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A Framework to Analyze the Feasibility of Vehicle Miles Traveled Fees to Finance a Sustainable Transportation System

by Marketa Vavrova, Carols M. Chang, and L. Bina (deceased)

This paper presents a framework to analyze the feasibility of vehicle miles travelled (VMT) fees as an alternative to finance maintenance, rehabilitation, and new construction transportation projects. The VMT feasibility framework addresses major factors related to public acceptance, revenues, technology, type of contract, government policies, enforcement, administration, and invoicing. We argue that our suggested VMT fee policy is an equitable usage-based system since in our analysis, VMT fees are differentiated by vehicle axles and emissions. In turn, VMT charges will also motivate fleet owners to renew vehicles or switch to alternative transportation modes such as mass transit, walking, and biking. An example based on data from the state of Texas illustrates some of the potential revenues and benefits associated with a VMT fee policy.

INTRODUCTION

A safe, reliable and well-maintained transportation network that serves users of all ages and incomes should be the ultimate goal of a sustainable transportation system. Due to aging, increasing traffic, and growing population, the U.S. transportation system demands larger investments to maintain expected levels of service. Unfortunately, limited budgets from traditional sources of revenues (e.g., taxes on fuels, vehicle registration fees) are not sufficient to cover future transportation needs. To support a sustainable transportation system, we need to consider alternative financial tools designed to generate sufficient revenues to cover the costs of maintenance, rehabilitation, and new transportation projects. The objective of this paper is to present one framework to analyze the feasibility of a Vehicle Miles Travelled (VMT) policy as a tool to finance a sustainable transportation system. The framework outlines the decision context for the implementation of VMT fees and identifies factors necessary to best evaluate its feasibility as a transportation funding alternative.

VMT fees could be used as a self-financing policy alone or in combination with other sources of transportation related revenue, including tolls, increased sales taxes on fuel, higher registration fees, or higher local taxes. Here, VMT fees are assigned to three classes of vehicles: [1] light duty vehicles, including passenger cars, light trucks, vans, and sport utility vehicles regardless of wheelbase (FHWA 2009), [2] single-unit trucka, [3] combination trucka, along with three emission classes differentiated according to Tier II emission standard: [1] BIN 11-6, [2] BIN 5-3, and [3] BIN 2-1. Tolling systems based on a combination of a vehicle class and emissions have been successfully implemented in the European Union (EU) and could be introduced to the U.S. to induce lower emissions and less damaging road use.

HOW IS THE TRANSPORTATION SYSTEM BEING FUNDED?

Based on the theory of taxation, Balducci et al. (2011) organized established revenue systems into four categories: vehicle ownership, highway user fees, energy consumption, and beneficiary and local option fees. These are shown in Table 1. Vehicle ownership revenue streams include income from registration fees, licensing fees, and personal property taxes. Highway user fees can include income from tolls, congestion/cordon pricing, high occupancy toll lanes, or VMT fees. Revenue from energy consumption can include fuel taxes, sales taxes on fuel, as well as utility fees. There are

also beneficiary and local option fees that can be sources of revenue, including beneficiary charges and value capture, transportation impact fees, local option sales taxes, and local option property taxes.

Table 1: Established Revenue Systems (Balducci et al. 2011)

Vehicle ownership	Highway user fees	Energy consumption	Beneficiary and local option fees
Registration fees	Toll roads	Motor fuel taxes	Beneficiary charges/value capture
Licensing fees	Congestion/cordon pricing	Sales taxes on motor fuels	Transportation impact fee
Personal property taxes	High occupancy toll lanes VMT fees	Utility fees	Local option sales taxes Local option property taxes

Currently in the U.S., highway revenues are mainly derived from the fuel tax. Apart from federal and state fuel taxes, there is also revenue generated from tolls, vehicle registrations and ownership taxes. Contrast this with what has happened in the EU, where the fuel tax is three times higher than in the U.S. Vehicles over 7,000 lbs. are charged distance-based fees, and vehicles below 7,000 lbs. must purchase a time-based vignette to travel on the European Interstate network. Certain road sections are also tolled. The majority of the revenue from EU fuel taxes goes to a general fund and about 20% is dedicated to road infrastructure (Silnice 2004).

Fuel taxes are becoming a less reliable source of revenue due to increasing fuel efficiency and alternative-fuel vehicles entering the market. Whitty (2007) points out that the fuel tax has now become “rather a general tax unrelated to use than a fee for service” as the correlation between fuel consumption and road usage is changing. Even though Baker et al. (2011) indicated that “government regulation and continued increases in fuel prices could cut fuel consumption in the United States by 20 percent by 2025,” declining fuel prices in 2014 seem to indicate that demand for gasoline is still relatively inelastic as “it takes a 25% to 50% decrease in the price of gasoline to raise automobile travel 1%” (U.S. Energy Information Administration 2014).

When considering the problem from a government perspective, approximately 83% to 87% of revenues from the fuel tax (depending on the fuel type) are deposited into the U.S. Highway Account and then redistributed to road infrastructure (FHWA 2010). Other contributions to the highway account come from excise taxes on the sale of tires, trucks, buses, trailers and heavy vehicle use, but compared with income generated by the fuel tax, they can be considered insignificant. As Elmendorf et al. (2008) highlight, balances in the highway account were stable at around \$10 billion during the 1980s and in the first half of the 1990s.

Since 2001 expenditures have exceeded revenues. Based on this trend, Elmendorf et al. (2008) predicted that balances in the highway account would be depleted during the fiscal year 2009. In reality, the highway account was depleted even earlier (September 2008) when Congress had to transfer \$8 billion from general funds to cover a shortfall in the highway account. This occurred again in 2009, when the highway account was unable to meet obligations and required an infusion from general funds of \$7 billion in 2009 (Elmendorf et al. 2010). In 2010, the highway account required another \$14.7 billion, followed by \$2.4 billion in 2012, \$6.3 billion in 2013, and \$10.4 billion in 2014 (FHWA 2015). Based on these figures, many conclude that the current highway financing system is experiencing serious problems and is far from being self-sufficient.

BACKGROUND ON VEHICLE-MILES TRAVELLED (VMT) FEES

While “distance traveled” may be a more accurate term to describe vehicle-miles traveled (or VMT), the term VMT fee or mileage-based user fee (MBUF) is more widely recognizable among policymakers and media in the U.S. A VMT fee policy can be designed to influence drivers and many argue that it is also more economically sustainable in the long run, offering greater consumer transparency. On the other hand, drawbacks include difficulty in passing a new user charge, costly implementation, as well as potential fights for transparency on returning money to those districts that contributed to the revenues (Schank and Rudnick-Thorpe 2011).

