet, some drivers might still choose or be willing to share more detailed travel information, perhaps stripped of specific driver or vehicle identification, to enable value-added services on the OBU or to provide data to support improved transportation system planning. Such sharing, however, should only be possibly with clear, unambiguous consent from the driver. With these broader issues and potential guidelines in mind, it is now possible to outline the specific privacy protection options that have been evaluated or discussed.

On-Board Data Aggregation / Fee Computation. Under this approach, demonstrated in the Oregon trials, detailed travel data would not be transmitted from the vehicle. Rather, the software on the OBU would aggregate the data, compute the fee, and determine how the fee should be divided among jurisdictions. Only the total fee, and possibly its division among jurisdictions, would then need to be reported to the collection authority (either at the pump or via cellular transmissions, depending on the selected payment mechanism). To further protect privacy under this approach, Forkenbrock and Kuhl (2002) described a two-stage data transmission process: the first message would include the user ID and the total amount owed to facilitate billing; the second message, not tied to any specific user ID, would be anonymously encrypted and only report the division of fees among jurisdictions (this same approach could be used to send more detailed travel data on an anonymous basis to provide real-time traffic information or support subsequent transportation planning analyses). Under this arrangement, the collection authority would not know the jurisdictions in which a specific driver had traveled, but would still be able to apportion fees correctly. To accommodate this form of privacy protection, the OBU would need to maintain detailed information about relevant charge rates, possibly varying by vehicle characteristics, jurisdiction, area, route, and/or time, in order to compute charges owed, and this information might need to be updated (via automated wireless transmission) fairly regularly.

Accordingly, the underlying architecture is sometimes referred to as a "smart" client, a "thick" client, or a "fat" client, as described above in the *Sofia Memorandum*.

Anonymous Proxy Fee Computation. This option, also referenced in the *Sofia Memorandum*, would involve setting up an off-board service—the anonymous proxy—capable of receiving a stream of travel data from a vehicle and computing the corresponding mileage fees. One might think of this as a wirelessly accessible mileage fee calculator (Bomberg et al. 2009). To facilitate the fee calculation and payment process, the vehicle would first stream its travel data to the fee computation service on an *anonymous* basis—hence the name "anonymous" proxy—and the proxy would then send back the computed fee. Next, the OBU would send a message to the collection authority containing the vehicle ID and the total amount owed, based on the anonymous proxy's calculations, to facilitate billing. The collection authority, and in turn the government, would thus never have access to specific travel data tied to a specific user. One advantage of this approach in comparison to on-board fee calculation is that OBUs would not need to be constantly updated with revised fee schedules, as that information would instead be stored on the anonymous proxy. On the negative side, however, detailed travel data would leave the vehicle, introducing some risk of interception by malicious third parties, and a greater volume of wireless communications would be required.

Trusted Third Party. In this concept, detailed travel location data would leave the vehicle but would not be shared with the government. Instead, a private or non-profit entity would, under contract, perform collection services for the government. That entity would receive detailed travel data, compute bills, collect fees, and remit payment to the relevant jurisdictions. Once paid, the detailed travel data underlying each bill would then be deleted (or, alternatively, it could be stripped of vehicle identification information and then preserved for subsequent planning analysis). The logic behind this concept is that our society appears more willing to share sensitive data with private firms than with the government—consider, for example, the nature of the data routinely shared with credit card companies (what we buy, where we buy it from, and how much we spend) and cellular service providers (who we call, how long we talk with them, and where we are located when we place the call). A key distinction, however, is that the use of credit cards and cell phones is entirely voluntary; strictly speaking, driving is also optional, of course, but in many areas the built environment is heavily tilted toward reliance on the automobile. Some might thus view driving (and paying road use fees) as "less" optional than using a cell phone or credit card. It therefore remains to be seen whether this option would be viewed as acceptable among those who place a high premium on privacy and also view driving as a necessity.

Prepaid Debit Cards. As described earlier, one of the principal motivations for including prepaid debit cards as a payment option would be for privacy protection. Specifically, any time that a vehicle's metering device included a debit card with a positive balance, mileage fees would simply be deducted from the debit card; there would be no need to send travel or fee data to the collection authority. Note, however, that if the device transmitted no travel data at all, it would not be possible to apportion fees based on jurisdiction of travel, nor would it be possible to make use of the travel data to determine real-time traffic conditions or support subsequent planning activities. Another option to consider, then, would be to configure the device to transmit detailed travel data, but only on an anonymous basis (because the fees would have been

automatically debited from the card, there would be no need to link the travel data to a specific vehicle or driver ID) and only with the explicit (possibly incentivized) permission of the vehicle owner. This would enable access to the underlying travel data while still protecting driver privacy.

Anonymous User Accounts. Another potential approach to privacy protection would be to allow users to set up anonymous, numbered accounts. This approach has been developed for several conventional electronic tolling systems.

Data Encryption. The preceding privacy strategies are mainly aimed at ensuring that the government is not privy to personal travel information. A related concern is the prevention of unauthorized access to personal data by malicious third parties ("hackers"). This implies that all data transmissions and data repositories should be protected through suitably rigorous forms of data encryption.

Summary of Privacy Protection Mechanisms. Privacy concerns would be most applicable for metering approaches able to determine the location of travel—notably, RFID tolling on a partial road network, an OBU with OBD II and cellular communications, and an OBU with GPS. Table 3.4 summarizes the applicability of the privacy protection approaches for these different metering options, with black dots representing potential metering and privacy protection combinations.

Table 3.4. Applicability of Potential Privacy Protection Mechanisms

Metering Option	On-Board Data Aggregation and Fee Computation	Anonymous Proxy Fee Computation	Trusted Third Party	Prepaid Debit Cards	Anonymous User Accounts	Data Encryption
Self-reported odometer readings	*Privacy not a major concern*					
Required odometer checks	*Privacy not a major concern*					
Optional odometer checks	*Privacy not a major concern*					
Fuel consumption-based estimates	*Privacy not a major concern*					
RFID tolling on a partial road network			●	●	●	●
OBU with OBD II	*Privacy not a major concern*					
OBU with OBD II / cellular	●	●	●	●	●	●
OBU with GPS	●	●	●	●	●	●

3.3. SYSTEM DESIGN AND DEPLOYMENT STRATEGIES

Setting aside for the moment the consideration of specific mechanisms for metering mileage, collecting payment, preventing evasion, and protecting privacy, there are three broader concerns related to implementing and phasing in a system of VMT fees that merit attention. The first is overall system cost, particularly for options that would require the installation of sophisticated metering equipment for each vehicle. Even if one makes the rather aggressive assumption that a GPS-based OBU could be produced at scale for $50 per unit, it would still cost on the order of $12.5 billion to equip the nation's fleet of 250 million vehicles. And that would not include additional costs related to installing the equipment, collecting payment, and preventing evasion. Second, few voters yet understand the motivations for transitioning to VMT fees, and building public acceptance would likely require a lengthy and concerted education and outreach effort. These lead, in turn, to a third concern, which centers on the time required to transition from fuel taxes to a system of VMT fees. Again under an assumption that the adopted approach would require sophisticated in-vehicle devices, cost considerations, along with lingering public skepticism, make it unlikely that decision makers would choose to require that all owners immediately retrofit their vehicles with the necessary metering equipment. A more probable scenario is that decision makers might adopt a strategy for phasing in the metering equipment over time, such as with the purchase of new vehicles. Yet this could result in a very lengthy transition, likely requiring the parallel operation of multiple revenue streams (i.e., fuel taxes and VMT fees) and delaying the potential benefits of a fully integrated VMT-fee system for many years.

This discussion invites consideration of broader design and deployment strategies that might help to address one or more of these interrelated concerns: reducing cost, overcoming acceptance barriers, and speeding the transition to VMT fees. Five concepts in this vein merit attention: the development of an "interoperable" system architecture (also referred to as an "open systems" approach), required retrofits, installation with new vehicles, incentives for voluntary adoption, and a broader emphasis on driver choice. We discuss each in turn.

3.3.1. Interoperability / Open Systems

The basic idea in this concept is to allow multiple firms to compete, on an ongoing basis, for the provision of metering devices and, potentially, collection services so as to drive down system costs and stimulate continued innovation. In prior VMT-fee trials in the United States, as well as in many of the European truck tolling programs, the approach has been to contract with a single firm or consortium for the provision of supporting technology and infrastructure. While this can stimulate competition during the bidding phase, the motivation for continued efforts to innovate and reduce costs is often lost once the contract has been awarded. As a result, such systems can experience technical "lock-in," with little opportunity to take advantage of continued technology advances in order to make the system more efficient over time.

Under an interoperability or open systems approach, the government would not award a massive technology contract to a single bidder. Rather, the government would develop a technical and functional architecture for the system and then allow vendors to compete for market share (e.g., for OBUs and/or for billing services) on the basis of cost and value-added services (potential

value-added services are discussed below in the section on voluntary opt-in strategies). Similar to the cell phone industry, users would be able to select their service providers or to switch from one provider to another.

Such a system would need to include a minimal set of functional requirements—for example, the ability to reliably meter the location of travel at some level of accuracy—as well as a process for certifying devices and services as "compliant." Additionally, it would be necessary to establish a set of data storage and communication protocols to facilitate billing, enforcement (i.e., methods to prevent tampering or "spoofing" payment), and the protection of privacy. The goal would be to foster interoperability among both metering devices and billing services. Such protocols would also need to allow for seamless interaction with existing toll roads in the country (i.e., collection of tolls and payment to tolling authorities). A recent forum hosted by IBTTA (2010) explored many of the issues that would be necessary to address in order to develop an interoperable system.

The term "open systems" has been used in a slightly different context as well. In a recent Transportation Investment Generating Economic Recovery (TIGER) grant application under the American Recovery and Reinvestment Act of 2009 (Whitty 2009b), the Oregon Department of Transportation joined with the New York City Department of Transportation and the District of Columbia Department of Transportation to propose the development and exploration of an OBU with an open operating system that would enable third party developers to design additional applications that could be loaded onto the device—much in the way that third party developers currently create "apps" for various smart phone platforms. Under such an arrangement, users could choose a particular OBU option and then purchase, on an individual basis, additional services that they found appealing. It is not clear, however, that the government should require OBU vendors to create an application programming interface (API) for third party service developers—that is, an open system in this sense of the term. Rather, this is a decision that vendors could choose to pursue, or not, to further their own strategic interests.

Considerable work towards the development interoperability standards for electronic road pricing applications is already underway. For example, the International Standards Organization (ISO) and the European Committee for Standardization (CEN) have recently collaborated to develop standards related to the use of DSRC, GNSS (global navigation satellite systems, including GPS and similar systems launched by other nations), and cellular communications for road pricing applications (the issue of interoperability has received much attention in Europe given the close geographical proximity of European countries and the rapid proliferation of road pricing applications on the continent). The aforementioned IBTTA (2010) report discusses additional interoperability efforts in the area of road pricing in the United States and abroad. In developing the requirements and protocols to support an interoperable system, the United States might begin with the recent ISO/CEN standards as a starting point. It would be helpful, however, to ensure that the resulting requirements and protocols are further tailored such that they could in principle accommodate existing toll operations within the United States and also support related in-vehicle technology development initiatives such as IntelliDrive (the U.S. Department of Transportation's program—formerly known as VII, for vehicle-infrastructure integration—to advance connectivity among vehicles and roadway infrastructure to significantly improve the safety and mobility of the U.S. transportation system).

In considering the interoperability approach, it might be important to ensure that any resulting standards would not preclude the adoption of simpler VMT-fee implementation concepts. For example, a particular state might choose to provide drivers with the choice of installing metering equipment or simply having their odometers read each year. In this case, the standards would logically apply to the metering devices but not to the odometer reading option.

3.3.2. Required Retrofits

The basic idea under this concept would be to require that all vehicles be retrofitted with the necessary metering equipment and then begin to pay VMT fees as of a certain date. With this approach it would not be necessary to maintain parallel revenue mechanisms. Rather, the switch from fuel taxes to VMT fees would occur on the date in question. As already discussed above, cost considerations along with public acceptance barriers make it unlikely that decision makers would opt for this choice for passenger vehicles. It might, however, be a suitable choice for VMT fees applied to commercial vehicles (indeed, recent weight-distance truck tolls in Europe have generally followed this strategy). Within the trucking industry it would be appropriate for all vehicles to begin paying VMT fees at the same time to maintain a level playing field. Additionally, in comparison to passenger vehicles, the higher annual fees that commercial vehicles would typically pay due to heavier weight and greater total travel would more easily justify the cost of installing retrofitted equipment.

3.3.3. Installation with New Vehicles

As an alternative to requiring that all vehicles be retrofitted with metering equipment, another option, discussed in Whitty (2003), would be to require that auto manufacturers, as of a certain model year, begin to install the required metering devices on all new vehicles. Drivers that purchased a new vehicle would then make the transition from paying fuel taxes to VMT fees. At some point, once a majority of vehicles had the necessary metering equipment, any remaining vehicles might be required to install retrofitted metering devices. One of the key motivations for this approach would be to reduce the cost of equipping vehicles. Produced at volume (i.e., for all new vehicles), the cost of the equipment itself could be much lower, and the cost of aftermarket installation would be eliminated. This approach might also reduce the overall cost to government of developing a VMT-fee system, as the metering equipment would be included in the price of new vehicles and therefore paid, by default, by the consumer (although the government might, for political considerations, choose to subsidize the cost of the devices). Though appealing in many ways, this approach would also face drawbacks. First, the vehicle fleet turns over relatively slowly, perhaps over a period of 15 to 20 years (Whitty 2003). The transition period would thus be rather lengthy. Second, the decision to require auto manufacturers to begin installing metering equipment with new vehicles, given the aggregate cost, would only be possible with a clear and unambiguous policy decision to initiate the transition to VMT fees. It would likely take time to build sufficient public support to reach such a decision, and this could further prolong the overall timeframe for planning and transitioning to a system VMT fees. Third, the cost and capabilities of metering equipment and related services have evolved considerably over the past few years, and the rapid pace of innovation is likely to continue. It might thus be viewed as premature to settle on a standardized configuration for all vehicles at this juncture.

3.3.4. Voluntary Opt-In

Voluntary adoption, which has received increasing attention in the past several years, has been proposed as a strategy to overcome some of the potential challenges of transition plans that rely solely on mandatory adoption—most notably political acceptance issues. The basic idea would be to (a) establish a system in which the adoption of mileage metering equipment and payment of mileage-based fees would initially be optional, and (b) create compelling incentives that would motivate drivers to "opt-in" on a voluntary basis. This would make it possible to demonstrate, through the participation of willing adopters, that the system worked as intended—e.g., that it metered mileage with precision, that it generated accurate bills, that it successfully collected revenue, and that it protected user privacy. This might help to assuage the concerns of more skeptical elected officials and members of the public, which in turn could reduce the amount of time required to build enough support to begin mandating the adoption of VMT fees. Note that the voluntary adoption approach need not preclude a decision to require that auto manufacturers begin to install metering equipment on new vehicles as of a certain model year. Even if the equipment were not initially used by many drivers during the opt-in period, it would still reduce the cost of mandating VMT fees at a later date because fewer vehicles would then need to be retrofitted with metering equipment.

The opt-in strategy can be viewed as complementing the interoperability approach described above in the sense that enhanced vendor competition should lead to a broader array of value-added services that might attract voluntary adopters. Incentives for early adoption might include financial savings, greater convenience, and access to desired functionality (see Bomberg et al. 2009, Grush 2009 and 2010d, Grush and Roth 2009, Sorensen et al. 2009, and Whitty 2009a). Many of the specific options—for example, PAYD insurance, real-time routing assistance, and automated payment of parking fees—were discussed earlier in Section 2.3.5. In addition to these previously outlined options, it is also possible that the government could structure VMT fees such that early adopters would save money in relation to other fee options. Possibilities in this vein include:

- **Savings versus current fuel taxes.** Depending on the structure of the fee, some users might save a modest amount of money by paying mileage fees rather than fuel taxes. Vehicles with lower fuel economy, for example, would save money if the mileage fees were relatively flat with respect to fuel economy. Another option would be to offer lower per-mile rates during the voluntary adoption phase.
- **Savings versus current annual fees.** A related option would be to allow early adopters to pay currently fixed fees—for example, state registration fees or the federal heavy vehicle use tax—on a per-mile basis instead (with the per-mile rate set for revenue neutrality based on average expected annual mileage). Under this arrangement, vehicle owners that traveled less than their peers would be able to save by adopting the mileage metering equipment.
- **Savings versus increased taxes and fees.** It would also be possible to increase other taxes and fees to make mileage fees look more attractive in comparison. Imagine, as an extreme example of this concept, setting mileage fee rates to be revenue neutral with current fuel taxes and then doubling fuel taxes. Users would then be presented with the choice of paying twice as much as they currently do for fuel taxes or instead paying (on average) the same as they do now, but in the form of mileage fees rather than fuel taxes. Another option in this

vein would be work with states to institute a new federal registration fee that would be paid alongside state registration fees and then remitted to the federal government. Perhaps framed as an "assumed mileage surcharge," this would be structured as a flat fee based on assumed annual mileage given the vehicle's classification and age. In lieu of paying this flat fee, however, drivers could instead adopt the metering equipment and pay charges by the mile. This would lead to savings for any driver that travels less than the assumed mileage.

Note that while several of these options (e.g., the opportunity to save on VMT fees vs. current fuel taxes) might result in a modest decrease in transportation funding, this loss could be viewed as an investment in speeding the transition to a fully operational VMT-fee system that would ultimately provide a more stable funding stream.

3.3.5. Driver Choice

The preceding strategy focuses on the choice between adopting VMT fees on a voluntary basis or continuing to pay fuel taxes. Taking this one step further, it might be possible to build greater public acceptance for VMT fees if the system is designed, from the start, to offer as many choices for the driver as possible. Potential options might include:

- **Choice of technology vendors and service providers.** As described above, if drivers were allowed to choose among the offering of different firms, those firms would strive to provide compelling and competitively priced options from which to choose.
- **Choice of additional services.** Some drivers might be willing to pay more for a broad range of added services. Others might prefer a simple meter configuration—perhaps subsidized by the government—that only collects VMT fees.
- **Choice of fee structure.** Some drivers, if offered the choice, might choose to pay a flat, but relatively high, per-mile rate based, for example, on an annual odometer reading. Others might choose to install metering equipment capable of determining the time and location of travel, in which case they could qualify for lower per-mile rates for uncongested travel but would pay higher per-mile rates when driving in peak-hour traffic.
- **Choice of payment.** Some drivers might prefer to pay at the pump, while others would prefer to pay via prepaid debit cards or monthly billing. Some might prefer cash, while others would prefer check or credit.
- **Choice of privacy protection.** Some drivers might prefer the highest possible level of privacy protection, even if it would make it more cumbersome to audit their bills. Others might trade some degree of privacy for greater convenience, or might be willing to share their detailed travel data in return for a small discount on mileage fees.

Some potential choices—for example, providing additional payment mechanisms—could be expected to increase the overall cost of developing and operating the system. Yet with careful planning and foresight, it might prove possible to provide at least some choices for the user at relatively low additional cost.

4. IMPLEMENTATION OPTIONS TO EXPLORE IN TRIALS

The previous chapter provided an overview of potential VMT-fee mechanisms and concepts that have been implemented, evaluated, or discussed to date. The goal in this chapter is to outline criteria for identifying which of those concepts appear to offer the greatest promise for a national system of VMT fees (or potentially for systems implemented at the state level) and in turn merit further evaluation in an expanded set of system trials.

Distinguishing the most promising concepts, however, poses several difficulties. Ideally, as suggested by Bomberg et al. (2009) and others, one would start with a set of specific system requirements and then seek out implementation options capable of meeting those requirements in the most cost-effective manner. In fact, though, agreement among policymakers on what a VMT-fee system should look like—for instance, whether the ability to meter mileage by jurisdiction should be viewed as essential or simply desirable—has yet to emerge. Additionally, there is not yet enough information about how much it would cost to implement and operate certain approaches at scale, making it difficult to compare the relative cost-effectiveness of the various alternatives.

The approach taken in this study is as follows. Drawing upon the preceding NCHRP 20-24(69) report (Sorensen et al. 2009) and several related works, we first enumerate and apply a broad set of relevant evaluation criteria—metering capabilities, cost, administrative complexity, ease of enforcement, and the like—to characterize the relative strengths and limitations of alternate implementation options. If such analysis were to identify one or more options without notable weaknesses, the selection of promising options to explore in the trials would be quite simple. In fact, though, all of the options face one or more key limitations. Some, for instance, offer only limited metering flexibility, while others would be very expensive to implement or challenging to administer. As such, any effort to discern the most promising implementation options must inevitably make tradeoffs among the possible criteria of interest.

As a basis for such tradeoffs, we next review recommendations from the NSTIFC (2009) report, which includes a detailed discussion of required and desirable attributes for a national system of VMT fees. While the NSTIFC recommendations do not constitute a national policy consensus, they nonetheless represent the results of a Congressionally-mandated study that drew upon considerable research and outreach with a broad range of stakeholders. By comparing NSTIFC recommendations with the assessed strengths and limitations of the various implementation approaches, it then becomes possible to identify a smaller set of options that would be beneficial to explore in the trials. The analysis also suggests several additional concepts that might be beneficial to examine for other reasons.

4.1. STRENGTHS AND LIMITATIONS OF VMT-FEE IMPLEMENTATION OPTIONS

In seeking to understand and characterize the strengths and limitations of alternate options for implementing VMT fees, it is helpful to consider two sets of criteria. The first focuses on the metering capabilities of the different options, which in turn determine the types of policy goals

that they could support. The second set of criteria includes a broader range of issues that could also affect the desirability of the potential implementation options, including cost, functional considerations, administrative complexity, and user acceptance. The logic of this organization is that if agreement on the types of policies to be supported in a national system of VMT fees were to emerge, one could use the first set of criteria to identify the subset of options capable of supporting the intended policies and then use the second set of criteria to compare the relative strengths and weaknesses of those options (Sorensen et al. 2009).

4.1.1. Metering Capabilities and Support for Policy Goals

Beyond simply providing a more stable source of transportation revenue, as discussed in Chapter 2, there are many additional policy goals that a system of mileage-based road use fees might be designed to address: accurately collecting and apportioning revenue by jurisdiction, helping to reduce emissions, helping to reduce recurrent traffic congestion, helping to reduce excessive road wear, collecting detailed travel data, and providing additional in-vehicle services for the driver. To support these various potential policy goals, a VMT-fee system must be capable of factoring in vehicle characteristics (emissions profile or axle weight), the location of travel (passing a specific charging point or traveling within a jurisdiction, within a smaller area or zone, or along a specific route), and/or the time of travel. The ability of the various metering options to store or determine such information was previously summarized in Table 3.1. Based on this breakdown, as well as the description in Section 2.3 of the potential policy goals a VMT-fee system might be designed to address, it is possible to determine the support offered by different metering options for the policy goals of interest.

This information is presented in Table 4.1. Within this table, a black dot indicates that the metering approach would be capable of supporting the fee structure or policy goal in question. A hollow dot, in turn, indicates conditional or partial support. For example, it might be possible to implement the goal in question only for travel along major routes (with RFID tolling), or through the addition of gantries along major routes to communicate with passing vehicles (with fuel consumption-based estimates and the OBU that only includes a connection to the OBD II port), or through the addition of DSRC on the OBU (for the DSRC-enabled safety features).

Table 4.1. System Capabilities Provided by the Metering Options

Potential System Capabilities	Odometer Options	Fuel Consumption-Based Estimates	RFID Tolling on a Partial Road Network	OBU with OBD II	OBU with OBD II and Cellular	OBU with GPS
Collecting and Apportioning VMT Fees						
Metering all miles of travel	●	●		●	●	●
Metering and apportioning fees by jurisdiction			○		●	●
Distinguishing applicable fees by route			○			●
Structuring Fees to Reflect the Full Cost of Travel						
Facility congestion tolls		○	●	○	○	●
Cordon congestion tolls		○	●	○	●	●
Zone-distance congestion tolls					●	●
Network-wide congestion tolls						●
General emissions fees	●	●	○	●	●	●
Zone-based emissions fees					●	●
General weight-distance truck tolls	●	●	○	●	●	●
Route-specific weight-distance truck tolls						●
Collecting Detailed Travel Data						
Vehicle travel information by route and time						●
Additional Traveler Services or Benefits						
Per-mile payment of fixed annual fees or taxes	●	●		●	●	●
General PAYD insurance	●	●		●	●	●
Location-based PAYD insurance					●	●
Automated payment of parking fees						●
Automated payment of tolls			●	●	●	●
Automated payment of weight-distance truck tolls					●	●
Location-dependent travel services						●
Media services				○	●	●
Location-dependent safety features						●
DSRC-enabled safety features				○	○	○

Reviewing the entries in Table 4.1, one can see that the GPS-based option provides the greatest flexibility. It is the only option capable of distinguishing applicable fees by route (for example, excluding the assessment of VMT fees for travel on private roads), implementing network-wide congestion tolls, implementing route-specific weight-distance truck tolls, enabling the automated payment of parking fees, or providing location-dependent safety features. The OBU with OBD II and cellular also provides a significant degree of flexibility. At the other end of the spectrum, the odometer options provide relatively few capabilities. The remaining options fall somewhere between these endpoints.

4.1.2. Additional Evaluation Criteria

Beyond the ability to support various policy goals, there are many additional criteria that could influence the desirability of alternate implementation options. For example, how much would the system cost to implement and operate? How difficult would it be to administer? Would it create privacy concerns, making it hard to gain public acceptance? The list of criteria presented below draws upon the previous NCHRP 20-24(69) study (Sorensen et al. 2009) as well as a recent study by Whitty and Svadlenak (2009). The criteria can be divided into four categories, as follows:

Implementation cost

- In-vehicle technology cost
- Supporting infrastructure cost
- Collections cost
- Preventing evasion / enforcement cost

Functional considerations

- Technical reliability
- Ease of enforcement
- Flexibility / extensibility
- Integration with other systems
- Accounting for all vehicle types
- Accounting for foreign vehicles
- Ability to manage transition
- Overall system risk

Institutional considerations

- Administrative complexity / required state support
- Legal barriers

User acceptability

- Burden on individual drivers
- Burden on private sector
- Ability to audit charges
- Privacy concerns

The previous NCHRP 20-24(69) study evaluated the different implementation options with respect to these criteria from the perspective of implementing a national system of VMT fees. In many cases, however, and particularly in the area of implementation costs, available data did not support definitive estimates or judgments. Even so, the analysis clearly indicated that *all* of the potential implementation options face at least some important obstacles. Table 4.2, adapted from a recent presentation by Sorensen and Ecola (2010), summarizes some of the key limitations that confront the various implementation options; a hollow dot indicates a potential limitation, a black dot indicates a known limitation, and gray shading indicates that further research would be helpful to quantify the issue. Note that several limitations for the odometer options stem from the fact that not all states currently conduct routine vehicle inspections, problematic from the perspective of designing a national system. If VMT fees were implemented in a single state that already inspected vehicles, rather than at the national level, then the odometer options could be much less expensive to administer.

Table 4.2. Key Limitations Faced By VMT-Fee Metering Concepts

Metering Approach	Tough to Enforce	Extensive Required State Support	Burden on Users	Privacy Concerns	Vehicle Equipment Cost	Other Capital & Operating Costs
Self-reported odometer readings	●	●				
Required odometer checks		●	●			●
Optional odometer checks		●				●
Fuel consumption-based estimates				○		●
RFID tolling on partial road network				●		●
OBU with OBD II	○				●	●
OBU with OBD II / cellular	○			○	●	●
OBU with GPS	○			●	●	●

4.2. NSTIFC RECOMMENDATIONS

After concluding that VMT fees represented a promising revenue option to pursue, the NSTIFC (2009) further specified the set of attributes that a system of VMT fees should provide. As described in the chapter opening, these can be applied as criteria to assist in distinguishing the most promising VMT fee implementation to examine within the trials. The Commission categorized their recommendations in terms of pricing capabilities, general attributes, and technical characteristics. These can be summarized (in condensed and slightly reordered fashion) as follows.

4.2.1. Pricing Capabilities

The Commission recommended that VMT fees should be able to serve as a single mechanism to be used for all transportation taxation and pricing. Specifically, such a system should be able to collect and properly apportion revenue for:

- Federal, state, and local VMT fees
- Public and private toll road charges
- Congestion pricing and managed lanes applications at the state and local level as desired
- Emissions charges, if not handled through other means
- Charges on heavy vehicles, possibly based on axle weight
- Transit fares via "mobile commerce" technology (e.g., smart cards and mobile phones) that could be integrated with in-vehicle VMT-fee technology

4.2.2. General Attributes

Additionally, the Commission recommended that a national VMT-fee system should:

- Be reliable, secure, and enforceable, and protect against identity theft
- Permit the efficient transfer of revenue among the federal government, states, local jurisdictions, and private service providers
- Provide travelers and commercial vehicle operators with information on applicable rates through a combination of roadway signage, in-vehicle devices, and the Internet
- Provide a means for preserving privacy and allow for anonymous operations for motorists desiring such protection; options include cash or cash card payment methods that separate use reporting from payer identity, limiting the amount or type of information collected, encrypting the information, or combining these approaches
- Maximize cost-effectiveness, with the goal of reducing annual net operating costs to less than 10 percent of revenue within a few years of implementation and less than 5 percent in the longer run
- Ensure that users, during the phase-in period, would not be required to simultaneously pay VMT fees and fuel taxes (unless a portion of fuel taxes were converted to "carbon taxes," in which case a user would either pay VMT fees plus the carbon tax component or fuel taxes that incorporate both the carbon tax and user fee components)

4.2.3. Additional Technical Characteristics

Finally, the Commission recommended that the technical design of the system should:

- Accommodate multiple forms of payment
- Facilitate integration with future ITS-related applications, including traveler information systems and vehicle-infrastructure integration programs (e.g., IntelliDrive), as well as with existing GPS-based navigation products

- Allow for (and eventually require) the metering equipment to be pre-installed with new vehicles and to be retrofitted for existing vehicles
- Rely on federal technical standards that would govern the design of any metering equipment provided by states, localities, or private operators or firms

4.3. PROMISING OPTIONS FOR FURTHER EVALUATION VIA TRIALS

Comparing the NSTIFC recommendations with the identified strengths and limitations of the various implementation mechanisms leads to a promising set of options for further exploration in the trials. In addition to describing the options that stem directly from the recommendations of the NSTIFC, this section also identifies several additional implementation approaches that might be beneficial to examine for other reasons. It is not argued, though, that the trials should seek to examine *all* of the options listed below. A competing objective of interest could be to keep the trials relatively simple to facilitate greater public understanding of VMT fees, and this might argue for examining a smaller subset of implementation options. In any event, the options listed below exhibit sufficient promise to merit consideration for inclusion in the trials.

