Reforming road user charges: A research challenge for regional science

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April 7, 2009

The way in which road usage is priced and road infrastructure is funded in the United States has become unsustainable. Traffic congestion and other external costs of road transportation are mounting while the gap is widening between revenues and the expenditures required for adequate road construction, operations and maintenance. Support is growing for a Vehicle Miles Traveled (VMT) fee to encourage efficient road usage and replace fuel taxes as the primary funding mechanism for roads. A national VMT fee would be a major change in U.S. surface transportation policy with potentially significant long-run effects on mobility, health and urban form. This paper addresses some questions about a VMT fee including what functions it should perform, how finely it should be differentiated and how users are likely to adapt to it. The design and analysis of a VMT fee pose challenges that extend across regional science, transportation economics and other disciplines.

Key words: Road pricing; Congestion pricing; Cost recovery; Transport policy implementation
JEL codes: D62, R41, R48

I would like to thank Marty Collier for helpful comments. Financial support from the Social Sciences and Humanities Research Council of Canada is gratefully acknowledged.

1 INTRODUCTION

The way in which road usage is priced and road infrastructure is funded in the United States has become unsustainable. Traffic congestion and other external costs of road transportation are mounting while the gap is widening between revenues and the expenditures required for adequate road construction, operations and maintenance.

Traffic congestion and other external costs of road transport

Traffic congestion is estimated to be responsible for 4.2 billion hours of travel delay and 2.9 billion gallons of extra fuel consumption that cost the U.S. economy more than $78 billion in 2005 (Schrank and Lomax, 2007). Accidents and vehicle emissions also impose substantial health and environmental costs. Some of these costs are incurred by travelers individually, but a large fraction is borne by other travelers or society as a whole. Table 1 provides a range of estimates of the major external costs compiled by Delucchi and McCubbin (2009) from various studies.

Table 1: Estimated marginal external costs of road transport [2006 cents]

	Passenger (per passenger-mile)	**Freight (per ton-mile)**
Congestion delay	0.88 - 7.5	0.54
Accidents	1.4 - 14.4	0.11 - 2.0
Air pollution, health	0.09 - 6.7	0.10 - 18.7
Climate change	0.06 - 4.8	0.02 - 5.9
Noise	0.0 - 3.5	0.0 - 5.3
Water pollution	0.01 - 0.05	0.003 - 0.05
Energy security	0.20 - 0.84	0.22 - 0.84

Source: Delucchi and McCubbin (2009, Table 11)

These estimates are national averages and mask large variations over time (e.g., congestion is worse at peak periods on weekdays than at night), place (e.g., pollution imposes higher health costs in cities than rural areas) and type of road (e.g., accident rates and severity vary with road design and speed limits). Congestion and accidents are the largest component costs for passenger traffic. Pollution and noise are relatively more important for trucks. Trucks are also responsible for road damage which is considerably higher per vehicle-mile on urban than rural roads (Parry, 2008). The estimates in Table 1 also mask variations in external costs within vehicle categories. Combination trucks impose more costs than single-unit trucks but the cost per ton-mile is often lower for large trucks. Light-duty passenger vehicles also vary considerably in their external costs. According to Lemp and Kockelman (2008) total external costs per vehicle-mile vary by a factor of about 2.5, and crash costs by a factor of nearly four.

The external costs of road transportation thus vary strongly by time, location, type of road, type of vehicle and other factors. To support efficient usage of roads user charges should vary along these dimensions too. But the existing system of charges does not reflect costs at all accurately. Vehicle sales taxes and registration and licensing fees are fixed charges that do not depend on amount driven. Federal and state fuel taxes are the principal, albeit indirect, form of variable charge. The federal fuel tax is a nearly ideal charge for global or national fuel-related externalities (the main ones being greenhouse gas emissions and energy security respectively). But according to Parry et al. (2007) average fuel-related externalities for light-duty vehicles amount to only 18 cents per gallon while mileage-related externalities are approximately $2.10 per gallon. Fuel tax payments do not track mileage-related externalities closely because they are insensitive to time and location, and fuel consumption is only weakly correlated with vehicle characteristics such as size and axle weight that contribute to congestion, accidents and road damage. And alternative-fuel vehicles escape fuel taxes altogether.

