Review and Synthesis of Road-Use Metering and Charging Systems

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Executive Summary

Many public officials and transportation analysts are concerned with what they perceive to be the waning buying power of the motor fuels tax. Because the tax is levied on a per-gallon basis, revenues do not rise and fall with fluctuations in inflation or vehicle fuel economy. Given the partisan political climate in which it has grown increasingly contentious to propose increased taxes, many are pessimistic about the prospects for significant increases in state or federal motor fuels tax levies in the years to come. Indeed, the occasional increases in state and federal motor fuels taxes in recent decades have fallen far short of keeping pace with the combined effects of inflation and gains in fuel economy over the same period. On the other hand, annual vehicle miles traveled in the United States have continued to skyrocket for a wide variety of reasons, including population growth, increased affluence and vehicle ownership, greater participation of women in the workforce, and increasingly decentralized metropolitan land use patterns, among others. These increases in vehicle travel have exacerbated both congestion of and wear and tear on roads, leading to calls for increased spending on the construction of new roads as well as on the maintenance of existing roads. The result has been a widening gap in many parts of the country between highway spending needs and available revenues. In the absence of significant fuels tax increases in the coming years this gap is likely to widen further, a trend that may accelerate in coming years with the gradual introduction of alternative fuel vehicles that pay less, or even no, motor fuels taxes.

In response to these challenges, the Transportation Research Board convened a special Committee for the Study of the Long-TermViability of Fuel Taxes for Transportation Finance. One of the many charges to the committee was to investigate the potential for a system of distance-based user fees [using recently developed electronic tolling technologies such as on-board computers, Global Positioning Systems (GPS), digital jurisdiction and road network maps, and wireless communications] to eventually replace fuels taxes. To inform their deliberations, the committee commissioned the authors of this report to perform an extensive review of innovative electronic tolling applications around the world. This review included projects already in operation as well as those that have been proposed or are in the advanced stages of planning; each was evaluated in terms of policy, technology, and political acceptance issues. This report summarizes the results of this research.

SCOPE AND METHODOLOGY

In selecting case studies to review for this research, we focused on applications that involve networkwide road-use metering and tolling, as we judged these to be the most relevant to the concept of distance-based user fees. As a secondary focus, we reviewed facility congestion toll projects and cordon toll projects that might be relevant from a political or technical perspective. We did not examine standard (time-invariant) toll projects that incorporate simple electronic tolling devices (such as in-vehicle transponders), given that such projects would likely offer little technical or political guidance in the design of a comprehensive distance-based user fee system.

Within the context of the study, the goal was to address three principal questions. First, where in the world have such innovative systems been proposed, planned, or developed? Second, how have these projects and proposals been structured in terms of technical design, institutional issues, and political considerations? Third, what is the current status of the projects and proposals, and what factors have aided or impeded their implementation?

In terms of methodology, possible case studies were identified and investigated for inclusion. The scan was based on a review of the literature, a comprehensive search for documents on the World Wide Web, and several phone interviews with experts in the field. The next step was to compile a set of detailed case studies for those projects deemed politically and technically relevant to the question at hand. Each detailed case study considered the following topics:

- Stated and implicit objectives of the system;
- Techniques of metering road use and collecting fees;
- Pricing policies;
- Governance;
- History and political setting;
- Experience with public acceptance or rejection;
- Financial structure; and
- Summary of any evaluations that have been conducted for the project or views of those involved with the project, or both.

Once the case studies were compiled, the final step was to compare and contrast the different projects in order to provide perspective on the prospects for implementing a comprehensive distance-based user fee system, including the advantages and the likely obstacles to such an approach. The synthetic analysis was divided into five main sections:

- Policy and pricing issues,
- Technical issues,
- Institutional governance issues,
- Implementation issues, and
- Public and political acceptance issues.

SUMMARY OF CASE STUDIES

Given the motivations for the study discussed above, the review focused on five distinct types of pricing applications. These included single-facility congestion tolls, cordon (or area) congestion tolls, weight-distance truck tolls, distance-based user fee proposals, and distance-based price-variabilization (e.g., insurance-by-the-mile) studies. In total, 88 different pricing schemes—either operational or in the advanced stages of research or planning—around the world were identified that fell into one of these categories. Of these, 20 were selected for detailed review—specifically, those that were considered to be technically and politically relevant to the question of distance-based user fees.

Ultimately, none of the facility or cordon congestion tolls identified in the initial survey (such as the central London program) were selected for the set of detailed case studies, because none of these uses a technology platform that potentially could be extended to implement a distance-based user fee program. On the other hand, many of these applications are already operational, and they certainly entail innovative pricing schemes in transportation finance. For this reason, there are occasional references made to relevant findings from such projects within the policy and political acceptance sections of the synthetic review. Most of these observations are drawn from the following projects, all of which have been operational for at least two years:

- Facility Congestion Tolls: I-15 HOT lanes, SR-91 HOT lanes, Katy HOT lanes, and
- Cordon Congestion Tolls: London, Singapore, Norway (Trondheim, Oslo).

For weight-distance truck tolls, distance-based user fee proposals, and distance-based price variabilization studies, most of the projects identified were included as detailed case studies. Although many of the truck tolls are already operational, most projects within the other two categories are still in the planning or demonstration trial phases. The specific set of case studies reviewed includes the following:

Weight-distance truck tolls (international)

- Australian "Austroads" truck monitoring proposal (planning phase),
- Austrian "GO" truck toll (operational 2004),
- Bristol truck toll/cordon toll (trial completed),
- German "Toll Collect" truck toll (operational 2005),
- Swiss "HVF" truck toll (operational 2001), and
- UK truck toll (planning phase).

Distance-based user fee proposals (United States)

- CWARUM, a conceptual proposal by Daniel Malick;
- University of Iowa study (trial pending);
- Oregon Department of Transportation study (trial pending); and
- Puget Sound Regional Council study (trial ongoing).