4.3.1. Metering Mechanisms

Based on the NSTIFC recommendations, a single metering option emerges as most promising:

- **OBU with GPS.** Only the GPS-based OBU option offers sufficient metering flexibility to easily accommodate all of the pricing capabilities related to vehicle travel recommended by the Commission. Additionally, this metering platform provides the greatest opportunities for developing value-added functionality in support of the voluntary opt-in strategy.

In addition to the GPS option, there are several additional metering approaches that might merit consideration in the trials for other reasons. These include:

- **OBU with OBD II and cellular.** Though this option is not able to provide all of the pricing capabilities called for in the NSTIFC report, it can in theory handle most of them, including several forms of congestion tolling. Perhaps the most important form of pricing that the option would not be able to support is truck tolls that vary with distance, axle-weight, and road class. Yet one could envision a system in which trucks were required to install GPS-based equipment for this purpose but passenger cars were allowed to install somewhat less precise metering equipment. This could be beneficial in the sense that there are far more passenger cars than trucks, and this configuration is likely to prove cheaper to manufacture and install than GPS equipment. It should also be noted that while this approach has been developed in concept, it has yet to be demonstrated in practice. This represents another motivation for including an OBU with OBD II and cellular communications in the expanded system trials.
- **Fuel consumption-based estimates.** If there were interest in exploring the concept of adopting an interim VMT-fee solution to be replaced, over time, with a more advanced system, and if pay-at-the-pump were considered as a viable option for collecting fees, then it would be beneficial to explore this metering concept in the trials. One possibility to consider is the idea of *emulating* fuel consumption-based estimates using more advanced metering

equipment. That is, instead of developing separate AVI devices that were only capable of providing vehicle identification and/or fuel economy information, the trials could include more advanced OBUs (i.e., OBUs with GPS or with cellular location) that were also capable of providing the information that would be expected from the AVI. A subset of participants in the trials would then use these OBUs in their intended fashion (i.e., metering mileage by location), while another subset would use these to emulate fuel consumption-based estimates. This would reduce the number of metering configurations that would need to be developed for the trials while simultaneously allowing the exploration of such issues as how the fuel consumption-based estimates compared to actual metered mileage, and how drivers responded to this concept in practice.

- **RFID tolling on a partial road network.** While the principal aim of the trials would be to explore alternate VMT-fee implementation approaches, the government might also wish to consider RFID tolling on major roads as an alternative to VMT fees. Yet it would not make sense to conduct a separate set of RFID tolling trials. To begin with, the technology for RFID tolling is already in wide use and well understood. Additionally, it would be necessary to install numerous gantries, at great expense, that might or might not be used after the trials had been completed. Here again, however, it might be possible to emulate RFID tolling within an expanded set of VMT trials. To achieve this, a subset of the trial participants with OBUs capable of metering the specific route of travel could be designated to evaluate the concept of RFID tolling on a partial road network. Rather than being subject to per-mile charges across all roads, these participants would instead be assessed fees when they passed designated charging points (i.e., virtual gantries) on major roads. Such a test design would help evaluate participant perceptions of the RFID tolling approach as well as driver responses to this form of pricing—e.g., the extent to which drivers would divert from tolled roads to untolled roads to avoid charges.
- **Odometer-based metering options.** From the perspective of developing a national system of VMT fees, reliance on odometer readings would prove problematic given that not all states currently conduct annual vehicle inspections. If the trials were intended to help individual states develop their own VMT-fee systems, however, then an annual odometer inspection might prove to be a relatively low-cost implementation option—perhaps one of several options that might be examined—in a state that already inspects all vehicles on a routine basis.

Finally, note that the trials need not be strictly limited to the technical approaches listed above. Consistent with the open systems philosophy, it would be reasonable to include any potential configuration that meets some defined set of requirements (e.g., metering capabilities, ability to support specified billing and enforcement approaches, and the like). For example, one vendor might develop an application that resides on a driver's smart phone, while another might create a device that couples with a driver's existing in-vehicle navigation system. In a competitive market it is simply difficult to predict what forms of innovation might arise, and there is no sense, especially in a trial setting, in limiting the types of options that might be evaluated provided that they are capable of meeting the specified requirements. To support the inclusion of multiple metering configurations within the trials, there would need to be a government-sponsored process for certifying that the equipment meets applicable technical requirements.

4.3.2. Payment Mechanisms

The Commission's recommendations explicitly call for accommodating multiple forms of payment. Options that would be beneficial to examine in the trials include:

- **Pay-at-the-pump.** This payment mechanism would be required for fuel consumption-based estimates and optional for any of the OBU options. Available estimates also suggest that this would be less expensive to implement and administer than transmitting data to a separate collection authority, though this proposition merits further study. Drawbacks include the need to install equipment at all fuel stations, to dramatically expand the current fuel tax collection system to include retailers, and to develop a parallel payment system for vehicles that do not purchase gas or diesel.
- **Transmission to collection authority.** In contrast to pay-at-the-pump, this option could support all types of vehicles, and it has received considerable attention as a potential payment mechanism. The main drawback pertains to the potential cost, and further evaluation of this issue would be helpful. There are also uncertainties regarding the most appropriate institutional structuring for such a system. Should the collection authority be publicly or privately administered? Should there be a single collection authority or multiple authorities operating in parallel?
- **Prepaid debit cards.** While it is not clear that this option would make sense as the *sole* payment option, it could be valuable to provide as one of several options. First, it would provide a means of anonymous payment for those concerned with maintaining absolute privacy. Second, it would provide a payment channel for the segment of the population that relies primarily on cash payments. Third, it could be designed to accommodate the payment of transit fares as well.

Depending on the structure and intent of the trials, one additional payment mechanism might be examined:

- **Payment with registration.** If the trials envisioned state-level implementation and included the evaluation of odometer-based metering approaches, as described above, then it might also be appropriate to examine payment with vehicle registration.

The NSTIFC recommendations also call attention to the issue of ensuring that those who pay mileage fees should not also be required to pay fuel taxes during the phase-in period. Fuel taxes would be automatically debited in the pay-at-the-pump model, but the best means of reimbursing fuel taxes for the other payment options is less clear and merits further attention. The fuel purchase card system suggested by Donath et al. (2009) would be one option to consider.

4.3.3. Mechanisms for Preventing Evasion

The NSTIFC report highlighted the importance of effective enforcement but was not specific with regard to preferred mechanisms. This would suggest that all viable options be explored in the trials. To help reduce system costs, heightened attention might be devoted to mechanisms that would help to automate the enforcement process:

- Fuel consumption redundancy checks (for pay-at-the-pump payment option)

- External DSRC/ANPR checks
- Device heartbeat signals
- Device distress signals

In the event that these could not be demonstrated as effective, in might prove necessary to rely on options that require a greater degree of manual intervention:

- Odometer redundancy checks
- Metering equipment inspections

4.3.4. Mechanisms for Protecting Privacy

The NSTIFIC recommendations also stress the importance of providing strong privacy protection for motorists that desire such functionality. While report notes several specific mechanisms, the importance of privacy as a public acceptance issue suggests the benefits of evaluating all potentially promising options—and in particular, seeking to gauge drivers' perceptions of these options. Potential options for shielding sensitive travel data, shielding the driver's identification, and/or protecting against malicious data access include:

- On-board data aggregation and fee computation
- Anonymous proxy fee computation
- Trusted third party
- Anonymous user accounts
- Data encryption

4.4.5. Broader Implementation and Phase-In Strategies

Finally, the NSTIFC report lends support, either explicitly or implicitly, for examining within the trials several of the broader concepts for implementing and transitioning to VMT fees:

- **Interoperability / Open Systems.** Following the logic of interoperability, multiple vendors might be encouraged to participate—through the provision of metering devices and possibly billing services—in the trials. This means, for example, that different participants within the same trials could be using metering devices provided by different vendors. To facilitate this approach, an important early task would be to develop an initial set of technical requirements for the trials along with a government-sponsored certification process to ensure that all devices met the required standards.
- **Required retrofits.** If the trials were to involve the use of in-vehicle metering equipment (i.e., any of the OBU options), this concept would be examined by default. That is, any of the devices used in the trials would have to be retrofitted.
- **Installation with new vehicles.** There would not be a way to easily examine this strategy in the trials—that is, to induce auto manufacturers to begin providing standardized metering equipment within their vehicles simply to support the trials. That said, it might be helpful to

consider, within the context of the trials, whether the various metering configurations examined in the trials could later be provided as standard equipment in new vehicles.

- **Voluntary Opt-In.** The trials would provide a valuable opportunity to test some of the incentives that might encourage voluntary adoption as an initial transition strategy once the actual system commences (while the NSTIFC report did not specifically recommend the voluntary adoption concept, it did mention various value-added features that might support this approach). As noted, many of the potential incentives—for example, the opportunity to purchase PAYD insurance or to automate the payment of parking fees—fall outside of the control of the federal government. This means that in setting up the trials, it would be helpful to enroll the participation of a broad range of third parties—including technology providers and software developers, insurance companies, and state and local governments—that might play a role in providing such incentives.
- **Driver Choice.** Potential dimensions of user choice to explore in the trials, as discussed in the preceding chapter and suggested in some of the NSTIFC recommendations, include choice of devices and service providers, choice of value-added services, choice of fee structures, choice of payment mode, and choice of privacy levels.

5. ADDITIONAL ISSUES TO EXAMINE IN THE TRIALS

The preceding chapters in this report outlined the policy objectives that might be addressed by a system of VMT fees, identified and characterized technical mechanisms and design strategies for implementing and deploying VMT fees, and applied criteria from NSTIFC (2009) to discern promising options to examine in the context of expanded system trials. The report now considers a broader range of questions related to the scope and structure for the trials. First, in addition to specific technical approaches, what additional issues or uncertainties (e.g., cost, user acceptance, institutional structure) would be beneficial to explore in the trials? Second, how might the trials be organized and structured to resolve these issues and uncertainties in order to inform debate and prepare for the potential implementation of VMT fees?

This chapter begins by cataloging the many issues and uncertainties related to VMT fees that could be helpful to address. Next, it considers which of these could be explored or resolved in the context of system trials. Finally, it discusses the process employed by the research team, including interviews and a one-day expert workshop, to solicit input from subject matter experts and stakeholders on how to design and organize the trials to address the critical issues and uncertainties. Chapter 6 outlines high-level strategic observations that emerged from the interviews and workshop, while Chapter 7 summarizes more detailed findings.

5.1. ISSUES AND UNCERTAINTIES TO RESOLVE

Implementing and transitioning to a system of VMT fees would present a high degree of technical, institutional, and political complexity. While the trials conducted to date (see, for example, Kuhl 2007, ODOT 2010, PSRC 2008, and Whitty 2007) have explored various fee structures and metering and collection mechanisms, numerous issues have yet to be addressed. Some, such as the cost of certain implementation mechanisms implemented at scale, would require further investigation; others, such as the types of pricing structures that the system should be able to support, could be resolved through policy decisions. Remaining uncertainties can be organized in the following categories: system requirements, technical approaches, institutional arrangements, implementation and transition strategies, user acceptance, and system cost. Clearly many of these are interrelated, and there is some inevitable overlap among the categories. For example, the choice of technology might affect both user acceptance and system cost. Still, it is helpful to lay the issues out in a systematic fashion to the extent possible.

5.1.1. Broad System Requirements

Lack of agreement among policymakers regarding required capabilities would hinder the ability to determine an appropriate design for a VMT-fee system. Key issues to resolve would include:

- **Metering capabilities.** The intent to support a given set of pricing policies implies a required set of metering capabilities—for example, the ability to meter mileage by jurisdiction, by smaller area, by specific route, and/or by time—and this in turn might constrain the set of implementation mechanisms that could be considered.

- **Applicable classes of vehicles.** In terms of vehicle classes, one question to resolve is whether the system would apply to passenger vehicles, to trucks, or to both. Another is whether the system would only apply to new vehicles or if instead it would be necessary to retrofit older vehicles with metering equipment.
- **Geographic scope.** It remains unclear whether a system of VMT fees would initially be implemented at the federal level, with states having the option to make use of the system if they wish, or would instead be implemented only in certain states to begin with.
- **Accuracy.** The required level of accuracy for metering mileage (e.g., ensuring that mileage recorded along a particular route did in fact occur along that route) and assessing fees would need to be specified.
- **Privacy.** Various degrees of privacy protection could be provided within the system, ranging from reasonable expectations of confidentiality to total anonymity. The question of which levels of privacy protection the system would need to support has yet to be determined.
- **Payment.** Another requirement to consider is which forms of payment—e.g., credit, cash, or check—the system should facilitate, an important question to consider given that not all drivers have bank accounts or credit cards.
- **Interoperability.** Interoperability standards could be employed to facilitate interactions among VMT-fee systems in different states or to enable multiple vendors to compete for the provision of metering devices and billing services. The question is whether interoperability would be viewed as a desirable goal or an absolute requirement for the system.
- **Complementary functions.** Another issue to consider in specifying requirements for the system is whether the in-vehicle metering equipment would be designed solely to support VMT fees or instead might support additional driver services.

5.1.2. Technical Implementation

Likewise there would be numerous options to consider in terms of technical implementation. Some of the uncertainties would relate to system design decisions, while others might be more dependent on cost considerations. Issues to be resolved would include:

- **Metering.** Relevant questions include which technical configuration(s) should be employed to meter mileage, potentially including the time and location of travel, and whether drivers should have the opportunity to choose among different metering devices.
- **Collection.** As with metering, decisions would need to be made about which mechanism(s) would be used to collect mileage fees and whether drivers would have the option of choosing among alternate payment channels.
- **Preventing evasion.** There is still considerable uncertainty about which methods for preventing evasion would provide the best tradeoff between the cost and effectiveness of enforcement.
- **Privacy.** As with metering and collection, questions include which specific options would be employed to protect privacy and whether drivers could choose among multiple options.

- **Data security.** The design of a VMT-fee system should be secure—that is, it should not be possible for malicious third parties to gain access to potentially sensitive data. Nor should it be possible to gain remote access to vehicle controls (e.g. braking or acceleration) via the on-board device (see Koscher et al. 2010). Data encryption and firewalls would obviously play an integral role in helping to secure the system, but specific details of the security structure would need to be resolved.
- **Interoperability standards.** If the goal of interoperability were pursued, the specific content and form of the standards would need to be determined.

5.1.3. Public and Private Institutional Arrangements

Issues surrounding the institutional structuring of VMT fees would face perhaps the greatest degree of uncertainty. Crucial decisions to address would include:

- **Provision of metering technology.** An important question to consider is whether a single firm should be engaged to provide the metering technology or multiple firms should instead be allowed to compete. Both approaches have been employed in prior road-pricing programs.
- **Provision of collection services.** Another issue to resolve would be the institutional roles in collecting and apportioning mileage fee revenue and managing accounts. Fees might be collected by the government, by a joint powers authority, by a not-for-profit entity, by a single firm or consortium, or by multiple firms in competition with one another. If fees were collected by the private sector, it would also be necessary to determine how to structure the interaction with federal, state, and local revenue agencies.
- **Default public metering/payment option.** If multiple firms were allowed to compete for the provision of metering equipment and billing services, likely on the basis of cost and value-added services, another question to consider is whether the government should also provide a default metering and payment option—either as a minimum cost option for drivers not interested in additional in-vehicle functionality beyond the payment of VMT fees or as a hedge in case the private sector failed to deliver acceptable options.
- **Enforcement of federal VMT fees.** The enforcement function would fall in the public domain, requiring the intervention of sworn law officers and the courts to prosecute those who sought to evade fees. For VMT fees implemented at the state level, state and local agencies would likely be engaged to help enforce the system. It is less, clear, however, how the enforcement of federal VMT fees would be structured, particularly in a state that had not chosen to levy its own VMT fees.
- **Vendor certification.** Under the assumption that multiple firms competed for the provision of metering equipment and billing services, there would need to be a process for certifying that their equipment and services meet minimum quality standards. It is unclear who should be involved in managing the certifications process, or what form the process should take.
- **Development of interoperability standards.** Should the decision be made to develop interoperability standards, it would be necessary to specify which organizations should be involved in managing or participating in the development and how the process should be structured.

- **Support and maintenance for the "price map."** In an advanced system of VMT fees, one could imagine the application of different per-mile rates in different jurisdictions, in different local areas, on different routes, and at different times of day. If the system also handled such functions as the automated payment of existing tolls or parking fees, additional rate data would need to be stored. The resulting database of price information could be massive and might need to be updated on a regular basis (e.g., each time a city changed its parking rates or a toll road operator updated the rate schedule). Questions to be addressed include what entity, new or existing, should manage the price map, and through what processes the price map should be updated?
- **Pricing guidelines.** In the case of a federally implemented system that also supports state and local VMT fees, it is possible that a state or local jurisdiction could levy exorbitant per-mile fees on stretches of highway that primarily serve non-local traffic. The question, then, is what types of constraints should be imposed on the type or level of fees that could be levied by states or local jurisdictions. This issue has also arisen in the context of traditional tolls.

5.1.4. Additional Implementation and Transition Issues

Several additional issues related to implementing and transitioning to a full-scale VMT-fee system would also need to be addressed:

- **Phase-in timeframe.** In planning the transition from fuel taxes to VMT fees, an important question is whether the system should be deployed all at once or phased in over time. Given the likely cost and complexity of the system, a gradual phase-in appears more likely, for passenger vehicles at least. For commercial vehicles, one could envision a transition that occurs for all trucks on the same date; the European weight-distance truck tolls have been implemented in this fashion.
- **Mandatory vs. voluntary adoption.** Assuming that the system would be phased in over a period of multiple years, another issue to determine is whether the initial adoption process would be mandatory (e.g., with the purchase of new vehicles) or optional (i.e., providing an initial period of voluntary adoption for several years before instituting mandatory adoption at a later date). A related question is whether the adoption of VMT fees might be mandated for some classes of vehicles (e.g., electric-powered cars not subject to fuel taxes) and optional for others (e.g., conventional gas-powered vehicles)?
- **Augmenting vs. replacing fuel taxes.** Another important transition issue is whether the system would be intended to augment or to replace fuel taxes. If the latter, and if it were envisioned that the system would be phased in over time, then it would be necessary to determine some mechanism for rebating fuel taxes to early adopters. Depending on the technical configuration of the system (specifically, whether the pay-at-the-pump collection mechanism were implemented), rebating fuel taxes could represent a significant challenge.
- **Charging foreign vehicles.** In the context of a national VMT-fee system, another question to resolve would be how to charge foreign vehicles (e.g. a vehicle visiting the United States from Canada or Mexico) for road use. If VMT fees were implemented at the state level, a similar question would arise with respect to charging drivers from other states.

5.1.5. System Cost

A system of VMT fees would almost certainly cost more to implement and administer than fuel taxes. The question is, just how much more? Key cost issues to resolve would include:

- **In-vehicle metering equipment costs.** Questions include how much it would cost to produce and install various metering configurations at scale, and how the cost might vary depending on whether the equipment were installed by the auto manufacturer or supplied by a third-party vendor.
- **Additional capital costs.** Another uncertainty is how much it would cost to acquire and deploy any additional infrastructure required to support the VMT-fee system (e.g., electronic readers at fuel stations to support fee collection or integrated cameras and readers located throughout the road network to support enforcement activities) within a state or across the nation.
- **Collection costs.** The cost of assessing fees and collecting payment under the alternate collection mechanisms would be a critical question to address.
- **Enforcement costs.** A better understanding of how much would it cost to prevent evasion under the alternative approaches, and to what extent might this be offset by violation fines, would also be valuable.
- **Cost sharing.** If the system encompassed additional paid services—for example, PAYD insurance, the payment of parking fees, and user fees for other value-added functions—it is possible that the cost to the federal or state government of equipping vehicles and collecting VMT fees could be reduced. It is not certain, however, whether such savings would in fact materialize or how significant the savings might be.

5.1.6. User Acceptance

The final category of questions to address, and likely the most crucial in terms of political feasibility, would involve user acceptance. Unresolved issues in this vein would include:

- **Support for VMT fees.** At present there is little public support for transitioning to VMT fees, in large part because not many citizens understand the shortfalls of continued reliance on fuel taxes, or the potential benefits of VMT fees. An important question is whether it would be possible to garner broader support through concerted education and outreach efforts. Related to this question is the observation from many prior road pricing programs that, while voters are often initially reluctant to change, support tends to increase once a program has been implemented and its benefits become more tangible.
- **Support for alternate pricing structures.** Another uncertainty is how the application of alternate fee structures—for example, reducing the fees for lower emissions vehicles or charging more to travel in congested areas during peak periods—might either enhance or undermine support for a system of VMT fees, taking into consideration relevant equity concerns.
- **Privacy concerns.** Though there are several effective means for protecting privacy, many in the public continue to view VMT fees, and in particular the use of GPS-based metering

equipment, as a significant threat to their privacy. It remains to be determined whether such concerns could be overcome through increased education and understanding of the system.

- **Value-added features.** Many proponents have argued that drivers would be more supportive of VMT fees if the required metering equipment could also be leveraged to provide a range of value-added features. It is unclear, however, whether this argument holds merit, or which among the many possible value-added features would be of greatest interest to drivers.

5.2. ROLE OF TRIALS IN RESOLVING ISSUES AND UNCERTAINTIES

As discussed earlier, the preceding NCHRP 20-24(69) report outlined five sets of activities that could help resolve remaining uncertainties during the next authorization to inform policy debate and assist in planning and preparing for a potential transition to VMT fees—planning and policy guidance, analytic studies, technical R&D, expanded system trials, and education and outreach. The intent in this study is to focus mainly on just one of these areas: system trials. The next step in the methodology thus involves considering which of the issues outlined above might be resolved or at least partially illuminated through system trials.

Table 5.1 summarizes the judgments of the authors—informed by prior trials, studies, and discussions with other experts—regarding the activities that could prove helpful in resolving remaining questions and uncertainties. For any given issue (shown in the left-most column), hollow dots indicate the activities (shown in columns two through six) likely to prove helpful or essential in resolving the question; black dots indicate cases in which it would be valuable to receive planning and policy guidance in advance of the trials (e.g., specifying a set of metering capabilities to be supported within the system would help guide the selection of metering mechanisms to examine in the trials).

Table 5.1. Resolving System Design and Implementation Uncertainties

Category / Issue	Means of Exploring or Resolving				
	Planning & Policy	Analytic Studies	Technical R&D	System Trials	Education & Outreach
System Requirements					
Metering capabilities	●			○	○
Vehicle classes	●			○	
Geographic scope	●			○	
Accuracy	●			○	
Privacy	●			○	○
Payment	●			○	
Interoperability	●			○	
Complementary functions	●			○	
Technical Implementation					
Metering	○	○	○	○	○
Collection	○	○	○	○	○
Enforcement	○	○	○	○	○
Privacy	○	○	○	○	○
Data security			○	○	
Interoperability standards	●			○	
Institutional Arrangements					
Provision of metering tech.	○	○		○	
Provision of billing services	○	○		○	
Default public option	○	○		○	
Federal fee enforcement	○	○		○	
Vendor certification	○	○		○	
Standards development	○	○		○	
Price map maintenance	○	○		○	
Pricing guidelines	○				
Implementation and Transition					
Phase-in timeframe	○			○	
Mandatory vs. opt-in	●			○	
Augment vs. replace fuel taxes	●	○	○	○	
Charging foreign vehicles	○			○	
System Cost					
Metering equipment		○		○	
Supporting infrastructure		○		○	
Collection		○		○	
Enforcement		○		○	
Cost sharing		○		○	
User Acceptance					
VMT fees				○	○
Alternate fee structures				○	○
Privacy concerns				○	○
Value-added features				○	○

There are at least two important observations to make from the entries in Table 5.1. First, there are circles in the "system trials" column for almost all of the rows. This suggests that the trials, if intelligently structured, could prove enormously helpful in providing the necessary information and experience to inform policy debate and prepare for possible implementation. Second, there are also circles in the "planning and policy" column for many of the rows. This is because relatively few of the issues to be addressed would have unambiguously correct answers. In most cases there would be multiple possibilities, each with its relative strengths and limitations. In this context, trials could help clarify the tradeoffs, but the resolution would ultimately rely on the deliberation and judgment of policymakers and planners.

5.3. GATHERING PERSPECTIVES ON SCOPING AND STRUCTURING TRIALS

With these two observations in mind, the next question is how to design a set of system trials to be as productive as possible. Our approach, as described earlier, was to outline a detailed set of relevant questions, solicit the ideas and perspectives of stakeholders and subject matter experts through a series of interviews, present preliminary findings and further explore the issues in a subsequent workshop, and then synthesize and interpret the findings.

5.3.1. Interview Questions

The questions posed during the interviews were intended to probe two related issues. First, of the many issues and uncertainties that system trials might be designed to address, which would be the most crucial? Second, how might the trials be scoped, funded, overseen, managed, and conducted to gain sufficient insight for the most crucial questions? Appendix B provides the interview guide that was distributed to interview participants, including a brief introduction to the project along with a lengthy set of detailed questions. The content of the questions can be organized and summarized as follows:

- **Broad policy considerations.** What potential policy goals should be considered in the trials? Which road user groups should be included?
- **Scale, geographic coverage, and duration.** How large should the trials be, and how long should they last? How many states should participate in the trials?
- **Specific goals of the trials.** What would be the most important technical, institutional, transitional, and user acceptance issues to examine in the trials?
- **Leadership roles and stakeholder participation.** Who should organize and oversee the trial program, and how should stakeholder input into the design of trials be incorporated?
- **Organization and management of the trials.** Should the trials be centrally organized and carefully coordinated to achieve particular outcomes, or should there be multiple independent trials to examine a broader range of potentially fruitful variations? Who should be eligible to conduct individual trials?
- **Funding allocation.** Through what program (new or existing) should the trials be funded? Should the federal government fully fund the trials or look for matching funds? On what basis should funding decisions be made?

- **State and local involvement.** What would be the appropriate role for various state and local agencies in conducting the trials? Under what circumstances would enabling state legislation be required to participate in the trials?
- **Private sector involvement.** How could the trials be structured to encourage multiple vendors to participate in the development and provision of competing metering and collection options? Would there be a role for auto insurers (pay-as-you-drive insurance), for auto manufacturers, or for other data-related service providers?
- **Trial participants.** How might individual drivers be enticed to participate in the trials? Should particular user groups be targeted for inclusion in the trials? What educational and outreach activities should accompany participation in the trials?
- **Cost estimates.** Based on prior VMT-fee system trials that have already been conducted or are underway, is it possible to estimate, at least roughly, the amount of funding that would be needed to support the trials?
- **Detailed structure.** What standards (e.g., for communications protocols) might be developed to facilitate the participation of multiple vendors? How might the trials address such issues as the accuracy of metering equipment and billing statements, the effectiveness of enforcement mechanisms and auditing, issues that might arise when phasing in a new VMT-fee system, and options for collecting road use charges from foreign visitors traveling in their own vehicles?
- **Other.** Would it be valuable to examine any additional issues in the trials?

5.3.2. Participation in the Interviews and Workshop

Legislating, implementing, and operating a system of VMT fees would require the participation and support of elected officials and agencies at various levels of governance along with the private sector. Additionally, many stakeholder and advocacy groups would have a strong interest in the design and structuring of such a system. It was therefore important to include a broad range of entities and actors within the interviews and workshop. Specific agencies or groups that we sought to involve include:

- U.S. Congressional staff
- U.S. Department of Transportation (U.S. DOT)
- Federal Highway Administration (FHWA)
- Research and Innovative Technology Administration (RITA)
- U.S. Department of the Treasury (Treasury)
- Internal Revenue Service (IRS)
- State legislative staff and the National Conference of State Legislatures (NCSL)
- State departments of transportation (DOTs) and the American Association of State Highway and Transportation Officials (AASHTO)

- State motor vehicle administrations (MVAs) / departments of motor vehicles (DMVs) and the American Association of Motor Vehicle Administrators (AAMVA)
- Metropolitan planning organizations (MPOs) and the Association of Metropolitan Planning Organizations (AMPO)
- Technology providers, system integrators, and tolling system operators
- Automobile insurance companies
- Stakeholders (e.g., road user groups, environmental advocates)
- Subject matter experts and policy thought leaders
- Managers of related road pricing trials and programs

Perhaps the only notable group not included in the interviews and workshop was automobile manufacturers, which might someday either choose or be required to install metering equipment with new vehicles. Yet most of the individuals with whom we spoke during the project viewed it as unlikely that such firms would voluntarily participate in the trials, for two reasons. First, they would likely be reluctant to become associated with new and potentially controversial forms of fees or taxation. Second, the technology for metering mileage is evolving so rapidly that auto manufacturers would be inclined to wait some time before choosing to provide standardized equipment in their vehicles.

As indicated above, the initial set of interview questions covered a broad set of considerations in great detail, and relatively few individuals would be expected to have the background to offer meaningful answers to all of the questions. Most of the interviews therefore centered on a smaller subset of questions that aligned most closely with the participants' areas of expertise. (Note that in describing responses to the questions in subsequent chapters, we often make statements such as "a majority of participants…" or "many respondents…" More precisely, what we are describing refers to the subset of interview participants who responded to a particular question.) Additionally, the interviews were conducted in a loosely structured, free-flowing manner; when a participant offered a particularly intriguing or insightful answer to a given question, we would often follow-up with additional queries and discussion before proceeding to the next topic in the prepared list of interview questions.

The vast majority of individuals that were asked to participate in the interviews and workshop agreed to do so, suggesting that interest in this subject is particularly high. In total we conducted 55 interviews involving 69 individuals (several of the interviews included more than one person from the same organization). The workshop included 32 participants in addition to the research team and TRB staff. Of these, 12 were affiliated with the project panel, and many of the remaining 20 had also participated in the interviews. Appendix C provides a comprehensive list of the interview and workshop participants.

The interviews and workshop proved extremely helpful in developing and refining thoughtful suggestions on how to scope and structure effective system trials. The next chapter summarizes high level observations from the interviews and workshop and interprets their implications, while the subsequent chapter presents the results for more detailed questions.

6. STRATEGIC CONSIDERATIONS FOR THE TRIALS

This chapter begins by summarizing several high level observations that emerged during the series of interviews and workshop. It then introduces and discusses three conceptual frameworks for organizing the trials. During the course of the interviews, certain questions elicited a surprising degree of variation in responses. Based on follow-up questions and further discussion with interview participants, the research team recognized that the appropriate scope and structure for the trials might depend, at least in part, on the envisioned pathway to implementing VMT fees. For example, should VMT fees initially be implemented at the state level or at the federal level, and should the transition to VMT fees involve a period of voluntary adoption? The intent of the frameworks is to represent different possible visions for the transition to VMT fees, which in turn might suggest alternate choices about how to scope and structure the trials.