Tolls are a potentially more efficient way to charge for mileage-related externalities. But fewer than 5,000 miles of roadway in the U.S. (less than one percent) are tolled. Moreover, only 25 of the 277 tolled facilities levy tolls that vary by either time of day or traffic volume (TollRoadNews, 2009). Trucks do pay higher tolls on most toll roads, but truck tolls are generally based on number of axles rather than axle weight or total vehicle weight that correlate more closely with external costs. Only four states have implemented distance or weight-based (Conway and Walton, 2009).

Deteriorating road infrastructure

The second paramount problem with U.S. road transportation — deteriorating infrastructure — is due to a growing gap between revenues and infrastructure needs. Maintenance costs are mounting as total vehicle miles traveled increase while older sections of the Interstate Highway System and other links show their age. Meanwhile, revenues per vehicle mile from federal and state fuel taxes are decreasing as vehicle fuel economy improves, and real tax rates decline due to inflation and opposition to increases in nominal tax rates. The decline in revenues is likely to accelerate as alternative fuel vehicles come into operation.

The National Surface Transportation Infrastructure Financing Commission (2009) (henceforth NSTIFC) reports several estimates of the combined gap for highways and transit systems between average annual capital needs and revenues over the period 2008–2035.[1] Estimates of the gap for all levels of government range from $134-262 billion (2008 dollars): a shortfall in revenues of 43 to 71 percent of needs. A further problem arises with the way in which fuel tax revenues are used. Federal fuel tax revenues are allocated to states through the Highway Trust Fund using a complicated formula and a process of earmarking that is widely criticized as inefficient and unfair. The American Recovery and Reinvestment Act of 2009 provides temporary extra funding for transportation, but a sustainable system is clearly required.

Recent plans and proposals

It is becoming increasingly clear that some form of distance-based user charge is needed to replace, or at the very least supplement, fuel taxes as a mechanism to encourage efficient road usage and fund infrastructure. Distance-based charging systems for trucks now exist in Germany, Austria, Switzerland and the Czech Republic. The UK Department for Transport (2004) proposed a national scheme of road pricing for Great Britain, but the plan was opposed and effort has been redirected toward funding urban road pricing schemes. The Netherlands has now taken the lead. In 2008 the Dutch Parliament approved a national distance-based system of user charges (the Dutch Mobility Plan) for passenger and freight vehicles. The fee per kilometer will

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[1] NSTIFC, Exhibit ES–1. Determining "needs" is difficult because of the multiple tradeoffs that need to be weighed in deciding optimal infrastructure and maintenance levels (Mintz and Roberts, 2006).

vary by time of day and with vehicle emissions. Registration fees and other fixed charges are to be reduced in order to make the scheme revenue neutral.

Several experiments in the U.S. with region-wide distance-based pricing have been conducted or are under way. Of particular note is the Oregon Vehicle Miles Traveled Pricing Pilot Project, completed in 2006, to assess the viability of replacing fuel taxes. Test vehicles were equipped with Global Positioning System (GPS) devices that recorded mileage. The distance-based charge was paid automatically when the vehicle refueled at participating gasoline stations and the state fuel tax was deducted from the bill.

Both the NSTIFC and the National Surface Transportation Policy and Revenue Study Commission (2008) have endorsed a Vehicle Miles Traveled (VMT) fee[2] as a primary user-based mechanism for pricing and funding roads. This paper addresses some questions about a VMT fee for the U.S.:

1. What externalities should be covered by a VMT fee? How finely should the fee be differentiated by time of day, location, type of vehicle and so on?
2. What types of transportation models are suitable for evaluating a VMT fee?
3. How will road users respond to introduction of a VMT fee?
4. How will optimal road capacity be affected by a VMT fee? Should the road network be redesigned in any way?
5. Would the revenues from a VMT fee cover the full costs of an optimal road network?
6. What sequence of steps should be followed in implementing a VMT fee and how quickly should each step be carried out?

Emphasis in the paper is given to the role of a VMT fee in pricing road usage efficiently although funding is also discussed. Private sector involvement in financing, construction and/or operation of roads is not addressed.[3]

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[2] The VMT fee is often called a VMT tax. The term “fee” is preferred because the charge is a price paid for service rendered and thus consistent with the user pay or beneficiary principle.

[3] For recent and insightful assessments of the private-sector role see Poole (2003), Small (2008, 2009) and Winston and Yan (2008).