Elmendorf et al. (2011) reported on four trial run projects in the U.S. investigating the feasibility of implementing a VMT fee. These were in Atlanta, Georgia (2003-2004), Seattle, Washington, (2005-2007), Portland, Oregon, during 2007 and 2012 (Whitty 2007), and a mileage-based road user charge pilot in 12 U.S. states during 2009-2010 (Hanley and Kuhl 2011). More recently, Oregon’s Voluntary Road Usage Charge Program (OreGo) was launched in July 2015. It comprises a fleet of 5,000 volunteer cars and light commercial vehicles with a fuel efficiency of 55 mpg or better (ODOT 2015). Volunteers in the project receive a gas tax credit but are charged a fee of 1.5 cents per mile. California also launched a nine-month VMT fee program in July 2016, where up to 5,000 participants did not pay any fuel tax in exchange for reporting their driving data from GPS or an odometer, data which will be used to help design a VMT program in the near future (Jones 2016). Other states, including Delaware, Vermont, Pennsylvania, New Hampshire, and Connecticut, are also interested in testing a multistate VMT fee program (Jones 2016).

As Rufolo (2011) points out, a VMT fee policy is already used for heavy vehicles when traveling the U.S. Interstate system. According to the International Fuel Tax Agreement, heavy vehicles are obliged to report mileage driven in every state to calculate the difference between the actual tax paid and the theoretical tax that should be paid according to state regulations. Trucking companies are either returned some amount or requested to pay the shortfall.

The possibility of replacing truck highway taxes with a satellite-based VMT fee is being explored in the state of New York, which reports diesel tax under payments of about \$90 million per year (Delcan et al. 2011). The latter observation points to the fact that the design and implementation of VMT fees applied to the U.S. interstate highway network may be a useful remedy for infrastructure funding issues. Some observe that the collection cost of a VMT fee system is notably higher than for a fuel tax. Rough estimates of operating cost per 1,000 VMT is \$0.10 for a fuel tax, versus \$1.79 for a VMT fee paid at the pump (as done in the Oregon study, see Whitty 2007) versus \$6.26 for the VMT fee collected in the Netherlands, the latter being withdrawn in 2009 before its implementation (Rufolo 2011). Fuel taxes were introduced in 1911 when Oregon became the first state to tax motor fuels (McCormally 2014). At the federal level, President Herbert Hoover signed the Revenue Act in 1932 (FHWA 2005), hence any prospective switch to a VMT fee policy must be gradual and well considered from the view of both financing and public acceptance.

Robitaille et al. (2011) examined the impact of a \$0.10 increase in the federal fuel tax, as well as the impact of a \$0.015/mi VMT fee in each state. Relevant to this study, the annual net change in revenue in the case of Texas would be \$514.9 million (for a \$0.10 increase in the federal fuel tax) or \$482.2 million (for a \$0.015/mi VMT fee) (Robitaille et al. 2011). This indicates in the short-term, the revenues from the fuel tax and from the VMT fee are essentially comparable. However, we offer that it is important for legislators to consider a switch to a VMT policy as a long-term solution because of increases in overall fuel efficiency and the large number of alternative-fuel vehicles coming on the road. As Robitaille et al. (2011) reported, VMT fees reduced vehicle miles travelled by users, resulting in lower fuel consumption, a situation beneficial to both energy policy and the environment. Research in variable pricing strategies indicates that VMT fees tend to affect travel behavior as well as activity participation and rescheduling patterns (Keuleers et al. 2006).

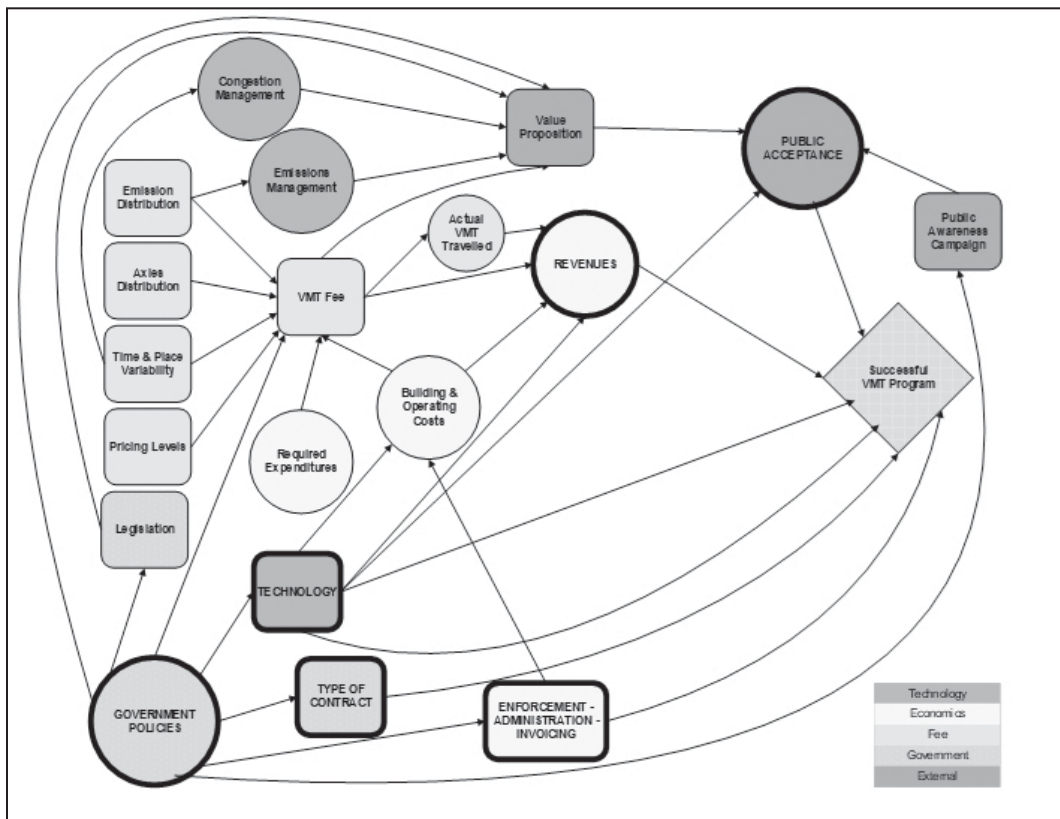
FRAMEWORK TO ANALYZE THE FEASIBILITY OF VMT FEE PROJECTS

An evaluation framework is presented here to assess the feasibility of implementing a VMT fee-based system for a transportation network. The ultimate goal of implementing new financial tools will be to generate sufficient revenues to finance existing and new road infrastructure, including operating and maintenance costs. In addition to revenues, there are well known secondary benefits associated with VMT implementation, including lower emissions and fleet renewal, as experience in the EU has shown (Vierth and Schleussner 2012). Additionally, the data collected for a VMT fee project could also be used for congestion management analysis to reduce travel time and mitigate air pollution.