6.1. OBSERVATIONS FROM THE INTERVIEWS AND WORKSHOP

This section begins by summarizing the research team's understanding of key insights from the interviews and workshop that might be helpful in framing the discussion of potential trials. It then comments upon the considerable degree of variation in the responses to certain interview questions and considers the implications for developing a coherent plan for an expanded set of system trials.

6.1.1. Perspectives Offered by Interview and Workshop Participants

Given the potential cost of implementing VMT fees, as well as the likely degree of controversy, several participants expressed skepticism that the nation would move in the direction of VMT fees or that Congress would devote significant resources to support system trials in the next authorization. As one participant put it, voters and elected officials have been generally unwilling to increase fuel taxes to provide sufficient funding, so it is difficult to see where the will to implement VMT fees would come from. Instead, these participants viewed it more likely that Congress would debate fuel tax increases or rely on continued allocations from the general fund to shore up the Highway Trust Fund (HTF). One of the interview participants suggested that the nation would be better served to focus efforts on the expansion of congestion tolling to help mitigate traffic and rely on increased vehicle registration fees for vehicles that pay little or no fuel taxes (e.g., plug-in hybrid or electric vehicles). Such comments did not necessarily indicate a lack of support for VMT fees on the part of participants; more commonly, they were expressed as views about what was most likely to occur given the current state of the political debate.

In addition, several respondents were skeptical about the complexity of the required technology within the context of trials and eventual implementation. Several indicated concern that the technologies were not as well-developed as advertised, and that past experience had shown that even technologies considered ready for implementation often proved not to be. One person thought that with more sophisticated systems and greater numbers of users, the potential for security problems would rise considerably—not due to flaws for any particular technology, but simply as a factor of increasing complexity. While most respondents expected that VMT fees

would be implemented through some type of in-vehicle device, these dissenting opinions suggest concern among some experts that a heavily technology-dependent solution might be problematic.

Yet most of the interview participants were intrigued or enthusiastic about the prospects for VMT fees and focused their commentary on how to structure the trials to be as effective as possible. Among the many comments received, several general themes emerged repeatedly:

- **The lack of clear policy direction is holding back implementation efforts.** Many of the respondents expressed the perception that remaining technical barriers could be readily resolved by the private sector, but only after the government had developed a clear policy framework. To date, there is not yet national agreement or policy direction on such crucial issues as what types of pricing the system should support and what levels of privacy protection should be assured. The implication, also supported by the entries in Table 5.1 in the preceding chapter, is that planning and policy decisions would be at least as important as system trials.
- **Federal leadership is needed.** Many of those interviewed suggested that federal leadership would be important, though they expressed varying views about the form that this leadership should take. Some indicated that the federal government should develop a national system in which states could choose to participate. Others, in contrast, felt that the states should lead implementation efforts, while the federal government should develop and promote standards to ensure that the systems developed in different states could interact with one another. A major concern was that in a vacuum of federal leadership, at least some states would begin to develop their own systems; absent federal guidelines or standards, as illustrated by the current variations in electronic tolling technologies in different regions of the country, the nation might easily end up with incompatible technologies and systems in different states.
- **Trials should set the stage for implementation.** Another recurrent theme was that the trials should not simply result in another interesting set of studies, but rather should be focused on resolving remaining uncertainties to inform policy debate and prepare for implementation. To begin with, revenue challenges are becoming increasingly acute, so it would be helpful to facilitate a potential transition in the near term. Additionally, the trials would likely entail considerable investment, so they should be designed to be as productive as possible. One implication of this perspective is that the trials should consider a broad range of issues to develop and adopt a fully functional system of VMT fees—including, for instance, privacy protection, system enforcement, actual (as opposed to simulated) collection of revenue, and payment options for those without credit cards or bank accounts. Another is that the trials might focus specifically on the subset of potential implementation options viewed as offering the greatest prospects for successful implementation. An intriguing variant on this theme expressed by several participants is the idea that trials might evolve directly into full-scale implementation, as with some tolling projects under the Value Pricing Pilot Program. This concept is considered at greater length later in this chapter.
- **The federal government should be prepared to invest considerably in trials.** Many of the interview participants argued that the investment in system trials (and related efforts) should be considerable—in short, whatever it takes to resolve remaining uncertainties and prepare for implementation. As one respondent suggested, a system of VMT fees would provide a platform that could eventually support virtually all other forms of federal, state, and local

user fee revenue collection. Additionally, such a system could enable variable fee structures to help reduce recurrent traffic congestion, harmful vehicular emissions, and excessive pavement damage—problems that have been difficult to address through other policy mechanisms. Finally, with the recent increases in corporate average fuel economy (CAFE) standards and the prospects for alternative fuel vehicles, transportation stands to lose billions of dollars in federal and state fuel tax revenues in the near future. This increases the urgency of finding a replacement revenue mechanism, such as VMT fees, sooner rather than later.

- **A VMT fee system should not focus on revenue alone.** A number of respondents stressed that a system of VMT fees should not be designed solely to raise revenue—that is, to charge flat per-mile fees to make up for shortfalls in the Federal HTF or comparable state accounts. Simply stated, such a system would be too expensive to implement and operate, particularly in comparison to the efficiency of fuel tax administration, if restricted to that purpose alone. Yet the same in-vehicle technology used to meter mileage could also support many other valuable services to help offset the cost. Some respondents stressed the potential benefits of developing variable fee structures to support other transportation goals; others focused on the inclusion of PAYD insurance, the ability to automate the payment of parking fees, the collection of accurate traffic information, the provision of real-time traffic alerts coupled with alternate routing suggestions, and the like. Generally speaking, though, most agreed that a system of VMT fees should be designed to serve as many ends as possible.
- **Principal obstacles include cost and user acceptance.** In discussing the greatest potential impediments to the implementation of VMT fees, respondents cited the issues of cost (for in-vehicle equipment, supporting infrastructure, collection, and enforcement) and user acceptance (particularly with respect to privacy and potential fee structures) as the most significant stumbling blocks. The trucking industry has additional concerns over VMT fees: that they might provide an easy way for states and localities to target trucks, since much truck traffic is pass-through, and that they could facilitate weight-distance truck tolls, which the industry generally opposes. Whether or not the system could be effectively enforced was another oft-cited concern. The implication is that the trials should devote ample attention to evaluating strategies for overcoming these potential barriers to adoption.
- **Building greater trust in the government is another key challenge.** A related theme discussed by several participants was the current lack of trust in government, particularly for the federal government, an issue that would surely compound the difficulty in building public acceptance for a sophisticated system of VMT fees. Concepts that might be important in helping to repair public trust include the idea that all vehicles would be paying their "fair share" with VMT fees, demonstrated accuracy of the fees charged, and a much more visible relationship between fees paid and investments made with the revenue (in contrast, for example, to the proliferation of earmarking and current donor/donee relationships in the allocation of federal fuel tax revenue).
- **Trial development should draw on "lessons learned" from past and existing programs.** In the course of discussing potential VMT fee trials, some respondents drew on what they interpreted as lessons learned from experience with similarly large or innovative programs (e.g., Value Pricing Pilot Program, TIGER Grants, and IntelliDrive). Specific suggestions in this vein included having a large coordinated program, since small and scattered pilots might not lead to broader implementation; awarding on a competitive basis rather than on political

considerations; conducting a multi-staged proposal process to help interested states refine their proposals; including additional time to build public support in funding programs for controversial projects; and exempting funding recipients from some requirements if they are not applicable to the project.

- **Authorizing legislation should not be overly prescriptive.** While the interview questions did not address the issue of how any authorizing legislation might be structured, a number of participants chose to voice their opinion on this matter, suggesting that legislation should not include detailed instructions. Rather, the program should simply be created and funded, perhaps allowing one to two years for planning, two or three years to operate the trials, and another year to evaluate the results. Beyond that, there would not be "specific instructions" as to what should be tested in terms of technology, location of trials, etc. Rather, the details of the trials would be delegated to those charged with overseeing and managing the program.

6.1.2. Variations in Interview Responses

Many of the questions posed during the interviews yielded similar answers from the participants. For certain issues, however, there was considerable divergence in the responses. When asked about the number of participants that should be involved in the trials, for instance, answers ranged from a few thousand to a million. And while some of the respondents indicated that congestion tolls should definitely be included within the trials, others were adamantly against this idea, arguing that transitioning to a VMT fee system would already pose substantial public-acceptance issues even without raising the specter of higher charges for peak-hour driving. As discussed next, the divergence in opinion for certain key issues led the research team to develop a set of alternate conceptual frameworks for scoping and organizing the trials.

6.2. FRAMEWORKS FOR SCOPING AND STRUCTURING TRIALS

As the divergence in opinions for certain key questions became apparent, the research team began to ask follow-up questions during the interviews to gain insight into the reasoning behind alternate responses. Based on the ensuing discussions, the research team observed that differing opinions regarding the appropriate scope and structure for the trials often stemmed from disparate views about the manner in which a transition to VMT fees would likely or should ideally unfold. In particular, respondents expressed differing perspectives for such questions as:

- Would it be more desirable (or, alternatively, more likely given political considerations) for the initial implementation of VMT fees to occur within states or at the federal level?
- Could VMT fees be implemented in just a few years, or would it take a decade or more?
- Should the transition rely solely on a mandatory phase-in process (e.g., with the purchase of new automobiles) or should it instead include a period of voluntary adoption for several years prior to the initiation of mandatory adoption? (Note that a period of voluntary adoption would not preclude the possibility of requiring that auto manufacturers begin to provide metering equipment with new vehicles as of a certain model year to reduce the number of vehicles that would need to be retrofitted at a later date.)

Different views on these questions suggest different pathways to implementation, and these in turn imply alternate goals and structures for the trials. In other words, *the most helpful scope and*

organization for the trials depends on how one expects that the transition to VMT fees might or should occur. Building on this recognition, we outlined three conceptual "frameworks," or visions, about how the transition to VMT fees might be pursued (while the three frameworks do not represent all possible pathways to implementation, they appear to encapsulate the alternatives envisioned by most of the interview and workshop participants and therefore serve as a useful construct for delineating alternate approaches to the trials). In essence, the three frameworks provide a lens through which to interpret the varied responses for many of the questions that were posed during the interviews and workshop. Specifically, they prompt consideration of whether certain choices for designing the trial might vary from one framework to the next. The three frameworks can be summarized as follows:

- Help states help themselves (state framework)
- Carefully plan a national system of VMT fees (federal framework)
- Foster a market for in-vehicle travel services (market framework)

The remainder of this section describes each of these frameworks in greater detail and considers their relative advantages and potential weaknesses. The discussion also highlights how the different frameworks for the trials might help to address and overcome (or fail to overcome) some of the greatest potential barriers to implementing VMT fees—most notably cost, user concerns, and political viability.

6.2.1. Help States Help Themselves (State Framework)

In this framework, VMT fees would first be adopted by willing states or groups of adjacent states (e.g., the I-95 Coalition). The main roles of the federal government would be to provide funding to assist their efforts (i.e., funding for trials) and to support the development of national standards and a certifications process to ensure interoperability among the systems deployed in different states. Additionally, the federal government might encourage states to examine implementation options that could later be extended to support national implementation. At some point in the future, the federal government could then draw upon the lessons from state implementation to develop a national system of VMT fees.

Within the state framework, a state might choose to organize the trials to carefully examine the various implementation options under consideration. Subsequent to the trials, and based on the results, the state could then debate whether to implement VMT fees and, if so, plan a VMT-fee system that would be initiated at a later date. It is also conceivable, however, that a state could plan for the trials to evolve directly to implementation; that is, there would be no intervening period for planning and public debate between the trials and system implementation. This might be feasible, from a political perspective, if it were intended that the payment of VMT fees would be optional for some period of time; for example, drivers within a state might be provided with the option of paying a fixed registration fee or paying a per-mile registration fee instead. It might also be feasible for the trials to evolve to implementation if it were intended that VMT fees, though mandated, would only apply to a limited subset of vehicles (e.g., electric and plug-in hybrid vehicles) that would not otherwise pay their share of road use costs.

A decision on the part of one or more states to pursue trials intended to evolve directly to implementation would have important implications for the overall trial program. To ensure that systems developed in different states would ultimately be compatible with one another, for example, it would be important to develop interoperability standards in advance of the trials. In the remainder of this document, such implications are noted where relevant.

Advantages. The concept of allowing states to lead the transition to VMT fees has much to recommend it. Potential advantages include:

- There would be less need to achieve widespread (i.e., national) public support for VMT fees. States in which the political will exists to raise revenue for the improvement of transportation infrastructure could choose to implement VMT fees; other states could choose not to.
- States have more opportunities than the federal government to create conditions that would encourage voluntary adoption or reduce objections to mandatory adoption. States could allow vehicle owners, for example, to pay for registration by the mile instead of as a fixed annual fee (this mirrors the approach in the planned Netherlands system, in which kilometer-based fees were intended to replace vehicle purchase and registration fees; see Dutch Ministry of Transport, Public Works, and Water Management 2009); they could require that drivers either have their odometer read each year or install metering equipment to automate the process (potentially qualifying for lower off-peak rates and avoiding the need to pay for mileage traveled out of state or on private roads, as in the planned Minnesota trial); they could structure insurance regulations to enable or encourage PAYD policies; and they could work directly with cities to allow for automated payment of parking fees. States that currently operate some form of weight-distance fees could also allow or require trucks to adopt metering equipment to automate fee computation and collection.
- States control resources—e.g., highway patrol officers and vehicle registration databases—that might more easily be applied to help enforce VMT fees. Additionally, the network of Interstates, highways, arterials, and local roads is collectively owned and operated by states, local governments, and tolling authorities, not by the federal government.
- States represent a laboratory for experimentation that might lead to innovative VMT fee concepts not yet considered. If a national system were to be developed instead, great care would need to be taken to ensure that the system provided enough flexibility to allow for continued policy exploration and innovation on the part of states.
- States that have a favorable experience with trials could choose to transition directly to full-scale implementation.

Potential drawbacks. Though appealing from certain perspectives, the state-led approach is not without potential drawbacks:

- Letting the states lead (presumably to levy their own road use fees, not fees for the federal government) would not help to reduce current revenue shortfalls in the HTF in the near term (in effect, this might lead to continued devolution of the responsibility for funding surface transportation from the federal government to states, counties, and cities, an ongoing trend that has provoked much discussion and debate among policymakers).

- Arguably this approach would introduce greater risk that systems in different states would not be interoperable. To avoid this potential pitfall, a concerted effort would be needed to (a) develop interoperability standards in advance of the first state deployment, and (b) find ways to encourage states to adopt those standards.
- As a corollary to the preceding point, if it were intended that one or more of the state trials might evolve directly to implementation, then it would be necessary to develop at least an initial version of the interoperability standards in advance of the trials. This represents a technically demanding, and potentially contentious, task that could be difficult to complete within just a year or two.
- There might be less opportunity to reduce system costs through economies of scale, since there are fewer drivers in any given state than in the nation as a whole.
- The implementation of VMT fees in some states but not others would inevitably create many challenges surrounding the collection and allocation of road use fees for interstate travel.
- Given the likely difficulty of building public support for VMT fees, it is possible that no states would choose to implement VMT fees following the trials, in which case there would be no progress towards a more sustainable system of transportation finance (on the other hand, the lack of any state-level implementation might also suggest that the concept of VMT fees is simply not yet politically viable in the United States as a whole).

6.2.2. Carefully Plan a National System (Federal Framework)

In this framework, the main goal in the trials would be to explore alternate implementation options to prepare for the potential implementation of a national system of VMT fees. Such a system would offer sufficient flexibility to enable states, and potentially local governments, to levy their own VMT fees if interested. It might support a broad range of additional value-added services as well, though this would not be a strict requirement. Following the trials, and pursuant to public debate, policymakers could then determine (a) whether to implement a national system of VMT fees and, if so, (b) what policy goals (e.g., the ability to meter mileage and apportion fees by jurisdiction, or to support local congestion pricing applications, or to offer certain forms of privacy protection) the system should support. Planners could then apply lessons learned during the trials to develop the most cost-effective system capable of meeting the indicated system requirements.

The trials results could also assist planners in determining the best strategy for phasing in the system. For example, the decision might be made to initiate the transition process by requiring auto manufacturers to begin equipping new vehicles with metering devices as of a certain year. Alternatively, mixed user response during the trials might suggest that it would be beneficial to institute a period of voluntary adoption (as envisioned in the market framework, discussed next) prior to mandatory adoption. It is also possible that trials aimed at planning a national system might instead lead to initial implementation at the state level. That is, following the trials, federal decision makers might opt not to develop a national system of VMT fees immediately. A state that participated in the national trials, however, might choose to implement its own system based on its experience during the trials. In short, the trials under the federal framework would be aimed at planning and developing a national system, but the intervening period of public debate and planning might lead to alternate outcomes.

Advantages. This framework offers a different set of advantages:

- It would address HTF revenue shortfalls by exploring a system capable of levying federal VMT fees.
- It would provide the greatest opportunity to reduce system costs through economies of scale.
- It would result in a consistent national system, thereby avoiding the potential outcome in which different systems in different states would not be interoperable.
- It would reduce the barriers for states (or local jurisdictions) that want to implement VMT fees. States would not need to develop their own technical configurations; rather, they could integrate their charges with the federal system.
- The system could be structured with sufficient flexibility to ensure that states have maximum latitude to explore innovative pricing policies (rather than innovative technical approaches). In essence, this would require that the system be able to determine both the time and location (by jurisdiction and potentially by route) of travel to provide maximum flexibility.
- A set of trials could be carefully coordinated to address all crucial issues required for full-scale national implementation. Trials aimed solely at state level implementation might fail to address issues that become more important at the federal level (e.g., any required state support for levying federal fees).

Potential drawbacks. The framework for developing a national system of VMT fees also faces some of the more daunting challenges and risks:

- Under the state framework, it is possible that just a few states might initially choose to implement fees, and others might subsequently follow. In other words, public acceptance would only be needed in a small number of states to initiate the transition. In the federal framework, however, it would be necessary to gain the support of elected officials from a majority of states in order to pass the legislation to establish a national system. This would likely prove more difficult to achieve, thus increasing the risk that trials would not lead to actual implementation.
- The federal government has fewer opportunities than individual states to create incentives for voluntary adoption. For example, there are no federal registration fees for passenger cars that could be levied on a per-mile basis, the federal government does not control state insurance policies, and the federal government can exert only limited, if any, influence on local parking policies. As a result, the federal government might need to rely on mandatory adoption. This would increase the political challenges associated with VMT fees and also necessitate a mechanism for rebating fuel taxes to early adopters. Alternatively, the federal government might pursue more creative—but still politically difficult—strategies to promote voluntary adoption. For instance, Congress might require that states begin to collect a national registration fee and then provide drivers with the option of paying either a fixed annual fee or installing the metering equipment and paying by the mile.

- It would be necessary to either expand the staffing levels and capabilities of current federal enforcement resources (e.g., IRS agents involved in fuel tax enforcement) or to rely on extensive state support in order to enforce federal VMT fees.

6.2.3. Foster a Market for In-Vehicle Travel Services (Market Framework)

This last framework, which represents the greatest departure from conventional thinking about how to accomplish a transition to VMT fees, is intended to address several goals in parallel: overcoming public acceptance challenges through voluntary adoption, implementing a fully operational (if initially voluntary) national system of VMT fees as quickly as possible, and reducing the cost to the government of collecting VMT fees.

In essence, this framework envisions, and seeks to foster, the emergence of a market for in-vehicle metering devices and billing services that are capable of levying VMT fees and simultaneously supporting numerous value-added services, such as automated payment of parking fees, PAYD insurance, real-time traffic alerts, and routing suggestions based on current traffic conditions. Firms (e.g., device manufacturers, software developers, system integrators, telecommunications providers, toll road operators, and the like) would compete to provide these services, thereby driving down the cost of the required technology. Additionally, because firms would be able to collect payment for some of the additional services (e.g., a small percentage of parking fees or PAYD insurance premiums), the amount that they would need to charge the government for collecting VMT fees would be reduced. The main goal of the trials in this framework, then, would be to support and accelerate the development of this market. To do so, the federal government would let contracts with several firms (the initial "competitors" in the market) to provide metering devices and collection services and help enroll trial participants. In parallel, the federal government would fund or subsidize states that wished to examine VMT fees, cities or counties that wished to explore automated parking payment or local VMT fees, and insurance firms that wished to offer PAYD policies. These parties would then link up with one or more of the technology vendors to conduct the trials. After several years, the trials would evolve to full-scale implementation of an initially voluntary system. Trial participants that valued the additional services would become the initial adopters, and additional drivers would be able to adopt the in-vehicle equipment on a voluntary basis as well. After several more years, once it had been demonstrated that the system was operating successfully (i.e., that it was collecting fees, preventing evasion, and protecting privacy as planned), the government might then mandate the adoption of VMT fees for all vehicles. This approach to trials and implementation is described in greater detail by Grush (2010a).

Note that the role of private firms in providing metering devices, billing services, and other value-added offering would be possible in the other frameworks as well, but would not be the only approach that might be contemplated (e.g., a particular state might choose to examine the collection of VMT fees with registration in a publicly-administered system). In this framework, in contrast, the involvement of multiple competing firms in the provision of metering and billing services would be viewed as a critical component in achieving the goals of driving down costs and stimulating the development of value added services to promote voluntary adoption.

Advantages. This framework offers several conceptually compelling advantages:

- The opt-in period would allow time to demonstrate the effectiveness of privacy protection, fee collection, and enforcement strategies through the participation of voluntary adopters. This should reduce the current degree of public and political skepticism surrounding VMT fees, making it less difficult to mandate the adoption of VMT fees at a later date.
- To gain market share, competing firms would be motivated to provide as many valuable add-on services as possible. This would help to maximize the benefits of the considerable social investment in in-vehicle metering technology.
- Because the service and technology providers could collect revenue from a broader range of sources, the cost to the government for installing equipment and collecting VMT fees should be reduced.
- On a related note, the cost to conduct the trials, on a per-participant basis, might be reduced in this framework. Provided that the government clearly signaled its intention to transition to a national system of VMT fees, firms might choose to cover some of the trial-related costs with their own resources in order to prepare a successful bid to participate in the trials, which would in turn position them as an early market leader. On the other hand, as expressed by one of the workshop participants, many firms have been "burned" by investing their own resources in European trials that did not lead to implementation and might therefore be less willing to do so again. This potential benefit is therefore far from certain.
- The cost of installing equipment in vehicles would not be lost; rather, the same equipment would continue to be used when the trials phased directly into implementation and trial participants became early system adopters.

Potential Drawbacks. This framework also faces several risks and obstacles:

- In a voluntary opt-in framework involving privately provided equipment and services, it is conceivable that drivers would choose to adopt the equipment for PAYD insurance, for the chance to automate the payment of parking fees, and to enjoy other services but then choose *not* to pay mileage-based fees. Assuming a relatively flat per-mile rate structure, drivers of highly fuel-efficient vehicles, in particular, would be better off paying current fuel taxes than mileage fees. In order to increase voluntary payment of federal road use fees, the government would likely need to create some form of incentives. For example, it might set federal fuel taxes somewhat higher than mileage fees and then rebate fuel taxes to adopters, or it might institute some form of federal registration fee (collected by states and remitted to the federal government) that would be rebated for VMT-fee system adopters.
- Under this framework, since it is envisioned that the trials would evolve directly to full-scale implementation, it would be appropriate to develop an initial set of interoperability standards and corresponding certification process in advance of the trials. Though possible, this would be challenging to achieve within just a year or two.
- As a corollary to the preceding point, it would be necessary to make certain system design decisions—for example, the decision that fee collection would be handled by multiple private firms operating in parallel, rather than by a single firm or by the public sector—in advance of the trials. There would not, therefore, be the opportunity to inform such decisions based on lessons learned during the trials themselves.

- With independently funded technology and service providers, states, cities, MPOs, insurance providers, research institutions, and the like, it could prove more difficult to manage and coordinate the trials under this framework.
- The success of an industry-led model would depend largely on voluntary consumer adoption. The assumption is that consumers would be willing to purchase devices to have access to the add-on services. However, it is not certain that a mass market will emerge for these devices. For example, while some drivers would undoubtedly find the prospect of paying for parking via an in-vehicle device appealing, a large share of drivers have free parking for most trips and would not be interested in this application. Moreover, many of the envisioned services, such as routing assistance or stranded driver assistance, are already available on other platforms. If relatively few consumers voluntarily chose to adopt the equipment in order to gain access to the value-added features, greater government subsidies or mandates could be required. Related to this point is the observation, offered by a private sector representative, that from the service provider perspective, the "base" business case has to make sense (i.e., the ability to earn some return on investment by charging for the collection of VMT fees); it cannot be assumed that firms would recoup all of their investment from value-added services.
- An industry-led model would create not one but two enforcement challenges: the potential for tax evasion by drivers, as well as the possibility that the firms or consortia collecting the fees would not remit them in an accurate or timely fashion. Firms might be responsible for collecting billions of dollars annually, necessitating sufficient staff on the government side to carefully monitor contracts and audit accounts as well as a plan for penalizing firms found to be in breach of contract. The federal government would also need to either augment its own enforcement resources or rely on state support to help prevent driver attempts to evade fees.

6.3. APPLICATION OF THE FRAMEWORKS

The three frameworks described above are offered as a means of conceptualizing alternate pathways for implementing and transitioning to VMT fees, which can in turn be used to help organize a coherent approach to planning and implementing a set of VMT-fee trials. It should be stressed, however, that the frameworks are not absolute; that is, they do not represent all possible pathways to implementing VMT fees, nor need they be viewed as mutually exclusive. For example, decision makers might choose to pursue the market framework for VMT fees applied to passenger vehicles and the federal framework for VMT fees applied to commercial vehicles. Or, they might choose a hybrid of the state and federal frameworks, funding some states to participate in trials for a national system and other states to conduct their own separate trials.

Still, the frameworks do have important implications for the appropriate scope and structure for the trials, and it would therefore be helpful for decision makers to choose among the frameworks in order to develop a coherent plan for the trials. Each, as described above, offers a combination of strengths and limitations, and none is inherently superior; rather, the decision requires a policy judgment. Distilled to the most basic level, the selection of a framework rests of two key questions:

1. Is it more likely (or, alternatively, more desirable) that the initial implementation of VMT fees would occur at the state level or at the national level?

2. Should the trials be designed to provide information to support subsequent planning efforts and public debate about the implementation of VMT fees, or should the trials be designed to evolve directly to actual implementation (likely involving a preliminary period of voluntary adoption)?

Table 6.1 indicates the appropriate selection of frameworks based on these questions.

Table 6.1. Selection of a Framework for Organizing the Trials

Goal of Trials	Initial Implementation	
	State level	**Federal level**
Inform planning, debate	State framework	Federal framework
Evolve directly to implementation	State framework*	Market framework

** with required modifications, such as the development of interoperability standards in advance of the trials, to allow state trials to evolve directly to implementation.*

The next chapter summarizes the responses from interview and workshop participants regarding more detailed questions about how to scope, structure, fund, manage, and conduct the trials and considers whether certain choices might vary depending on the preferred framework.

7. DESIGN OF THE TRIALS

The preceding chapter addressed strategic themes and issues that arose during the interviews and workshop, including the development of alternate frameworks for the trials. This chapter focuses on more detailed questions related to the design of the trials, summarizing the input offered by interview and workshop participants in response to specific questions about scoping, structuring, funding, managing, and conducting the trials (Appendix D provides more detailed discussion of the responses to the questions). The set of issues addressed in this chapter is based on the list of questions posed in the interview guide (see Appendix B). In the interest of providing a more logical narrative flow of the material, the questions have been reorganized (and in some cases combined) in this chapter, in the following categories:

- Roles in overseeing, managing, and conducting the trials
- Organizing, coordinating, and funding the trials
- Size, participation, duration, and cost of the trials
- Pricing policies to examine in the trials
- High priority issues to examine in the trials
- Detailed trial implementation strategies

For each of the specific issues discussed within these categories, we first outline the relevant question(s) posed to interview and workshop participants (note that the question numbers appearing in the text, e.g. question 1.2, refer to the numbered list of questions in Appendix B). We then synthesize the perspectives that emerged based on the interviews and workshop. For questions that elicited considerable divergence in opinion among stakeholders and subject matter experts, the discussion considers whether the appropriate choice might depend on the selected framework for the trials. Any additional analysis conducted by the research team to supplement the input of interview and workshop participants, where needed, is also reviewed.

7.1. ROLES IN OVERSEEING, MANAGING, AND CONDUCTING THE TRIALS

This section summarizes the responses to questions related to the potential roles of various organizations in overseeing, managing, and conducting the trials.

7.1.1. Planning and Overseeing the Trials

Questions 4.1 and 4.2 asked about how planning and oversight for the trials should be structured. Specifically, what entity, new or existing, should ideally guide this effort? Many interview and workshop participants suggested that an advisory panel—either in the form of a committee or commission—should be established to oversee the effort to plan and prepare for VMT fees, including trials and related activities. At minimum, respondents indicated that the panel should include representation from Treasury, U.S. DOT, FHWA, AASHTO, and states. A separate entity, acting under guidance of the panel, would be charged with managing the details of implementing the trials along with any parallel planning, analysis, R&D, and education and

outreach efforts. Many respondents argued that TRB would be the best candidate to fulfill this research management role, though other organizations (e.g., FHWA) would also be possible.

7.1.2. Soliciting Stakeholder Input for the Trial Program

Question 4.3 asked about the best way to accommodate stakeholder input into the design of the trials. Respondents indicated that there should be some type of opportunity for stakeholders to provide input on the design of the trials—for example, a stakeholder advisory council, invited input from stakeholders, an open comment period, or meetings with stakeholders conducted around to the country—but also suggested that the period for input should be constrained to at most 3 to 6 months so as not to delay the trials.

7.1.3. Conducting the Trials

Question 5.2 asked about who should be eligible to conduct trials—that is, to bid for and/or receive funding to implement a trial. The three prior U.S. cases provide examples of trials being led by a state (Oregon DOT), by an MPO (Puget Sound Regional Council), and by a university (University of Iowa). It is also conceivable that trials could be conducted by private or non-profit entities. The question posed to interview and workshop participants, then, was which of these options would be the best choice for leading expanded system trials.

Respondents recognized that states, cities, counties, private firms, and research institutions could all play important roles in conducting the trials. In terms of who should lead the effort, however, two distinct models emerged. Many respondents argued that states should take a leadership role in structuring teams and conducting the trials, given that states would ultimately need to be integrally involved in any effort to implement VMT fees. A smaller number supported the concept of directly funding the various organizations that would be involved in the trials (so as to ensure their participation) for the specific contributions that each would make—for example, contracting with firms to provide the metering devices and billing services, funding states to examine state-level VMT fees and issues related to administration and enforcement, funding local governments to examine local VMT fees and automated payment of parking fees, funding insurance providers interested in testing out PAYD insurance, and funding research institutions or MPOs for data analysis and evaluation. This latter option was suggested as being appropriate for the market framework because it would directly engage the various parties—service providers, insurers, and cities—that could play an important role in the provision of value-added services, such as PAYD insurance or automated parking payment, to entice voluntary adoption.