Distance-based user fee proposals (international)

- ARMAS Pan European Tolling Project (trial ongoing),
- Copenhagen demonstration project (trial completed),
- Gothenburg demonstration project (trial completed),
- Helsinki modeling study (study completed),
- Netherlands "Mobimiles" proposal (cancelled 2002), and
- Newcastle on Tyne research project (study completed).

Distance-based cost variabilization studies (United States)

- Atlanta variable insurance study (study ongoing),
- Minnesota "PAYD" study (study ongoing), and
- Progressive Insurance study (study ongoing).

POLICY AND PRICING OBJECTIVES

Collectively, the pricing projects that were examined incorporate a wide range of policy objectives, though the specific goals tend to vary depending on the type of application. Table 1 provides a list of the most common stated and implicit objectives and indicates the most relevant policy goals for each category of projects. Note that an entry of “primary” indicates that the objective is one of the driving motivations behind most or all of the projects within a given category, while an entry of “secondary” indicates that the goal was identified explicitly in only a minority of the projects reviewed. Note also that under the category of distance-based road-user fees, several of the objectives (such as reducing demand for travel by increasing its marginal cost or encouraging the adoption of lower emission vehicles through appropriate fee offsets) are considered by the project developers to be of primary importance for the international projects but only of secondary importance for those in the United States.

In addition to policy objectives, the projects studied also exhibit considerable variation in terms of the travel characteristics to be metered and priced. At the highest level, these characteristics can be divided into four separate categories. First, each of the projects includes, at a minimum, a measure of *total distance traveled* (which is not surprising, given the selection criteria through which the projects were chosen). Second, a number of the projects also consider the *time of travel*, either for the application of congestion toll surcharges during hours of peak travel or for the enforcement of operating regulations (in the case of trucks only). Third, most of the projects also incorporate some determination of the *location of travel*. In the simplest case, this might be limited to geographic area, for the basic identification of separate charging zones (e.g., determining whether the user is traveling in California or Oregon). At finer levels of detail, the pricing schemes seek to distinguish between different road classes (e.g., to vary truck tolls based on highway versus nonhighway use), between specific links in the road network (e.g., to layer on additional fees for traveling on pre-existing toll facilities), or even between different lanes on a given link [e.g., for the hypothetical implementation of virtual high-occupancy toll (HOT) lanes]. Fourth, some of the projects also include the *characteristics of the vehicle* in determining fee levels. The most common examples of this fee structure include weight and axle configuration (for trucks) and vehicle emissions categories (to provide incentive for purchasing cleaner and more efficient vehicles).

TABLE 1 Policy Objective Summary

Policy/Pricing Objectives	Weight-Distance Truck Tolls	Distance-based User Fees	Cost Variabilization
Preserve Revenue		Primary	Secondary
Charge Equitable Costs	Primary	Primary	Primary
Charge External Users	Primary	Secondary	
Enforcement	Secondary		
Efficient Regulation	Secondary		
Reduce Road Wear	Secondary		
Improve Safety	Secondary	Secondary	
Optimize Capacity		Primary (Intl)	Secondary
Reduce Demand	Secondary	Primary (Intl)	Primary
Improve Environment	Secondary	Primary (Intl)	

The final major consideration in the area of policy and pricing pertained to the distribution of revenues. For most of the projects evaluated, the majority of the funds are dedicated to road maintenance and expansion. In several cases, however, a considerable portion of the revenue has been set aside to subsidize alternate modes such as transit or rail freight.

TECHNOLOGY APPROACHES

The in-vehicle equipment used within the various projects studied incorporates a wide array of technologies. In all cases, the equipment includes an on-board unit (OBU), essentially a computer that serves to integrate the other components, store data, and calculate charges owed. In addition, each configuration relies on one or more technologies to determine vehicle location or distance traveled, or both. Here, the range of possible options includes dedicated short-range communications (DSRC) devices, GPS receivers, geographic information systems (GIS) loaded with digital jurisdiction or road network maps (or both), odometer feeds, and dead-reckoning systems. Finally, each design also must include a means of transferring billing data to the collection agency. The three primary technology choices for this component include DSRC, global system for mobile (GSM) communications (satellite-based cellular), and removable smart cards.

Collectively, the set of technologies incorporated within the OBU must facilitate four important functions: (1) measuring usage to determine fees owed; (2) communicating usage and billing information; (3) maintaining user privacy for passenger vehicles (this is less relevant for commercial trucks); and (4) preventing toll evasion.

To meter road usage, several different technology configurations have been proposed, studied, or employed:

- **DSRC communicating with readers along the roadway:** This is typically applicable for weight-distance truck tolls that apply only on highway links, where it is relatively easy and cost-effective to mount transponders on overhead gantries. Given the impracticality of installing DSRC transponders throughout the entire road system, this option has not been proposed for full, networkwide pricing schemes.
- **Odometer with DSRC on/off toggle:** In this option, DSRC transponders are mounted at the entrances to a jurisdiction (e.g., where a highway crosses from one country to another). When a vehicle enters a charging jurisdiction, the DSRC signal sets the on-board unit status to “on.” From that point, the odometer is used to measure distance traveled within the jurisdiction. When the vehicle exits once again, another signal from the DSRC transponder sets the on-board unit back into the “off” status.
- **Odometer with GPS on/off toggle:** This is similar to the DSRC toggle option. Instead of relying on transponders mounted at border crossings, however, the on-board unit relies upon a GPS signal (combined with a digital jurisdiction boundary map) to determine whether the vehicle is within a particular charging zone or not.
- **GPS standalone:** In this case, the GPS is used to determine both position and distance traveled. Unfortunately, the GPS signal may at times be lost temporarily (especially in urban or mountainous regions), making this approach impractical for full-scale implementation.