Factors Affecting the Implementation of VMT Fee Projects

An influence diagram illustrates the decision context for VMT fee implementation, including technological, economical, governmental, and external factors. The influence diagram applicable to this analysis is shown in Figure 1, where a circle is used to represent uncertain events and a rectangle represents decisions. This visualization indicates that a successful implementation of a VMT fee policy will be influenced several factors, including [1] public acceptance, [2] revenues, [3] technology, [4] type of contract, [5] government policies, and [6] enforcement, administration and invoicing. These factors are highlighted in the diagram and will be discussed in turn (Vavrova 2012).

Figure 1: Influence Diagram of Factors Influencing VMT Implementation (after Vavrova 2012)



Public Acceptance and Government Policies. As CURACAO (2008) noted, “We live in a democratic society, so societal, political and technological innovations must be introduced via the democratic process.” Since the users of such a system are not only the VMT fee payers, but also voters and payers of many other public taxes, it is vital for the success of a program to help the public understand that a VMT fee will also promote equity and fairness and that generated revenues will be used wisely, while the entire system will remain transparent to implement and monitor (Zmud and Arce 2008). Public acceptance is facilitated by extensive communication, where the items previously mentioned are discussed and clarified. To this end, Langmyhr and Sager (1997) describe a step-by-step implementation of the Trondheim urban road pricing project initiated in 1985 in Norway. They highlight the issues faced by the public and politicians during the implementation process. Ultimately, they suggest deploying contemporary communicative planning theory during the planning process.

We offer that a VMT fee policy should differ by emission class to support fleet renewal, manifesting in lower emissions and better air quality. This outcome could be one of the best ways to gain public support for a new road user fee structure (Dill and Weinstein 2007). However, it is important to consider that even though cleaner vehicles lead to less air pollution, other externalities such as congestion or accidents cannot necessarily be mitigated.

Other social aspects of VMT fee implementation to be considered are equity/distributive issues that will need to be addressed by appropriate legislation. For example, the affected public should possess available alternative modes of transportation, such as mass transit, cycling, or walking to make their daily trips to work and to other destinations in a convenient, safe, and reliable manner. We offer that such a transportation system would promote sustainability and livability, fundamental principles that are becoming popular within modern cities.

Revenues from a VMT fee could also be used for enhancing multi-modal transportation networks. An equity analysis done in Houston, Texas, indicates that implementation of VMT fees “would not have a pronounced effect on the current distribution of what household pays versus what they receive in transportation expenditures” (Carlton and Burris 2014). As for the current fleet of commercial vehicles, including heavy trucks, there is a possibility that an increase in road user fees would temporarily drive up prices of goods. However, there is evidence that in the long term we should expect changes in logistics behavior, including modal shifts to rail transportation, which is four times more energy efficient than a truck (AAR 2012a), along with fleet renewal as the effect of an emission class differentiated fee. To this end, Railex (AAR 2012b) estimates that each 70-car unit train removes 250 trucks off highways, alleviating highway congestion and reducing CO₂ emissions by 135,000 metric tons annually.

Increasing the awareness of miles traveled can lead to a decrease of total VMT and, as Cooper (2007) notes, a reduction in VMT will necessarily reduce air pollution. A VMT fee can also be designed to vary across time and place to facilitate congestion management. For example, in the Czech Republic, a 25% to 50% increase in VMT fees for trucks on Friday afternoon peak hours (3 pm–9 pm) induced a reduction of congestion along with savings in travel time (Bina, Cerny, and Novakova 2012).

“A strong public resistance may inhibit implementation as political parties fear consequences for their next election” (CURACAO 2008). Without question, political commitment is very important. Another vital step to public acceptance is to carefully plan changes in current tax laws concerning fuel taxes. Absence of this step in the planning process was probably the major reason for the VMT fee implementation failure in the Netherlands referred to earlier. In this case, the VMT fee was supposed to substitute for the property tax rather than the fuel tax. In fact, the public saw the new fee as a double taxation on travel. The implementation was cancelled a few months before it should have been launched.

To support such change, a stable government policy is needed since a VMT fee is a long-term policy decision and the highest level of support is vital for its success. An example of such support

is the Stockholm congestion charging trial, where surveys showed that less than 30% public support before the trial changed to 50% support toward the end of the trial, finally going up to 70% after the reintroduction of the policy (Eliasson 2008).

Another major issue in planning for VMT fee implementation surrounds privacy, as the need for tracking technology may arouse public fears of surveillance. For example, in the 2012 Oregon study, drivers were able to choose the way they wanted to report their miles driven (ODOT 2012). In Singapore, the privacy issue of electronic payment systems for parking and other facilities was solved with a smart cash type card that contains only account balance and no user data (Arnold et al. 2010). Ultimately, since the number of vehicles connected in some way to the internet is projected to rise in the near future, this may significantly open the door to pay-as-you-drive methods for both road user charges as well as car insurance.

Revenues. Revenues are vital for successful implementation of a VMT fee-based system, so the level of revenues is the fundamental objective considered in this study. This effectively depends on [1] vehicle miles travelled estimate, [2] vehicle class distribution, [3] emission class distribution, [4] target VMT fee revenue, and [5] pricing levels for each combination of vehicle class and distribution class. Apart from these, VMT revenues are influenced by annual costs and technology reliability.

Technology. Current possible technologies for electronic fee collection are microwave and satellite systems. Additionally, these can be combined with odometer readings or cellular network technology. Depending on the VMT fee and road length, various technologies might be preferred to others. The 2012 Oregon study (ODOT 2012) proposed an open technology system, where drivers had an option to choose how to report their miles – either directly from their odometer, or their own GPS unit, or they could choose a non-technological option and purchase unlimited miles in advance. A pre-paid unlimited mile option should remain an alternative for drivers with high privacy concerns but who are willing to pay for this, taking into account projected mileage and uncertainty, but also, in this latter case, technology costs are minimal.