7.1.4. Roles for DOTS, DMVs/MVAs, and MPOS

Question 7.1 asked about the appropriate roles for state DOTs, DMVs/MVAs, and MPOs within the trials. Participants indicated that general state roles within the trials would involve certain elements of fee and data collection along with enforcement support. Specific state roles would vary depending on certain policy decisions (such as the choice of technology to be examined) and the state's institutional structure. While many participants did not expect that MPOs would assume a major role in leading the trials, several noted that their participation could be valuable in helping to design certain aspects of the trials (e.g., variable pricing structures), facilitating outreach with local stakeholders, and helping to analyze data and evaluate trial results.

7.1.5. State Legislative Requirements

Question 7.2 asked about the conditions under which enabling state legislation would be required for states to participate in the trials. The response was that legislation would likely be required for states to collect actual revenue in the context of VMT fee trials, and that the passage of such legislation could be expected to take between one and five years. State legislation might be needed in some states even to conduct a trial. State legislation might also be required in some states to allow PAYD insurance to be examined in the trials.

7.1.6. Engaging Multiple Service Providers within a Trial

Questions 8.1 and 8.2 asked about potential strategies for including, within the same trial, metering devices and billing services provided by multiple vendors. The intent would be to examine the concept of implementing an interoperable system in which multiple firms could compete for market share on the basis of cost and value-added services (this would be a critical issue to examine under the market framework; for the other frameworks, it might be viewed as valuable but not essential during the trials). Interview and workshop participants suggested that it would be valuable to involve multiple technology vendors within the trials, and indicated that this could be achieved by setting up the competition to allow for multiple award recipients. They also underscored that the competition should be based on more than just cost—for example, it might seek to include different metering approaches or different value-added features from different vendors.

7.1.7. Encouraging PAYD Insurance within the Trials

Question 8.3 asked how the trials might be structured to allow and encourage participation among auto insurance companies, if desired. The underlying premise of the question was that PAYD insurance represents a commonly cited value-added service that might encourage voluntary adoption and help defray the cost of metering devices and collection services. Views were mixed among interview and workshop participants as to whether the inclusion of PAYD insurance within the trials should be viewed as optional or required; it would be most beneficial in the market framework in which the goal would be to offer as many value-added services as possible to increase voluntary adoption. Respondents suggested two factors that could encourage auto insurers to participate, if desired: access to detailed travel data (including claim events) to help them calibrate PAYD insurance rate structures, and/or a cash subsidy (likely on the order of $200 per policy) to cover the costs associated with switching policies.

7.1.8. Role for Auto Manufacturers

Question 8.4 asked whether auto manufacturers should be involved in the trials, and, if so, in what capacity. Respondents suggested that the voluntary participation of auto manufactures in the trials at this time would neither be likely nor essential (note, however, that the interviews did not include any representatives of auto manufacturers, and many participants did not comment on this question).

7.2. ORGANIZING AND FUNDING THE TRIALS

This section reviews questions related to organizing the trials—determining how many trials there should be, where they should be located, and the required degree of coordination among

the trials—and the approach to funding the trials (note that discussion of how much the trials might actually cost is presented in the following section).

7.2.1. Number and Location of Trials

Question 2.4 asked whether trials should ideally be conducted in all states or, alternatively, in multiple adjacent states. The majority of interview and workshop participants indicated that the trials should not include all states; rather, there should be several trials (most suggestions fell in the range of three to six trials) in individual states or groups of adjacent states (e.g., the I-95 Corridor Coalition) that are interested in exploring, and potentially implementing, VMT fees. Ideally, based on the comments we received, the set of selected trial locations would span different geographic regions of the country, include both "red" and "blue" states, include major metropolitan regions, and include at least one multi-state trial configuration.

7.2.2. Coordination among the Trials

Question 5.1 asked about how the trials should be organized and coordinated. At one end of the spectrum, one could envision a large, carefully coordinated trial that would span multiple states and be designed to gather information on a specific set of issues in order to prepare for subsequent implementation of a national system. At the opposite end, it would be possible to fund a set of largely independent trials in which states would have much greater latitude to explore alternate policy structures and implementation designs. Between these two conceptual endpoints, there could also be some sort of hybrid approach—an attempt to structure the multiple trials to address core national implementation issues while simultaneously allowing for state innovation.

Interview and workshop participants favored the hybrid concept; that is, the trials should collectively address any crucial issues needed to plan and implement a national system of VMT fees, but there should still be enough flexibility for states to explore innovative policy options. Several responses also suggested, however, that the organizational structure might depend on the selected framework. Specifically, under the state framework states might be given even broader latitude in terms of technical and institutional approaches considered; the main connecting theme among different trials in the state framework would be to examine interoperability standards and certification processes. States might also choose to examine the possibility of shared revenue collection and distribution systems (akin to the International Registration Plan and International Fuel Tax Agreement) for economies of scale.

7.2.3. Basis for Allocating or Awarding Funding

Question 6.3 asked about the most appropriate mechanism for distributing funds to support trials. Potential models included earmarks, competitive grants, and proportional funding available to all states on the basis of population or other factors. Interview and workshop participants indicted that funding for the trials should be allocated on the basis of competition rather than earmarking. Several participants suggested that it might be helpful to first request initial expressions of interest and then invite and provide seed funding for a subset of states to develop more detailed proposals. Another idea that emerged was to set aside a modest amount of funding (in addition to funding for the trials) that would be available to any state, on a non-competitive basis, to begin preliminary exploration of VMT fees (i.e., conducting studies rather than trials).

7.2.4. Criteria for Competitive Awards

Questions 6.4 and 6.5 asked about the criteria that should be applied if the funding for trials were to be awarded on a competitive basis. Most participants indicated that the trials should involve some required elements (e.g., examining one or more metering options, collection mechanisms, and enforcement strategies of interest and perhaps helping to test out interoperability standards) along with some optional elements. Qualification for trial participation would be based on the former, while competition among qualifying bids would be based on the latter. Suggestions for the potential criteria that might be used to evaluate and rank competing proposals, under the assumption that base requirements had been met, included cost, number of participants, capacity of the proposing entity, innovation, inclusion or simulation of variable pricing, intent to collect actual revenue, and intent to explore use of travel data from the system to support improved planning and operations.

7.2.5. Federal Share of Funding

Question 6.2 asked about the share of trial funding that might be provided by the federal government. Some interview and workshop participants indicated that the federal government should pay for the trials in their entirety, while others thought a modest state match of perhaps 10 to 20 percent should be required. While the latter would help to ensure that states that applied for funding were committed to the concept of VMT fees, it might also prevent otherwise interested states from participating given the current state of the economy.

7.2.6. Funding Program

Question 6.1 asked whether funding for trials should be channeled through an existing program with related scope (e.g., the Value Pricing Pilot Program) or though a new program. Only a small number of respondents chose to answer this question, but many of those who did felt that the evaluation of VMT fees was important enough, and sufficiently distinct from the scope of existing programs, to merit the creation of a new program.

7.3. SIZE, DURATION, AND COST OF THE TRIALS

This section summarizes the responses for questions related to the appropriate size (number of participants) and duration of the trials, what they are likely to cost, and how much the federal government should be willing to invest in trials.

7.3.1. Number of Participants

Questions 2.2 and 2.3 asked about the appropriate number of participants to include within the trials, as well as the relative importance of various factors that might influence this number: testing the feasibility and cost of certain implementation options at scale, gathering and assessing data on participant responses to alternate implementation options and fee structures, and building greater awareness of (and ideally support for) distance-based user fees.

Interview and workshop participants suggested that it would take thousands of participants to properly assess user perceptions of implementation options and fee structures, tens of thousands to gain greater clarity on the feasibility and cost of various implementation options at scale, and hundreds of thousands of participants to have a strong affect on national awareness of and

support for VMT fees. Within the context of trials intended to help plan and prepare for implementation, all of these goals would be valuable. Developing a better understanding of cost and feasibility of alternate implementation options at scale, however, would be especially critical. This suggests that it would be appropriate to aim for at least tens of thousands of participants in the trials, a level that would also provide better understanding of how drivers perceive and respond to the various options.

While building broader understanding of and support for VMT fees was also considered important, it was noted that this goal could be achieved at lower cost through more traditional education and outreach activities. Yet if the trials were intended to evolve directly to full-scale implementation featuring an initial period of voluntary adoption, as several respondents argued, scaling the trials to include hundreds of thousands of participants would also create a large base of initial adopters, helping to build momentum for the program. Additionally, it would likely encourage service providers to invest more resources in the development of value-added services to increase market share. These advantages might prove helpful in the state framework, if one or more states pursued trials intended to transition directly to implementation. It would be difficult, however, to predict in advance whether states would elect this path. Moreover, as the state framework would not initially lead to the development of a national system, the case for funding hundreds of thousands of participants from federal dollars would be diminished. It would thus appear reasonable to aim for tens of thousands of participants, rather than hundreds of thousands, under the state framework. In contrast, the explicit goal within the market framework would be to evolve directly to full-scale national implementation, so the inclusion of hundreds of thousands of participants would be valuable in this case.

To sum up, under either the state or federal frameworks it would be appropriate to aim for tens of thousands of participants (perhaps 10,000 to 20,000 per trial, and 50,000 to 100,000 across all trials). Under the market framework it would be valuable, if possible, to scale the trials to include hundreds of thousands of participants (perhaps 100,000 to 200,000 per trial, and 500,000 to 1,000,000 across all trials). It is worth noting that the overall cost of funding the trials depends to a significant degree on the number of participants; further analysis of the appropriate number of participants to include would therefore be valuable.

7.3.2. Duration of the Trials

Question 2.5 asked about the appropriate duration for the trials. The responses of interviews and workshop participants suggest that the trials should last a total of four to six years, including at least one and possibly two years for planning and preparation (two years would be particularly helpful if the intent were to develop initial interoperability standards and certification processes in advance of the trials), two to three years of in-vehicle trials, and another year for evaluation. This timeframe would allow the trials to examine additional functionality (e.g., collecting actual revenue and preventing evasion) that has not been explored in prior U.S. trials. In two of the frameworks—potentially in the state framework and definitely in the market framework—the trials might evolve directly into full-scale implementation at the end of this period.

7.3.3. Cost of Trials

Question 10.1 asked about how much it might cost to implement the trials. As context, the scope of the project did not support the development of a detailed model to make this calculation. We were therefore particularly interested in the perspectives or insights of participants who had either (a) conducted trials, or (b) examined the cost structure of other trials or programs.

Though several respondents offered ballpark estimates in the range of $1,000 to $2,000 participant, they also suggested reviewing prior trials and recent program implementations to get a better sense of the likely cost. Such analysis suggests that a more realistic estimate of the cost of the trials might fall in the range of $2,000 to $4,000 per participant, including roughly $1,000 to provide the metering devices and billing services over a three year period and another $1,000 to $3,000 for additional trial-related costs—e.g., planning and managing the trials, evaluating the results, and enrolling and interacting with trial participants. One individual who participated in the interviews and workshop suggested that under the market framework, though the per-vehicle costs might be similar, it might be helpful to alter the allocation of the costs. Specifically, more resources might be directed to municipalities (to develop automated parking payment), to auto insurers (to develop and offer PAYD products), and to technology providers for the development of additional value-added services, all with the intent of creating more incentives for voluntary adoption. Fewer resources, in turn, would be needed to pay participants to volunteer (participants would instead be enticed by the value-added services) or for post-trial analysis and evaluation (given that the trials would directly evolve to implementation).

Based on these numbers (and regardless of the specific allocation), if the trials included 50,000 to 100,000 participants in total (as in the state or federal frameworks), then the cost would fall in the range of $100 million to $400 million. If the trials included 500,000 to 1,000,000 participants in total (desirable under the market framework to create an initial pool of voluntary adopters as the trials evolve to full-scale implementation), then the cost would fall in the range of $1 billion and $4 billion. It should be stressed that the analysis behind these numbers is limited, and there are numerous cost-related uncertainties that would be difficult to predict in advance; further investigation of this question would therefore be helpful.

7.3.4. Value of Trials

Looking at the issue of cost from another perspective, Question 2.1 solicited opinions about how much it would be worth spending on trials, under the assumption that the trials would be needed for, and ultimately lead to, implementation. A common response was that the federal government should be willing to invest as much as needed, within reason, to ensure that the trials address any remaining uncertainties to facilitate informed debate and prepare for implementation. Two arguments for spending significant resources on VMT-fee trials were offered. First, a system of VMT fees might ultimately supplant most road revenue sources at the federal, state, and local levels (e.g., fuel taxes, license and registration fees, heavy vehicle use taxes, dedicated sales taxes, and the like), potentially generating hundreds of billions of dollars annually. Second, switching to VMT fees would prevent the loss of billions of dollars in fuel taxes in the coming decades due to more efficient conventional vehicles and alternative-fuel vehicles. When pressed for a specific amount that the federal government would likely need to invest in the trials in order to achieve the intended aims, most answers varied between $200 million and $500 million, with

a few suggesting $1 billion or more (interesting, these dollar figures fall in the same range as the estimates of what the trials might actually cost, as discussed above).

7.4. PRICING POLICIES TO EXAMINE IN THE TRIALS

The issues reviewed in this section reviews relate to the types of pricing policies that would be helpful to examine within the trials.

7.4.1. Metering All Mileage vs. Tolling a Subset of the Road Network

Question 1.1 asked whether, in addition to the concept of charging for travel on all public roads, an expanded set of VMT-fee trials should also examine the potential for tolling on a partial road network. As context, VMT fees constitute one option for reforming surface transportation finance, but there are others. Another possibility would be to toll just the most heavily traveled segments of the road network (e.g., the Interstate system) using simpler RFID technology. While there are possible drawbacks to this strategy—most notably the potential for significant traffic diversion—it could also prove less costly and less politically controversial. In response to the question, participants confirmed that it would be relatively easy, from a technical perspective, to augment VMT trials to examine the concept of tolling on a limited road network. While opinions were somewhat mixed, many respondents suggested that the trials should only examine tolling on a partial road network if the concept were receiving serious consideration as a potential policy direction among decision makers. Otherwise, the trials should focus solely on VMT fees—that is, fees that cover all miles of travel on all public roads.

7.4.2. VMT Fees for Passenger Cars, Trucks, or Both

Question 1.2 asked whether the trials should examine mileage-based fees for passenger cars, for trucks, or both. Many interview and workshop participants agreed that the trials should include both cars and trucks (possibly distinguishing between smaller commercial vehicles and long-haul trucks, given their different travel patterns), possibly in the context of separate trials.

7.4.3. Potential Pricing Structures

Question 1.3 asked about the potential pricing structures to examine within the trials. Options included flat fees, fees that vary by jurisdiction, fees that vary by time and location, fees that vary by vehicle weight and potentially by road class (for trucks), and fees that vary by emissions characteristics. This question elicited a broad range of responses. Many agreed that the trials should consider, at minimum, flat fees that vary by jurisdiction (to allow, for example, separate collection of federal, state, and possibly local VMT fees). While participants often viewed other forms of pricing as highly desirable, it was also acknowledged that their inclusion could make the trials more controversial. This led to the suggestion that more sophisticated fee structures be viewed as optional within the trials (for example, those bidding to conduct trials might choose, at their discretion, to examine congestion tolls, but this would not be required in order to qualify for funding).

7.5. HIGH PRIORITY ISSUES TO EXAMINE IN THE TRIALS

This section summarizes responses for questions related to specific technical, institutional, implementation and transition, and user acceptances issues that the trials might be designed to address.

7.5.1. Technical Issues

Question 3.1 asked about the relative importance of different technical issues that the trials might be designed to address. Options included alternate metering configurations, alternate collection mechanisms, alternate means of protecting privacy, alternate enforcement approaches, an open systems technology platform (including relevant interoperability standards and certifications), and the potential use of detailed travel data to support other transportation goals (e.g., providing real-time traffic congestion data, calibrating transportation demand models, and the like). While these are all important issues, the purpose of the question was to elicit from the respondents their sense of which should be viewed with the highest priority, and why.

Based on comments from interview and workshop participants, the three technical issues viewed as highest priority included alternate collection mechanisms, alternate privacy mechanisms, and alternate enforcement mechanisms. Under the state framework, if it were envisioned that the trials might evolve directly to implementation, then it would also be important to develop and test interoperability standards as part of the trials to reduce the risk that different states would adopt incompatible systems. Under the market framework, with the explicit goal of evolving directly to an initially voluntary system, then it would be beneficial to examine interoperability standards within the trials as well as the development of value-added services based on detailed travel data.

7.5.2. Institutional Issues

Question 3.2 asked about the relative importance of different institutional issues that the trials might examine. The options included actual (rather than simulated) collection and apportionment of revenue, simultaneous collection of federal and state (and possibly local) VMT fees, alternate collection systems for passenger cars and trucks, alternate institutional configurations for billing and account management (e.g., publicly administered, administered by a single vendor, or administered by multiple vendors), and competition among multiple vendors within the same trial.

The institutional issues commonly cited as high priority to address in the trials included the simultaneous collection of federal, state, and possibly local VMT fees and multiple institutional configurations for billing and account management. Under the state framework, if it were intended that the trials be designed such that states could transition directly to implementation, then it would be crucial to include actual revenue collection. Under the market framework, collecting actual revenue would be essential, and allowing for competition among multiple firms in the same trials would also be very valuable.

7.5.3. Implementation and Phase-In Issues

Question 3.3 asked about the relative importance of examining additional implementation and phase-in issues in the trials, such as integration with existing toll systems, including different

classes of vehicles (e.g., older vehicles without the OBD II port that might require distinct metering device configurations), charging foreign vehicles, rebating fuel taxes to those who pay VMT fees (if needed), and incentives for voluntary adoption to speed the transition period.

Based on the responses of interview and workshop participants, the two issues that emerged as highest priority for the trials included integration with tolling systems and the exploration of incentives for voluntary adoption. Two additional issues received qualified recommendations. If it were intended that VMT fees replace fuel taxes, then the trials should examine methods for rebating fuel taxes for early adopters. Likewise, if were envisioned that all existing vehicles might at some point be required to install retrofitted metering equipment, then it would also be very helpful to examine multiple vehicle classes (i.e., both newer vehicles and older vehicles without an OBD II port).

7.5.4. User Perceptions and Acceptance

Question 3.4 asked about different user perception and acceptance issues that could potentially be examined in the trials. Options included user understanding of and support for distance-based road-use charges, user response to alternate fee structures, user response to alternate privacy protection mechanisms, user response with respect to potential tradeoffs between privacy and ability to audit, and user response to the choice of value-added features. Participants generally viewed user understanding and acceptance of VMT fees and privacy concerns as the highest priority issues to examine in the trials. Other issues were viewed as valuable but not equally essential.

7.6. DETAILED TRIAL IMPLEMENTATION STRATEGIES

This section summarizes the responses to more detailed questions about how to implement and conduct the trials successfully—for example, enrolling participants, examining interoperability standards, and probing the effectiveness of approaches for preventing evasion.

7.6.1. Strategies for Enrolling Participants

Question 9.1 asked about how to encourage both car and truck drivers to participate in trials. Many respondents felt that the trials would need to offer some form of incentive—likely financial, and on the order of several hundred dollars per participant, but perhaps involving the provision of value-added services—to entice sufficient participation. It was also noted that effective incentives for passenger car drivers would likely differ from those for trucking firms; specifically, the opportunity to provide input on the design of the VMT-fee system and pricing policies might be a stronger incentive to participate among trucking firms.

7.6.2. Groups to Include

Question 9.2 asked whether efforts should be made to include specific types of vehicles or groups of users in the trials, such as electric vehicles, older vehicles without OBD-II ports, rental fleets, government fleets, or trucking fleets. Based on responses from interview and workshop participants, it would be valuable for the trials to encompass as many vehicle classes and user groups as possible, but few respondents viewed the inclusion of any specific group as being a critical requirement for the trials.

7.6.3. Parallel Education Activities

Though the project focused mainly on the trials themselves, question 9.3 asked interview and workshop participants to consider complementary education and outreach activities that might be included before, during, and after the trials. Many respondents indicated that the trials should ideally be accompanied by large-scale public outreach and education (though it was noted that this might be less important in the market framework, where participating firms would be motivated to market their services) and the campaign should start early. Other suggestions included designing the trials based in part on public input, using innovative means of outreach, and working through membership organizations. It was also noted that education and outreach would be a sensitive task and should be approached accordingly.

7.6.4. Interoperability Standards

Question 11.1 asked whether the federal government should endorse a set of interoperability standards in advance of the trials and, if so, who should take the lead in developing them. Respondents indicated that the development of interoperability standards, along with a process for certifying vendor products and services as compliant, would be a critical area for federal leadership. Issues to address within the standards would include support for fee collection options, privacy protection options, and enforcement options; data storage, communication, and security protocols; and support for IntelliDrive functions. Interviews and workshop participants expressed varied opinions as to who should lead this effort, but suggestions on who should be involved in developing the standards included representatives from device manufacturers and service providers, related industry consortia, IBTTA, ITS America, the IntelliDrive program, and academic institutions. Several respondents also noted that it would be helpful to reference related standards work, such as ISO/CEN 17575, as a starting point to speed the development process. Opinions were mixed, however, on whether standards should be developed in advance of or following the trials. Seeking to develop an initial set of standards in advance of trials would make it possible to examine how well the interoperability concept works in practice during the course of the trials, but it might also delay the timeframe for initiating the trials. Waiting until after the trials, in contrast, would provide a greater opportunity to apply the lessons learned during the trials to the standards development process. As discussed earlier, developing an initial draft of the standards prior to the trials would be important if it were intended that the trials might evolve directly to implementation—this would be applicable for the market framework and possibly for the state framework.

7.6.5. Accuracy of Metering and Billing

Question 11.2 and 11.3 asked about how to test the accuracy of metering devices and billing statements. Respondents indicated that accuracy issues should be tested and verified in advance of the trials; that is, there should be some set of tests to certify minimum accuracy requirements before initiating the trials. It was also noted, though, that the trials would provide the opportunity to further evaluate accuracy over a broader range of situations.

7.6.6. Effectiveness of Privacy Protection Mechanisms

Question 11.4 asked about how to verify, and demonstrate to users, the proper functioning of alternate mechanisms for protecting privacy. Interview and workshop participants indicated that it would be beneficial to involve, within the trials, a reputable organization committed to privacy

protection to help verify that the adopted privacy mechanisms work at intended. It would also be valuable to engage a firm with telecommunications and data security expertise to identify any potential vulnerabilities in the area of data security.

7.6.7. Effectiveness of Mechanisms for Preventing Evasion

Question 11.5 asked about how to test the effectiveness of alternate mechanisms for detecting and preventing fee evasion within the trials. States and the federal government would be understandably reluctant to proceed to implementation unless decision makers were confident that VMT fees could be effectively enforced. Yet within the context of trials, the level of participation might prove insufficient to fully stress the enforcement mechanisms. Additionally, if the trials did not involve the actual collection of revenue, there would be little incentive for participants to try to cheat the system. How, then, might the trials be structured to probe the effectiveness of proposed mechanisms for detecting and prevention evasion? Two suggestions emerged from the interviews and workshop: hiring a firm with relevant expertise to systematically search for weaknesses, and offering cash rewards to individual trial participants that find a way to avoid full payment without being detected.

7.6.8. VMT Fees for Foreign-Owned Vehicles

Question 11.6 asked about potential ways to test the application of VMT fees to foreign-owned vehicles in the trials, should that be desired. Interview and workshop participants did not provide any specific suggestions for this question. As discussed earlier in Section 7.5.3, the testing of VMT-fees for foreign-owned vehicles did not emerge as one of the highest priority issues for inclusion within the trials.

7.6.9. Additional Uses of Travel Data

Question 11.7 asked about how to evaluate, within the trials, the possibility of using detailed travel data to support other transportation applications—for example, developing real time traffic information or calibrating regional transportation demand models. Several respondents suggested paying a subset of trial participants to share their detailed travel data (perhaps on an anonymous basis) and using it to develop real-time traffic congestion information.

7.6.10. Transition Issues

Question 11.8 asked about how the trials might be structured to examine certain issues related to transitioning to VMT fees, including strategies for promoting voluntary adoption, methods for rebating fuel taxes (if VMT fees were to replace rather than augment fuel taxes), and the demonstration of a transition strategy. To examine potential responses to a voluntary opt-in transition strategy, respondents stressed the value of including a set of value-added features on the in-vehicle equipment within the trials. Specific suggestions for issues to probe included distinguishing between participant perceptions of VMT fees and perceptions of the value-added services and exploring whether the value-added services used to encourage participation in the trials would prove sufficient to entice the actual adoption of VMT fees. Interview and workshop participants did not provide specific suggestions on the issues of rebating fuel taxes or demonstrating a transition strategy.

8. SYNTHESIS OF OPTIONS FOR THE TRIALS

Based on the analysis conducted in this study—the review of related distance-based road use charging trials and programs, the identification of potential VMT-fee implementation options, the review and application of criteria for assessing the strengths and limitations of these options, the identification of remaining uncertainties that might be addressed within the context of system trials, the interviews and workshop conducted with stakeholders and subject matter experts, and additional supporting analysis—it is possible to outline several options for funding, organizing, structuring, managing, and conducing an expanded set of system trials with the aim of informing public policy debate and preparing for the possible implementation of VMT fees. While alternate designs for an effective trial program might also be possible, the options outlined here reflect the efforts of the research team to:

- Comprehensively address the broad range of issues and uncertainties associated with VMT fees to inform the policy debate and explore and refine implementation options
- Reflect frequently expressed perspectives and well-reasoned insights offered by stakeholders and subject matter experts during the interviews and workshops, augmented by additional analysis where helpful
- Support alternative potential pathways for implementing and transitioning to VMT fees, as embodied in the three conceptual frameworks for the trials

Largely influenced by the informed views of stakeholders and subject matter experts, the trial options outlined in this chapter might be viewed as an initial assessment of the many interrelated issues that would be important to consider in designing and implementing the trials; for certain questions—most notably the number of participants to include in the trials and the estimated cost of the trials—further analysis would be beneficial.

The chapter begins by briefly reviewing the three possible frameworks for the trials introduced in Chapter 6. These correspond to alternate vision of the pathway to implementing VMT fees, and in turn might influence certain attributes of the trials. Next, drawing on the input of participants in the interviews and workshop, the chapter summarizes detailed design elements of the trials, indicating where the appropriate choice might vary depending on the preferred framework. The final section of the chapter outlines parallel efforts that might be undertaken in the areas of planning and policy guidance, analytic studies, technical R&D, and education and outreach. As indicated in the preceding NCHRP 20-24(69) study (Sorensen et al. 2009), such activities could be an important complement to system trials in preparing for a possible transition to VMT fees.

8.1. CONCEPTUAL FRAMEWORKS FOR THE TRIALS

There are alternate potential pathways for implementing and transitioning to a system of VMT fees. VMT fees might first be implemented at the federal level, for example, or instead by states. And the transition strategy could rely solely on mandatory adoption or it might include an initial period of voluntary adoption. The envisioned pathway to VMT fees, in turn, could influence the

set of issues that would be important to examine in the trials. The three frameworks outlined in Chapter 6 correspond to alternate implementation and transition pathways and can thus serve as organizational constructs for helping to design specific attributes of the trials. The frameworks can be summarized as follows:

- **State framework.** In this framework, the trials would be aimed at helping interested states (or groups of adjacent states, such as the I-95 Corridor Coalition) develop their own systems. The federal government might then develop a national system at a later date based on the lessons learned in state programs. In addition to funding, a key federal role in this framework would be to foster the development of interoperability standards and a certifications process to ensure that systems developed in different states could interact with one another. The federal government might also encourage states to examine options that might later be extended to implement a national system. While some states might structure the trials to provide information to support subsequent planning and public debate, it is conceivable that others might intend that the trials would evolve directly to implementation.
- **Federal framework.** In this framework, the trials would aim to provide the necessary information to plan a capable, cost-effective, and politically viable system of VMT fees implemented at the national level. By design, the system would be sufficiently flexible to enable states, and possibly counties and cities, to implement their own VMT fees as well, though they would not be required to do so. While the trials would still be conducted in states interested in adopting their own VMT fees, the effort would be more carefully coordinated to examine issues involved in setting up a national system. Following the trials, and subject to political debate, efforts to plan and implement the system would commence.
- **Market framework.** This last framework represents the greatest departure from conventional thinking about how to accomplish a transition to VMT fees. It envisions the development and rapid deployment of in-vehicle metering devices that are simultaneously capable of levying federal, state, and potentially local VMT fees and supporting numerous value-added services such as automated payment of parking fees, PAYD insurance, real-time traffic alerts, traffic-based routing suggestions, and the like. Firms would compete to provide these services, thereby stimulating innovation and driving down system costs. Additionally, because firms would be able to collect payment for some of the additional services (e.g., a percentage of parking fees or PAYD insurance premiums), the amount that they would need to charge the government for collecting VMT fees would be reduced. The main goal of the trials in this framework would be to accelerate the development of this market. To do so, the federal government would separately contract with, fund, or subsidize technology providers, states, cities, and auto insurers for their respective roles in the trials, and the intent would be for the trials to evolve directly to system implementation. Trial participants that valued the additional services would become the initial adopters, and additional drivers would be able to adopt the in-vehicle equipment on a voluntary basis as well. After several more years, once the system had been demonstrated to function as intended, the government might mandate the adoption of VMT fees for all vehicles.

Each of the frameworks, as described at length in Chapter 6, presents its own strengths, weaknesses, and potential risks, and there is no inherently "right" answer. Rather, the selection of a framework would be a matter for policy judgment, one that would ultimately rest on two

questions. First, would the principal objective of the trials be to facilitate the implementation of VMT fees by individual states or to explore the development of a national system (capable of supporting federal, state, and possibly local VMT fees)? If the former, the state framework would be the appropriate choice. If the latter, then the second question to consider is whether VMT trials for a national system would be intended to provide data and insights to inform subsequent public debate and system planning or instead to evolve directly (through an initial period of voluntary adoption) to full-scale operation. The former would suggest the federal framework, while the latter would suggest the market framework.

While it would be possible for decision makers to sponsor a set of trials without a specific framework in mind, making an explicit choice among the frameworks could prove very helpful. It would clarify the goals of the trials, and this in turn would assist in designing certain elements of the trials to support those goals. In considering this question, the frameworks need not be viewed as entirely mutually exclusive. It would be possible, for example, for decision makers to select the market framework for passenger vehicle trials and the federal framework for truck trials. It would also be possible to blend elements from multiple frameworks within a set of trials—for instance, funding some states to conduct their own independent trials and funding others to participate in federal trials.