- **GPS with odometer backup:** To account for periods when the GPS signal is not available, the odometer can be used as a backup measure for distance traveled until the signal is available once again. Regrettably, the odometer is not capable of providing location information, making it difficult to determine whether the vehicle has remained within the same charging zone.
- **GPS with odometer and dead-reckoning backup:** To help determine location (and thus applicable charging zone) while a GPS signal is down, the unit also can be equipped with dead-reckoning equipment in addition to the odometer feed.

As noted, there are three primary approaches for communicating usage and billing data:

- **GSM:** This is the most costly option but also the most flexible. Because it allows for real time communication from anywhere within the network, it also can be used to facilitate value-added capabilities such as way-finding, fleet management, and emergency distress signals.
- **DSRC:** Although this technology is robust, well tested, and inexpensive, it can be used only for communicating at fixed points throughout the network (specifically, where transponders have been mounted, such as on overhead gantries or at fueling stations). Though adequate for many applications, it does not provide the opportunity for value-added services, as does GSM.
- **Smart cards:** These are essentially small data-carrying devices that can be removed from the OBU and inserted into card readers (for example, at gas stations or on a home computer) to send billing data to the collections authority. With this option, the end user has full control in determining when the data is transferred; on the other hand, smart cards do not facilitate a fully automated billing process because some manual intervention is required.

Most of the systems studied devoted considerable attention to protecting user privacy. The primary concern has been to ensure that governments do not have unrestricted access to detailed travel records for individual drivers (this has been more of a concern for private passenger vehicles than for commercial trucking operations). To achieve this aim, two primary approaches have been proposed:

- **On-board aggregation:** The first approach, which is more prevalent for full-scale operational proposals, is to aggregate all travel information and determine the total bill owed on the on-board unit itself. With this strategy, the government never sees any of the details of the travel history for any individual, just the total amount of the bill.
- **Third party privacy agreements:** In this second approach, the on-board unit communicates detailed travel information to a third party billing agent, which in turn aggregates the data and submits only the total bill to the government. As with phone companies, the third party is legally obligated to keep these data private except in the case of a court subpoena. Consumers appear to be more wary of this approach, however, and to date it has been employed only within truck tolling projects or in research trial projects.

To help prevent toll evasion, two potentially complementary strategies have been discussed:

- **Tamper-proof OBUs:** Here the goal is to ensure that users are unable to turn off or temporarily disable the on-board units during periods of travel. Some of the alternatives suggested include tamper-proof seals on the OBU itself, disabling the engine if the OBU is not functional, and checking the OBU against the odometer to ensure that the mileage records are consistent.

- **External verification:** Under this strategy, DSRC transponders are mounted at various locations throughout the network, sending signals to passing cars to ensure that the on-board equipment is activated and functioning properly.

INSTITUTIONAL ISSUES

In reviewing the case studies, two major institutional issues of importance were identified. First, is the system designed to handle a single jurisdiction or multiple jurisdictions? Second, what are the respective public and private roles for oversight, operations, and the provision of technology?

About two-thirds of the case studies identified, including all of the weight-distance truck tolls and several of the distance-based user fee proposals, were designed, at least initially, to be implemented for single jurisdictions. Over the longer term, however, there appears to be a high probability that many single jurisdictions programs will evolve to include multiple jurisdictions. For example, the distance-based user fee proposal in Oregon is currently structured to measure mileage within that state alone. However, if California or Washington elected to pursue a similar pricing scheme at some point in the future, then they might very well seek to leverage the same technology that Oregon already has developed. Fortunately, from a technical standpoint, it is relatively trivial to structure the on-board unit to record data and calculate fees for single or multiple jurisdictions. On the other hand, once peer-level jurisdictions (e.g., multiple states or countries) join together in a road pricing project, it may be necessary to develop new institutional capabilities for collecting the revenues and distributing the appropriate amounts to the different parties involved.

In terms of public and private roles, oversight responsibilities for most of the programs reviewed (with the exception of some of the distance-based insurance pricing studies) fell primarily within the public realm. For operations, in contrast, there was a roughly even split between public and private responsibility; most of the multiple jurisdiction programs relied on private contractors for routine administration duties, whereas a larger percentage of the single jurisdiction programs opted for public administration. Finally, all of the cases studies tapped the private sector for the provision of the on-board equipment and supporting technology. In most of the cases, especially those for which user participation is mandatory, single firms (or consortia) were contracted to be the sole providers of the technology. However, for a few of the intended applications in which participation would be optional, the proposals have been structured to allow multiple vendors to compete for users on the basis of price as well as additional value-added services (such as navigational aids or fleet management).

IMPLEMENTATION ISSUES

Two principal implementation issues were identified: whether user participation is required or optional and whether the rollout is immediate or phased in over time. For most of the user-fee programs, participation is mandatory, particularly for “internal” users (i.e., those who live or work within the charging jurisdiction). In contrast, participation is usually optional for travel monitoring (as opposed to pricing) programs (as in the case of the Australian “Austroads” program), variabilized insurance pricing, or “external” users (e.g., foreign truckers operating within a country with weight-distance truck tolls).

The mandatory participation programs must determine in advance whether the equipment rollout will be staged simultaneously or phased in over time (for optional programs, in contrast, the rollout is phased in by definition). Most of the weight-distance truck tolls, for example, have opted to require internal users to install the on-board equipment at the onset of the charging program. In contrast, most of the distance-based user fees that involve private passenger vehicles have envisioned some strategy for phasing in the equipment over time (for instance, with the purchase of new vehicles). It is important to note that for programs in which the rollout occurs gradually, it is necessary to develop a strategy for operating multiple charging schemes in parallel throughout the transition phase (for example, newer cars with on-board equipment installed might pay mileage-based fees while older cars continued to pay the fuels tax).