Type of contract. The decision of how to finance the project is vital for future revenues and therefore the whole success of such a project. There are traditional methods for project delivery, such as design-bid-build, and design-build, but also newer methods, such as public-private-partnership (PPP). In the EU, PPP is a popular design-build-finance-operate-maintain concept, where countries like the United Kingdom and Portugal finance with PPP in more than 20% of their infrastructure projects (Engel et al. 2011). A PPP contract, when correctly designed, helps to manage public risk by shifting some of it onto the provider. The Hamilton project (Engel et al. 2011) discusses the opportunities for PPP in U.S. infrastructure, including the conditions when a PPP is suitable, as well as different types of contracts and best practices of PPP projects in the U.S. and Europe.

Enforcement – Administration – Invoicing. Enforcement is a vital part of the management system, as together with the chosen technology it affects the success rate of fee collection. A reasonable collection success rate, where a majority of those who are required to pay actually pay, is crucial in order to maintain public trust in the equity and fairness of a VMT fee system. Administration and invoicing can raise operating costs dramatically, so electronic bills or paying at a fuel station together with the fuel are ways to cut these costs.

HOW TO DETERMINE THE FEASIBILITY OF A VMT FEE PROJECT

The steps to determine the feasibility of a VMT fee project are outlined in Figure 2. First, a background study is conducted to investigate which alternative funding source is the best solution. A feasibility study follows performing a technology study and the consequences of implementing

different levels of VMT fees. The last step is to analyze the external relationships with a public opinion poll and a trial run. All steps are discussed in the following section.

Step 1. Background Study

First, the VMT fee is compared with other alternative funding options. The National Surface Transportation Infrastructure Financing Commission (NSTIFC 2009) offers a set of criteria to assign weighting factors taking into consideration revenue streams, economic efficiency/impact, implementation and administration, and equity.

A background study explores, through a series of questions, if there are stable government policies and legislative support. At this early stage, a public awareness campaign should be launched to explain the reasons why a VMT policy is under consideration. This should prevent the problem that occurred in Netherlands in 2010, when the distance-based fee was shelved after elections when the ruling party changed. To support public acceptance, extensive legislation changes regarding taxes and privacy need to be carried out.

Step 2. Feasibility Study

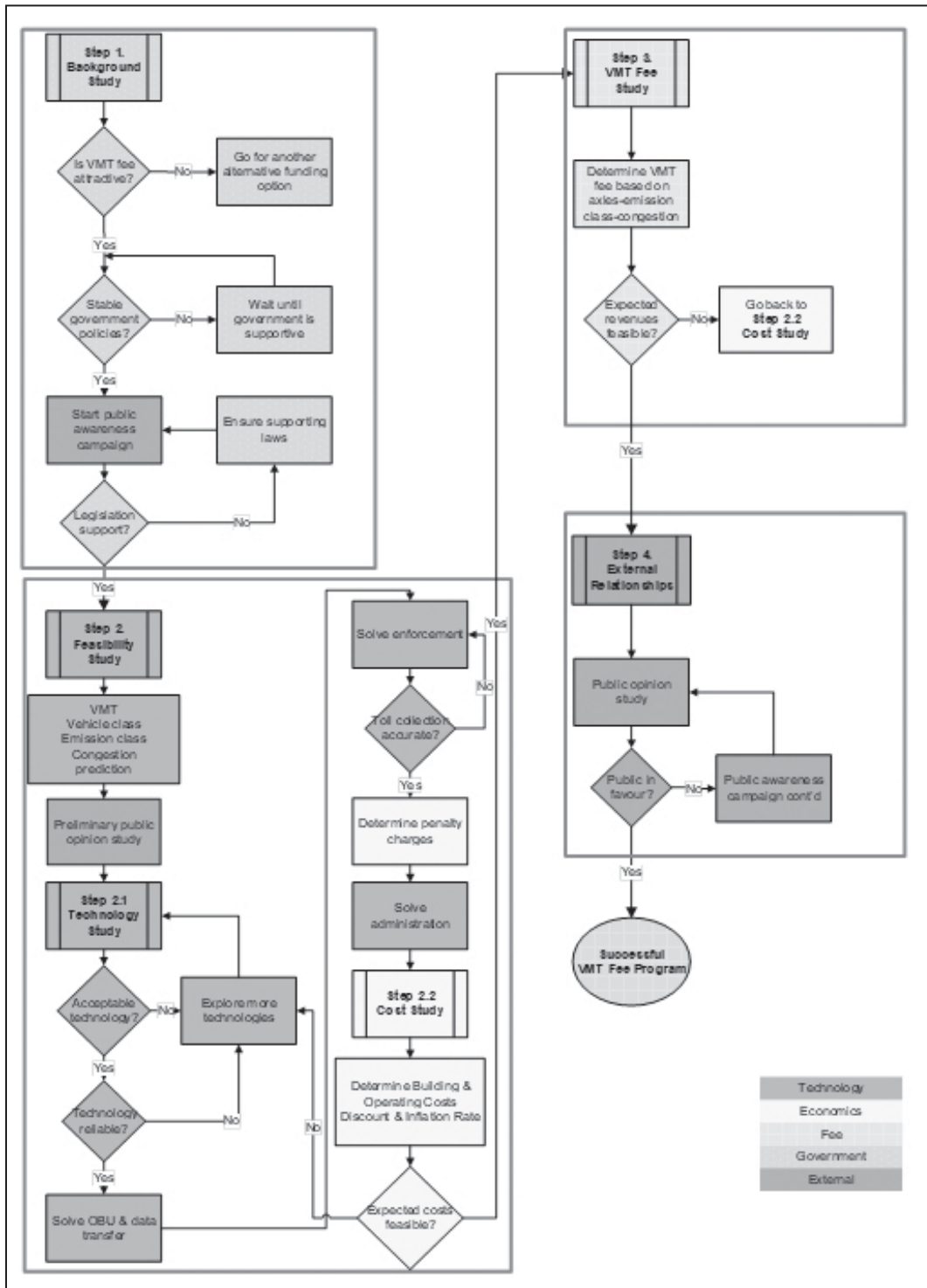
The feasibility study consists of a preliminary technology and cost study. A preliminary study of public opinion is recommended to explore the perceptions of the public, how much they would be willing to pay, what technology would be most acceptable, and what method of payment would be most convenient. The next task is the technology study. It is fundamental to find a technology, or a combination of technologies, that will comply with privacy issues and are acceptable from a building and operating costs perspective. For example, odometer reading technology is potentially a good candidate, because there are minimal privacy issues and also building and operating costs of a system based on this technology are reasonable. However, this technology is easily tampered with and will not necessarily satisfy the requirement of reliability and a reasonable fee collection success rate. For that reason, we consider acceptability and reliability as separate components as shown in the flowchart.