8.2. OPTIONS FOR THE TRIALS

This section summarizes the detailed options for designing the trials that emerged from the study. Information about the technical implementation mechanisms to examine in the trials draws upon the analysis in Chapter 4, and has been further augmented with the research team's expectations regarding which of the specific metering and collection mechanisms would be most logical to examine in each of the three frameworks. All other elements of the outlined options for the trials are based upon the input received during the interviews and workshop along with any supplementary analysis, as summarized in Chapter 7.

The detailed options for the trials are presented in Table 8.1. The first column in this table lists the various issues or attributes of the trials to be considered (e.g., the number of participants to include within the trials or the pricing policies to examine in the trials); the next three correspond to the frameworks. For certain design elements, as indicated in the table, the indicated approach would be consistent across all three frameworks; for others, the answer might vary depending on the selected framework for the trials.

Table 8.1. Options for the Trials

Issues	Frameworks		
	State	Federal	Market
Overseeing, Managing, and Conducting the Trials			
Overseeing the trials	Decision makers designate an oversight panel to provide guidance on the trials and related activities. The panel includes, at minimum, representation from Treasury, USDOT, FHWA, AASHTO, and individual states.		
Managing the trials	Decision makers designate TRB to manage the overall effort in a program similar to SHRP2. Alternatively decision makers assign this role to FHWA, RITA, or Volpe, or delegate the choice to the Secretary of Transportation.		
Conducting the trials	States assemble teams to bid for trial funding, including technology vendors (to provide metering and billing services) and possibly cities or counties (to test local VMT fees and/or automated payment of parking fees), auto insurers (to test PAYD insurance), and MPOs or research organizations (for education, outreach, and/or analysis).		Technology vendors, states, auto insurers, local jurisdictions, and research institutions are separately funded for their distinct roles in conducting the trials.
Organizing, Funding, and Coordinating the Trials			
Number / location of trials	Trials are conducted in 3 to 6 states or groups of adjacent states. Ideally the selected trial locations span different geographic regions of the country, include predominantly urban and predominantly rural states, include several large urban regions, include "red" and "blue" states, and include one or more multi-state trial configurations.		
Awarding trials	Trial funding is awarded on a competitive basis. Subject to meeting certain proposal requirements, criteria for judging bids could include cost, number of participants, capacity of the proposing entity, provision of value-added services with the in-vehicle equipment, intent to explore more advanced forms of pricing, intent to collect actual revenue, and intent to explore the use of travel data from the system to support improved planning. Additionally, a modest amount of funding might be set aside for any state that wishes to conduct a preliminary investigation of VMT fees (i.e., studies, not trials).		
Coordinating multiple trials	Trials are loosely coordinated. Main unifying theme is the examination of interoperability standards.	Trials are more carefully coordinated to address all issues relevant to developing a national system.	
Size, Duration, and Cost of the Trials			
Size (number of participants)	10K – 20K per trial 50K – 100K total		100K – 200K per trial 500K – 1M total
Duration of the trials	4-6 years total, including 1-2 years for initial preparation, 2-3 years for conducting the trials, and 1 year for evaluation		
Cost of the trials	$100M – $400M		$1B – $4B
Federal share of funding	Federal government either fully funds trials or requires a modest state match of ten to twenty percent. The latter would help ensure that states that apply are committed to the concept, but it might prevent the participation of otherwise interested states given current economic conditions.		

Table 8.1. Options for the Trials (cont.)

Issues	Frameworks		
	State	Federal	Market
Implementation Options to Examine in the Trials			
Metering options	OBU with GPS. Also possible: OBU with OBD II / cellular, odometer-based options, other innovative options.	OBU with GPS. Also possible: OBU with OBD II / cellular, other innovative options.	OBU with GPS. Also possible: other innovative options.
Options for collecting fees	Pay with registration, pay at the pump, wireless transmission to collection authority, debit cards	Pay at the pump, wireless transmission to collection authority, debit cards	Wireless transmission to collection authority, debit cards
Options for preventing evasion	All options, but with special focus on those that reduce required manual intervention, including fuel consumption redundancy checks, external DSRC/ANPR checks, device heartbeat signals, and device distress signals		
Options for protecting privacy	All options, including on-board data aggregation and fee computation, anonymous proxy fee computation, trusted third party, prepaid debit cards, anonymous user accounts, and relevant encryption strategies		
Implementation concepts	Interoperability standards, retrofits, voluntary opt-in incentives, user choice		
Metering and Pricing Policies to Examine in the Trials			
Metering VMT on all public roads	Yes (by definition)		
Tolling on a partial road network	Only if viewed by policymakers as a potential alternative to VMT fees		
VMT fees for passenger cars	Yes		
VMT fees for trucks	Yes		
Fees that vary by jurisdiction	Yes		
Congestion tolls	Optional (desirable but potentially too controversial)		
Emissions-based fees	Optional (desirable but potentially too controversial)		
Weight-distance truck tolls	Optional (desirable but potentially too controversial)		
Technical Issues to Examine in the Trials			
Metering options	Optional (acceptable if GPS is only option evaluated)		
Fee collection options	Yes (evaluate multiple options)		
Options for preventing evasion	Yes (evaluate multiple options)		
Options for protecting privacy	Yes (evaluate multiple options)		
Interoperability standards	Yes if envisioned that trials might evolve directly to state implementation, otherwise optional	Optional	Yes
Use of travel data from system	Optional		Yes

Table 8.1. Options for the Trials (cont.)

Issues	Frameworks		
	State	Federal	Market
Institutional Issues to Examine in Trials			
Actual revenue collection	Yes if envisioned that trails might evolve directly to state implementation, otherwise optional	Optional	Yes
Collect federal and state fees	Optional	Yes	
Parallel auto / truck systems	Optional		
Alternate billing arrangements	Yes		
Competition among firms	Optional		Yes
Implementation and Phase-In Issues to Examine in Trials			
Integration with toll systems	Yes		
Different vehicle classes	If envisioned that retrofits would someday be mandated		
Charging foreign vehicles	Optional		
Rebating fuel taxes	If envisioned that VMT fees would replace rather than augment fuel taxes		
Voluntary adoption incentives	Yes		
User Acceptance Issues to Examine in Trials			
Concept of VMT fees	Yes		
Alternate fee structures	Optional		
Alternate privacy protection	Yes		
Privacy vs. auditability	Optional		
Value-added services	Optional		
Detailed Strategies for Implementing the Trials			
Interoperability standards	Standards encompass accuracy requirements, privacy protection, support for preventing evasion, data storage and communication protocols, data security, and related functionality. Standards development involves device manufacturers and service providers, related industry consortia, IBTTA, ITS America, IntelliDrive program representatives, and academic institutions. Effort references ISO/CEN 17575 and related efforts as initial starting point.		
Privacy protection	Privacy advocacy organization enrolled to verify privacy protection methods.		
Preventing evasion	Firm with telecommunications and security expertise enrolled to probe for vulnerabilities related to fee evasion or system security.		

8.3. ACTIVITIES TO COMPLEMENT THE TRIALS

As indicated in the preceding NCHRP 20-24(69) project (Sorensen et al. 2009) and supported by the research in this study (see, e.g., Table 5.1), the effort to plan and design a system of VMT fees that is capable, cost-effective, and politically viable would benefit from several interrelated activities: planning and policy guidance, analytic studies, targeted R&D, trials, and education and outreach. Decision makers interested in funding expanded system trials with the intent of further exploring and refining potential VMT-fee implementation concepts might therefore consider embedding the trials within a broader effort that includes these additional activities. With that possibility in mind it could prove helpful, in closing, to briefly comment on some of the more critical related efforts that could complement the trials.

The ideas presented in the following draw upon the information in Chapter 5 as well as the preceding NCHRP 20-24(69) study. Given that this study focused principally on trials, however, further assessment of the issues to address in these parallel efforts would be valuable.

8.3.1. Planning and Policy Guidance

Critical planning and policy guidance tasks would include establishing the policy objectives and in turn the functional requirements for the system, guiding the technical and institutional design of the system, and planning the process for transitioning from fuel taxes to VMT fees. Specifics are as follows:

- **System requirements.** Key system requirements that would need to be determined include metering capabilities to be supported by the system, which would in turn influence the policy goals that could be addressed; whether the system would apply to passenger cars, trucks, or both; whether the system would apply only to new vehicles or to older vehicles (thus requiring equipment retrofits) as well; whether VMT fees would first be implemented by individual states or instead at the federal level; the required level of metering and billing accuracy; the forms of privacy protection that the system should provide; the forms of payment that the system should support; whether interoperability among state systems (if not implemented at the federal level) should be viewed as essential; and whether the system should be designed to support a broad range of complementary value-added functions.
- **Technical implementation.** Technical planning would help to determine the approaches employed to meter mileage, collect fees, prevent evasion, and protect privacy. Additionally, it would include the development of system interoperability standards.
- **Institutional arrangements.** Institutional planning efforts would need to address the public and private roles in providing metering devices and billing services; whether there should be a default, low cost "public option" for metering and collecting VMT fees (and, if so, how it should be structured); federal and state roles in the enforcement of federal VMT fees; the processes and institutional responsibilities for certifying vendors of metering equipment and billing services, developing and maintaining interoperability standards, and developing and maintaining the "price map" of applicable VMT fees in different states, counties, cities, etc.; and the development of pricing guidelines that would constrain the fees that could be set by different jurisdictions.

- **Implementation and transition issues.** Finally, there would be a need to plan several detailed issues related to implementing and transitioning to VMT fees. Such issues would include the timeframe for phasing in the system; whether the initial adoption of VMT fees would be mandatory (e.g., required with the purchase of new passenger vehicles or required by a certain date for commercial vehicles) or voluntary; whether VMT fees would augment or replace fuel taxes, in turn influencing whether the system would need to provide a mechanism for rebating fuel taxes; and the approach that would be used for assessing road use fees for foreign-owned vehicles (in the case of a national system) or out-of-state drivers (in the case of a state system).

Many of these issues could be informed by the trial results. That is, the evaluation of alternative implementation option and institutional arrangements within the trials would shed light on their relative strengths and limitations, and this would serve as a basis for making specific design and planning decisions for full-scale implementation and deployment. Several of the issues, however, would ideally be addressed *in advance of the trials* (possibly by the oversight panel for the trials discussed above). These are as follows:

- **System requirements.** All of the issues listed above under system requirements might influence or constrain the options for implementing VMT fees. To make the trials as productive as possible—that is, to ensure that the trials examine an appropriate set of implementation options—it would be helpful to address these issues in advance of the trials.
- **Interoperability standards.** If it were envisioned that trials might evolve directly to implementation—a possibility in the state framework and an explicit goal within the market framework—then it would be valuable to develop the interoperability standards in advance of the trials.
- **Mandatory adoption vs. voluntary opt-in.** This decision would influence the relative importance of examining value-added services within the trials as a means of spurring voluntary adoption.
- **Augment vs. replace fuel taxes.** This decision would influence the utility of examining mechanisms for rebating fuel taxes within the trials.

8.3.2. Analytic Studies

Many of the uncertainties involved in planning and implementing a VMT fee system could benefit from additional analytic study. Higher priority issues in this area might include:

- **Cost of implementation options at scale.** While the trials could shed some light on the cost of various implementation options at scale (most notably metering devices and mechanisms for collecting fees), they would likely include at most hundreds of thousands of participants. To gain insight on the cost implications of expanding to a full-scale system with hundreds of millions of drivers, it would be helpful to complement the trials with additional cost analysis. Note as well that the pace of technical innovation in this field is rapid, suggesting that it might be beneficial to revisit cost estimates every few years.
- **Institutional arrangements for collecting and apportioning revenue.** Further analysis would be helpful to better understand the benefits and drawbacks of alternate institutional

configurations of the billing process. Options to examine might include administration by a public agency (similar to fuel taxes), by a consortium of stakeholders (similar to IRP and IFTA), or by multiple firms in a competitive framework (similar to cellular service). The analysis should also consider how the adoption of alternate payment mechanisms (i.e., pay-at-the-pump vs. transmission of billing data to a collection authority vs. debit cards) might influence the appropriate administrative configuration.

- **Methods for rebating fuel taxes.** Under the assumption that VMT fees would replace rather than augment fuel taxes, it would also be beneficial to conduct more thorough analysis on the range of possibilities for rebating fuel taxes. In comparing alternatives, the analysis should consider such issues as accuracy, burden on users, and cost of administration.
- **Methods for charging foreign vehicles.** It would be useful to conduct more research to understand the options for assessing VMT fees for foreign-owned vehicles (or out-of-state vehicles, in the case of a state VMT-fee system) and their relative strengths and limitations. This did not emerge as a high priority issue to examine in the trials, but it would certainly need to be addressed to implement a system.
- **Legal barriers to VMT fees.** It would be helpful to identify and evaluate any federal or state legal barriers that would need to be addressed through legislation in order to allow for the implementation of federal or state VMT fees (possibly including any issues related to state administration or enforcement of federal fees).
- **Fee vs. tax.** It would be beneficial to briefly examine the question of whether VMT fees should be adopted, in a legal sense, as a fee or as a tax. This could affect such matters as the burden of proof in disputes over fees owed and whether fee increases could be instituted by an administrative agency or would instead require legislative action.
- **Education and outreach strategies.** Prior to embarking on the education and outreach effort, it would be helpful to research the most cost-effective options for increasing public understanding of the motivations for and potential benefits of a transition to VMT fees.

8.3.3. Targeted R&D

Though many of the potential mechanisms for implementing VMT fees have already been developed, it might still be useful to provide additional research and development support in several areas:

- **Metering devices.** The goal here would be to continue efforts to develop low-cost metering devices that offer flexible metering capabilities (able to determine area or route of travel).
- **Methods for preventing evasion.** Efforts in this area would focus on developing technical methods for preventing evasion (e.g., efforts to tamper with an OBU) that are effective and minimize the required degree of manual intervention.
- **Value-added services.** Finally, to maximize the social value provided by the investment in sophisticated metering devices, it could be worthwhile to allocate resources toward the development of value-added services that could be supported on the devices. This effort might focus on applications that serve a clear public goal—for example, the porting of

safety-related features envisioned within the IntelliDrive program or the development of real-time traffic information across the road network in areas prone to recurrent congestion.

8.3.4. Outreach and Education

An extensive education and outreach effort would be needed to facilitate greater understanding of current transportation funding challenges associated with reliance on fuel taxes along with the potential benefits of VMT fees. Regarding the former, the current influx of federal transportation stimulus dollars likely masks, for many, the extent of current funding shortfalls. While the trials would play a role in building public awareness of VMT fees, it could be beneficial to develop and implement a more comprehensive plan—potentially including, for example, education of state and local leaders, focus groups, media campaigns, "branding" of the program, and the like. As suggested earlier, it would be helpful to conduct additional analysis of effective education and outreach strategies in order to plan such an effort.

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Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ECMT	European Conference of Ministers of Transport
EIA	Energy Information Agency
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
IBTTA	International Bridge, Tunnel and Turnpike Association
NCHRP	National Cooperative Highway Research Program
NSTIFC	National Surface Transportation Infrastructure Financing Commission
NSTPRSC	National Surface Transportation Policy and Revenue Study Commission
ODOT	Oregon Department of Transportation
OIPAF	ODOT Office of Innovative Partnerships and Alternative Funding
PSRC	Puget Sound Regional Council
RITA	Research and Innovative Technology Administration
TRB	Transportation Research Board

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APPENDIX A. RELATED TRIALS AND PROGRAMS

The past decade has witnessed increasing interest in distance-based road use charges. This chapter briefly describes the pilot tests and program implementation efforts listed in Chapter 3 (for more in-depth discussion of some of the programs, see Sorensen and Taylor 2005). The cases are organized in three categories: general purpose distance-based road use charges, weight-distance truck tolls, and PAYD insurance/leasing.

A.1. GENERAL PURPOSE DISTANCE-BASED ROAD USE CHARGES

Distance-based systems for levying road use charges that would apply to all vehicles on the road have yet to be implemented, but more limited systems do exist. In New Zealand, a system of distance-based road use charges for passenger vehicles that do not pay fuel taxes (principally diesel-powered vehicles) as well as vehicles weighing in excess of 3.5 tons has already been instituted (Land Transport NZ 2008). The idea of developing more robust and flexible distance-based road-use charging systems, however, has received considerable attention in recent years. Well-known examples in this category include:

- Oregon Department of Transportation Road User Fee Pilot Program
- University of Iowa Mileage-Based Road User Charge study
- Puget Sound Regional Council Traffic Choices Study
- Georgia Tech Commute Atlanta study and trials
- The planned Netherlands VKT (Vehicle Kilometers Traveled) system
- The New Zealand road user charges

Note that the United Kingdom has also reportedly conducted trials of distance-based road use charges but we were not able to locate documents describing the results.

Oregon Department of Transportation's Road User Fee Pilot Program. Under a mandate from the State Legislature, the Oregon Department of Transportation planned and conducted a pilot study of mileage-based user fees and area-wide congestion tolls. The 12-month pilot project took place from 2006 to 2007 and included 285 vehicles, 299 drivers, and two gas stations. Participating vehicles were equipped with OBUs featuring a GPS receiver to determine the geographic zone of travel (within or outside of Oregon and within or outside of a designated congestion charging zone) and a connection to the speed sensor to meter mileage (note that for a small set of participating vehicles, due to difficulties accessing the speed sensor, GPS was used to meter both location and mileage). To simulate the payment of mileage fees, billing data were transmitted wirelessly to an electronic reader at the pump of the participating gas stations, which in turn calculated the difference between the gas tax that would have been paid and the mileage fee. After an initial phase in which all drivers paid the regular gas tax, drivers were divided into two groups to test various pricing concepts: some were charged a flat fee of 1.2 cents per mile in one zone; others were charged 10 cents per mile during peak hours in the "congestion zone" but

only 0.43 cents per mile for other travel. At the beginning of the trial period, drivers received an endowment account, and mileage fees were debited from this account as the trial progressed. At the conclusion of the trial, participants received any remaining balance in the account. Thus motivated, drivers in both test groups reduced their overall VMT during the study, and the technology functioned as planned. For more information, see Whitty (2003, 2007, 2008).

University of Iowa Mileage-Based Road User Charge study. The University of Iowa is conducting an extensive set of VMT-fee trials involving close to 2,700 participants in 12 locations around the country, including Albuquerque, Austin, Baltimore, Billings, Boise, Chicago, eastern Iowa, Miami, Portland (Maine), the Research Triangle in North Carolina, San Diego, and Wichita. Vehicles are outfitted with an OBU that combines GPS with an OBD II port connection; the GPS unit determines the location of travel, while vehicle speed data from the OBD II port is used to compute travel distance. Charges vary with two criteria–the vehicle's fuel economy profile and the jurisdiction in which travel occurs—but are generally set to be revenue neutral in comparison to current fuel taxes. For example, the rate for fuel efficient vehicles in the 48 to 53 mpg range might be as low as 0.36 cents per mile; the rate for less fuel efficient vehicles in the 8.8 to 9.7 mpg range might be as high as 1.99 cents per mile. The per-mile rates might also differ by state to account for state-by-state variations in fuel taxes. Within each jurisdiction, however, all miles driven by a vehicle are charged the same rate; neither time nor specific location is considered. Data from the instrumented vehicles are transmitted wirelessly to a "back office" operated by the University, which then sends mock invoices to the drivers in all twelve regions on a monthly basis. Drivers continue to pay normal gas taxes, though; the invoices only demonstrate how much they would have paid if the system were fully operational. For further information, see Forkenbrock and Kuhl (2002) and Kuhl (2007).

Puget Sound Regional Council's Traffic Choice Study. The Puget Sound Regional Council conducted a study of distance-based, network-wide congestion tolls from 2005 to 2006. Approximately 275 households, with 500 vehicles in total, participated. Each vehicle was equipped with an OBU featuring cellular communications and a GPS receiver. The study was designed to test driver response to distance-based congestion pricing; tolls were levied on freeways and major arterials, with per-mile rates ranging from 0 to 40 cents depending on the link and the time of day (note that tolls did not vary dynamically with current traffic conditions, but rather were determined according to a pre-set schedule). The OBU detected when the vehicle traveled on a link subject to tolls, calculated the charge, and periodically uploaded the data to a central computer center. The OBU display also showed drivers the current cost per mile as well as the cumulative cost for the trip. To gauge driver response, the study team monitored the travel patterns for each participant before the trials began and then set up an individualized endowment account based on those patterns. Congestion charges were debited from the endowment account during the trials, but participants were allowed to keep any remaining balance at the end of the trials, thus creating a financial incentive for drivers to reduce their peak-hour travel on routes subject to the charges. Results from the study demonstrated that drivers did in fact change their travel behavior in response to the charges, and that the equipment functioned as planned. For more information, see Puget Sound Regional Council (2008).

Georgia Tech Commute Atlanta study. The Georgia Institute of Technology conducted the Commute Atlanta study to examine the effects of converting fuel taxes, registration fees, and

insurance costs to variable costs. The first phase of the project collected baseline data from 475 vehicles in 273 households in 13 counties. In addition to conventional travel diaries, data were collected via GT Trip Data Collectors that were installed in the vehicles. These GPS devices collected data on vehicle location, speed, and acceleration every second. The second phase of the project studied travel behavior with a mileage-based incentive simulation. Participating households received rebates on travel costs based on their miles traveled in the preceding year; that is, if they drove fewer miles, they earned a certain number of cents per for each of the miles not driven (the number started at 5 cents per mile and increased to 15 cents). A third phase, to study the impacts of congestion tolls, was not funded. For further information, see Guensler and Ogle (2004).

Planned Netherlands VKT system. The Dutch have been planning a system of road use charges for passenger and commercial vehicles based on vehicle kilometers of travel. Planners initially expected to launch the system as early as 2013 or 2014, likely beginning with trucks, will full-scale implementation for all vehicles by 2018; with the recent collapse of the Dutch governing coalition over foreign policy differences, however, further implementation efforts have been put on hold. The broad goals of the system, as planned, included reducing congestion, reducing emissions, and, more broadly, employing a "user pays" philosophy for raising road revenue. VKT fees were not intended to replace existing fuel taxes, which would remain in place; rather, the fees would replace, on a revenue-neutral basis, current vehicle purchase taxes and motor vehicle taxes (akin to annual registration fees), both of which are levied by the national government. The planned fee structure would vary by vehicle class (e.g., passenger cars, light commercial vehicles, heavy trucks), and within each vehicle class the fee would vary by such factors as emissions profile and vehicle weight. Additionally, rush-hour surcharges would be levied in areas prone to recurrent congestion. The planned implementation mechanism involved the use of an OBU that incorporates satellite positioning to determine location of travel, cellular communications to transmit billing data, and DSRC to assist in enforcement (mobile and fixed compliance check gates would be scattered throughout the road network to electronically probe passing vehicles and verify that their OBUs are operational). The technical design would meet relevant European road pricing interoperability and data protection standards. It was expected that private vendors would provide compliant OBUs that drivers could choose on the basis of price and value-added functions. The public sector would initially handle billing and collection, though planners anticipated that this function might be transferred to the private sector as well at some point. Prior to implementation, two trials were planned. The first, expected to last four months, would consist of a series of technical tests for key components of the system. The second, expected to last ten months, would involve 60,000 vehicles and focus on the functionality of the OBUs and the collection systems. For more information on the planned Dutch VKT program, see Dutch Ministry of Transport, Public Works, and Water Management (undated and 2009).

New Zealand Road User Charges. Since the late 1970s, New Zealand has had a distance-based fee system in place for passenger vehicles whose fuel is not taxed at the source (mainly diesel) and vehicles that weigh over 3.5 tons. The fees vary by vehicle weight and the number of axles. Traditionally, passenger vehicle owners have been required to purchase licenses for a specific distance in 1000-km increments and display them in the vehicle, while trucks have been outfitted with a hub-odometer which measures distance by the rotation of the wheels. As of the beginning

of 2010, however, vehicle operators now have the option of installing in-vehicle equipment to meter mileage and pay the charges rather than installing hub-odometers or purchasing paper licenses. This option is offered by private service providers whose equipment has been certified for the collection of road use charges by the government. For further information, see Land Transport NZ (2008), New Zealand Transport Agency (2009) and New Zealand Ministry of Transport (undated).

A.2. WEIGHT-DISTANCE TRUCK TOLLS

Weight-distance truck tolls are not a new concept, and many states have in the past instituted this form of road-use charges. Previous programs were implemented through cumbersome manual means, however, and only four states currently levy weight-distance road-use fees. Within the past decade, though, several European nations have successfully implemented automated weight-distance truck charges through the use of electronic tolling technology, and this has stimulated a renewed interest in the concept within the United States as well. Examples in this category include:

- The Austrian GO program
- The Swiss Heavy Goods Vehicle Fee (HVF)
- The German Toll Collect program
- The Czech Republic truck toll
- The Slovakia truck toll
- The Oregon Truck Road Use Electronics (TRUE) pilot project

Note that an effort to scope potential trials of truck VMT fees in New York, sponsored by the Greater Buffalo Niagara Regional Transportation Council, is also underway, though information about this project was not publicly available at the time of writing. The truck component of the New Zealand road use charging program, described in the previous section, also represents a weight-distance truck toll.

The Austrian GO program. Successfully launched on time and within budget in January 2004, the Austrian GO truck-tolling program is managed by Europpass, a subsidiary of the Italian firm Autostrade. The GO program applies distance charges on the motorway for all vehicles whose maximum admissible weight exceeds 3.5 tons, with specific fee levels that depend on the weight class and the number of axles. From a technical perspective, the GO program is one of the simplest of the recently implemented or proposed truck tolling schemes reviewed here. To participate in the GO program (and thus avoid the inconvenience of paying tolls manually), each vehicle is equipped with an on-board unit featuring DSRC. These units communicate with overhead gantries located on different links throughout highway system. Each time a vehicle passes one of the 420 gantries distributed throughout the network, a distance charge for the link in question is applied. If the gantry fails to detect an on-board receiver, the vehicle will be flagged for investigation of possible toll evasion. One notable feature of the GO system is interoperability with the Swiss tolling program; by inserting a simple chip within their “Tripon”

on-board units, Swiss drivers traveling in Austria can pay their tolls automatically as well. For further information, see Schwarz-Herda (2004).

The Swiss Heavy Goods Vehicle Fee (HVF). Following a lengthy political acceptance process, Switzerland successfully launched its heavy goods vehicle fee (HVF) on time and within budget in January of 2001. The HVF applies to all vehicles with a maximum laden weight in excess of 3.5 tons. The fee is calculated based on the distance driven (on all Swiss roads, not just the highways) as well as the maximum laden weight and the emissions class of the vehicle. The price structure is designed to account for both direct and external costs of trucking and to encourage a freight mode shift from road to rail. The supporting technology includes an on-board unit (mandatory for all Swiss vehicles and optional, though encouraged, for foreign vehicles) featuring GPS and DSRC, as well as a connection to the vehicle's tachometer (including odometer information). DSRC signals from overhead gantries at border crossings (in the case of primary arteries) and/or the GPS position signals (in the case of smaller roads without DSRC gantries) are used to set the status of the OBU (within Switzerland or traveling abroad), and odometer information is used to register miles driven on Swiss roads. DSRC stations mounted throughout the network are also used to verify the correct functioning of passing trucks as a means to prevent toll evasion. For further information, see Balmer (2004) and Werder (2004).

The German Toll Collect program. The German Toll Collect truck toll system was initially targeted for implementation in the fall of 2003, but due to technical and contractual difficulties the launch was delayed until January of 2005. Per European Union directive, the fee system applies only to vehicles over 12 tons and principally to use of motorways (some adjacent surface streets are tolled to prevent truck diversion). The price varies by distance traveled, by the number of axles (as a surrogate for weight), and by the emissions class of the vehicle. The overall fee structure is designed to recoup direct capital and operating costs to the motorway system imposed by truck traffic. The technology supporting Toll Collect involves an on-board unit equipped with GPS (to determine both entry to and exit from the motorway network and distance traveled), cellular communications (to transmit billing data to the central computer system), and DSRC (for enforcement purposes). Toll Collect is administered by a private consortium that collects the tolls on behalf of the German government. The government then spends most of the revenue on road maintenance and improvement projects that reflect government priorities. For further information, see Broaddus and Gertz (2008), Kossak (2003), Rothengatter (2004), and Ruidisch (2004).

The Czech Republic truck toll. The Czech Republic recently implemented a DSRC-based weight-distance truck toll for major thoroughfares. The system became operational in January 2007 for trucks over 12,000 kg (13.2 tons), and was expanded to include trucks over 3,500 kg (3.8 tons) in January 2010. The managing authority is the Czech Ministry of Transport, but implementation is under contract to a private vendor. Fees are based on distance, vehicle types, and emissions class. The average toll rate translates to $0.35 per mile (freeway) and the system collected $350 million in 2008. Enforcement is based on automated number plate recognition (ANPR) for vehicles lacking the necessary metering equipment. Trucks are prohibited from operating on Sundays and during peak hours on Friday evening and Saturday morning. For more information, see AASHTO et al. (2010).

The Slovakia truck toll. In January, 2010, Slovakia introduced an automated weight-distance truck tolling system that uses OBUs combining cellular communications and GPS. All trucks over 3,500 kg are required to participate, as well as buses that carry nine or more passengers. The system covers approximately 2,400 km (1,500 miles) of roads, and the charge rate is based on vehicle category, number of axles, and emissions class. The system administrator is the National Highway Company, which has a contract with the SkyToll consortium (a joint venture between Ibertax and SanToll). During the first two months of operation, the system collected €12.8 million (US $17.4 million). The implementation of the system has been somewhat controversial; the government selected the highest bidder after finding the other three bidders ineligible, and truckers protested when the system was introduced, claiming that the units were incorrectly recording more miles than they had driven. For more information see Electronic Tolling System (2009) and SkyToll (2009).

The Oregon Truck Road Use Electronic pilot project. At the request of Oregon Congressman Peter DeFazio, Chairman of the House Transportation and Infrastructure Committee, the Oregon Department of Transportation (ODOT) is working with an Oregon trucking company to test a GPS-based device that would automate the collection of the state's existing weight-mile fee, which is currently implemented manually. The device, called Truck Road Use Electronics (TRUE), will record the miles that the truck travels in Oregon, as well as the declared weight and number of axles, and send the data to ODOT to produce the company's weight-mile fee report. Goals of the project include demonstrating the ability to replace recordkeeping paperwork while ensuring the greatest accuracy for road-use reporting. The pilot project, involving five to ten trucks, began in January 2010 and was scheduled to last for 90 days. During this period, the participating company has been instructed to continue its normal processes for keeping mileage records and filing weight-mile tax reports, thus enabling comparison of the accuracy of the TRUE device. For more information, see ODOT (2010) and OIPAF (2010).