Regional science is concerned with the location of economic activities, and transportation determines the cost of distance that separates locations. Given this central role of transportation in regional science why focus on a VMT fee as a specific transportation topic for the golden anniversary issue of the Journal of Regional Science? There are several reasons. First, the general role of transportation is eloquently described and analyzed by Glaeser and Kohlhase (2004) and Rietveld and Vickerman (2004) in the golden anniversary of Papers in Regional Science.[4] Second, the VMT fee is topical and it is also forward-looking since implementation of a national VMT fee will take many years to complete. Third, roads are the dominant mode of passenger and freight transportation in the U.S.[5] Fourth, reform of road user charges will have potentially significant long-run effects on urban form and regional development: central topics in regional science. Fifth, the subject engages researchers from a number of disciplines: chiefly economics and transportation engineering, but also geography, urban planning, operations research and other fields. Sixth, research on road pricing over the last several decades has benefited from cross-fertilization of ideas not only between disciplines but also between continents (Richardson and Bae, 2008). Finally, it has been argued that regional science needs to become more practical and policy-oriented (Bailly and Coffey, 1994). Reform of road user charges and infrastructure funding is a task in which regional scientists can make a valuable contribution.

2 FUNCTIONS OF A VMT FEE

The functions that a VMT fee could perform depend on what technology is used to implement it. The most technically advanced urban road pricing system is in Singapore which uses Electronic Toll Collection technology and gantries on a network of roads to levy tolls that are differentiated by time of day and vehicle type. The system is reliable and relatively user-friendly. But an

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[4] Glaeser and Kohlhase (2004) document the historical decline in transport costs and assess its implications for past and future city and regional development. Rietveld and Vickerman (2004) explain why transport costs remain an important determinant of location choice.

[5] In 2006 road transportation accounted for 87.4 percent of passenger miles (BTS, 2009a) and 27.9 percent of freight ton-miles (BTS, 2009b). In 2001 (the latest year for which BTS statistics are available) it accounted for 80.6 percent of freight transportation expenditures (BTS, 2009c).

infrastructure-based system would not be economic for tolling intercity roads and it would be inflexible in terms of where charges are levied. Satellite-based systems have clear and growing advantages. The list of possible functions includes: congestion pricing, charging for parking, charging for emissions, charging heavy vehicles for road damage, payment of insurance and revenue generation. Grush and Roth (2008) describe a system — similar to that used for telecommunications — that would perform these functions with charges differentiated by time, distance and place.

Satellite-based technology has proved its worth with the German Heavy Goods Vehicle charge. Tolls are charged on 12,000 km of motorways as a function of distance traveled, number of axles and emission class. The system has exceeded expectations in terms of reliability and enforcement and has led to reductions in empty truck trips and an increase in the proportion of trucks that meet high emissions standards. The system can be expanded to include additional roads, and tolls can be differentiated by road type and time of day. Collection costs amount to 15 to 20 percent of revenues. These costs are comparable to those for established infrastructure-based urban systems and they are likely to decrease with advances in technology and experience. The German system is considered a plausible model for the U.S. (Robinson, 2008).

A U.S. VMT fee would probably yield the greatest benefits from pricing congestion but the potential gains from charging for insurance would also be large. Studies of pay-as-you-drive (PAYD) insurance by Edlin (2003), Parry (2005) and Bordoff and Noel (2008) suggest that it would induce reductions in distance driven of 10 percent or more and yield significant benefits from fewer accidents while leaving a majority of drivers better off because of lower insurance costs. The premium rate per kilometer could be conditioned on driver characteristics that are used for pricing insurance today such as age, sex and driving record.

3 MODELING APPROACHES

The literature on road pricing goes back to Pigou (1920). Although economists have written the most on the subject, transport engineers have become increasingly prominent and have contributed much to the development of mathematical programming methods for analyzing traffic flows and congestion tolls on transport networks.[6] Most studies concern urban road congestion pricing. Distance-based charging for intercity transport and pricing externalities other than congestion have only recently gained much attention.

3.1 Types of models

Several types of models have been used to study urban road congestion pricing and other travel demand management policies. These models are worth briefly reviewing since the U.S. does not have a national transport model[7] and different types of models may be useful in analyzing different features and impacts of a VMT fee.