In addition, penalty charges should be determined and administration issues resolved, addressing such issues as whether drivers will pay at the fuel station, online, or by mail with a bill, and the possible cooperation between adjoining systems (bordering states) on how to charge the miles traveled beyond the border of the area. The cost study is the next step in the analysis process. All previous decisions influence operating costs and building costs. These costs should be determined, along with the discount and inflation rate. In case the expected costs are not covered by existing financial sources, even with a PPP contract, planning should be diverted toward exploring more cost-efficient technologies. Also, the income from possible violations of the system, such as failure to report miles, failure to pay bills, evasion of the system, and other heavy violations, should be taken into consideration.

Step 3. VMT Fee Study

Having all previous issues addressed, a VMT fee is differentiated by vehicle class and emission class. Results of preliminary public opinion can be used to adjust the VMT fee. For example, for the transition years, the VMT fee can be lowered to make the process more viable. This approach can give users more experience on the efficiency of the VMT fee system, with the possibility of eliminating flaws before beginning full operation.

Figure 2. Flow Chart Step-by-Step Framework to Determine the Feasibility of a VMT fee
(from Vavrova 2012)



Step 4. External Relationships Study

As mentioned earlier, public acceptance influences the success of implementing a VMT fee-based revenue system. The acceptability of VMT fee charging is “closely linked to the perception of freedom, fairness and efficiency” (Di Ciommo et al. 2013) and can be analyzed from both a psychological and sociological standpoint. When compared with other road pricing schemes, a VMT fee ranks highest on preference compared with other road pricing alternatives that vary based on the time of day and place (Francke and Kaniok 2014). Gaunt et al. (2007) report that, in the case of a city of Edinburgh poll regarding acceptability of road user charging, car users were strongly opposed to a road user fee while non-car owners weakly supported it. Retrospectively, “more attention should have been paid to designing a simpler, more easily communicated scheme and convincing residents, particularly public transport users, of its benefits” (Gaunt et al. 2007).

After a successful completion of these steps, a trial run in a restricted geographic area or in full-scale with volunteers (e.g., government vehicles, alternative fuel vehicles, new vehicles) should be carried out. The trial run should be conducted in conditions similar to the full operation as possible, using the same technology, rates, and billing options. We also recommend that public polls be conducted before and after the trial run to identify the strengths and weaknesses of the project. The output from the polls should be used for future improvement before the full operation is initiated.

CASE STUDY ON VMT FEE RATES

A case study to illustrate a basic comparison with the current fuel taxation system uses Texas historical VMT data, vehicle class VMT distribution data, and average miles travelled per gallon for each vehicle class in the years 2001-2014. Based on past trends as well as expert judgment, the data were projected for years 2015-2060, where VMT miles were assumed to increase 1% every year, the latter being a simplification for the analysis based on the average yearly difference of 1% in Texas VMT between years 2001 and 2014. To clarify, our VMT forecast in the year 2035 is about 20% below the estimate found in the Texas Statewide Long-Range Transportation Plan 2035 (TxDOT 2010).

The VMT fee scheme proposed in this study differentiates the VMT fee according to three classes of vehicles: [1] light duty vehicle - including passenger cars, light trucks, vans, and sport utility vehicles regardless of wheelbase (FHWA 2009), [2] single-unit truck, [3] combination truck, and three emission classes according to the Tier II emission standard: [1] BIN 11-6, [2] BIN 5-3, and [3] BIN 2-1. In this case study, for simplification, VMT fee prices were set at the levels imposed as of 2011 in the Czech Republic, where the cleanest vehicles received an adjustment coefficient of 1.00 and the dirtiest combination trucks were given a coefficient of 4.46.

A VMT fee based on a combination of a vehicle class and an emission class is not commonly used in the U.S., but it has been successfully implemented in the EU. It seems to have motivated lower emissions and noise reductions and boosted fleet renewal. For instance, in the Czech Republic and Germany, the yearly increase in tolls for trucks with the cleanest emission classes (EURO 5 and higher) is not as high as the toll increase for the dirtier classes with lower EURO emission standards. This led to a substantial increase in the EURO 5 truck fleet with a positive impact on the environment (Bina, L. unpublished data, Jun. 2, 2012).

A sensitivity analysis was performed to identify the major factors affecting the revenues. To address uncertainty in the projection of revenues from the VMT fee, all these data were modeled with triangular probability distributions. A triangular distribution was chosen due to limited data and expert knowledge considerations. Top Rank® software was used to conduct the analysis and, according to the Spearman correlation coefficients, factors that influence revenues are (in descending order): VMT volume (0.61), vehicle class share (0.50), VMT fee pricing levels (0.50), emission class share (0.29), and violations (0.18). The correlation coefficients reflect the statistical

dependence between variables, therefore we expect that even under the assumption of a different probability distribution, as a normal distribution, the relative values of the coefficients would be similar.

Table 2 shows the estimated current fuel taxation per mile for the classes of vehicles considered in our study. These values were obtained by dividing the current state fuel tax per gallon on gasoline (\$0.208/gal) by average miles traveled by every vehicle class per gallon (22.3 mi/gal, 8.2 mi/gal, 5.6 mi/gal). It is important to note that this projection is generated with the state fuel tax, but apart from the state fuel tax on fuel (\$0.208/gal), there is also a federal fuel tax (\$0.184/gal on gasoline and \$0.244/gal on diesel).

Table 2. Estimation of the Current State Fuel Taxation per Mile, Texas

Type of vehicle	Estimated state fuel tax
Light duty vehicle	\$0.009/mi
Single-unit truck	\$0.025/mi
Combination truck	\$0.037/mi

Data for the VMT Fee Scenarios

Based on these estimates, we developed three different scenarios to illustrate potential revenues available from a VMT fee system. To start, we considered the estimates of the 2030 Committee (2011) made up of experienced and respected business leaders and transportation researchers. This analysis reported that the funds needed in Texas to ensure at least minimum competitive conditions in pavements, bridges, and urban and rural system performance from 2011- 2035 is approximately \$217 billion, which is about twice the projected income from the fuel tax (\$100 billion), resulting in a funding gap of \$117 billion. Based on these estimates, we analyzed three alternative scenarios: (1) a VMT fee designed to generate similar revenues as the fuel tax–100% revenues, (2) a fee comprising 150% of the fuel tax revenues, and (3) a fee set to collect 200% of current fuel tax revenues. These are done in an effort to fully address the financial needs indicated by the 2030 Committee.