POLITICAL AND PUBLIC ACCEPTANCE ISSUES

In reviewing the various factors that influence the prospects for political and public acceptance of new pricing schemes, two issues stood out most prominently: equity concerns and privacy concerns. With respect to equity, proposals for new pricing mechanisms invariably are subjected to higher levels of scrutiny than existing transportation finance programs. For example, equity concerns rarely are raised over the increasingly common dedication of sales taxes, despite the fact that such taxes are recognized widely to be regressive with respect to both income and highway system use. On the other hand, equity concerns almost always loom large for electronic tolling proposals, especially congestion tolls. This likely is due to the fact that they usually represent a “new” form of pricing (as opposed to a distance fee, which essentially would replace the existing gas tax), and because they place the correlation between ability to pay and benefits received into especially sharp relief. For the various projects that incorporated some form of congestion tolling, we observed the following:

- Equity concerns have contributed to the demise of many congestion pricing proposals.
- Actual equity outcomes can vary considerably from one project to the next, depending on user demographics and program design.
- Despite frequent equity concerns, congestion tolling is on the rise.
- Many congestion tolling programs have mitigated equity concerns through the dedication of revenues (for instance, to subsidize transit).

In contrast to congestion toll proposals, equity issues are not usually raised with regard to weight-distance truck tolls, distance-based user fees, or variabilized insurance.

As with the question of equity, the level of concern over privacy issues depends on the nature of the pricing program. Generally speaking, privacy issues are less relevant for weight-distance truck tolls, given their commercial nature, or for congestion tolls, which don’t typically track vehicles continuously through time and space. In contrast, privacy can be perceived as a significant issue for general-purpose distance-based user fees, as such programs involve private citizens and use equipment that, at least theoretically, allows for extensive vehicle tracking and monitoring. From the review of the various case studies, the following observations were made:

- Privacy concerns do not appear to pose legal issues.
- Public concern over privacy issues may not in fact be particularly widespread, given the prevalence of credit cards and cell phones, two other devices that provide a wealth of detailed information about individual behavior.
- Where privacy is a significant concern, it has been addressed at the technical level (through on-board aggregation of data) or at the programmatic level (with third-party billing and confidentiality agreements).

In addition to equity and privacy concerns, several additional factors that may also play a strong role in the level of public and political acceptance of new pricing schemes were identified. These include the following:

- **Severity of the problem and effectiveness of the solution:** New pricing schemes appear more likely to be accepted if the problem is considered severe, if other solution strategies have already failed, and if the proposed pricing scheme is deemed likely (or has been demonstrated elsewhere) to be effective.
- **Integration with complementary policies:** New road pricing schemes that integrate complementary policies—such as the improvement of transit options—appear to have increased the likelihood of implementation.
- **Size and scope of the project:** Projects of larger size and scope—with more users affected and more aspects of road use priced—appear to face more difficult prospects for political success given that they may engender resistance from a larger and more diverse array of stakeholders.
- **Dedication of revenues:** From the cases reviewed, it appears that the public is more willing to accept pricing programs when revenues are dedicated to transportation improvement projects rather than allocated into general funds.
- **Manner in which stakeholders are compensated:** In most of the programs investigated, one or more stakeholder groups will be affected adversely by the new pricing scheme. To counter or mitigate potential political resistance, many of the successful programs developed some way to compensate such groups. For instance, the weight-distance user fee in Switzerland raised the overall level of user fees for truckers (so as to encourage mode shift to rail) but also allowed for higher weight limits on the highway network in order to facilitate greater operating efficiencies among trucking firms.
- **Degree of choice offered, or precluded, by the program:** Findings show that programs seeking to expand the choices available to travelers (such as HOT lanes or cordon congestion tolls integrated with improved transit facilities) have tended to enjoy greater prospects for success than programs that limit or preclude the level of choice (such as all-lanes congestion tolls or cordon toll proposals in cities not well served by transit).
- **Transparency and user-friendliness of the system:** Developing fare structures that are readily understood and payment collection technologies that are seamless from the user's perspective appears, from the case studies reviewed, to be critical to establishing a high level of public and political acceptance.

- **Effectiveness of the enforcement strategy:** In many of the case studies reviewed, the effectiveness of the enforcement strategy was cited as a major issue for public acceptance; more specifically, users appear more likely to resent a new pricing scheme if they perceive that others may be able to cheat the system and evade payment.

CLOSING OBSERVATIONS

Of the many types of issues involved in our case studies of electronic tolling, three appear to exert the greatest influence on the prospects for the success of distance-based user fees: (1) the embedded policy objectives, (2) the technical strategy, and (3) the factors that influence political and public acceptance. Institutional and technical implementation issues are also important, of course, but these details appear less likely to affect the technical and political feasibility of electronically based pricing programs.

With respect to policy objectives, distance-based user fees can be designed to accomplish a wide array of goals, depending on the characteristics of travel that are metered or priced.

- **Revenue enhancement or preservation:** A distance-based user fee can readily serve as a replacement to the standard fuels tax, and its effectiveness would not be compromised by increasing vehicle fuel efficiency (or even the introduction of alternative fuel vehicles) in the years ahead. Given the substantial price tags associated with transitioning to these types of systems, however, it is not clear whether this approach would be superior to simply increasing current fuels taxes over the short term (though, as noted above, such increases face increasingly difficult political odds). Conversely, a distance-based user fee may very well prove necessary within several decades with the anticipated widespread introduction of alternative-fuel vehicles.
- **Optimizing road capacity, managing demand:** Using the technology base for a distance-based user fee system, it is relatively straightforward (from a technical standpoint) to layer on congestion tolls that would apply along specific corridors or within crowded urban areas during periods of peak travel for the purposes of optimizing road capacity or managing demand and encouraging mode shift.
- **Reducing road damage, improving the environment:** It is also possible to build in offsets to the standard distance fee based on axle weight or emissions class in order to encourage users to purchase and operate vehicles that impose less damage on roadways or the environment.