Analytical models

Analytical models are useful for obtaining insights, inferring the direction of responses to changes in transport prices and doing back-of-the-envelope calculations (Boyce, 2007). Examples include Edlin's (2003) study of PAYD insurance, Prud'homme and Bocarejo's (2005) critique of the London congestion charge and Lewis's (2008) preliminary assessment of a VMT fee for the U.S.

More complicated models that require numerical solution can be classified into one or more of five categories: detailed micro-simulation models, tactical network models, strategic transport models, integrated transport and land use models and general equilibrium models.[8]

Detailed micro-simulation models

Detailed micro-simulation models treat vehicles individually and are typically dynamic. They are well-suited for tracking variations in vehicle speed that can affect emissions and accident severity, and for modeling the effects of time-varying tolls on congestion delays on individual road links. But these models usually assume inelastic demand, lack adequate welfare economic foundations and are limited in the geographical area they can handle.

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[6] Boyce et al. (2005) and Tsekeris and Voß (2008) review the literature.

[7] National models have been used in Europe for nearly 20 years. These are reviewed in Daly and Sillaparcharn (2008).

[8] This taxonomy follows Milne et al. (2000) and the summary draws on De Palma and Lindsey (2001).

Tactical network models

Unlike micro-simulation models tactical network models treat vehicular flows as aggregates and can represent traffic interactions on relatively large networks. They also focus on the computation of steady states rather than analyzing traffic dynamics. A limitation of these models is that trip demands are specified using fixed origin-destination matrices that have to be updated if the models are used for forecasting or assessing policy impacts over extended time periods.

Strategic transport models

Strategic transport models focus on long-run equilibria for urban areas. They specify demand in terms of person-trips rather than vehicle-trips. This has advantages with respect to the generation of trips, disaggregation by traveler type and analysis of the welfare effects of pricing. One disadvantage is their coarse representation of transport supply and demand, and another is that their temporal resolution may be insufficient to model trip-timing choices accurately.

Integrated transport and land use models

Integrated transport and land use models usually employ random-utility or discrete choice theories. Similar to theoretical urban land-use models they use land rent as the equilibrating mechanism to match supply and demand for land. A virtue is their disaggregated categorization of households and employment sectors, but a downside is their coarse spatial division. Some models, such as MEPLAN, are capable of inter-urban analysis. Although land use models have been under development at least since Alonso (1964) and Lowry (1964) the complexities of spatial externalities are still not completely understood. Moreover, many land-use models exclude agglomeration economies. Nevertheless, at least in urban areas land-use effects may be too large to ignore when evaluating a VMT fee.[9]

[9] Using a hedonic housing model for the 98 largest metropolitan statistical areas in the U.S. Winston and Langer (2008) estimate that comprehensive road congestion pricing would yield an annual benefit of about $40 billion "considerably greater than previous estimates that do not account for adjustments in land use" (p.129).

General equilibrium models

A national VMT fee would have wide-ranging effects that could exacerbate, or ameliorate, distortions in other sectors of the economy. Depending on how they are used, the revenues could also provide benefits by loosening government budget constraints. These effects can be valued in rough-and-ready fashion by using an estimate of the Marginal Cost of Public Funds (MCPF).[10] However, the MCPF depends on how the revenues are allocated, and given the large revenue base of a VMT fee the MCPF could depend on the level chosen for the fee. General equilibrium models are required to quantify the MCPF and to account properly for distortions.

3.2 Choice of model

The ideal model for designing and analyzing a national VMT fee would handle large-scale networks using fine spatial and temporal resolutions and it would have both land use and general equilibrium capabilities. Not surprisingly, no such model exists and the challenges of developing one would be formidable. As Boyce (2007) remarks, despite major advances in network models, solution algorithms and computer power, large-scale network models (without land use or general equilibrium features) have not yet been widely used for policy analysis.

One way to ease modeling requirements might be to use existing metropolitan transport models for urban areas and to model interurban travel separately using coarser spatial and temporal resolutions. Alternatively, a common strategic transport model could be developed for urban areas that would help to generate comparable results across cities. With either approach it would be helpful to know whether spatial or temporal aggregation introduces systematic biases as far as computing optimal fee levels and estimating their effects.[11] Models with fine spatial and temporal resolutions effectively give travelers more scope to respond to prices by switching routes and retiming trips, and in this respect one might expect the estimated impacts and benefit from a fee to be smaller with a crude model. However, if the fee were set too high or low, or differentiated too coarsely, users may respond in unfavorable ways that are not adequately

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[10] The MCPF is formally defined as “the efficiency cost of raising one unit of tax revenue, given that the tax revenue is spent on a public good that does not affect the consumption of taxed commodities” (Proost et al., 2007, p.66).