Scenario 1 represents VMT fee taxation levels similar to what a driver pays in the current fuel tax system. In this scenario, the VMT base fee is set to \$0.009/mi, which should generate revenues similar to the current fuel tax. The \$0.009/mi fee proposed in this scenario is similar to the level of revenue-neutral VMT fees identified by Robitaille et al. (2011). Drivers of vehicles with high emission standards would benefit from this scenario by paying a lower fee than under the fuel tax, and the fee would increase only for vehicles with low emission standards. This should motivate the usage of cleaner vehicles, while concurrently not forcing an overall greater cost of transportation. The estimated break-even year is 2055.

Scenario 2 has the VMT base set to \$0.013/mi. This reflects about a 50% increase in the fee from the previous scenario, which should generate revenues roughly 150% of current fuel tax revenues. A similar fee was charged per vehicle mile in the Oregon Mileage Fee Project. In addition, Durden (2010) reported that to generate total revenues for Texas highways equal to the \$258 billion needed between 2012 and 2030, a VMT fee would need to be set between \$0.0143/mi and \$0.0164/mi. According to our VMT fee projection, prices for Scenario 2 are similar to those Durden (2010) reported for Texas. However, the revenues generated between 2012 and 2030 according to our projection are \$99 billion (gross) and \$61 billion (net). The difference between our total revenues projection and Durden’s estimate are due to the interpolation of the expected VMT volume, as well as different building costs, operating costs, penalty income, and discount rate used in Scenario 2.

Scenario 3 sets the VMT base fee to \$0.018/mi, which is double what a driver pays under the current fuel tax system. We understand that these pricing levels might not be acceptable to the public

or, in a more optimistic case, these fees would simply motivate users to opt for alternative modes of transportation such as mass transit, biking, and walking. In the case of freight transportation, the high fee might induce a modal shift to rail and force usage of trucks for shorter distance hauls. To compare the hypothetical fee with the current tolling situation in Texas, the actual toll rate on specific sections of interstates, according to the North Texas Tollway Authority, is \$0.153 per mile (NTTA 2011) and by 2017 is expected to increase to \$0.1801 per mile. However, NTTA charges drivers by section, not distance, and the toll is differentiated only by number of axles into five classes.

Results of the VMT Fee Scenario Analysis

Table 3 shows a summary of the VMT fee revenue results for each scenario as compared with the fuel tax. VMT fees, building costs, operating costs, assumed average funding levels for transportation projects, average net revenues, and break-even year are all shown in this table.

Our assumption of building costs of \$6 billion across Texas was based on a GPS/GSM cost model developed for Germany and Austria (IBTTA 2004). In this model, costs were estimated to be three times greater for a sixfold larger network. The majority of the building costs for a satellite/cellular data collection system comes from on-board units, so that the idea to build the system as an open architecture and let the users and market decide how they want to report mileage helps to mitigate costs. Operating costs were assumed to be 6.6% of revenues (based on Balducci et al. 2011). Annual average funding for transportation projects was set to \$1,759,177,973 (average through the years 1-60), and is based on current spending as of 2010-2011, coupled an increase of 0.5% every year. Not surprisingly, the scenario with a \$0.018/mi VMT fee was estimated to breakeven in 2006.

Based on the scenario results we find that, all things considered, a base fee of at least \$0.018/mi should be sufficient to cover the projected funding needed to address current road transportation needs in Texas. For less expansive states in the U.S., building costs/miles ratio may be higher, so that implementation of VMT fees concurrently in several states would result in lower costs.

VMT fees may be perceived by the public in the short term as a significant increase in costs compared with the current fuel tax. But in a VMT regime, vehicle owners may be motivated to renew their fleet to cleaner vehicles (Bina, L. unpublished data, Jun. 2, 2012) or, in the case of commercial transport, induce a shift to rail. However, a VMT regime may also result in either higher priced for rail services or less readily available consumer goods. Therefore, alternative transportation modes, including mass transit, walking, and biking, may become more attractive to the public due to their affordability.

These changes would promote societal benefits, including environmental sustainability, generating fewer emissions of greenhouse gases, and less use of non-renewable resources.

Table 3: Comparison of the State Fuel Tax and the VMT Fee Scenarios

		Fuel tax	Scenario 1	Scenario 2	Scenario 3
Type of Vehicle	Base Fee	–	0.009/mi	0.013/mi	0.018/mi
Light Duty Vehicle	BIN 11-6	\$0.009	\$0.015 (69%)	\$0.022 (144%)	\$0.031 (239%)
	BIN 5-3	\$0.009	\$0.011 (26%)	\$0.016 (81%)	\$0.023 (150%)
	BIN 2-1	\$0.009	\$0.009 (0%)	\$0.013 (44%)	\$0.018 (100%)
Single-Unit Truck	BIN 11-6	\$0.025	\$0.028 (10%)	\$0.040 (59%)	\$0.055 (120%)
	BIN 5-3	\$0.025	\$0.022 (-14%)	\$0.031 (25%)	\$0.043 (72%)
	BIN 2-1	\$0.025	\$0.017 (-31%)	\$0.025 (0%)	\$0.035 (38%)
Combination Truck	BIN 11-6	\$0.037	\$0.040 (9%)	\$0.058 (57%)	\$0.080 (117%)
	BIN 5-3	\$0.037	\$0.031 (-16%)	\$0.045 (22%)	\$0.062 (69%)
	BIN 2-1	\$0.037	\$0.025 (-32%)	\$0.036 (-2%)	\$0.050 (35%)
Building costs		–	\$6,000,000,000	\$6,000,000,000	\$6,000,000,000
Operating costs (6.6% of revenues)		–	\$180,737,384	\$261,065,110	\$361,474,768
Assumed average funding for transportation projects in year 2001-2060, incl. 3% discount rate		\$1,759,177,973	\$1,759,177,973	\$1,759,177,973	\$1,759,177,973
Average net revenues in year 2001-2013		\$2,951,383,398	\$2,696,003,024	\$4,060,271,035	\$5,765,606,049
Break-even year		–	2055	2024	2006

CONCLUDING REMARKS

Since revenues from the current transportation funding system in the United States are not nearly sufficient to address the needs of a future transportation network, alternative funding approaches are gaining more interest if for no other reason than to bridge this funding gap. A VMT fee is one interesting alternative to flat user fees since it accounts for the actual usage of the transportation network by vehicles, and also helps to internalize environmental externalities. The literature indicates that the key factors influencing the development of a VMT fee regime can be grouped in the following categories: [1] public acceptance, [2] revenues, [3] technology, [4] type of contract, [5] government policies, and [6] enforcement, administration, and invoicing. We conclude that the basic policy framework needed to analyze the feasibility of VMT fee implementation consists of four steps: [1] background study, [2] feasibility study, [3] VMT fee study, and [4] external relationships study.