A.3. PAY-AS-YOU-DRIVE (PAYD) INSURANCE / LEASING

The PAYD insurance concept appears to be gaining significant traction, with many companies in the United States and abroad either offering or experimenting with this type of program. Note that some examples are more aptly described as mileage-based discounts, in which the rates depend, for example, on whether a vehicle travels between 0 and 2,500 miles in a year, between 2,500 and 5,000 miles in a year, between 5,000 and 7,500 miles in a year, etc. Even in such cases, however, it is still necessary to meter miles of travel. Though PAYD leasing – that is, varying the lease payment on the basis of miles traveled – has also been explored, to our knowledge this related concept has not yet been implemented in practice. Examples of PAYD insurance for which we were able to find documentation include:

- Massachusetts, with multiple companies offering mileage-based insurance discounts
- GMAC, offering mileage-based insurance discounts for OnStar customers in 34 states
- MileMeter, offering PAYD insurance in Texas
- Progressive Insurance, offering PAYD insurance in nine states
- Aviva, offering PAYD insurance in Canada

- CoverBox, offering PAYD insurance in England
- Hollard Insurance, offering PAYD insurance in South Africa
- Nedbank, offering PAYD insurance in South Africa
- Real Insurance, offering PAYD insurance in Australia

Massachusetts. Massachusetts introduced competitively priced auto insurance in April 2008; previously, rates had been set by the state. Insurance companies can now offer discounts for low mileage: specifically, a ten percent discount for driving between 0 and 5,000 miles annually, and a five percent discount for mileage between 5,000 and 7,500. Mileage is verified by the Massachusetts Registry of Motor Vehicles. For more information, see Bingham et al. (2009) and Boston Consumer's Checkbook (undated).

GMAC. In 34 states, drivers of General Motors vehicles equipped with OnStar GPS systems can sign up for mileage-based insurance discounts. The discounts are based on mileage bands; for example, drivers who drive 5,000 to 7,500 miles per year receive a 34 percent discount over the standard premium they would otherwise pay, while those who drive 7,500 to 10,000 miles could receive a 26 percent discount. The mileage is calculated by the vehicle diagnostics system; location of driving is not used to calculate the premium. For more information, see OnStar (2007).

MileMeter. This Texas firm offers PAYD with the cost per mile based on the driver's age, vehicle type, and residential location. All miles driven carry the same cost. The driver purchases a six-month policy for a specific number of miles from 1,000 to 6,000; the policy ends when either the six-month mark is reached or the driver has driven the number of miles purchased. MileMeter does not actively keep track of the number of miles driven; if a claim is filed, it is matched against the policy, and the policy is considered invalid if the odometer reads over the specified number. For more information, see MileMeter (undated).

Progressive Insurance. Progressive offers PAYD in ten states, under a program called MyRate. Pricing is based on distance driven but also takes into account the time of day (miles driven during peak hours and after midnight are more expensive than at other times of day) and sudden starts and stops. Drivers receive a discount on their next policy renewal. Discounts currently go up to 25 percent; drivers are also subject to a nine-percent surcharge if they are deemed more risky based on their driving habits. Mileage, time of day, and driving habits are computed with an OBU connected to the OBD-II port that transmits data wirelessly to Progressive at the end of each trip. For more information, see Donohue (2008) and Progressive Insurance (undated).

Aviva (Canada). Aviva has a pilot program called Autograph offering PAYD insurance in the province of Ontario. Much like Progressive Insurance, from whom it licenses the technology, Aviva offers discounts based on distance driven, time of day, and speed; distance is the most important in terms of calculating the discount. While potential discount ranges between 5 percent and 35 percent, averaging around 20 percent (Aviva does not raise rates based on high mileage). The OBD II device that records the data requires the driver to take the device out, upload the data to a computer, and send it to Aviva. Aviva plans to move to wireless transmittal of data in the future. For more information, see Bettencourt (2005) and Insurance-Canada (2005). Note that

Aviva also offers PAYD in France and Turkey, but further information was not readily available in English.

Coverbox (United Kingdom). Coverbox (owned by Wunelli Limited) offers PAYD insurance with costs based on distance and time of day driven (off-peak, peak, and "super-peak" periods). The per-kilometer cost is calculated for each driver; as Coverbox functions as a broker, drives can choose between quotes. Drivers estimate when they take out a policy the number of kilometers they think they will drive. They can either pay monthly, like a utility bill, or pay the whole premium up front and be credited or debited at the end of the premium period for any difference from their estimate. Kilometers are metered by the Coverbox, a GPS unit produced by Cobra that must be professionally installed and offers anti-theft protection. For more information, see CoverBox (undated).

Hollard Insurance (South Africa). As with the Real Insurance program in Australia, Hollard offers PAYD insurance with a two-part fee, fixed and variable. However, the customer receives a monthly bill for the number of kilometers driven, much like a utility bill. The variable fee is applied for monthly distances driven between 417 and 3,200 km (259 to 1,988 miles) per month. All kilometers are charged at a flat rate, which is calculated separately for each driver. Kilometers are measured by a GPS device called Skytrax, produced by the firm Tracker and professionally installed. Skytrax offers roadside assistance and theft tracking. For more information, see Hollard Insurance (undated).

Real Insurance (Australia). Real Insurance's PAYD program operates with a two-part fee. Drivers pay a fixed fee per month (legal liability coverage) and a variable fee based on distance driven (comprehensive coverage). The initial purchase must cover at least 5,000 km, which can be rolled to the following period if the driver travels fewer kilometers. All miles are charged at the same rate. Real Insurance verifies mileage when claims are filed, and a claim can be refused if the odometer shows more kilometers than last purchased. The liability coverage remains in place even if the comprehensive coverage has run out. For more information, see Real Insurance (undated).

APPENDIX B. INTERVIEW GUIDE

The following pages in this appendix provide the text of the interview guide that was provided to participants in advance of the interviews. Note that not all participants were asked to answer all questions; rather, they were invited to respond to the subset of questions most relevant to their own interests, perspectives, and areas of expertise.

NCHRP VMT Fee System Trials Project
Interview Questions for Stakeholders and Subject Matter Experts

Purpose of the Interviews

Current federal and state fuel taxes are beset with structural and political liabilities that have undermined their ability to raise sufficient transportation revenue over recent decades. In the coming years, expected increases in the fuel economy of conventional vehicles along with the adoption of alternative fuel vehicles are likely to further exacerbate this problem.

Against this backdrop, many analysts and decision makers have argued that the nation should transition from reliance on fuel taxes to a transportation finance system in which road use fees are charged on the basis of vehicle miles of travel (VMT fees). In addition to providing a more sustainable revenue source, such a system could, through appropriate structuring of the fees (i.e., varying the per-mile charge based on vehicle characteristics and the time and location of travel), help to reduce traffic congestion, harmful emissions, and excessive road wear.

In a recent AASHTO-funded NCHRP study, RAND, in collaboration with several partners, examined possible mechanisms through which a national system of VMT fees might be implemented in the near term (i.e., within the next five years). Though several options emerged as promising, the report also noted that remaining uncertainties related to such issues as policy goals, cost, institutional structure, and user acceptance make it difficult to select the best and most cost-effective approach at this juncture. The report therefore recommended a set of activities – including planning, analytic studies, targeted research and development, system trials, and education and outreach – that might be funded in the next surface transportation bill to resolve uncertainties and prepare for the possibility of implementing a national system of VMT fees beginning in 2015.

RAND is now conducting a follow-on study, in the same NCHRP series, to further examine and specify the types of system trials that would be most helpful to fund in the next transportation authorization. One of the key elements in this study is to speak with knowledgeable experts to gain their insights into the appropriate scale, scope, design, and management of the trials. Based on your background and experience, we would value your participation in the series of interviews that we are conducting.

Recognizing that the individuals with whom we will speak have different areas of expertise, we have organized the extensive set of questions into a smaller number of topical categories. While we welcome your responses to as many questions as you would like to address, we also expect that some participants will choose to focus on just a few categories that align most closely to their areas of expertise.

In the following, we first briefly introduce the categories into which the questions have been divided. We then enumerate the specific questions within each category in turn.

Categories of Questions

- **Scope – Broad Policy Considerations.** What potential system policy goals should be considered in the trials? Which road user groups should be included?
- **Scope – Scale, Geographic Coverage, and Duration.** How large should the trials be, and how long should they last? How many states should participate in the trials?
- **Scope – Specific Goals of the Trials.** What key issues – technology considerations, institutional structure, implementation and phase-in issues, and user acceptance – should the trials be designed to illumine?
- **Institutional – Federal Leadership and Stakeholder Participation.** Who should organize and oversee the trials, and how should stakeholder input be incorporated?
- **Institutional – Organization and Management of the Trials.** Should the trials be centrally organized and carefully coordinated to achieve particular outcomes, or should there be numerous, independent trials to examine potentially fruitful variations? Who should be eligible to conduct individual trials?
- **Institutional – Funding Allocation.** Through what program(s) (new or existing) should the trials be funded? Should the federal government fully fund the trials or look for matching funds? On what basis should funding decisions be made?
- **Participation – State and Local Involvement.** What is the appropriate role for various state and local agencies? Under what circumstances would enabling state legislation be required to participate in the trials?
- **Participation – Private Sector Involvement.** How can the trials be structured to encourage multiple vendors to participate in the development and provision of competing metering, data transfer, fee calculation, and collection options? Is there a role for the participation of insurers (pay-as-you-drive insurance)? Auto manufacturers? Other motorist data-related services?
- **Participation – Trial Participants.** How can individual drivers be enticed to participate in the trials? Are there particular user groups to target? What educational and outreach activities should accompany participation in the trials?
- **Implementation – Cost Estimates.** Based on prior VMT-fee system trials that have already been conducted or are underway, how can we estimate, with some accuracy, the amount of funding necessary to support the needed trials?
- **Implementation – Detailed Structure.** What standards (e.g., for communications protocols) might be developed to facilitate the participation of multiple vendors? How can the trials be structured to address such considerations as the accuracy of metering equipment and billing statements, the effectiveness of enforcement mechanisms and auditing, issues that might arise when phasing in a new VMT-fee system, and options for collecting road use charges from foreign visitors traveling in their own vehicles?
- **Other.** Any additional issues that should receive consideration?

1. Scoping Questions – Broad Policy Considerations

1.1. Should the trials only include metering options that can track all miles of travel, or should they also include the possibility of assessing fees on just a subset of the road network (e.g., RFID tolling on all freeways and major roads)?

1.2. Should the trials focus on passenger vehicles, trucks, or both?

1.3. What pricing structures / policy goals should the trials include? Which are essential? Which are optional?

- Flat fees (raise revenue)
- Allocation of fees by jurisdiction of travel (geographic equity)
- Fees that vary by time and location of travel (congestion)
- Fees that vary by vehicle weight and road class (road damages)
- Fees that vary by emissions characteristics (environment)

2. Scoping Questions – Scale, Geographic Coverage, and Duration of Trials

2.1. How much should the federal government be prepared to invest in trials (point of reference: federal excise taxes on gasoline and diesel yield approximately $35 billion each year)?

2.2. How many participants should be involved in the trials?

2.3. What are the most important factors (choose one or more) in determining the appropriate number of participants?

- Testing the feasibility and/or cost of certain implementation options at scale
- Gathering and assessing data on participant perceptions of implementation options and fee structures
- Building public awareness of (and ideally support for) distance-based user fees

2.4. Should the trials seek to involve participants in all states or, if not, in multiple adjacent states?

2.5. How long should the trials last?

3. Scoping Questions – Specific Goals of the Trials

3.1. Among the technical issues that the trials might be structured to address, which (choose one or more) should have the highest priority?

- Alternate metering configurations with different metering capabilities

- Alternate collection mechanisms (e.g., pay-at-the-pump, cellular transmission to a back office, a debit card system), potentially operated in parallel
- Alternate means of protecting privacy
- Alternate enforcement mechanisms
- An "open systems" technology platform approach, including relevant standards and certifications
- Potential use of travel data to support other transportation goals (e.g. calibrating regional transportation demand models, providing real-time traffic congestion data, etc.)
- Others?

3.2. Among the institutional, organizational, and public-private sector issues that the trials might be structured to address, which (choose one or more) should have the highest priority?

- Actual collection and apportionment of revenue (vs. simulated collection)
- Simultaneous collection and apportionment of federal and state/local road use fees
- Alternate collection systems for automobiles and trucks
- Alternate institutional configurations of the billing process (e.g., publicly administered, administered by a single private vendor, administered by multiple private vendors)
- Competition among multiple technology vendors within the same trial
- Others?

3.3. Among the range of implementation and phase-in issues that the trials might be structured to address, which (choose one or more) should have the highest priority?

- Integration with existing toll systems
- Different classes of vehicles (e.g., older vehicles without OBD II port)
- Charging foreign visitors
- Transition issues (e.g., avoiding double payment with fuel taxes)
- Incentives for voluntary adoption to speed up the transition period (e.g., value-added features, relation of VMT fees to other fees/taxes)
- Others?

3.4. Among the issues related to user perceptions and acceptance that the trials might be structured to address, which (choose one or more) should have the highest priority?

- User understanding of and support for distance-based user fees
- User response to alternate fee structures
- User response to alternate mechanisms for protecting privacy

- User response with respect to privacy vs. auditability to audit
- User response to choice of value-added features on OBU
- Others?

4. Institutional Questions – Federal Leadership and Stakeholder Participation

4.1. What entity should oversee the trials? Should this role be assigned to an existing entity, or should a new entity be created to oversee the trials and conduct other activities related to planning the potential transition to mileage-based user fees (e.g., developing agreed-upon policy goals, funding needed analytic studies and research and development activities, organizing public education and outreach efforts)?

4.2. If a new entity is created to oversee the trials (and possibly other related activities), what form should it take? A new position or unit within DOT or FHWA? A joint effort among several departments (e.g., Transportation and Treasury)? An appointed commission to oversee a federal program?

4.3. To what extent should non-federal stakeholders (states, local jurisdictions, industry, advocacy organizations) be able to participate and provide input into the planning, organization, and structure of the trials? How should this interaction be structured or enabled?

5. Institutional Questions – Organization and Management of Trials

5.1. How should the trials be organized, managed, and coordinated?

- A centrally organized and highly coordinated set of trials with a careful research design to guarantee that all relevant issues will be addressed within the trials
- A loosely organized set of independently operated trials, with the goal of fostering state and local innovation
- Some combination of the above; e.g., a larger set of highly organized trials to examine critical issues along with smaller independent trials to consider interesting and potentially fruitful variations

5.2. Who should conduct (or be eligible to conduct) the trials? FHWA? States? MPOs? University research centers? Private firms or consortia? On what criteria should such a decision be based?

- Credibility
- Cost-effectiveness
- Capacity building

6. Institutional Questions – Funding Allocation

6.1 Should funding be channeled through an existing program, or should a new program be created?

6.2. Should the federal government fund trials in their entirety or look for state or local matching funds?

6.3. How should funding for the trials be allocated or awarded? In the ideal? To be politically feasible?

- Earmarks
- Competitive awards
- Proportional allocation to states based on population or other criteria (with state participation being viewed as optional)

6.4. If competitively awarded, should there be a very specific list of technical approaches and pricing structures that applicants must pursue (to foster progress towards implementation), or should the competition be more open-ended (to allow for continued exploration and innovation)?

6.5. If competitively awarded, what criteria (choose one or more) should receive the highest priority in the evaluation of proposal submissions?

- Application of state, and possibly local, road use fees in addition to federal fees?
- More controversial forms of user fees, such as congestion tolls?
- Addition of "value-added" features such as PAYD insurance or automated payment of parking charges?
- Others?

7. Participation Questions – State and Local Involvement

7.1. If states choose to participate in the trials, what are the appropriate (or helpful) roles for state revenue agencies, DOTs, DMV/MVAs, and MPOs?

7.2. If states choose to participate in the trials, under what circumstances might enabling state legislation be required? How much lead time might be required to develop and pass such legislation?

8. Participation Questions – Private Sector Involvement

8.1. If desired, how can the trials be structured to allow and encourage multiple vendors to participate in the provision of competing metering technologies?

8.2. If desired, how can the trials be structured to allow and encourage multiple vendors to participate in the provision of competing collections/billing/back office approaches? Should the government provide a default option?

8.3. If desired, how can the trials be structured to allow and encourage auto insurers to include PAYD insurance within the trials?

8.4. Should auto manufacturers be involved? If so, in what capacity?

9. Participation Questions – Trial Participants

9.1. What strategies or enticements can be used to encourage voluntary participation?

9.2. Are there particular groups of users or vehicle classes (choose one or more) that would be helpful to include in the testing? For example:

- Electric vehicles
- Older vehicles without an OBD II port
- Rental fleets
- Truck fleets
- Government fleets
- Insurance companies that want to explore PAYD insurance options

9.3. What educational activities should accompany participation in the trials, before, during, and after?

10. Implementation Questions – Cost Estimates

10.1. From prior trials and program implementations, what have we learned about how much the trials might cost based on such factors as:

- Number of participants (cost of in-vehicle technology, installation, billing or simulated billing, etc.)
- Any needed supporting infrastructure (e.g., RFID readers at fueling stations, in the pay-at-the-pump model, or gantry-mounted RFID readers and ANPR cameras for enforcement)
- Back-office functionality
- Duration of the trials
- Associated education and outreach activities
- Management of the trials and analysis of the results
- Any media and public relations efforts related to the trials
- Other factors

11. Implementation Questions – Detailed Structure

11.1. If it is intended that multiple vendors have the opportunity to provide competing metering mechanisms, should the federal government endorse a set of standards related to minimum metering capabilities and communications protocols to which vendors would need to adhere? If so, who might logically take the lead in developing these standards?

11.2. How can the trials be structured to test the accuracy of the metering equipment (or might this instead be evaluated through separate tests prior to the trials)?

11.3. How can the trials be structured to test the accuracy of billing statements?

11.4. How can the trials be structured to test the effectiveness and user perceptions of alternate strategies for protecting the privacy of travel data (e.g., sending aggregated data vs. all travel data, trusted third party, data encryption)?

11.5. How, if desired, can the trials be structured to test the effectiveness of proposed enforcement options in terms of detecting/preventing fraud or evasion (e.g., promise rewards to those who can identify ways to cheat the system)?

11.6. How, if desired, can the trials be structured to evaluate options for charging foreign vehicles lacking any required metering equipment?

11.7. How, if desired, can the trials be structured to evaluate the potential use of travel data to support other transportation goals (e.g., real-time traffic flow data) and user willingness to allow such use of data?

11.8. How, if desired, can the trials be structured to evaluate additional issues related to managing the transition to VMT fees?

- Strategies to promote voluntary adoption of metering equipment
- Managing parallel payment options (i.e., VMT fees and fuel taxes)
- Demonstrating a transition strategy

12. Other Questions

12.1. Beyond the questions listed above, are there additional issues or concerns that should be considered?

APPENDIX C. INTERVIEW AND WORKSHOP PARTICIPANTS

Table C.1 provides a categorized list of the individuals that participated in the project interviews, the workshop, or both. In total we conducted 55 interviews involving 69 respondents (several interviews included more than one person from the same organization). While most of the interviews were by phone, several involved formal or informal in-person discussions, and in several other cases the respondents provided written answers via email. In addition to three members of the research team and TRB project staff, the workshop was attended by 32 individuals, including 12 affiliated with the project panel (members, liaisons, or interested observers). Most of the remaining workshop attendees had also participated in the interviews.

Table C.1. Interview and Workshop Participants

Category / Name	Affiliation	Interview Participant	Workshop Participant
Project Panel Members, Liaisons, and Interested Observers			
Cian Cashin (co-chair)	AAMVA		●
Neil Schuster (co-chair)	AAMVA		●
Roberta Broeker	Missouri DOT		●
Lowell Clary	P3 Development Company		●
Ian Grossman	AAMVA		●
Patrick Harrison	Virginia DMV	●	●
Joung Lee	AASHTO		●
Jim March	FHWA	●	●
Mark Muriello	Port Authority of New York and New Jersey		●
Kurt Myers	Pennsylvania DMV	●	●
Lynn Weiskopf	New York State DOT		●
James Whitty	Oregon DOT	●	●
U.S. Congress			
Susan Binder	Former Senate Environment and Public Works	●	●
Alex Herrgott	Senate Environment and Public Works staff	●	●
Paul Schmid	Office of Senator Tom Carper	●	
Perry Beider	Congressional Budget Office		
U.S. Department of Transportation			
Jack Wells	Office of Economic and Strategic Analysis	●	●
Patrick DeCorla-Souza	FHWA	●	●
Allen Greenberg	FHWA	●	●
Ben Hawkinson	FHWA		
Mary Lynn Tischer	FHWA		●
Rob Bertini	RITA	●	

Table C.1. Interview and Workshop Participants (cont.)

Category / Name	Affiliation	Interview Participant	Workshop Participant
U.S. Department of the Treasury			
Jason DeBaker	Office of Tax Policy		●
Richard Prisinzano	Office of Tax Policy	●	●
John Imhoff	Internal Revenue Service	●	
Darren Lefebvre	Internal Revenue Service	●	
Richard Little	Internal Revenue Service	●	●
Holly McCann	Internal Revenue Service	●	
Larry Porter	Internal Revenue Service	●	
Michael Solomon	Internal Revenue Service	●	
State Departments of Transportation			
Randall Iwasaki	Former Director, Caltrans	●	
Debra Miller	Secretary of Transportation, Kansas	●	
Ray Starr	Minnesota DOT	●	
Nathan Earlbaum	New York State DOT	●	
Gregg Dal Ponte	Oregon DOT	●	
Mary Meyland	Texas DOT	●	
John Sabala	Texas DOT	●	
Jim Ritzman	Pennsylvania DOT	●	
State Departments of Motor Vehicles			
Michael Harrell	Delaware DMV	●	
Rena Hussey	Virginia DMV	●	
Ellen Marie Hess	Virginia DMV	●	
State Legislatures			
Jim Reed	NCSL	●	
Steven Polunsky	Texas Legislature, State Transportation & Homeland Security Committee	●	
Metropolitan Planning Organizations			
DeLania Hardy	AMPO	●	
Ashby Johnson	Houston-Galveston Area Council	●	
Steve Heminger	Metropolitan Transportation Commission	●	
Stakeholder Advocacy Groups			
Jill Ingrassia	AAA	●	●
Bob Pitcher	ATA	●	
Darrin Roth	ATA	●	●
George Schoener	I-95 Coalition	●	
Neil Gray	IBTTA	●	
Patrick Jones	IBTTA	●	
Kathryn Phillips	Environmental Defense Fund	●	
John Holtzclaw	Sierra Club	●	

Table C.1. Interview and Workshop Participants (cont.)

Category / Name	Affiliation	Interview Participant	Workshop Participant
Automobile Insurance Companies			
Tom Warden	Allstate Insurance	●	
Colin Wright	Aviva Canada	●	
David Huber	California AAA	●	
Bill Martin	Farmers Insurance	●	
Chris Gay	MileMeter Insurance	●	
Technology Providers and Systems Integrators			
Parker Williams	ACS	●	●
Ken Philmus	ACS Transportation Solutions Group	●	
Lukas van der Kroft	Alcatel-Lucent (consultant)	●	
Steve Morello	Egis Projects		●
Roy Russell	Meadow Networks	●	
Bern Grush	SkyMeter	●	●
Related Trial and Program Managers			
Monique van Wortel	Dutch Ministry of Transport, Public Works, and Water Management	●	
Matthew Kitchen	PSRC	●	●
Paul Hanley	University of Iowa	●	
Jon Kuhl	University of Iowa	●	
Thought Leaders and Subject Matter Experts			
Emil Frankel	Bipartisan Policy Commission	●	
Jack Opiola	D'Artagnan Consulting	●	●
Scott Wilson	D'Artagnan Consulting	●	
Dick Mudge	Delcan Corporation	●	
Robert Atkinson	Information Technology and Innovation Foundation	●	
Mort Downey	Parsons Brinkerhoff	●	
Adrian Moore	Reason Foundation	●	
Ginger Goodin	Texas Transportation Institute	●	●
Trey Baker	Texas Transportation Institute	●	
Bob Skinner	Transportation Research Board	●	●
Lee Munnich	University of Minnesota	●	
Larry Frank	University of British Columbia	●	
Ed Regan	Wilbur Smith	●	

APPENDIX D. DISCUSSION OF RESEARCH FINDINGS

Chapter 7 summarized and synthesized the responses of interview and workshop participants, along with any related analysis conducted by the research team, for a detailed set of questions about how to scope, structure, fund, manage, and conduct an expanded set of VMT-fee trials. This appendix provides further discussion of these findings, following the same organizational structure:

- Roles in overseeing, managing, and conducting the trials
- Organizing, coordinating, and funding the trials
- Size, participation, duration, and cost of the trials
- Pricing policies to examine in the trials
- High priority issues to examine in the trials
- Detailed trial implementation strategies

The set of issues that interview and workshop participants were asked to consider can be found in the interview guide, which is listed in Appendix C. References to specific question numbers (e.g., question 2.1) within the text that follows refer to the numbered list within the interview guide. For each of the specific issues, we first summarize the question (or, in a few cases, several related questions) posed to the participants. Next, the text outlines the thoughts and perspectives offered in response. For a subset of the questions, the research team found it helpful to conduct additional assessment or analysis to supplement the input of the interview and workshop participants. For such cases, the additional analysis is discussed following the review of participant responses.

D.1. ROLES IN OVERSEEING, MANAGING, AND CONDUCTING THE TRIALS

This section discusses responses and any additional analysis for questions related to the potential roles of various organizations in overseeing, managing, and conducting the trials.

D.1.1. Planning and Overseeing the Trials

Questions 4.1 and 4.2 asked about how planning and oversight for the trials should be structured. Specifically, what entity, new or existing, should ideally guide this effort?

Interview and workshop discussion. Many respondents discussed the importance of credibility in overseeing the trials. Whatever entity is selected must not only be impartial and objective, but widely perceived as such, for the trials to be credible overall. Selecting an entity perceived—fairly or unfairly—as biased in any way would have a negative effect on public perceptions and in turn political acceptance. Several mentioned in particular that the entity should also be seen as immune from lobbying of private firms who might benefit financially from participating in trials.

Several of the early participants offered a valuable insight that helped frame later responses to this question. Specifically, they noted that there are two main oversight functions to consider: (a) providing high-level policy guidance on the trials, and (b) conducting the actual work of managing the trials—for example, crafting and issuing RFPs, awarding funding, reviewing progress reports, compiling results, and the like.

With respect to the first of these functions, respondents generally expressed support for the concept of an advisory panel charged with providing general guidance on the trials as well as related efforts (e.g., planning, analytic studies, R&D, and education and outreach efforts). Most thought that the panel should be structured as a committee, though a few argued that an officially appointed commission might provide a greater perception of objectivity and independence. Most also believed that the panel, at minimum, should include representation from:

- Treasury
- USDOT
- FHWA
- AASHTO
- Individual states

Other suggestions for participation on the panel included:

- U.S. Department of Commerce (Commerce), for the link to interstate trucking
- Environmental Protection Agency (EPA), for the potential environmental implications of alternate fee structures
- RITA, for the potential integration with IntelliDrive functionality
- National Highway Transportation Safety Administration (NHTSA) or Federal Motor Carrier Safety Administration (FMCSA), for their experience in regulating in-vehicle technology
- AAMVA, for the potential role of DMV/MVA's in helping to administer system
- International Registration Plan (IRP) or International Fuel Tax Agreement (IFTA), for their experience in apportioning interstate trucking fees
- Cities or counties interested in levying local VMT fees
- Academia, for objective expertise
- Technology/service providers, though likely in a non-voting role
- Other stakeholders, such as road user groups, environmental organizations, and the like

In terms of who should manage the trials, interview and workshop participants indicated that the selected entity should be credible, objective, and able to focus considerable effort on the task. Potential suggestions included FHWA, RITA, the Volpe National Transportation Systems Center, and TRB (perhaps structuring the program similar to SHRP2). Several participants thought that the Secretary of Transportation should be granted the discretion to place the

program anywhere he wished, including the potential of creating a separate office reporting to the Secretary. Other respondents indicated a preference for developing a new entity to oversee the trials. Suggested models for a new entity included a non-profit state consortium resembling IRP or IFTA, a commission modeled after the Base Realignment and Closure Commission to insulate it from political interference with selecting the locations for trials, or some type of public-private partnership.

Among the various options suggested, however, the idea of managing the program through TRB received the greatest support. This was due to TRB's efficient contracting process and proven capabilities for managing large and complex research undertakings involving numerous activities that need to be carefully coordinated. It was also noted that the SHRP2 Naturalistic Driver Behavior Study has demonstrated that TRB is capable of managing national field tests.

D.1.2. Soliciting Stakeholder Input for the Trial Program

Question 4.3 asked about the best way to accommodate stakeholder input into the design of the trials.

Interview and workshop discussion. Two general points emerged in response to this question: (a) providing the opportunity for stakeholder input would be important, and (b) care should be taken to ensure that the process for stakeholder input does not grow unwieldy and is not dominated by any particular group. Several people also noted that stakeholder input should be provided in a transparent fashion, perhaps through open meetings; the program should not appear to be designed "behind closed doors." Specific options for stakeholder involvement suggested by participants included:

- Create a stakeholder advisory panel to report to the oversight panel
- Invite known stakeholders to appear before the oversight panel
- Establish an open comment period
- Hold meetings around the country to obtain stakeholder input from different regions

Under any of these arrangements, however, most interview participants expressed the opinion that the period for stakeholder input should not last too long—perhaps 3 to 6 months at most—so as to prevent unnecessary delays in the trials.

D.1.3. Conducting the Trials

Question 5.2 asked about who should be eligible to conduct trials—that is, to bid for and/or receive funding to implement a trial. The three prior U.S. cases provide examples of trials being led by a state (Oregon DOT), by an MPO (Puget Sound Regional Council), and by a university (University of Iowa). It is also conceivable that trials could be conducted by private or non-profit entities. The question posed to respondents, then, was which of these options would be the best choice for leading expanded system trials.

Interview and workshop discussion. Respondents indicated that the trials would inevitably involve partnerships among multiple entities. For example, states might take the lead on setting

policies, developing the administrative structure, and enrolling participants; private industry might be engaged to provide metering devices and billing services; universities, consultants, or MPOs might help with data analysis; insurance companies might participate by offering PAYD policies; and cities or counties might choose to test out local VMT fees or automated parking payment. As with the entity overseeing the trial, credibility was mentioned frequently as an important selection criterion. Institutions or agencies that might be perceived to steer the trial results to a desired outcome might undermine the chances for acceptance among the public and elected officials.

With respect to the question of who among these should *lead* the trial (i.e., assemble the team and request or bid for trial funding), two main responses were offered. The majority view was that, within the context of trials intended to support potential implementation, states (either individually or in partnership with one another) should take the lead role. The decision to implement VMT fees within a state, after all, ultimate rests with the state. Additionally, it is the state that would need to administer and enforce the fees. While a few respondents thought that universities or research centers could fulfill this coordinating role, it was also noted that such organizations would have difficulty with the issue of fee collection since it falls beyond their domain.

