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NCHRP

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System Trials to Demonstrate Mileage-Based Road Use Charges

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National Cooperative Highway Research Program
TRANSPORTATION RESEARCH BOARD
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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. Additionally, 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
<ul style="list-style-type: none"> • Odometer options: <ul style="list-style-type: none"> – 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 <ul style="list-style-type: none"> – On-board diagnostics (OBD II) connection – OBD II / cellular – GPS 	<ul style="list-style-type: none"> • Pay with registration • Pay at the pump • Wireless transmission to billing authority • Debit cards 	<ul style="list-style-type: none"> • 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 	<ul style="list-style-type: none"> • 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
<i>Metering and Pricing Policies to Examine in the Trials</i>			
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)		
<i>Technical Issues to Examine in the Trials</i>			
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
<i>Institutional Issues to Examine in Trials</i>			
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
<i>Implementation and Phase-In Issues to Examine in Trials</i>			
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		
<i>User Acceptance Issues to Examine in Trials</i>			
Concept of VMT fees	Yes		
Alternate fee structures	Optional		
Alternate privacy protection	Yes		
Privacy vs. auditability	Optional		
Value-added services	Optional		
<i>Detailed Strategies for Implementing the Trials</i>			
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.