[11] De Palma, Lindsey and Niskanen (2006) address this question.

captured by a crude model.[12] Adverse responses would, of course, not be a problem with a comprehensive and finely differentiated VMT fee. But a model with a fine-grained resolution is needed to determine the optimal degree of differentiation.

A number of studies of urban road pricing have been conducted for the U.S. but none of a national VMT fee other than for the insightful but preliminary analyses in Lewis (2008) and NSTIFC (2009). The only published studies of national distance-based road pricing are two for the U.K. Glaister and Graham (2005) examine the impacts of U.K.-wide congestion and environmental charges. Their model does not fall neatly into any one of the model categories described in Section 3.1. It is similar to a tactical network model in using data on aggregate travel demand rather than individual trips. But it does not include origin-destination matrixes or an explicit transport network, and trip-timing is not considered either.

In a follow-up study Graham et al. (2009) use a variant of the Glaister and Graham (2005) model — now with endogenous trip timing — to estimate the welfare-distributional effects of introducing congestion and emissions charges while holding existing fuel taxes fixed. In the status quo, transport in U.K. cities and on major interurban routes tends to be priced below marginal social cost. The reverse is true for smaller roads in rural areas. Introducing congestion and emissions charges therefore raises transport costs more in urban areas. But Graham et al. (2009) find no systematic relationship between average levels of income deprivation within census areas and changes in either money prices or generalized travel costs. From this they conclude that national road pricing for the U.K. would be neither regressive nor progressive. Whether this finding is indicative for the U.S. is unclear. The two countries differ in various ways that could affect the welfare impacts: average congestion and pollution levels, population density, city structure, reliance on public transport and other factors.

4 CHALLENGES IN PREDICTING USER BEHAVIOUR

Of obvious importance in forecasting the impacts and welfare-distributional consequences of a VMT fee is to predict accurately how road users will respond to it. Inaccurate demand forecasts

[12] For example, users may switch from heavily tolled links to untolled links or retime trips just before or after a period with peak tolls.

are common. Traffic forecasts on new toll roads have often been optimistic. And the London congestion charge, introduced in 2003, induced an unexpectedly large reduction in traffic and generated correspondingly low revenues. It is now widely recognized that traveler heterogeneity needs to be modeled in order to generate accurate forecasts.[13] Passenger values of travel time, values of reliability and other behavioral parameters differ by trip purpose, age and other socioeconomic characteristics. Freight values vary by commodity type, vehicle ownership, trip length and so on. Some groups of travelers are more sensitive to prices than others. Using representative or average motorists and freight shippers in lieu of the distribution of types could lead to either overestimation or underestimation of the aggregate response to introduction of a VMT fee.[14]

Forecasting the response of road users to a VMT fee presents some challenges. One is that toll roads are not as common in the U.S. as in many other countries and motorists could react to a fee in unexpected ways. One anomaly that has been observed on High Occupancy Toll (HOT) lane facilities is that travelers overestimate (by a factor up to two) the amount of travel time they save by using the toll lanes. Whether similar misperceptions would arise with a comprehensive VMT fee is unclear. Another complication is that estimated values of travel time can depend on the level of tolls and are therefore context specific (Hensher and Puckett, 2008).

A third consideration is that users may find it difficult to adapt to a VMT. As the NSTIFC report remarks (p.141):

> "Changing to a comprehensive, nationwide pricing system would be a significant change for users accustomed to a simple and nearly invisible motor fuel tax system that requires limited decision making about travel choices and their associated costs. Even a road pricing system … where the payment system does not change, entails new information about the costs of traveling at certain times and on certain roads. This requires people to know more and to make more informed and more frequent decisions about travel."

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[13] Mixed logit and other random parameter models are now standard for estimating distributions of behavioral parameter values.

[14] See Small and Verhoef (2007, §2.2.6).