The other alternative, supported by a smaller number of respondents but nonetheless intriguing, would be to directly fund different entities for their distinct roles in the trials. Under this view, the federal government might initially fund four or five private consortia to provide metering devices and billing services for some number of participants, say 100,000 per consortium under the assumption of very large-scale trials. Under separate streams of funding, states could apply for support to conduct VMT-fee trials, cities could apply for support to examine automated payment of parking fees, insurers could apply for support to examine PAYD policies, and universities, research institutions, or MPOs could apply for support to examine trial data and results. Participating states, cities, insurers, and research institutions would then be directed collaborate with one or more of the consortia, who would be responsible for instrumenting vehicles and collecting data and/or payment. Note that this latter option was suggested as being appropriate for the market framework because it would directly engage the various parties—service providers, insurers, and cities—that could play an important role in the provision of value-added services, such as PAYD insurance or automated parking payment, to entice voluntary adoption. On the other hand, this option would likely pose greater challenges in coordinating the trials.

D.1.4. Roles for DOTS, DMVs/MVAs, and MPOS

Question 7.1 asked about the appropriate roles for state DOTs, DMVs/MVAs, and MPOs within the trials.

Interview and workshop discussion. Interview and workshop participants suggested that appropriate state roles might include fee collection, especially for revenue agencies; data collection, especially for DMVs/MVAs; and supporting enforcement via making the vehicle registration databases available. States might also take on some public outreach functions.

While there was agreement that states should be heavily involved in trial implementation, appropriate roles might vary from state to state for institutional reasons. In some states, DMV/MVAs collect not only registration fees but fuel taxes, while in others fuel tax collection is handled by a revenue agency. In some states the DMV is a component of the DOT, while in others it is a separate agency. One respondent suggested that the governor decide which agency would lead that state's involvement.

State agency roles could differ for other reasons as well. States might have some capabilities for implementation, given for example the usual function of DMVs/MVAs in maintaining a vehicle registration database and collecting registration fees. However, some states might lack the funding or staff to expand their functions to VMT fee collection. It is also difficult to determine appropriate roles for states without knowing the fee collection mechanism; would, for instance, VMT fees be collected at the pump, or via cellular transmission to a billing service being provided by a private vendor?

Participants suggested that MPOs would not be natural candidates for leading the trials, due to lack of implementation authority as well as widely varying levels of interest and institutional capacity. It was indicated, however, that the participation of MPOs could be valuable in (a) helping to design certain aspects of the trials (e.g., variable pricing); (b) advising on such issues as current VMT within states and regions and how current revenue sources are structured and spent; (c) sharing lessons learned (for example, from the SB 375 implementation in California); (d) conducting public outreach to both the general public and elected officials; and (e) assisting in data analysis and evaluation

D.1.5. State Legislative Requirements

Question 7.2 asked about the conditions under which enabling state legislation would be required for states to participate in the trials.

Interview and workshop discussion. As with the preceding question on roles for state agencies, the general response from participants was that legislative requirements would vary by state. One observer thought that it would largely depend on the degree of autonomy already granted to the state DOT in the state's existing laws. Some state DOT mandates allow them to act relatively independently, while others require legislation for even modest program changes. Perhaps roughly half the states fall in each of these two groups.

Several respondents noted that in their state, collection of actual revenue would trigger legislative requirements, while simulated collection would not. This could be a key decision point for determining the timeframe from proposal development to implementation. Passing such legislation would likely require a year if political support is forthcoming (viewed as unlikely in an election year), and perhaps from two to five years if elected officials do not currently understand or support VMT fees. Given that passing legislation implies a degree of public support, the timeline might need to include several years for the agency to build support in the state, and perhaps even a small grant to help build such support.

State legislation could also be needed to allow PAYD elements in the trials, as automobile insurance is regulated by the states. Currently, not all states allow PAYD insurance products in

their insurance market. Regulations that prohibit such policies include, for example, provisions that consumers must be told their premium in advance. Regulations also influence the average premiums and the amount of competition in a state insurance market, and as a result PAYD might be more attractive to drivers in some states than in others.

D.1.6. Engaging Multiple Service Providers within a Trial

Questions 8.1 and 8.2 asked about potential strategies for including, within the same trial, metering devices and billing services provided by multiple vendors. The intent would be to examine the concept of implementing an open system in which multiple firms could compete for market share on the basis of cost and value-added services (this would be a critical issue to examine under the market framework; for the other frameworks, it might be viewed as valuable but not essential during the trials).

Interview and workshop discussion. Interview participants indicated that it should be possible to engage multiple competing firms in the same trials, if desired, by setting up the bidding competition appropriately. For example, contracts might be let to the top three bidding firms or consortia, each of whom would supply the metering devices and services for a third of the trial participants. Several respondents stressed that the competition should be based on both quality and price; that is, a slightly higher cost proposal that included many innovative value-added services should be viewed as superior to a slightly lower cost proposal with no value-added services. Another respondent suggested the benefit of engaging multiple firms to explore different technical approaches; for example, one firm might supply a GPS-based unit, another might supply a unit reliant on cellular location, and yet another might supply a solution based on a smart phone platform.

D.1.7. Encouraging PAYD Insurance within the Trials

Question 8.3 asked how the trials might be structured to allow and encourage participation among auto insurance companies, if desired. The underlying premise of the question was that PAYD insurance represents a commonly cited value-added service that might encourage voluntary adoption and help defray the cost of metering devices and collection services.

Interview and workshop discussion. Participant opinions were divided on whether or not PAYD insurance should be included in the trials. Those who felt that the trial should concentrate exclusively on VMT fees tended to think that including PAYD was an unnecessary distraction from the main goal. On the other hand, those who thought the trials should examine a wide range of questions—for example, potential changes in travel behavior—and those who favored the concept of voluntary adoption based on value-added services viewed the inclusion of PAYD insurance as very important, even critical.

Based on comments from our interviews with insurance firm representatives, there appear to be two factors that might entice their participation. The first would be to gain access to the rich stream of data that the trials would provide about driver behavior. Insurance companies are in various stages of deploying PAYD—some firms we spoke with already had PAYD policies available in some markets, while others were considering them—and the opportunity to analyze travel data from an expanded set of system trials would help them determine how to develop

appropriately structured PAYD insurance policies. Having access to a large amount of driver data, provided it contained information on claim events, would therefore be an enticement.

In terms of the number of trial participants that would be needed to entice firms, no firm threshold emerged. Insurance companies tend to look at "vehicle-years" or "vehicle-miles" of data, so they are indifferent to having data from 50,000 vehicles for one year or from 100,000 vehicles for six months. One person suggested 10 million vehicle miles as an appropriate target for the trials (translating to approximately a year's travel for around a thousand vehicles). The data would also be more valuable if it represented a good cross-section of drivers, not only low-mileage drivers. For insurance companies, the larger and more comprehensive the data stream, the more resources of their own they might be willing to commit to trials.

Some people thought that the mileage data would be secondary to information that could be collected about speed, braking, and other characteristics of driving that might help predict which drivers are at greatest risk of crashes. Devices that analyze other aspects of driver behavior are already on the commercial market, and some companies use them for PAYD implementation. Some respondents posited that data on behavior could lead to better driving habits when drivers understand the risks they are taking—for example, through seeing personalized analysis of their own driving. This could be one of the applications that companies use to compete for customers.

A second potential enticement that might be offered to encourage insurance company participation in the trials is a subsidy for each PAYD policy included. Recognizing that there is some cost involved in switching policies, as well as some potential risk of net losses, one insurance company representative suggested that a subsidy of about $200 per PAYD policy would be an appropriate figure.

As a final note, many environmental advocates and proponents of VMT fees with whom we spoke favor PAYD insurance, generally on the grounds that it will reward drivers for driving less and therefore reduce overall VMT. However, our interviews suggest that insurers, despite their interest, might be slow to introduce PAYD policies even when regulatory and technical barriers are removed. If an insurer offers PAYD policies, its lower-mileage clients would likely switch to save money. Its higher-mileage clients, on the other hand, would rationally choose to keep their existing policies so that they do not end up paying higher premiums. As a result, an insurer that offers PAYD policies could end up collecting less total insurance premiums for the same pool of clients unless it is able to attract new customers based on its PAYD products; in a competitive market, this could be difficult to achieve.

D.1.8. Role for Auto Manufacturers

Question 8.4 asked whether auto manufacturers should be involved in the trials, and, if so, what roles they might play (note, however, that the interviews did not include any representatives of auto manufacturers, and many participants did not comment on this question).

Interview and workshop discussion. None of the respondents argued that auto manufacturers should definitely be involved, either for technological reasons or for the validity of the trials. In fact, several suggested that such firms would not want to be associated with a program related to taxation. Some suggested that auto manufacturers might be consulted as to how the different

metering technologies might later be built into new vehicles, and several believed that the federal government should require auto manufacturers to install metering equipment once the appropriate technical configuration has been agreed upon. Others, however, argued that the technology is evolving rapidly such that any large-scale standardization is still years off; for the near term, at least, the technology can be added as an after-market device, thus allowing drivers to upgrade the units to take advantage of new innovations.

D.2. ORGANIZING AND FUNDING THE TRIALS

This section provides detailed discussion of the responses to questions about how to organize the trials—for example, how many trials should there be, where should they be located, and to what degree should they be coordinated with one another—and the basis for funding the trials (note that discussion of how much the trials might actually cost is presented in the following section).

D.2.1. Number and Location of Trials

Question 2.4 asked whether trials should ideally be conducted in all states or, alternatively, in multiple adjacent states.

Interview and workshop discussion. Almost all interview and workshop participants agreed that the trials should *not* include all states, simply because not all states are yet ready to consider VMT fees. Rather, they should be conducted in those states with the political will to evaluate and potentially adopt such a system. The sole argument offered for including all 50 states was to mirror the sampling design for the National Household Travel Survey (NHTS).

Most also agreed that it would be extremely valuable to conduct at least some of the trials in multiple adjacent states to explore the collection and distribution of VMT fee revenue across jurisdictions. Along these lines, some suggested that it would be beneficial to look at regions in which states are already working together on other transportation issues, such as the I-95 Corridor Coalition or Oregon and Washington.

Respondents also recognized the potential value in allowing single-state trials. Some argued that certain states, such as California or Texas, would be large enough to hold meaningful trials on their own. Others noted that a state should not be precluded from participating in trials just because its neighboring states are not similarly inclined. One respondent observed that it might prove sagacious, from a political perspective, to include states with influential members of Congress and the Administration.

One respondent argued that the trials should focus on mega-regions rather than states—for example, such regions as New York, Washington, D.C., Seattle, San Francisco, Los Angeles, Atlanta, or Miami. Many also stressed that, collectively, the trials should encompass rural, urban, and suburban settings to explore the issue of whether VMT fees would be inequitable for rural drivers.

Although one individual suggested that it should be possible to learn everything that is needed from a single state, most liked the idea of trials conducted in several regions—both to test out the concept in different physical, political, and institutional settings and to increase awareness of

VMT fees across the country. The majority of respondents suggested that somewhere between three and six trials would be a good number, though we heard suggestions as low as two and as high as eight. The reason for limiting the trials to a relatively small number would be to prevent the funding from being spread so thinly as to prevent the ability to conduct meaningful trials.

D.2.2. Coordination among the Trials

Question 5.1 asked about how the trials should be organized and coordinated. At one end of the spectrum, one could envision a large, carefully coordinated trial that would span multiple states and be designed to gather information on a specific set of issues in order to prepare for subsequent implementation of a national system. At the opposite end, it would be possible to fund a set of largely independent trials in which states have much greater latitude to explore alternate policy structures and implementation designs. Between these two conceptual endpoints, there could also be some sort of hybrid approach—an attempt to structure the multiple trials to address core implementation issues while simultaneously allowing for state innovation.

Interview and workshop discussion. Many of the respondents who addressed this question saw value in both (a) ensuring that the trials would address some core set of issues to enable implementation, and (b) allowing continued room for states to be innovative. As a result, the majority of participants expressed a preference for some sort of hybrid approach. Three potential hybrid structures emerged from the interviews and workshop:

- One idea would be to conduct one large, carefully organized trial to test core issues along with several smaller trials to foster innovative concepts. States might choose to opt in to the main trial or compete for one of the more innovative trials.
- A second idea would be to conduct several parallel trials in different states or groups of adjacent states. Each trial would be required to examine the same core implementation issues and options, but there would otherwise be flexibility to examine different pricing policies, institutional structures, and the like.
- A third idea would be to conduct several parallel trials with the aim of covering all of the core implementation issues and options in at least one of the trials. So, for example, if ten states applied for funding to conduct trials, the decision might be made to fund five of those trials based on (a) the individual merits of the proposals, and (b) the extent to which the awarded proposals, in combination, encompass all of the necessary core issues.

Additional analysis. Based on just a few of the comments that were offered, it appears that a slight deviation from this approach might be appropriate under one of the frameworks:

- **Help states help themselves.** Under this framework, states might be given even broader latitude in terms of technical and institutional approaches considered, as the near-term goal would be to foster state-level rather than national implementation of VMT fees. Perhaps the most important commonality between trials in different states or collections of states would be the need to develop standards and certification processes that would ultimately allow for interoperability between different systems in different states.

D.2.3. Basis for Allocating or Awarding Funding

Question 6.3 asked about the most appropriate mechanisms for distributing funds to support trials. Potential models included earmarks, competitive grants, and proportional funding available to all states on the basis of population or other factors.

Interview and workshop discussion. Among the options for allocating or awarding funding, respondents were universally against earmarking. As one respondent observed, the concept of VMT fee trials is already controversial; any further criticism of earmarks could easily undermine the entire effort.

The vast majority supported a competitive process both to enhance credibility and reward innovation. Potential models for the structure of competition suggested by participants included TIGER grants and the Urban Partnership Program. The latter allows the funding agency to work with the recipient to further develop the proposal, and this was viewed as a particularly helpful attribute within the context of VMT-fee trials. Several suggested that the program involve an initial call for expressions of interest, after which a subset of the respondents would be invited to develop more detailed proposals. States invited to submit detailed proposals might receive funding to support their planning efforts, though no participants thought that states should receive funding to help with the initial expressions of interest. Another suggestion was to hold regional competitions in order to foster geographic diversity in the set of trials ultimately funded.

Several respondents also advocated setting aside a small amount of funding—perhaps up to $1 million per state—that would be available to help states just beginning the process of exploring VMT fees. Such funding might be used, for example, to conduct focus groups or to explore legal or administrative issues that would need to be addressed in order to implement VMT fees within the state.

D.2.4. Criteria for Competitive Awards

Questions 6.4 and 6.5 asked about the criteria that should be applied if the funding for trials were to be awarded on a competitive basis.

Interview and workshop discussion. Most interview and workshop participants thought that there should be certain base requirements that proposals must meet (e.g., examining one or more metering options, collection mechanisms, and enforcement strategies of interest and perhaps helping to test out interoperability standards) in order to qualify for funding; beyond that, a set of optional criteria could be used to judge the relative merits of one proposal against another. When prompted about which criteria might be used evaluate and rank the proposals, under the assumption that the base requirements had already been met, interview participants suggested such criteria as cost, number of planned participants, capacity of the proposing entity, provision of value-added services with the in-vehicle equipment, intent to explore or simulate more controversial forms of pricing (e.g., congestion tolls), intent to collect actual revenue, and intent to explore the use of travel data from the system to improve planning and operations.

D.2.5. Federal Share of Funding

Question 6.2 asked about the share of trial funding that might be provided by the federal government.

Interview and workshop discussion. Almost all of the answers we received for this question fell into one of two categories: either the federal government should fund trials in their entirety or the federal government should require a modest state match of no more than 10 to 20 percent.

The stated logic for the first response was that the recession has severely undercut the ability of most states to provide their own funding at this time; thus requiring even a small match might deter states that would otherwise choose to participate in the trials. Several respondents in this camp also expressed the desirability of the federal government helping states to be in a better position to address their own future revenue needs through state-level VMT fees, akin to the adage about giving someone a fish versus teaching them to fish for themselves.

Proponents of the second view also echoed the concern that state budgets are very tight at the moment, leading to the suggestion of a relatively small match in percentage terms. Still, they argued that it would be beneficial to include at least some level of local match so that states would have some "skin in the game." That is, the matching funds requirement would help to ensure that the states that do choose to apply for trial funding are indeed committed to the exploration and potential adoption of VMT fees.

D.2.6. Funding Program

Question 6.1 asked whether funding for trials should be channeled through an existing program with related scope (e.g., the Value Pricing Pilot Program) or though a new program.

Interview and workshop discussion. Only a small number of respondents chose to answer this question, but most of those who did felt that the evaluation of VMT fees was important enough, and sufficiently distinct from the scope of existing programs, to merit the creation of a new program.

D.3. SIZE, DURATION, AND COST OF THE TRIALS

This section details the findings for questions related to the appropriate size (number of participants) and duration of the trials (number of participants), what they are likely to cost, and how much the federal government should be willing to invest in trials.

D.3.1. Number of Participants

Questions 2.2 and 2.3 asked about the appropriate number of participants to include within the trials, as well as the relative importance of various factors that might influence this number:

- Testing the feasibility and cost of certain implementation options at scale
- Gathering and assessing data on participant perceptions of various implementation options and fee structures
- Building awareness of (and ideally support for) distance-based user fees

Interview and workshop discussion. Respondents expressed varying opinions regarding which of the potential factors for determining the appropriate number of participants is most important. In general, though, all of potential goals—evaluating cost and feasibility at scale, evaluating user perceptions and response, and building awareness and support for VMT fees—were viewed as at least relatively important. One respondent argued that the trials should be designed to transition directly into implementation, and that this goal should be considered in determining the number of participants to include.

Several of those who viewed gathering and assessing data on user perceptions as a principal goal offered their thoughts on how to structure the statistical sampling. For passenger vehicles, suggested variables to examine include income, household size, households per acre (as a proxy for urban vs. suburban vs. rural), vehicle types, and level of car use. For trucks, recommended variations to consider include truck load vs. less than truckload; shippers that carry their own goods (e.g., Walmart); intermodal trucks (i.e., trucks that carry containers); long vs. medium vs. short-haul trucks; large vs. small companies; and owner-operators vs. company drivers. One respondent argued for adopting a sampling strategy that mirrors the National Household Travel Survey (NHTS).

In terms of the appropriate number of participants to target, the divergence in opinion was striking; answers varied from a thousand participants to a million, a range spanning three orders of magnitude. Fortunately there was some consistency in the underlying logic for the different answers. The following guidelines emerged:

- Thousands of participants would be needed to achieve statistical significance and gather perceptions of various implementation options and fee structures
- Tens of thousands of participants would be needed to examine the feasibility and cost of various implementation options at scale
- Hundreds of thousands of participants would be needed (or at least highly desirable) to build awareness of and (ideally) support for VMT fees and to facilitate a direct transition from trials to implementation.

Regarding the latter goal, one interview participant noted that building greater awareness of and support for VMT fees could likely be achieved at much lower cost through more traditional education and outreach activities. Yet several other respondents pointed out several additional benefits that would result from larger trials. Specifically, if the trials were intended to evolve directly to full-scale implementation featuring an initial period of voluntary adoption, scaling the trials to include hundreds of thousands of participants would create a large base of initial adopters, helping to build momentum for the program. Additionally, it would likely encourage service providers to invest more resources in the development of value-added services to increase market share.

Additional analysis. Gathering data on user perceptions of alternate implementation options and fee structures would be an important goal of the trials. To prepare for potential implementation, however, better understanding of the cost and feasibility of alternate implementation options at

scale would also be required. This suggests that the trials, collectively, should include at least tens of thousands of participants. Whether a greater level of participation would be helpful depends on the framework:

- **State framework.** Under the state framework it is possible that some states might choose to pursue trials with the intent of transitioning directly to implementation. Should this occur, it would be valuable, for the reasons outlined above, to increase participation into the hundreds of thousands. Yet it would be difficult to predict in advance whether states would elect this path. Moreover, as the state framework would not initially lead to the development of a national system, the case for funding hundreds of thousands of participants from federal dollars would be diminished. Given these factors, it would be reasonable to aim for tens of thousands of participants (perhaps 10,000 to 20,000 per trial, and 50,000 to 100,000 in total) in the state framework, even if more might prove helpful.
- **Federal framework.** Under this framework the principal goal of the trials would be to gather enough information and experience to (a) help policymakers determine whether to support a transition to VMT fees and what policy goals to incorporate within the system, and (b) help planners design the most cost-effective system to meet those requirements. This staged and deliberate approach, which might involve examination of many potential options, does not align with the concept of transitioning directly from trials to implementation. Thus tens of thousands of participants (again, perhaps 10,000 to 20,000 per trial, and 50,000 to 100,000 in total) would be appropriate.
- **Accelerate the market for in-vehicle travel services.** This framework explicitly calls for trials that evolve directly into implementation; that is, the trial participants become the first adopters of the system. This suggests that it would be beneficial, if possible, to increase the participation in the trials to hundreds of thousands (perhaps 100,000 to 200,000 per trial, and 500,000 to 1,000,000 in total) to create a large base of initial adopters, build momentum for the program, and motivate service providers to invest more in value-added services to gain greater market share.

D.3.2. Duration of the Trials

Question 2.5 asked about the appropriate duration for the trials.

Interview and workshop discussion. Three different response patterns for this question emerged. Most agreed that drivers should be paying (or emulating the payment of) VMT fees for at least six months, and ideally a year. This would provide sufficient time to observe how their driving patterns might shift in response to the fee structure or might vary during different seasons of the year. One of the respondents also noted that user attitudes evolved considerably during the eight-month trial period in the University of Iowa study. Respondents also indicated that there would need to be at least one year, and ideally two years, for initial planning and preparation (two years would likely be needed if the intent was to develop initial standards and certification processes in advance of the trials) as well as an additional year following the trials for analysis and evaluation. This would suggest a minimum overall timeframe of three to four years.

Many, however, suggested that it would be helpful for the in-vehicle testing to last two to three years, for several possible reasons. From an experimental design perspective, one participant

indicated that it would be useful to have one year for a control period (metering travel data but not assessing fees) followed by a second year as the treatment period (assessing fees based on metered travel). It was also noted that longer trials could prove more helpful in building public understanding and, ideally, acceptance. Another suggested reason for lengthening the duration would be to allow for the progressive inclusion of additional elements within the trials. For instance, during the first year a trial might focus on the functionality of metering, billing, and privacy protection. During the second, the trial might begin to examine alternate enforcement strategies. During the third, the trial might shift from emulating the payment of fees to actual revenue collection. As discussed earlier, most state staff with whom we spoke indicated that enabling state legislation would be required for actual revenue collection, and that enacting such legislation would take time; staging trials in the manner just described would allow some time for this step to be completed. Under this perspective, then, the overall trial period, including one or two years for planning and preparation and another year post-trial evaluation, would be on the order of four to six years.

A final perspective shared by several respondents is that the trials, ideally, would be indefinite. That is, they would be explicitly intended to evolve directly into implementation. In practical terms, however, the trials would not be subsidized indefinitely; rather, the funding might last for four to six years, after which the collection of fees would begin to pay for continued operation.

Additional analysis. Prior U.S. trials have lasted in the vicinity of two to three years, with perhaps eight to twelve months of in-vehicle equipment use. This timeframe has proven sufficient to examine a more limited set of goals—for example, verifying the proper functioning of a given technical configuration or examining user perceptions of and responses to certain fee structures. Trials intended to resolve remaining uncertainties in order to prepare for potential implementation, in contrast, would need to address a much broader and more complex set of issues, including the processes and institutional arrangements for collecting actual revenue and preventing evasion. This suggests that the longer timeframe of four to six years suggested by many interview and workshop participants would be a better choice, allowing for a staged progression in which the trials move closer to actual implementation as additional system functionality is added. Additionally, the longer timeframe would provide more time for states to pass enabling legislation to allow for the collection of actual revenue during the trials, if desired.

D.3.3. Cost of Trials

Question 10.1 asked about how much it might cost to implement the trials. As context, the scope of the project did not support the development of a detailed model to make this calculation. We were therefore particularly interested in the perspectives or insights of participants who had either (a) conducted trials, or (b) examined the cost structure of other trials or programs.

Interview and workshop discussion. While several respondents offered their best guesses, which fell in the range of $1000 to $2000 per trial participant, the most helpful suggestion was to examine the per-vehicle cost of other trials and programs and reason by analogy.

Additional analysis. Following the advice to examine related trials and programs, Table D.1 provides an aggregate summary of the costs and number of participating vehicles for the trials conducted by PSRC, Oregon DOT, and the University of Iowa, as well as the planned trials in

Minnesota (data based on email communications with Matthew Kitchen at PSRC, James Whitty at Oregon DOT, Jon Kuhl at University of Iowa, and Cory Johnson at Minnesota DOT). As a point of comparison, the table also provides the costs for the recently launched Slovakian truck toll (data provided in Grush 2010c). The Slovakian data reflect the costs of implementing and operating the system with more than a hundred thousand vehicles for a three year period, resulting in greater economies of scale.

Table D.1. Per-Vehicle Cost Analysis for Recent Trials and Programs

Trial / Program	Vehicles	Total Cost	Cost per Vehicle
PSRC trials	450	$2,350,000	$5,222
Oregon DOT trials	300	$2,617,528	$9,184
University of Iowa trials	2700	$15,120,000	$5,600
Minnesota DOT trials (planned)	500	$7,612,484	$15,225
Slovakian Truck Toll	120,000	$119,400,000	$995

From the trial data in this table, one might conclude that the per-participant costs of conducting additional trials could vary between $5,000 and $15,000, depending on the specific elements included. If the intent were to fund additional trials involving one or two thousand participants, this might be a reasonable estimate. The trials envisioned in this study, however, would be much larger—involving at least tens of thousands of participating vehicles, and perhaps even hundreds of thousands. This makes it important to understand what portion of the costs reflected in the table correspond to fixed costs (i.e., costs independent of the number of participants) and what portion would vary with the number of vehicles. In the context of trials with tens or hundreds of thousands of participants, the overall cost of the trials would be driven mainly by the latter category.

Along these lines, we solicited further input from the managers of these trials to better understand the breakdown of their costs. The intent was to distinguish both (a) between the cost to develop, implement, and operate the VMT-fee system and all other trial-related costs, and (b) between fixed costs and variable costs. This led to four cost allocation categories:

- **Fixed system costs.** Elements in this category include the cost of designing, implementing, and integrating the various system components, such as in-vehicle metering devices, billing databases, communication channels, and any additional supporting infrastructure.
- **Variable system costs.** Components in this category include the cost of purchasing, installing, and maintaining in-vehicle metering equipment and any ongoing costs related to user account management, such as communications or billing.
- **Other fixed costs**. This category includes a broad range of additional fixed costs associated with planning and managing the trials, evaluating trials results, and conducting related outreach activities.
- **Other variable costs.** This last category includes the cost of enrolling participants, paying participants for their involvement, training participants, surveying participants regarding their perceptions of the system, and the like.

Representatives from three of the trials—James Whitty from Oregon DOT, Matthew Kitchen from PSRC, and Cory Johnson from Minnesota DOT—were able to provide estimates of their cost data broken down by these categories. Their results are presented in Table D.2.

Table D.2. Detailed Cost Allocation for Oregon and Minnesota Trials

Trial Cost Allocation	System Cost		Other Trial Costs		Total
	Fixed	Variable	Fixed	Variable	
Oregon RUFTF Trials – 285 Vehicles (299 Participants)					
Total Cost	$1,474,092	$226,636	$677,640	$239,160	$2,617,528
Variable Cost / Vehicle		$795		$840	$1,635
PSRC Trials – 450 Vehicles					
Total	$150,000	$850,000	$750,000	$575,000	$1,525,000
Variable Cost / Vehicle		$1,889		$1,278	$3,167
Planned Minnesota Trials – 500 Vehicles					
Total	$3,293,500	$1,073,812	$2,124,952	$1,120,220	$7,612,484
Variable Cost / Vehicle		$2,148		$2,240	$4,388

The data here suggest much lower per-participant costs, ranging from around $1,600 at the lower end to $4,400 at the upper end: still considerable variation, but these figures are much lower than the numbers indicated earlier in Table D.1. (Note that the cost data for Oregon and PSRC are several years old; over this period, technology costs have fallen, but other cost elements have likely increased a modest degree with inflation).

How, then, to estimate the cost of the trials? The basic challenge is that the costs would depend on many inherently uncertain factors that might only become clear in the context of specific trial proposals. Some of these factors might lead to higher costs than suggested above, while others might lead to other costs. For still others, the potential effect is unclear.

Uncertainties that might lead to higher trial costs:

- What portion of the costs listed as fixed in Table D.2 might prove to be variable if the level of participation in the trials were scaled up by several orders of magnitude? For instance, while the cost of managing the trials in the above examples might remain constant with the addition of a few hundred extra vehicles (and thus be reasonably categorized as a fixed cost in the table), management costs might increase significantly with the addition of tens of thousands of vehicles.
- How long would the trials last, and how would this affect both fixed and variable costs? Most prior U.S. trials have lasted approximately one year, but the results of this study suggest that it would be helpful to conduct trials lasting two or three years (four to six in total, including initial preparation and subsequent evaluation). This would logically increase the cost of the trials.
- Would the OBU be designed to include additional value-added features? This is planned for the Minnesota trials (helping to explain the higher fixed and variable system costs), but was not examined in the earlier trials.

- How much would it cost to examine such issues as actual revenue collection and preventing evasion, which prior trials have not addressed?

Uncertainties that might lead to lower trial costs:

- What type of metering equipment would be used? All of the trials listed above, as well as the Slovakian truck toll, have relied on GPS-based OBUs, but an OBU configured with OBD II and cellular communications could be less expensive. Under the state framework, states that already inspect vehicles each year might even choose to look at odometer-based options, and this could be much cheaper.
- Would vendors choose to partially subsidize system costs to become early participants in the potential U.S. market for metering devices and billing services? Or, in a related vein, would they be able to offer additional value-added services for which participants would willingly pay, thus reducing the cost to the government?
- Would the intensity of interaction with each trial participant (e.g., focus groups, training, surveys, and the like) be reduced in larger scale trials?
- To what extent might competition among states for trial funding motivate the development of less expensive trial proposals?

Uncertainties with ambiguous effects on trial costs:

- What payment collection option or options would be employed? The Oregon trial examined pay-at-the-pump, which likely requires the lowest ongoing per-vehicle operating costs (at the cost of additional required infrastructure investment to equip filling stations); other trials have relied on cellular transmission of billing data, which increases the per-vehicle costs.
- How much would participants need to be paid for their involvement? In the University of Iowa trials participants received close to $900, while in the Oregon trials they received $300 (plus any remaining balance on their endowment accounts). If the OBU included desirable value-added features, might that serve, in lieu of cash, as an incentive for participation?