At present, there have been a number of small scale trial runs of distance-based user charges throughout the U.S. Distance-based truck charges are popular in Europe, where major highways in some countries are equipped with toll gantries with microwave technology that enables communication with on-board units. However, with ongoing progress in satellite navigation, the usage of a GPS/Galileo/GLONASS signal seems like the best choice for future broad-based tolling systems. In the U.S., we offer that statewide VMT fee implementation is an interesting option that can be used to better address transportation funding needs. A VMT fee-based charging system ensures a more sustainable source of revenues, although it can be strongly affected over time by changes in fuel efficiency or increased use of alternative-fuel vehicles.

Implementation costs of a VMT fee system may be perceived as high over the short term, but we argue that it will be a more reliable source of revenues in the long term. A VMT fee is also designed to be equitable. It is usage-based since it can be differentiated by axles (an indicator of road damage) and by vehicle emission class (an indicator of pollution). Significant improvements in air quality and savings in non-renewable resources are to be expected due to VMT fee implementation because emission class differentiation will ultimately motivate drivers to own cleaner vehicles.

Further research about pricing levels for a VMT policy as well as more consideration about the factors that influence the acceptance of those levels is needed, since there is justifiable concern about the public reaction to a financially acceptable VMT fee. Uncertainty can also be considered in the future using a probabilistic approach in scenario analysis. This would allow the researcher to evaluate the sensitivity of these results to a number of factors, including changes in fleet composition as well as traffic volumes associated with different pricing levels.

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References

2030 Committee: Walton, C.M., D. Marcus, K. Allen, D. Crutcher, E. Emmet, J. Hawley, T. Johnson, C. Looney, R. Nober, and G. Thomas. "It's About Time: Investing in Transportation to Keep Texas Economically Competitive." 2011. http://texas2030committee.tamu.edu/documents/final_03-2011_report.pdf, accessed September 12, 2013.

Association of American Railroads. "Freight Rail: Moving More Goods on Less Fuel." 2012a. <http://freightrailworks.org/#innovation/fuel>, accessed March 18, 2013.

Association of American Railroads. "Freight Rail: The Best Way to Ship Perishable Products." 2012b. <http://freightrailworks.org/#agriculture/perishable>, accessed March 18, 2013.

Arnold, R., et al. "Reducing Congestion and Funding Transportation Using Road Pricing in Europe and Singapore." Federal Highway Administration (FHWA), Research Report FHWA-PL-10-030, 2010.

Baker, T., G. Goodin, and C. Pourteau. "Is Texas Ready for Mileage Fees? A Briefing Paper." Texas Transportation Institute for Texas Department of Transportation (TXDOT), 2011.

Balducci, P., G. Shao, A. Amos, and A. Rufolo. "Costs of Alternative Revenue-Generation Systems." Transportation Research Board of the National Academies, National Highway Cooperative Research (NCHRP) Report 689, 2011.

Bina, L., F. Lehovc, P. Moos, H. Novakova, and P. Karlicky. "Analysis of Electronic Toll System in the Czech Republic and Conformity with EU Directives, Tariffs and Toll Revenue in Connection to Investment and Maintenance Costs." – Report in Czech. Prague, Czech Republic: Ceske vysoké ucení technické v Praze, Fakulta dopravní, 2011.

Bina, L., V. Cerny, and H. Novakova. "Road Charging in the Czech Republic and EU and External Costs of Transport." *Journal of Civil Engineering and Architecture*, ISSN 1934-6 (5), (2012): 562-568.

Carlton, J. and M. Burris. "Comprehensive Equity Analysis of Mileage-Based User Fees: Taxation and Expenditures for Roadways and Transit." *Journal of the Transportation Research Forum*, 53 (2), (2014): 21-43.

Cooper, C.D. "Air Pollution Control Methods." Kirk-Othmer Encyclopedia of Chemical Technology, 2007.

CURACAO. "Acceptability." Coordination of Urban Road-User Charging Organizational Issues, 2008. <http://www.curacaoproject.eu/workfiles/files/workpackages/WP4/Fact%20Sheets/Final%20Version%20Themes/Acceptability.pdf>, accessed February 8, 2012.

Delcan Corporation, Calmar Telematics. "A Practical Approach to Truck VMT Fees, Including Some Financial Implications and Possible Impacts on Traffic Congestion." by Delcan Corporation, Calmar Telematics, and Greater Buffalo Niagara Regional Transportation Council with support from Capital District Transportation Committee Binghamton Metropolitan Transportation Study, NY, 2011.

Di Ciommo, F., A. Monzon, and A. Fernandez-Heredia. "Improving the Analysis of Road Pricing Acceptability Surveys by Using Hybrid Models." *Transportation Research Part A* (2013). <http://dx.doi.org/10.1016/j.tra.2013.01.007>

Dill, J. and A. Weinstein. "How to Pay for Transportation? A Survey of Public Preferences in California." *Transport Policy* 14 (4), (2007): 346-356.

Durden, D.J. "Funding Texas Highways for the Next 20 Years." *Texas Civil Engineer*, Winter 2010, Volume 81, 2010.

Eliasson, J. "Lessons from the Stockholm Congestion Charging Trial." *Transport Policy*, Decision-Support for Sustainable Urban Transport Strategies 15 (6), (2008): 395-404.

Francke, A. and D. Kaniok. "Responses to Differentiated Road Pricing Schemes." *Transportation Research Part A*. <http://dx.doi.org/10.1016/j.tra.2012.10.002>, 2014.

Elmendorf, D.W., J. Holland, B. Blom, R. Arnold, C. Hawley Anthony, M. Booth, A. Marcellino, S. Vallinas, J. Brewster, and H. Battelle. "Trust Funds and Measures of Federal Debt." *The Budget and Economic Outlook: Fiscal Years 2010 to 2020*, The Congress of the United States - Congressional Budget Office, 2008. <http://www.cbo.gov/ftpdocs/108xx/doc10871/AppendixD.shtml>, accessed October 30, 2011.