Similar concerns were expressed in the Smeed Report that advised the UK Ministry of Transport on different forms of road taxes in the 1960s[15]:

> "If the price system is complicated road users will probably find simple 'rule of thumb' methods to tell them approximately what the average prices are and roughly what the prices of particular journeys are likely to be, and they will act accordingly. If this is so the complicated system may be no more efficient than a simpler system."

Planning trips will be all the more difficult if a VMT fee varies not only by time of day and road but also dynamically according to circumstances such as weather and accidents.[16] Dynamic pricing has worked well on HOT lanes in the U.S. but it has not been implemented anywhere else in the world. Dynamic pricing has several limitations and potential drawbacks. One is high system and administration costs (Levinson and Odlyzko, 2008). Another is that varying charges dynamically can influence travellers' decisions in a useful way only if they learn how much they will pay far enough in advance. A third is that users may not react predictably or efficiently to uncertain charges. May and Milne (2004) report experimental evidence that drivers are less responsive to unpredictable charges such as time-based and delay-based tolls than they are to predictable charges such as cordon tolls or (uniform) distance-based charges. They attribute the weaker response to unpredictable charges to risk aversion. In theory one might expect the opposite: risk-averse drivers would be more inclined to avoid uncertain charges. However, congestion tolls are highly correlated with travel time and there is strong evidence that drivers are averse to travel time uncertainty (Small, Winston and Yan, 2005). The merits of varying a VMT fee dynamically are likely to depend on the setting and more research is clearly called for.

Dynamic pricing would be more practical and user-friendly if Advanced Traveler Information Systems (ATIS) are available to provide information to drivers about tolls and travel

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[15] UK Ministry of Transport (1964, p.48). A recent example of complicated tolls was recently reported in The Yomiuri Shimbun (2009). To help boost the Japanese economy a system of discounts on expressway tolls was introduced on March 28, 2009. Tolls differ according to the day of the week, time of day, type of vehicle and expressway. Eighteen types of tolls apply for a standard-size car travelling from Ginza, Tokyo, to Nagoya on the Shuto Expressway and Tomei Expressway. The cheapest toll costs 2,050 yen and the most expensive toll for the same route costs 7,130 yen.

[16] Nonrecurring traffic congestion accounts for half or more of travel delays in major urban areas.

conditions. Depending on their preferences travelers could program an ATIS to select a route with the shortest distance, shortest expected travel time or lowest expected generalized cost. Information could also be provided about parking availability and cost, locations of services and so on. The potential synergies of road pricing and information technology in terms of both benefits, and system infrastructure and operating costs, have received some attention in the literature.[17]

5 OPTIMAL ROAD CAPACITY AND COST RECOVERY

Most U.S. roads are not tolled and most were built to operate as untolled facilities. A national VMT fee would change that. By increasing the marginal cost of driving it would almost certainly reduce traffic volumes. This might suggest that optimal road capacity would be reduced as well. But pricing usage efficiently would curb latent demand which partially undermines the potential benefits in congestion relief from adding capacity. The net effect of these two opposing forces is ambiguous *a priori* although on balance it seems likely that optimal capacity would be reduced.[18]

In addition to affecting optimal capacity a VMT fee could have implications for optimal road design. The Interstate Highway System and many urban expressways were built to accommodate large and heavy vehicles and to be safe at high speeds. Although beneficial to drivers, the system as a whole is overbuilt for light-duty vehicles and also overbuilt for speed during periods of severe congestion. One option to address the first problem is to build truck-only toll lanes and corridors.[19] By restricting trucks to part of the road network the remainder could be built more cheaply to handle smaller and lighter vehicles. And to exploit economics of vehicle size, truck-only facilities could be designed to handle Long Combination Vehicles that are currently prohibited in the U.S. Although truck-only toll facilities need not be part of a VMT fee, tolls could be collected using the same technology and administrative system.

To address the second problem that roads are overbuilt for speed, Small (2008) has suggested that roads could be built to a lower design standard that would provide higher capacity at low

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[17] See Tsekeris and Voß (2008) for a review.

[18] See Small and Verhoef (2007, §5.1.3).

[19] See Samuel et al. (2002) and Poole (2007).

speeds.[20] This idea may well be worth pursuing. But it is a second-best policy insofar as heavy congestion is due to underpricing usage of roads. The case for (selectively) redesigning roads may therefore be weaker if a national VMT fee is implemented.