On the technology front, the most significant finding is that it is technically feasible and increasingly cost-effective to develop a system for distance-based user fees. In terms of specific technologies and general technical strategies:

- **GPS:** GPS by itself is not sufficiently reliable to measure location and distance traveled, given that the signal often may go down while traveling between tall buildings or in mountainous areas. For this reason, such systems need to be supplemented by an odometer feed (as a backup for distance traveled) and possibly a dead-reckoning system (as a backup for location). The question of accuracy may be another important issue. For applications where it is necessary only to determine whether or not a vehicle is within a particular jurisdiction (e.g., a country or a state), GPS and existing digital maps provide a sufficient level of accuracy. However, for applications in which it is necessary to distinguish between different road links on the network, differential GPS signal correction and highly accurate (and expensive-to-create) road network maps will be required.

- **Communications strategies:** DSRC, GSM, and smart cards all represent viable communications options; the appropriate choice depends on price (GSM is the most expensive by far) as well as desired functionality (GSM is also the most flexible).
- **Enforcement strategies:** To prevent toll evasion, tamper-proof OBU strategies appear to offer the most promise, though external roadside checks using DSRC transponders may add a useful level of redundancy.
- **Simple system designs:** Generally speaking, and not surprisingly, applications that have relied on relatively simple technical configurations (leveraging, as often as possible, off-the-shelf technologies) have experienced the greatest implementation and budgetary success. Increasingly, electronic tolling programs are starting with simple systems that are upgraded to a greater level of complexity later.
- **Conservative implementation schedules:** For many projects, the process of development, integration, and planning has taken far longer than originally anticipated. This underscores the importance of providing sufficient flexibility within the implementation timelines to account for unanticipated technical difficulties.
- **Backup plans:** As a corollary to the above, program designers (in most, though not all, cases studied) have designed system redundancy and backup plans for levying user fees should technical difficulties lead to delays in the implementation of the electronic tolling system.

Finally, in terms of the factors that influence the prospects for political and public acceptance of distance-based user fees, the following issues are the most relevant:

- **Equity concerns:** In general, equity is raised as a concern more for congestion tolls than for distance-based charging schemes. In distance-based user fee proposals not involving congestion surcharges, equity concerns have been far less of a political barrier. But since one of the ultimate goals of many distance-based electronic tolling programs is to develop systems that eventually include both distance fees and congestion tolls, equity concerns may be raised subsequently for already established tolling programs.
- **Privacy concerns:** In contrast to equity, concerns over privacy are most common in distance-based user fee programs, given that the combination of technologies employed within on-board equipment can be used to record and disseminate detailed information on the travel patterns of individual drivers. Fortunately, it is possible to ensure the privacy of user data, both at the technical and institutional levels. On the other hand, many press accounts continue to highlight concerns over privacy, despite the fact that this issue has been addressed satisfactorily in many of the cases studied. For this reason, efforts to implement distance-based charging schemes often include coordinated public education campaigns to address and diffuse popular and political objections to tolling proposals on privacy grounds.
- **Other factors influencing public and political acceptance:** Along with equity and privacy, a number of other issues appear to be important with respect to building public and political support for new pricing programs such as distance-based user fees. Most notably, these include the severity of the problem to be addressed and the inadequacy of other solution strategies, the degree of integration with other related policies (such as the provision of improved transit service), the degree to which “losers” under the new pricing regime can be compensated

in some manner, perceptions over the adequacy of the proposed enforcement scheme, and the expansion or contraction of travel options created by the program.

- **Keys to building public and political support:** In addition to the programmatic factors that can influence the level of public and political acceptance, experience from the various cases studied indicates that there are a variety of strategies that pricing program proponents have pursued to enhance the prospects for political success. These include establishing the technical details of the program early on (so as to build confidence in the feasibility of the project), engaging in sophisticated marketing efforts (including focus groups, targeted messaging, and coordinated framing of the debate), reaching out to key stakeholder groups early in the process, cultivating political champions, actively courting the media, and providing positive testimonials from other successful projects of a similar nature.

1

Introduction

PURPOSE OF STUDY

Since the 1920s the motor fuels tax has been the principal user fee through which revenues have been raised for the construction and maintenance of U.S. highways (and later public transit systems). The motor fuels tax has numerous merits, and many observers believe that it will remain the mainstay of transportation finance for years to come. Others, however, pointing to the growing political resistance to fuels tax increases, the rise of alternative propulsion vehicles, and the need for better pricing to manage road use, argue that the days of the motor fuels tax are numbered—and that new technologies now allow new and better ways to price the use of highways. This resource paper informs this debate over the future of the motor fuels tax by examining in considerable detail many of the latest efforts worldwide to develop new ways to fairly and efficiently charge for highway system use.

IS THE GAS TAX OUT OF GAS?

The motor fuels tax is unique in many respects. Because drivers of motor vehicles impose costs on the transportation network that, to a certain extent, are proportional to their use of fuel, the motor fuels tax has been considered a transportation user fee since its inception in the 1920s. In particular, those who drive more pay more, and those who drive large, fuel-guzzling vehicles also pay more. During the Great Depression in the 1930s, and then again in the 1990s, the federal government used federal fuels tax revenues for nontransportation purposes, but for the most part fuels tax revenues finance transportation.