Taking the above data and uncertainties into consideration, it appears reasonable to expect that the trials might cost in the range of $2,000 to $4,000 per participant in total. The logic is as follows. Beginning with the question of system costs, the Slovakia truck toll, at roughly $1,000 per vehicle, provides a useful estimate. It relies on GPS equipment, the most likely option to examine in the trials. The figure includes fixed costs as well as three years of operating costs, the likely length of the trials. The cost is based on 120,000 vehicles, similar to the envisioned number of participants in the trials. Finally, the system was just implemented, and thus reflects current equipment costs.

This leaves an estimate of an additional $1,000 to $3,000 per participant for other trial-related costs. This is slightly higher than the range of non-system variable costs in Table D.2 (between $840 and $2,240); the additional cushion is intended to account for other fixed costs associated with the trials (divided on a per-participant basis), additional costs related to examining such issues as actual revenue collection or preventing evasion, and additional costs that would result from a longer trial period. While such factors might be expected to exert even greater upward

pressure on the cost of the trials, other considerations—such as competition for trial funding, the potential examination of less expensive metering options, or the possibility of less intensive interaction with each trial participant—should help to stem the higher costs to some extent.

With an estimate of roughly $1,000 per vehicle for system costs and between $1,000 and $3,000 per vehicle for other trial-related activities, the trials would cost between $2,000 and $4,000 on a per-vehicle basis. How much in total, then, might the trials cost? As discussed above, it would be helpful to aim for a total of 50,000 to a 100,000 participants across all trials in either the state or the federal frameworks. This would result in a total cost for the trials in the range of $100 million ($2,000 x 50,000) to $400 million ($4,000 x 100,000). Under the market framework, it would be beneficial to aim for 500,000 to 1,000,000 participants if possible. This would result in total trial costs in the range of $1 billion ($2,000 x 500,000) to $4 billion ($4,000 x 1,000,000).

As a final note, one participant observed that while the per-participant cost might be similar under the various frameworks, the appropriate allocation of the costs could vary. In the market framework, in particular, the intention would for the trials to evolve directly to implementation featuring voluntary adoption, and it is assumed that the OBU would be equipped with numerous value-added services to promote such adoption. Based on these characteristics, it would not be necessary to devote significant resources to post-trial evaluation and planning (since the system would already be up and running) and it might prove unnecessary to pay drivers to participate (provided that the value-added services on the OBU are sufficiently compelling). The money saved in these areas could instead be channeled help fund the development of an even broader array of value-added services.

D.3.4. Value of Trials

Looking at the issue of cost from another perspective, Question 2.1 solicited opinions about how much it would be worth spending on trials, under the assumption that the trials would be needed for, and ultimately lead to, implementation.

Interview and workshop discussion. When asked about how much the federal government should be willing to invest in trials, the most common answer offered by interview and workshop participants was, “as much as it takes” (within reason). Most of the respondents view current fuel taxes as broken and look to VMT fees as the most compelling opportunity to reinvigorate the “user pays” principle in order to achieve a sustainable transportation revenue source.

When pressed for more specific responses, there was considerable variation in the numbers suggested, ranging from about $50 million at the low end to $1 billion at the high end. The majority of responses fell in the range of $200 million to $500 million.

Two thoughtful arguments for investing significantly in trials were articulated. One participant focused on the magnitude of the revenue stream that might one day flow from a system of VMT fees. At present, the total national annual investment in surface transportation (federal, state, and local) stands at about $195 billion each year, and in the view of this participant it should be closer to $300 billion. He further argued that a properly designed system of VMT fees would eventually replace almost every other source of transportation revenue. From that perspective, investing several hundred million dollars (or even a billion dollars) to properly scope and design

a system that could one day collect three hundred billion each year can be viewed as a reasonable allocation of resources. Two other participants argued that continued reliance on fuel taxes as the automotive fleet becomes more fuel efficient in the coming years and as the market share for alternative fuel vehicles increases would result in the loss of billions of dollars per year in transportation revenue; this also provides a valid rationale for investing considerably in trials.

Additional analysis. To illustrate the potential loss in revenue that would result from continued reliance on fuel taxes, consider findings from the preceding NCHRP 20-24(69) study (Sorensen et al. 2009). Within that report, as already discussed earlier in Chapter 2, the authors examined the effects of an initially revenue-neutral switch from federal fuel taxes to VMT fees (with a flat per-mile rate for all vehicles) in 2015 based on EIA's long-range fuel consumption and VMT forecasts. Under the assumption that either the per-gallon or per-mile rates would remain constant thereafter, the authors calculated that federal fuel-tax revenues, in 2009 dollars, would increase from close to $36 billion per year in 2015 to just over $39 billion. In contrast, given that EIA expects VMT to grow much faster than fuel consumption, VMT fees would increase from about $36 billion in 2015 to more than $47 billion per year by 2030. Over the entire 15-year forecast period, VMT fees would yield an additional $60 billion in comparison to fuel taxes, and the differential would continue to expand with each passing year

D.4. PRICING POLICIES TO EXAMINE IN THE TRIALS

This section discusses participant responses to questions about the types of pricing policies that would be helpful to examine in the trials.

D.4.1. Metering All Mileage vs. Tolling a Subset of the Road Network

Question 1.1 asked whether in addition to the concept of charging for travel on all public roads, an expanded set of VMT-fee trials should also examine the potential for tolling on a partial road network. As context, VMT fees constitute one option for reforming surface transportation finance, but there are others. There has been some discussion, for instance, of tolling just the most heavily traveled segments of the road network (e.g., the Interstate system) using simpler RFID technology. While there are possible drawbacks to this strategy—most notably the potential for significant traffic diversion—it could also prove less costly and less politically controversial.

Interview and workshop discussion. This question did not elicit a particularly strong response among participants, and opinions were generally mixed. One noted that this would be especially helpful if there were a strong interest in the application of congestion tolls to support more efficient use of our existing Interstates and other major highways.

Additional analysis. In framing this question, the research team did *not* envision that examining tolling on a partial road network within the context of the trials would entail setting up actual gantries and equipping vehicles with transponders—such technology is already used in many areas and well understood. Rather, the metering devices for a subset of the participants could be configured to apply charges on just the most heavily traveled roads in the network, such as freeways and potentially major arterials, rather than on all roads. The main goals of such an experiment would be to assess (a) the degree of support for this form of pricing in comparison to

VMT fees on all roads, and (b) the likely effect on travel decisions (i.e., the extent to which such tolls would lead to diversion onto local streets).

D.4.2. VMT Fees for Passenger Cars, Trucks, or Both

Question 1.2 asked whether the trials should examine mileage-based fees for passenger cars, for trucks, or both.

Interview and workshop discussion. Almost uniformly, respondents argued that the trials should include both cars and trucks. One individual suggested that the trials should further distinguish between smaller commercial vehicles (typically operating within an urban area or region) and larger trucks (typically involving interstate travel).

Several of the respondents observed that the implementation issues and goals would likely be different for cars and trucks; for example, many trucks are already equipped with technology that could support the metering of mileage, and privacy concerns are less pervasive given that the industry is already heavily regulated. (It should be noted that certain routing information might be viewed as integral to a trucking firm's competitive advantage, and such information obviously merits strong confidentiality protection; beyond that consideration, however, there appears to be less concern over the system metering the location of any particular driver.) This suggests that it might be beneficial to examine VMT fees for passenger cars and trucks in separate trials, though it was also noted that there would be value in determining whether the same fee collection mechanisms could be used for both passenger and commercial vehicles.

D.4.3. Potential Pricing Structures

Question 1.3 asked about the potential pricing structures to consider within the trials. Options included flat fees, fees that vary by jurisdiction, fees that vary by time and location, fees that vary by vehicle weight and potentially by road class (for trucks), and fees that vary by emissions characteristics.

Interview and workshop discussion. Two schools of thought emerged with respect to this question. Some respondents argued that the main motivation for adopting VMT fees is to switch to a more stable revenue source. Based on this perspective, it would make sense to focus mainly on flat fees and fees that vary by jurisdiction (such that different states, for instance, could set their own fee rates). Adding additional forms of pricing would introduce greater complexity and likely raise additional political concerns; simply switching to VMT fees is already a major policy shift. Respondents in this group indicated that additional forms of pricing might be added once the system is already up and running.

Other interview participants asserted that the principal justification for implementing a more complex and costly system would be the ability to address additional transportation policy goals beyond revenue collection—to charge based on time and location to reduce traffic congestion, to charge based on emissions characteristics to improve environmental outcomes, and to assess trucks based on weight and distance (and potentially road class) to properly account for their wear and tear on roads. While recognizing that such forms of pricing might increase the degree of controversy, respondents in this group also viewed it as important to examine these

alternatives within the trials to ensure that the system ultimately adopted would provide the necessary flexibility to accommodate a range of pricing policies at some future date.

Several respondents suggested potential opportunities for testing some of the more refined forms of pricing in less controversial formats. To examine congestion tolls, for example, a trial could be structured to ensure that the metering equipment works properly on existing managed lanes (e.g., the I-15 HOT lanes and SR-91 Express lanes in Southern California). To test weight-distance truck tolls, in turn, a trial might be designed to simply automate an existing ton-mile tax in one of the states that relies on this form of fee (in fact, Oregon recently completed a small scale trial to do just that, and is currently expanding the trial to examine alternate technology and include larger numbers of vehicles; see Oregon Department of Transportation 2010).

D.5. HIGH PRIORITY ISSUES TO EXAMINE IN THE TRIALS

This section summarizes responses for questions related to specific technical, institutional, implementation and transition, and user acceptances issues that the trials might be designed to address.

D.5.1. Technical Issues

Question 3.1 asked about the relative importance of different technical issues that the trials might be designed to address. Options included alternate metering configurations, alternate collection mechanisms, alternate means of protecting privacy, alternate enforcement approaches, an open systems technology platform (including relevant interoperability standards and certifications), and the potential use of detailed travel data to support other transportation goals (e.g., providing real-time traffic congestion data, calibrating transportation demand models, and the like). While these are all important issues, the purpose of the question was to elicit from the respondents their sense of which should be viewed with the highest priority, and why.

Interview and workshop discussion. Based on comments from interview and workshop participants, the three technical issues that emerged as most crucial included alternate collection mechanisms, alternate privacy mechanisms, and alternate enforcement mechanisms. At least four compelling reasons for examining a range of collection mechanisms were cited. First, the overall cost of the system would depend heavily on the means of collection operated at scale, and that needs to be better understood. Second, the means of collection would directly affect the institutional structuring of the program—whether, for example, the IRS will interact with fuel retailers or with firms that offer back office functionality. Third, it would be valuable to support alternate forms of payment—i.e., credit, debit, check, or cash—and this might require multiple collection options. Fourth, considering the likelihood that private firms would participate in the billing function, it would be helpful to examine different potential interfaces between the public and private sectors.

With respect the protection of privacy, a number of respondents indicated that this could be readily solved through technical means. Still, most thought it important to look at different options to (a) convince decision makers that privacy could be protected, and (b) gauge user acceptance for different ways of protecting privacy. One of the participants also stressed the importance of distinguishing between privacy and data security.

Looking at different ways to enforce the system—that is, to detect and prosecute drivers that attempt to evade fees owed (e.g., by disabling a metering device)—also received near uniform support. For one thing, none of the trials conducted to date has focused on enforcement; additionally, there is much debate surrounding the question of how to enforce the system in a cost-effective manner. This argues for examining different options within the trials.

Perspectives regarding the relative importance of the other technical issues were mixed. While developing and testing standards to support interoperability was viewed as critical by many, some respondents felt that it was a bit premature to focus on this issue in the trials; that is, they felt that the standards should be developed following the trials based on what is learned. Some suggested that the trials should include multiple metering devices—the options based on GPS and cellular location were the most commonly cited—but others argued that vendors should be allowed to supply any form of device that meets the metering requirements, even if they all choose to supply the same configuration (e.g., GPS-based). Respondents also viewed the use of travel data to support other transportation goals as being ultimately important to the system, though many were not convinced that it would be essential to include this in the trials; it was also suggested that including the collection of travel data within the trials (even though it would likely be collected anonymously) might exacerbate privacy concerns.

Additional analysis. While interview and workshop participants generally agreed that the most important technical issues to examine in the trials include alternate means of collecting payment, protecting privacy, and preventing evasion, it could be important to prioritize additional elements under two of the frameworks:

- **State framework.** If, under this framework, it were intended that states might transition from trials directly to implementation (i.e., participants become initial adopters), then it would be important to develop, at least in rough draft, the interoperability standards in advance of the trials. Otherwise, the system that the state puts in place might not be able to interact with systems in other states.
- **Market framework.** Here, of course, the explicit goal is for the trials to evolve into implementation, mandating the development of interoperability standards in advance of the trials. Additionally, this framework stresses the importance of developing an in-vehicle device that can support as many value-added services as possible to lower the overall cost of collecting VMT fees and encourage voluntary adoption; this increases the importance of examining additional uses of real-time travel information that could be provided by the devices.

D.5.2. Institutional Issues

Question 3.2 asked about the relative importance of different institutional issues that the trials might examine. The options included actual (rather than simulated) collection and apportionment of revenue, simultaneous collection of federal and state (and possibly local) VMT fees, alternate collection systems for passenger cars and trucks, alternate institutional configurations for billing and account management (e.g., publicly administered, administered by a single vendor, or

administered by multiple vendors), and competition among multiple vendors within the same trial.

Interview and workshop discussion. Most interview and workshop participants agreed that it would be important to examine simultaneous collection of federal, state, and potentially local fees and to look at alternate institutional configurations for billing and account management. For the latter, respondents stressed the importance of understanding different ways that the system might be configured in practice and how those might vary in terms of administrative cost and complexity. Some also suggested the importance of determining an appropriate publicly-managed default collection option.

Most participants also agreed that it would be very valuable to include the actual collection of revenue; in short, jurisdictions want proof that the new system will continue to provide revenue and be able to collect fees from out-of-state drivers. Additionally, respondents argued that the demonstration of actual revenue collection would provide compelling evidence that the system could be implemented in practice. That said, many also recognized that the goal of collecting actual revenue would also increase the difficulty of trials; among other things, it would almost certainly require enabling federal and/or state legislation, and this would likely prolong the timeframe for the trials. States might also fear that they would lose revenue if the system did not work as envisioned, while participants might be reluctant to face the prospect of potentially paying more for their travel. To mitigate such concerns, one interview participant suggested that the federal government might commit to making states and participants whole—that is, covering any revenue shortfalls or rebating any addition road use fees that result from collecting VMT fees and potentially rebating fuel taxes during the trials.

Most thought that the inclusion of multiple private vendors within a trial would be interesting, but few viewed it as essential at this stage. Likewise, setting up separate collection mechanisms for passenger cars and trucks was not viewed as critical.

Additional analysis. Interview and workshop participants concluded that among the various potential institutional issues to consider, the trials should prioritize the examination of collecting both federal and state/local VMT fees and assessing multiple configurations of the collections process. In two of the frameworks, however, it would be important to include additional issues:

- **State framework.** If it were intended that the trials be designed such that states could transition directly into implementation, then it would be very important to include actual revenue collection. Recognizing that this would likely require supporting legislation, it might be helpful to stage a multiple-year trial in which actual revenue collection would be introduced in one of the latter years.
- **Market framework.** With the explicit goal in this framework of transitioning directly to implementation, the inclusion of actual revenue collection would be essential (though here again it might take place near the end of a multi-year trial). This framework also highlights competition among firms to help drive down prices and stimulate the introduction of value-added services; thus it would also be very valuable to include multiple vendors within a single trial.

D.5.3. Implementation and Phase-In Issues

Question 3.3 asked about the relative importance of examining additional implementation and phase-in issues that the trials might examine. Issues on the list included integration with existing toll systems, including different classes of vehicles (e.g., older vehicles without the OBD II port that might require distinct metering device configurations), charging foreign vehicles, rebating fuel taxes to those who pay VMT fees (if needed), and incentives for voluntary adoption to speed the transition period.

Interview and workshop discussion. Most participants viewed integration with tolling systems as relatively trivial in a technical sense but nonetheless important to demonstrate in the trials. One respondent noted that annual toll collection across the United States amounts to roughly $10 billion per year, making it a sizable share (about ten percent) of overall user fee collection in this country. Another observed that many in the tolling industry view VMT fees as a potential threat, and their willingness to cooperate could hinge on whether they perceive that VMT fees are being done *with* them or *to* them (though in contrast, another respondent noted that the creation of a VMT fee system might actually facilitate an increase in public-private tolling projects by eliminating the need to deploy additional collection systems). The importance of looking at incentives for voluntary adoption was also stressed by many of the interviewees; the idea that a voluntary opt-in period might prove to be more politically viable than a phased mandatory transition (e.g., metering equipment installed with all new vehicle purchases) is intriguing, and there appears to be considerable interest in examining this concept more fully within the trials.

Under the assumption that VMT fees would replace rather than augment fuel taxes, and that the phase-in period for VMT fees would be lengthy, most participants also viewed it as important to examine strategies for rebating fuel taxes to early system adopters. Examining different classes of vehicles—particularly vehicles manufactured prior to 1996 when the OBD II port became standard—was also viewed as potentially valuable, but only if it were envisioned that all older vehicles might someday be required to be retrofitted with metering equipment.

There were mixed opinions surrounding the issue of charging foreign-owned vehicles. Some border-state representatives viewed this as very important, while others suggested that it would be possible to develop appropriate strategies through studies rather than trials.

D.5.4. User Perceptions and Acceptance

Question 3.4 asked about different user perception and acceptance issues that could potentially be examined in the trials. Options included user understanding and support for distance-based road-use charges, user response to alternate fee structures, user response to alternate privacy protection mechanisms, user response with respect to potential tradeoffs between privacy and ability to audit, and user response to the choice of value-added features.

Interview and workshop discussion. Among the potential user issues related to user perceptions and acceptance, most interview and workshop participants identified user acceptance of VMT fees and user perceptions of privacy issues as the most critical to address in the trials. Along with system cost, most respondents viewed user acceptance as one of the two most critical factors standing in the way of implementing VMT fees. They therefore argued that it would be critical to use the trials to learn as much as possible about user perceptions in order to design a

system that would be politically viable. In addition, privacy is often identified as the greatest barrier to public acceptance; most respondents thus argued that it would be important to examine driver perceptions of privacy protection in the trials. Other issues related to user perceptions and acceptance were viewed as valuable but not equally essential.

D.6. DETAILED TRIAL IMPLEMENTATION STRATEGIES

This section reviews the results for more detailed questions about how to implement and conduct the trials successfully—for example, enticing drivers to participate in the trials, developing and examining interoperability standards, and probing the effectiveness of approaches for preventing evasion.

D.6.1. Strategies for Enrolling Participants

Question 9.1 asked about how to encourage both car and truck drivers to participate in trials.

Interview and workshop discussion. Perhaps not surprisingly, the most often mentioned suggestion for enticing participation was a direct financial incentive. It was also noted that the cash-incentive approach might become expensive in a large-scale trial (as a point of reference, participants in the Oregon trials received $300, while participants in the Iowa trials received roughly $900, and in each of these cases the trials lasted a year or less).

Many respondents also suggested indirect financial incentives, such as letting participants pay less in gas taxes or structuring an incentive program in which driving fewer miles would lead to higher rewards. Other ideas included value-added services (e.g., smart parking information, reduced parking rates, or PAYD insurance) or services such as a "personalized transit marketing program" that looks at a person's travel habits and suggests opportunities for reducing personal vehicular travel.

A number of respondents noted that it would be important for the trials to include a large cross-section of the driving public. The trials would not be deemed credible if it were perceived that the volunteers were mostly environmentalists concerned mainly with reducing VMT. Another person cautioned that the "early adopters" who might find add-on applications attractive do not necessarily represent the entire population.

Incentives for trucking companies might also include direct financial incentives, although larger firms might find enough benefits in the research (e.g., the opportunity to ensure that their concerns would be addressed in subsequent system planning) to join a trial without such an incentive. It was also noted that the more the trial interferes with ongoing business operations, the less likely firms would be to join.

D.6.2. Groups to Include

Question 9.2 asked whether efforts should be made to include specific types of vehicles or groups of users in the trials, such as electric vehicles, older vehicles without OBD-II ports, rental fleets, government fleets, or trucking fleets.

Interview and workshop discussion. Relatively few interview participants responded to this question. Among those that did, opinions ranged from not making the effort to include any particular groups—on the grounds that the trials will be sufficiently complicated without trying to capture specific participants—to including all of them. Those who opted for inclusion of some or all wanted to ensure that the trials were capturing as much diversity in vehicle types as possible to gain information for implementation.

D.6.3. Parallel Education Activities

Though the project focused mainly on the trials themselves, question 9.3 asked interview and workshop participants to consider complementary education and outreach activities that might be included before, during, and after the trials.

Interview and workshop discussion. Most participants viewed education as a critical dimension of the trials, for two reasons. First, public support would be crucial to eventual implementation, and the trials could help build support if they allay the inevitable concerns about privacy and increased tax payment. Second, the trials and related education efforts would offer an important opportunity to inform the public about the need to reform transportation finance and the benefits of reinvigorating the user-pay principle. It was also stressed that public education and outreach would be a sensitive issue and should be approached accordingly.

The interviews and workshop yielded thoughtful discussion about overall outreach efforts. Several respondents noted the importance of early marketing to gain public support, as opposed to waiting until the trials were underway or completed. One person suggested that focus groups conducted before a trial could elicit important concerns that the trials could then be structured to address. Focus groups were mentioned as particularly important pre-trial because the gas tax and VMT fees are so poorly understood; it would be difficult to conduct a useful survey on a low base of knowledge.

Another suggestion was to emphasize the "trial" nature of the program; several respondents felt it important to stress that the trials did not represent the direct route to implementation, but rather would provide information to inform subsequent debate about whether and how to implement VMT fees (note, however, that this suggestion runs contradictory to the market framework, in which the goal would be for the trials to evolve directly to implementation). In this same vein, several participants mentioned the success of the Stockholm congestion cordon trial, in which residents were first able to see how the system worked and then vote on whether to continue it. This also relates to another point several people made—that public opinion might change, even dramatically, during the course of a trial as people better understand VMT fees.

Several other suggestions related to public outreach were offered. Outreach should not be seen as a "one-way" street in which information flows from the government to the participants, but rather a "two-way" street in which public opinions are solicited. In addition, some considered it very important to be honest and transparent about the potential outcomes of the trials, which might include congestion pricing in some areas. Those who made this point noted that building public trust would depend on such transparency. In terms of specific ideas for public education, the following options were discussed:

- Reach out to various groups, including state legislative committees, bicycle/transit groups, environmental organizations that work on related issues, air districts and state environmental agencies, Transportation for America, AAA, AARP, and trucking and industry trade associations.
- Use public service announcements and educational materials.
- Involve a professional public relations or advertising firm.
- Use new methods of outreach; the "usual suspects" will not be enough. Have participants "blog" and "tweet" about their experiences, set up a Facebook fan page, invite a celebrity to participate, and visit people where they gather rather than expecting them to attend public meetings (e.g., booths at festivals).

One participant had a markedly different opinion: specifically, that in the market framework the value-added services bundled in to the product would be sufficient enticement to join and a major public education effort would be unnecessary. If drivers are presented with "convenience, services, bundles, rewards, discounts, loyalty payments, deals, and savings" the program will essentially market itself. Along similar lines, another participant suggested that the trials would benefit from branding, perhaps something along the lines of "Smart Choice," to give the program an identity. Any phrase including "pricing," it was suggested, would probably not be a good choice for a brand name.

D.6.4. Interoperability Standards

Question 11.1 asked whether the federal government should endorse a set of interoperability standards in advance of the trials and, if so, who should take the lead in developing them.

Interview and workshop discussion. As noted earlier in Section D.5.1, there was general agreement that the federal government should establish a set of standards for metering equipment and billing processes to ensure that multiple vendors could compete for market share (thus driving down price and encouraging innovation) and/or that systems developed in separate states would be interoperable. Opinions were mixed, however, on whether standards would need to be developed in advance of or following the trials. Seeking to develop an initial set of standards in advance of trials would make it possible to examine how well the interoperability concept works in practice during the course of the trials, but it might also delay the timeframe for initiating the trials. Waiting until after the trials, in contrast, would provide a greater opportunity to apply the lessons learned during the trials to the standards development process.

Several respondents suggested key issues that would need to be addressed within the standards. These include:

- Minimum required accuracy for metering and billing
- Support for some set of fee collection mechanisms
- Support for some set of privacy protection and protocols
- Support for some set of strategies for preventing evasion

- Data storage and communication protocols
- Data security protocols
- Support for IntelliDrive functions (respondents indicated that if sophisticated and costly devices were to be installed in vehicles, the devices should support the broadest possible range of functionality, including envisioned IntelliDrive applications)

A few respondents highlighted several related efforts to develop road pricing standards and principles that could serve as a helpful starting point for crafting a national set of interoperability standards. These sources included ISO/CEN 17575, standards on DSRC- and GPS-based road use charging systems jointly produced by the International Standards Organization (ISO) and the European Committee for Standardization (CEN); the Sofia Memorandum, a set of guidelines on privacy protection within the context of electronic road pricing produced by the International Working Group on Data Protection in Telecommunications; and the privacy principles from the IntelliDrive program.

In terms of who would lead the standards development effort, suggestions included a technical committee operating under the oversight panel for the trials, a committee within AASHTO (which manages several other national design standards), groups that set ITS standards, or ASTM International (formerly the American Society for Testing and Materials, a voluntary standards development organization). Wherever the effort is ultimately housed, respondents suggested that it would be beneficial to include representation from such groups as device manufacturers and service providers, related industry consortia, IBTTA, ITS America, the IntelliDrive program, and academic institutions.

Additional analysis. The appropriate timing for developing standards—in advance of or following the trials—depends on the selected framework:

- **State framework.** If, under this framework, it were intended that state trials might evolve directly to full-scale implementation, then standards should be developed in advance of the trials (mainly to ensure interoperability across different state systems). If a direct transition from trials to implementation were not envisioned, then standards could be formulated following the trials.
- **Federal framework.** This framework assumes that the trials would not evolve directly to implementation, but rather would serve as a basis for planning a federal system that would be implemented at a later date. This would allow the standards to be developed following the trials in preparation for full-scale implementation.
- **Market framework.** This framework explicitly assumes that trials would evolve directly to implementation. The standards would thus need to be developed in advance of the trials (mainly, in this case, to ensure interoperability across different device and service providers).

D.6.5. Accuracy of Metering and Billing

Question 11.2 and 11.3 asked about how to test the accuracy of metering devices and billing statements.

Interview and workshop discussion. Only a few interview participants chose to address this question, but the general response was that accuracy issues should be tested in advance of the trials. That is, there should some set of tests to certify equipment and services before they could be deployed in the trials. It was also noted, though, that the trials would the opportunity to further evaluate accuracy over a broader range of situations.

D.6.6. Effectiveness of Privacy Protection Mechanisms

Question 11.4 asked about how to verify, and demonstrate to users, the proper functioning of alternate mechanisms for protecting privacy.

Interview and workshop discussion. As several respondents noted, it would be difficult to demonstrate the proper functioning of privacy protection mechanisms in the trials given that users would have no way to detect whether or not their data were being protected as advertised. One respondent therefore suggested enrolling a reputable organization committed to privacy protection to serve as a third party auditor of the privacy approaches. Such an organization could be expected to subject the privacy protection strategies to intense scrutiny, helping to ensure their proper functioning. It was further noted that if such a group were to validate the mechanisms for protecting privacy, it might help to assuage privacy concerns among the general public.

Several participants also highlighted the distinction between privacy and data security; the latter involves protecting sensitive data from malicious third parties who might attempt to gain unauthorized access, e.g., via "hacking," to the data. To ensure system security, participants suggested the idea of employing a firm with data security expertise to stress-test the system and ensure that databases and communications—between metering devices, billing service providers, and the government—have been properly secured and cannot be breached.

D.6.7. Effectiveness of Mechanisms for Preventing Evasion

Question 11.5 asked about how to test the effectiveness of alternate mechanisms for detecting and preventing fee evasion within the trials. States and the federal government would be understandably reluctant to proceed to implementation unless they were confident that VMT fees could be effectively enforced. Yet within the context of trials, the level of participation might prove insufficient to fully stress the enforcement mechanisms. Additionally, if the trials did not involve the actual collection of revenue, there would be little incentive for participants to try to cheat the system. How, then, might the trials be structured to probe the effectiveness of proposed mechanisms for detecting and prevention evasion?

Interview and workshop discussion. In response to this question, interview and workshop participants offered two potentially promising ideas. The first concept was to offer rewards to trial participants who are able to "defeat" the system—for example, to disable their in-vehicle meter without being detected. Though intriguing, it is not clear that most participants would possess the necessary technical skills to identify and capitalize upon enforcement vulnerabilities. This led to the second suggestion of engaging one or more firms with relevant expertise in the areas of telecommunications and system design to systematically search for ways to defeat the system—that is, to probe any potential weaknesses.

D.6.8. VMT Fees for Foreign-Owned Vehicles

Question 11.6 asked about potential ways to test the application of VMT fees to foreign-owned vehicles in the trials, should that be desired.

Interview and workshop discussion. Interview and workshop participants did not provide any specific suggestions for this question. As discussed earlier in Section D.5.3, the testing of VMT-fees for foreign-owned vehicles did not emerge as a high priority issue for inclusion within the trials.

D.6.9. Additional Uses of Travel Data

Question 11.7 asked about how to evaluate, within the trials, the possibility of using detailed travel data to support other transportation applications—for example, developing real time traffic information or calibrating regional transportation demand models.

Interview and workshop discussion. Two respondents suggested the idea of paying participants to share their data as opposed to keeping it private. The payment would, in essence, reflect the public benefit that might be derived through better real-time information about traffic conditions on the road network. One suggested establishing a non-profit that would collect and aggregate the information to provide real-time traffic congestion data across the nation's roadways.

D.6.10. Transition Issues

Question 11.8 asked about how the trials might be structured to examine certain issues related to transitioning to VMT fees, including strategies for promoting voluntary adoption, methods for rebating fuel taxes (if VMT fees replace rather than augment fuel taxes), and demonstration of the transition strategy.

Interview and workshop discussion. With regard to promoting voluntary adoption, many participants expressed the opinion that the trials should explicitly strive to include additional value-added features, such as PAYD insurance, parking payment, traffic alerts and routing, and the like, in order to gauge user response to this concept. Along these lines, the provision of additional services could be one of the criteria for judging proposals to conduct trials. Specific suggestions for issues that might be valuable to probe within the trials included distinguishing between participant perceptions of VMT fees and perceptions of the value-added services and exploring whether the value-added services used to encourage participation in the trials would prove sufficient to entice the actual adoption of VMT fees. Interview and workshop participants did not offer ideas on how to examine the issues of rebating fuel taxes or demonstrating a transition strategy within the trials.