As discussed earlier a VMT fee would serve two purposes: to price roads more efficiently and to generate money for road construction and maintenance. There is a tension between the two goals insofar as the revenues raised by the fee need not match the expenditures required to pay for optimal road infrastructure. In their famous Cost Recovery Theorem, Mohring and Harwitz (1962) showed that revenues and expenditures are in fact equal if three conditions hold: (a) user costs are homogeneous of degree zero in usage and capacity, (b) capacity is perfectly divisible, and (c) capacity is supplied with a unit cost elasticity. Although the empirical evidence is equivocal it appears that conditions (a) and (c) are satisfied at least approximately. Assumption (b) is more disputable since traffic lanes are indivisible. This is consequential for rural roads that carry little traffic and most likely could not be self-financing at any fee level.

In its basic form the Cost Recovery Theorem applies to a single, isolated link. It extends to a network only if all links are efficiently priced. This is clearly not the case for either individual toll roads or for limited area-based schemes. But a national VMT fee would entail charging all links, and in this respect full cost recovery is a more realistic goal for a national VMT fee than for urban road pricing schemes.[21]

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[20] One way to do so is to narrow traffic lanes from 12 feet down to 10 or 11 feet so as to squeeze in an additional lane.

[21] The Cost Recovery Theorem has been extended in various directions and has proved to be fairly robust (Small and Verhoef, 2007, §5.1). Under plausible assumptions the theorem holds if the costs of road durability are included in capacity costs and heavy vehicles are assessed damage charges in addition to congestion tolls. Using a VMT fee to charge for road damage and congestion would, therefore, be consistent with cost recovery. An additional condition for cost recovery is that the fee be differentiated by time, place and vehicle characteristics in order to match the marginal social cost of travel (Arnott and Kraus, 1998). If the fee lacks sufficient flexibility both surpluses and deficits are possible.

6 IMPLEMENTATION OF A VMT FEE

A national VMT fee will not become reality in the near future and it is unlikely to be introduced all at once. What sequence of steps is likely to be followed and how quickly will — or should — each step be carried out? The European Commission funded two projects, AFFORD and MC-ICAM, that addressed these questions in the context of comprehensive marginal cost pricing of transportation within the European Union.[22] The questions were formulated in terms of an optimal implementation path and constraints of a technical, practical, legal, institutional or acceptability-related nature that limit what policies can be employed at a given stage.

The stages involved in implementing a U.S. VMT fee have yet to be determined. Each stage can be defined by what externalities are covered; what vehicle types, geographical regions and types of roads are charged; the degree of fee differentiation by link and time of day, and so on. Germany and the Netherlands have started down their implementation paths. The Germany Heavy Goods Vehicle charge applies to vehicles over 12 tonnes GVW using federal motorways, and it varies by number of axles and emissions class. The Dutch Mobility Plan calls for charging trucks initially and extending fees to passenger vehicles later.

Similar to the Dutch plan, the European MC-ICAM project included a case study of interurban transportation in which trucks were charged in an initial stage and cars phased in later.[23] Not surprisingly, the study found that the percentage increase in benefits from extending the charge to cars was higher in countries with high volumes of car traffic. Less obviously, it also found that the optimal charge for trucks fell when charging of cars began.[24] The trucking industry might well object to such a time path and lobby strenuously for including passenger vehicles from the outset.

Two further considerations in designing an implementation path are worth noting. One is the obvious point that policies adopted at one stage of implementation can have consequences for later stages if they induce responses with long-lasting or irreversible effects such as purchases of

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[22] See Milne et al. (2000) and Project MC-ICAM (no date).

[23] See Henstra et al. (2003).

[24] The direction of change is theoretically ambiguous. On the one hand charging cars reduces total traffic and hence the external congestion cost of truck trips. On the other hand charging cars also restrains car traffic and there is no longer a motive to hold down the truck charge in order to curb latent car demand.

fuel-efficient vehicles or changes in land use.[25] The other, related, consideration is time-consistency. A government may announce plans for a VMT fee that entails progressively wider coverage and higher per-mile charges in the hope that this will accelerate behavioral adjustments. But the government may be reluctant or unable to follow through with the plans when the time comes.[26]