As an instrument of taxation, the motor fuels tax has much to recommend it—fiscally, politically, and administratively. First, as motor fuels consumption has soared over the past eight decades so have tax proceeds. The motor fuels tax is a phenomenal revenue producer, yielding $75.6 billion in the United States in fiscal year 2000 (U.S. DOT FHWA, 2001). Second, the tax is paid in relatively small increments—the average per gallon levy in 2000 was $0.377 per gallon; $0.184 federal tax, plus an average state levy of $0.193—so it is relatively hidden in the price of motor fuel (U.S. DOT FHWA, 2000). This particular feature of the tax has tended to minimize organized public opposition to it, though other taxes collected in even smaller increments (like sales taxes) are eclipsing the fuels tax in popularity.[1] Finally, the tax is, from the taxpayers' and the government's point of view, easy to administer and collect. The gasoline tax is collected from gasoline distributors rather than directly from retailers or consumers, which serves to minimize the opportunities for gas tax evasion and to reduce the cost of collection to an

[1] Voters in recent years have consistently expressed a preference for small, frequent levies (like sales taxes) over larger, infrequent levies (like property taxes) (Goldman and Wachs, 2003). Given such preferences, it's likely that—if fuels today were sold by the liter instead of the gallon—proposals for $0.01 or $0.02 per liter additions to a current $0.099 per liter fuels tax would encounter far less popular and political resistance than would similar (in effect) proposals for $0.04 to $0.08 per gallon increase in state or federal fuels taxes.

historical average of one-half of one percent of tax proceeds (Brown, DiFrancia, Hill, Law, Olson, Taylor, Wachs, and Weinstein, 1999).

As population, personal travel, and especially vehicle use have increased dramatically in recent years, the relationship between motor fuels tax revenues collected and total miles driven has gradually weakened. Three factors have combined to make it difficult for fuels taxes to keep up with expanding needs: increasing vehicle fuel efficiency, the fact that per-gallon fuels tax revenues do not increase with inflation, and increasing transportation program commitments (Taylor, 1995; Brown, 2001).

First, automobile fuel efficiency has increased significantly over the past 30 years, though this trend has slowed recently because of the increasing popularity of pick-up trucks and sport utility vehicles. Table 2 shows that for each gallon of fuel consumed, vehicles in 2000 traveled 63 percent farther than they did in 1970. And since most fuels taxes are levied on a per-gallon basis, fuels tax revenues cannot keep pace with the growth in travel without substantial increases in the per gallon levy (U.S. DOT BTS, 2002). Even though improvements in vehicle fuel efficiency undoubtedly have benefited the environment, they also have substantially reduced fuels tax revenues per mile driven. Plans to promote conversion of the automobile fleet to alternative fuels or electric power further threaten fuels tax revenues. Alternative fuel and electric powered vehicles use roadways to the same extent as traditional gasoline and diesel-powered vehicles, but they do not produce fuels tax revenues (Rufolo and Bertini, 2003; Wachs, 2003).

Second, inflation has diminished the purchasing power of the motor fuels tax. Many other forms of taxation, such as sales, property, and income taxes, are able to maintain their productivity in the face of inflation because the tax base rises with inflation. Motor fuels taxes, however, are generally levied on a per-gallon basis, and thus their proceeds do not increase automatically in response to inflation. Furthermore, because the cost of materials used in transportation projects and the cost of land for transportation facilities have risen faster than the general rate of inflation, the buying power of fuels tax revenues has eroded even faster than the inflation rate would suggest (Taylor, 1995).

To keep pace with rising costs, gas and diesel fuel taxes must be increased periodically through legislative action with the approval of a governor or the president. Despite public concern over congestion and, to a lesser extent, deteriorating transportation infrastructure, however, achieving the political consensus necessary to raise fuels taxes has become increasingly difficult. User fee or not, changes to fuels tax levies have been central to many partisan debates over tax increases since the so-called tax revolts of the 1970s. As such, legislators have become increasingly wary of potential voter hostility toward tax increases of any sort and have been reluctant to accept regular increases in the motor fuels tax levies to keep pace with increasing fuel efficiency and inflation.

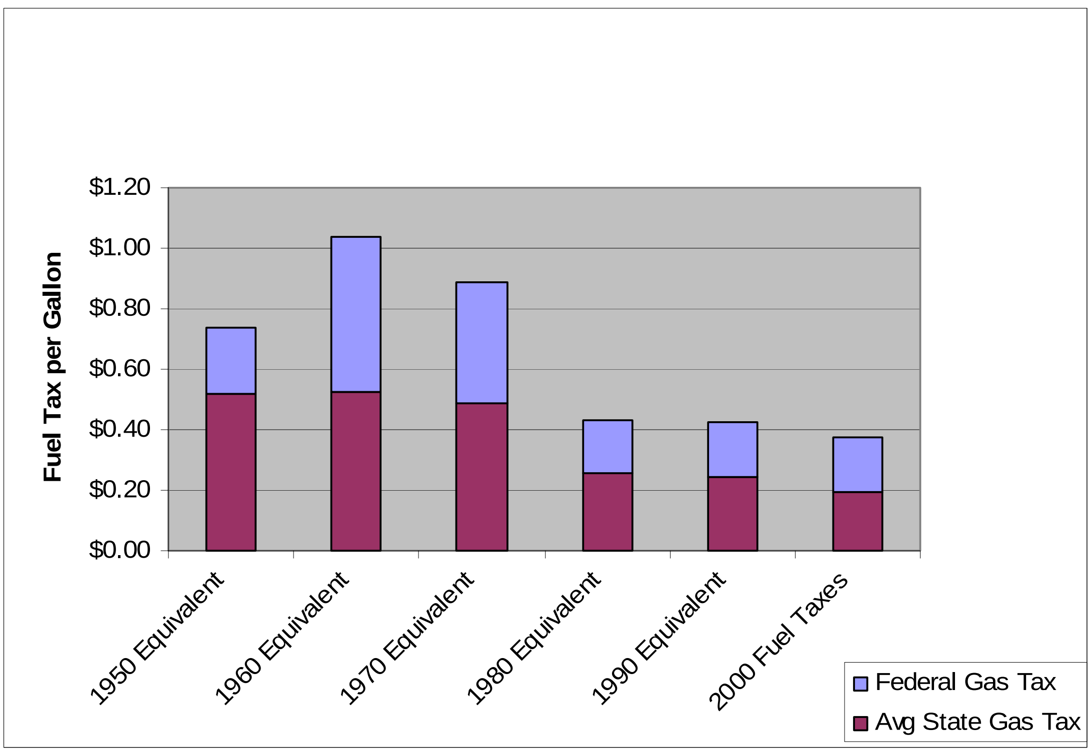
TABLE 2 Trend in Average U.S. Vehicle Fleet Fuel Economy Since 1970