Elmendorf, D.W., P. Beider, J. Kile, and D. Moore. "Alternative Approaches to Funding Highways." The Congress of the United States - Congressional Budget Office, 2011. <http://www.cbo.gov/ftpdocs/121xx/doc12101/03-23-HighwayFunding.pdf>, accessed October 30, 2011.

Engel, E., R. Fischer, and A. Galetovic. "Public-Private Partnerships to Revamp U.S. Infrastructure." The Hamilton Project, Washington D.C., 2011. http://cowles.econ.yale.edu/~engel/pubs/efg_revamp.pdf, accessed November 11, 2012.

Federal Highway Administration, "Annual Vehicle Distance Traveled in Miles and Related Data 2009 By Highway Category and Vehicle Type." Highway Statistics 2009, Federal Highway Administration, 2009. <http://www.fhwa.dot.gov/policyinformation/statistics/2009/vm1.cfm>, accessed March 2, 2012.

Federal Highway Administration, "Motor Fuel Tax Compliance Outreach." Frequently Asked Questions, 2010. <http://www.fhwa.dot.gov/motorfuel/faqs.htm>, accessed October 30, 2011.

Federal Highway Administration. "Status of the Highway Trust Fund." 2015. <http://www.fhwa.dot.gov/highwaytrustfund/index.htm>, accessed January 31, 2015.

Federal Highway Administration. "General Highway History: When Did the Federal Government Begin Collecting the Gas Tax?" 2005. <https://www.fhwa.dot.gov/infrastructure/gastax.cfm>, accessed July 15, 2017.

Gaunt, M., T. Rye, and S. Allen. "Public Acceptability of Road User Charging: The Case of Edinburgh and the 2005 Referendum." *Transport Reviews* 27 (1), (2007): 85-102.

Hanley, P.F. and J.G. Kuhl. "National Evaluation of Mileage-Based Charges for Drivers - Initial Results," *Transportation Research Record: Journal of the Transportation Research Board*, 2221, (2001): 10-15.

International Bridge, Tunnel and Turnpike Association, "State of the Art Analysis of European Toll Collection Systems." Fall Technology Workshop, November 2004, Spain. http://www.ibtta.org/files/FileDownloads/Sage_Dieter.pdf, accessed November 12, 2012.

Jones, P. "Several States Give Green Light to Mileage Fee Pilot Programs." 2016. <http://www.taxanalysts.org/content/several-states-give-green-light-mileage-fee-pilot-programs>, accessed July 17, 2016.

Keuleers, B., V. Chow, N. Thorpe, H. Timmermans, and G. Wets. "Behavioural Change in Activity-Travel Pattern in Response to Road User Charging." *Journal of Transport Economics and Policy* 40 (1), (2006): 119-134.

Langmyhr, T. and T. Sager. "Implementing the Improbable Urban Road Pricing Scheme." *Journal of Advanced Transportation* 31 (2), (1997): 139-158.

McCormally, K. "A Brief History of the Federal Gasoline Tax." Kiplinger, 2014. <http://www.kiplinger.com/article/spending/T063-C000-S001-a-brief-history-of-the-federal-gasoline-tax.html>, accessed July 15, 2017.

National Surface Transportation Infrastructure Financing Commission. "Paying Our Way. A New Framework for Transportation Finance." 2009. http://financecommission.dot.gov/Documents/NSTIF_Commission_Final_Report_Advance%20Copy_Feb09.pdf, accessed November 13, 2012.

North Texas Tollway Authority. "Toll Rates." North Texas Tollway Authority, 2011. <http://www.ntta.org/AboutUs/TollRates/Toll+Rate+FAQ>, assessed March 28, 2012.

Oregon Department of Transportation. "Road Usage Charge Pilot Program." 2012. <http://www.oregon.gov/ODOT/HWY/RUFPP/Pages/rucpp.aspx>, accessed November 11, 2012.

Oregon Department of Transportation. "Road Usage Charge Program." 2015. <http://www.oregon.gov/ODOT/HWY/RUFPP/pages/index.aspx>, accessed January 31, 2015.

Robitaille, A.M., J. Methipara, and L. Zhang. "Effectiveness and Equity of Vehicle Mileage Fee at Federal and State Levels." *Transportation Research Record: Journal of the Transportation Research Board*. Report number 11-4102, (2011): 27-98.

Rufolo, A.M. "Cost Estimates for Collecting Fees for Vehicle Miles Traveled." *Transportation Research Record: Journal of the Transportation Research Board*. Report number 11-2168, pp. 39-45, 2011.

Silnice-Zeleznice.cz. "Financování rozvoje dopravní infrastruktury." – Report in Czech. 2014. <http://www.silnice-zeleznice.cz/clanek/financovani-rozvoje-dopravni-infrastruktury>, accessed April 20, 2012.

Schank, J. and N. Rudnick-Thorp. "End of the Highway Trust Fund? Long-Term Options for Funding Federal Surface Transportation." Presented at the Transportation Research Board Annual Meeting, 2011, Washington, D.C.

Texas Department of Transportation. "Total Daily Statewide 2035 Forecast Vehicle Miles Traveled (VMT) Map." Texas Statewide Long-Range Transportation Plan, 2010. http://ftp.dot.state.tx.us/pub/txdot-info/tpp/plan_2035/boards/vmt_map.pdf, accessed on February 20, 2015.

U.S. Energy Information Administration. "Gasoline Prices Tend to Have Little Effect on Demand for Car Travel." 2014. <http://www.eia.gov/todayinenergy/detail.cfm?id=19191>, accessed February 20, 2015.

Vavrova, M. "Development of an Electronic Vehicle Miles Travelled Toll Model." MSc. Thesis, Dept. of Civil Engineering, University of Texas at El Paso, 2012.

Vierth, I. and H. Schleussner. "Impacts of Different Environmentally Differentiated Truck Charges on Mileage, Fleet Composition and Emissions in Germany and Sweden." Centre for Transport Studies Stockholm, 2002.

Whitty, J.M. "Oregon's Mileage Fee Concept and Road User Fee Pilot Program, Final Report," Oregon Department of Transportation, 2007.

Zmud, J. and C. Arce. "Compilation of Public Opinion Data on Tolls and Road Pricing." Transportation Research Board of the National Academies, National Cooperative Highway Research Program (NCHRP) Report 377, 2008.

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