Various other practical and institutional questions will have to be addressed in implementing a VMT fee for the U.S.[27] One is whether to increase federal gasoline and diesel tax rates, or broaden the tax base to include alternative fuels, as interim measures to narrow the funding gap. Another is whether to introduce a satellite-based system while giving owners of older vehicles a choice between retrofitting their vehicles with equipment required to pay the fee or continuing to pay the fuel tax. A third question is whether to set a VMT fee at its optimal (Pigouvian) level from the outset. Particularly since user responses may be difficult to predict (cf. Section 4) it may be wiser to set the fee on the low side initially. Doing so may sacrifice some efficiency and revenue generation but it will almost certainly guarantee that the fee is beneficial. By contrast, setting the fee inadvertently too high could be worse than doing nothing. Beginning with a low fee may also enhance acceptability, which was a consideration for the Singapore government when it introduced Electronic Road Pricing in 1998.[28]

Governance is a further important issue since the states could switch from fuel taxes to VMT fees of their own. There is a danger that states could end up either competing with each other for traffic by setting their fees below marginal social cost or engaging in tax exporting by setting fees too high.[29] These are also concerns for the European Union and much of the recent literature on transport pricing and intergovernmental competition has been European.

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[25] See De Palma, Lindsey and Niskanen (2006) and Verhoef et al. (2007).

[26] Glazer (2000) develops this idea using a simple analytical model.

[27] Some of these are discussed in NSTIFC (2009).

[28] Singapore adjusts tolls every three months to maintain average vehicle speeds within a target range. Tolls are also adjusted periodically on SR-91 in California to maintain a high quality of service on the toll lanes. In principle a VMT fee could be adjusted likewise.

[29] See De Borger et al. (2005, 2008).

7 CONCLUDING REMARKS

A VMT fee has become practical recently thanks to advances in information and communications technology. In assessing the merits of a VMT fee it has been implicitly assumed here that no further technological changes will occur in the future. In some respects road transportation is not very different in 2009 than it was in 1959 — just three years after the Highway Trust Fund was created and construction of the Interstate Highway System began. But it is hard to envisage what road transportation will be like in 2059. Both technology and travel behavior could change in ways that affect the economics of a VMT fee (as well as transport policies more generally). Continuing improvements in vehicle safety, such as Intelligent Speed Adaptation and Collision Avoidance, could reduce accident rates and diminish the benefits of PAYD insurance. Further advances in emissions control could do likewise for air pollution and emissions charging. And automated roads could dramatically increase road capacity and reduce congestion. As far as demand for travel is concerned a carbon tax or cap-and-trade permits system would raise the cost of driving whether or not a VMT fee is implemented. Changes in social attitudes towards the automobile could lead to widespread adoption of car-sharing, a resurgence of public transport or development of a high-speed intercity passenger rail network, that could depress car usage. Telecommuting could do so as well although its long-run promise has yet to be realized.

Regardless of what the future brings a national VMT fee poses economic, engineering and institutional challenges for regional scientists to tackle. In some respects the task appears harder than for facility-based or area-based urban congestion pricing schemes that have been the subject of most research to date. A VMT fee has more control variables in terms of what externalities are covered and how charges are differentiated. A fee will also be more challenging for users to adapt to, and predicting their behavior is correspondingly more difficult.

In other respects, however, a VMT fee may actually be easier to study than localized schemes. A comprehensive and differentiated VMT fee would bring the market for road transport closer to first-best conditions which are much more analytically tractable than second-best conditions. Gaining public acceptance may also be easier because motorists and truckers would be treated on a more equal footing. A smooth, distance-based, charge would reduce the scope for disputes about charge boundaries and weaken the case for granting discounts or exemptions.

For decades economists have supported road pricing but many have expressed doubts that it will ever be implemented on a large scale.[30] Research and experience with urban road pricing has shown how abstract ivory tower ideas are not enough to convince decision makers to act, and that economists must combine their efforts with those of transportation engineers, planners and researchers in other fields to address the numerous, and often arcane, details.[31] The successful introduction of High Occupancy Toll lanes in the U.S., an area charge in London and a cordon in Stockholm show that progress can be made. Technological advances offer hope that road pricing can now be applied more widely to address the twin problems of inefficient road usage and crumbling infrastructure.

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[30] Lindsey (2006) provides a historical review of economists' attitudes towards road pricing.

[31] It is also fair to say that within the economics profession an integration of the largely separate research streams in regional science and transport economics would be advantageous. Rietveld and Vickerman (2004) view such a fusion as an important research agenda for years to come.

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