	1970	1980	1990	2000
Fleet Mileage	13.5 mpg	15.9 mpg	20.2 mpg	22.0 mpg
10-Year Change (absolute)	–	+ 2.4 mpg	+ 4.3 mpg	+ 1.8 mpg
10-Year Change (percent)	–	17.8%	27.0%	8.9%
Change Since 1970 (absolute)	–	+ 2.4 mpg	+ 6.7 mpg	+ 8.5 mpg
Change Since 1970 (percent)	–	17.8%	49.6%	63.0%

Source: Calculated by Authors from U.S. Department of Transportation, Bureau of Statistics [2002]. National Transportation Statistics 2001, BTS02-06, Washington, DC, U.S. Government Printing Office, July 2002
http://www.bts.gov/publications/nts/

Finally, the demands on faltering motor fuels tax revenues have increased as improved safety standards and environmental safeguards have been added to highway projects, and as new types of projects (public transit, bicycle, and so on) have been made eligible for fuels tax funding. This so-called "program creep" has helped to increase the fiscal squeeze on motor fuels tax revenues (Brown, DiFrancia, Hill, Law, Olson, Taylor, Wachs, and Weinstein, 1999).

The result has been a widening gap since the 1970s between transportation finance revenues and transportation construction and maintenance needs. Legislators have responded by enacting periodic stopgap revenue enhancement measures, but no meaningful structural reforms of motor fuels taxes have emerged. Fuels taxes have been increased occasionally since the early 1980s, but the tax increases have failed to keep pace with the combined effects of inflation, increasing vehicle fuel efficiency, and new program responsibilities. Figure 1 below shows that



Source: Hill, Taylor, Weinstein, and Wachs, 2000

FIGURE 1 Changes in per gallon fuels taxes required in 2000 to restore inflation-adjusted revenues per vehicle mile of travel to level of prior years.

to return the buying power of the 2000 fuels tax to its 1960 level, the combined state and federal gas tax would have to more than double to nearly $1.00 per gallon.

Despite their erosion, state and federal motor fuels taxes still account for 57 percent of all highway revenues (U.S. DOT FHWA, 2001); in 1960, the figure was 66 percent (U.S. DOT FHWA, 1997). Taken as a whole, transportation-related revenue sources (motor fuels taxes, registration fees, weight fees, tolls, and driver's license fees) accounted for 77 percent of U.S. revenues for highways in 2000, while nontransportation-related revenue sources (sales taxes, property taxes, and the like) accounted for nearly 23 percent (U.S. DOT FHWA, 2001). Whether this gradual drift away from transportation user fees will continue in the years ahead is unclear.

These trends raise legitimate questions about the future viability of motor fuels taxes and the feasibility of possible alternatives. Accordingly, this report examines recently implemented and currently proposed road pricing alternatives to the venerable fuels tax. In turn the folloing are examined: (1) the policy logic of marginal cost pricing of roads, (2) the technical feasibility of pricing alternatives to the fuels tax, (3) governance and institutional issues with new road pricing regimes, (4) implementation issues, and (5) questions of popular and political acceptability. The focus of this report is on the experience to date with various forms of road-use metering and charging systems that might one day serve as a supplement or alternative to motor fuels taxes. We do not in this report assess the viability of motor fuels taxes is not assessed in this report, and the motor fuels tax is not compared or contrasted with its alternatives. Rather, the specific focus is on evaluating the feasibility of various new approaches to road-use metering and charging.

METHODOLOGY

The overall goal of the work reported in this document has been to gather and synthesize information on road pricing programs or proposals that are relevant to the concept of distance-based user fees as a potential long-term replacement to the fuels tax. Data have been collected from three distinct sources:

- Web searches and on-line documents,
- A review of the academic literature, and
- Interviews with key personnel in various programs.

Initially, the net was cast broadly, including road pricing applications such as congestion tolls, weight-distance truck tolls, general purpose distance-based user charges, and distance-based cost variabilization studies [note that new-construction road projects using electronic tolling to levy uniform fees were not included in the review given that (a) they do not represent a new form of charging, and (b) the technology employed in such cases is not extensible to area-wide charging]. The wider set of identified applications and studies was then winnowed down to a collection of highly relevant case studies on the basis of three criteria: political relevance, technical relevance, and the availability of sufficient information on which to base the review.

After selecting the case studies, each was reviewed in detail, and in certain cases key personnel associated with the programs were interviewed via telephone in order to gather additional data. Following the detailed reviews, results and observations from the case studies were synthesized across several topical areas, including policy and pricing issues, technical approaches, structures of governance, implementation issues, and public and political acceptance issues.

For each of these areas, the goals of the synthesis were twofold: first, to introduce the basic issues and options available to planners and policy makers, and second, to report observations and lessons learned from the various case studies. In the summary section of the document, final thoughts and recommendations with respect to these different areas are offered.

ORGANIZATION OF THE PAPER

The paper is organized into eight sections as well as a number of appendixes:

- Section 1 provides an introduction and overview of the paper.
- Section 2 provides an overview of the case studies reviewed.
- Section 3 provides a synthesis of policy and pricing issues.
- Section 4 provides a synthesis of technical issues.
- Section 5 provides a synthesis of governance issues.
- Section 6 provides a synthesis of program implementation issues.
- Section 7 provides a synthesis of public and political acceptance issues.
- Section 8 provides a summary of the findings.
- The References section lists all source material cited in the report.
- Appendix A provides a glossary of terminology.
- Appendixes B through F provide complete listings of all programs, proposals, and studies identified.
- Appendixes G through R provide detailed reviews for the most relevant case studies.

2

Case Studies

This section provides an overview of the case studies reviewed for this report. The material is organized as follows:

- Types of applications and proposals investigated,
- Criteria for the selection of case studies for detailed review, and
- Overview of the case studies.

TYPES OF APPLICATIONS REVIEWED

In reviewing road pricing applications, proposals, and studies for this report, the goal was to focus on cases potentially relevant—either from the political or the technical perspective—to the concept of distance-based road user fees. In order to ensure that the review was of sufficient scope, five distinct pricing concepts were evaluated:

Facility Congestion Tolls

In facility congestion tolls, users pay a fee to use a given facility (e.g., a bridge, tunnel, or specified length of highway), the level of which depends on the ambient level congestion. The usual motivation for such programs is to ensure free-flowing traffic, thus maximizing capacity.

Cordon Congestion Tolls

In cordon congestion tolls, users pay a fee to enter or travel within a specified charging zone during peak travel hours, usually a cordon that surrounds a congested urban area. The typical motivation for this type of program is to reduce demand, thereby easing congestion and pollution.

Weight-Distance Truck Tolls

With weight-distance truck tolls, freight carriers are charged a fee for use of the road system that depends on weight and distance traveled. Depending on the specific program, the measurement of weight may be based on actual weight, maximum laden weight, or axle configuration. The usual motive for such tolls is to recover fully the costs associated with the operation of heavy vehicles on the road network.

General Purpose Distance-Based Road User Fees

With general-purpose distance-based road user fees, private passenger vehicles (and potentially trucks as well, depending on the proposal) are charged a fee for road use that depends on the number of miles driven. The motivation behind such proposals is to develop a long-range alternative for the fuels tax. Although the fuels tax historically has been the primary source of highway finance, its effectiveness in raising revenues is currently suffering erosion because of improvements in vehicle fuel economy combined with voter reluctance to raise the tax rate.

Distance-Based Price Variabilization Programs

With price variabilization studies, the idea is to replace currently fixed prices of automobile ownership and usage, such as registration fees, leasing fees, or insurance costs, with variable prices that depend on miles driven. The underlying theory is that variabilizing such costs will enable users to save money by traveling less and result in a net reduction in distance traveled across the aggregate population, thereby easing problems related to congestion and environmental pollution.

CRITERIA FOR THE SELECTION OF CASE STUDIES

During the initial search for potentially applicable case studies, the set of programs, proposals, and studies identified was large. To pare the list to a more manageable set, only those that met the following criteria were addressed:

- Technical relevance to distance-based road user charges,
- Political relevance to distance-based road user charges, and
- Availability of sufficient information on which to base the review.

The full sets of studies reviewed, sorted according to the categories discussed above, are listed in Appendixes B through F. Table 3 provides an overview of the number of studies reviewed initially within each of the categories listed above, as well as the number ultimately selected as case studies.

SELECTED CASE STUDIES

As indicated within Table 3, no facility congestion toll or cordon congestion toll projects were selected as case studies. In contrast, the majority of weight-distance truck tolls, distance-based user fee proposals, and distance based cost variabilization studies were included.

TABLE 3 Case Study Review and Selection

Road Pricing Category	Projects Reviewed	Selected for Case Studies
Facility Congestion Tolls	45	0
Cordon Congestion Tolls	18	0
Weight-Distance Truck Tolls	7	6
Distance-Based User Fees	13	11
Distance-Based Variable Cost Studies	5	3
Total	**88**	**20**

Facility and Cordon Congestion Tolls

The primary reason that none of the facility or cordon congestion tolls were selected as case studies is because they are all, without exception, based on technology platforms that are not extensible to area-wide distance-based pricing programs. On the other hand, these projects have resulted in a wealth of experience in the area of policy and public acceptance issues. For this reason, in the topical syntheses references will be made to an individual facility or cordon toll projects when appropriate. The majority of such observations will be drawn from the following projects:

- The San Diego I-15 HOT lanes,
- The Orange County SR-91 HOT lanes,
- The Houston I-10/Katy Freeway HOT lanes,
- The Minnesota Value Pricing Study,
- The Singapore Cordon Toll,
- The London Cordon Toll, and
- The Norwegian Cordon Tolls.

Useful references for the above projects are as follows: for I-15, see Brownstone et al. (2003); Supernak et al. (2002); and Supernak, Kaschade, and Steffy (2003); for SR-91, see Sullivan (2002); for I-10/Katy, see Shin and Hickman (1999) and Stockton (2002); for Minnesota, see Lari and Buckeye (1999), Loveland (2003), and Munnich and Barnes (2003); for Singapore, see Fabian (2003) and Phang and Toh (2003); for London, see Transport for London (2003); for Norway, see Larsen and Ostmoe (2001) and Odeck and Brathen (2002).

Final Selections

The set of case studies ultimately selected, sorted by category and location, are listed below.

Weight-Distance Truck Tolls (international)

- **Australia**: Austroads "IAP" truck monitoring proposal,
- **Austria**: "GO" weight-distance truck toll,
- **Bristol (United Kingdom)**: Combined truck toll/cordon toll demonstration,
- **Germany**: "Toll Collect" weight-distance-emissions truck toll,
- **Switzerland**: "HVF" weight-distance-emissions truck toll, and
- **United Kingdom**: Proposed weight-distance-emissions truck toll.

Distance-Based User Fees (United States)

- **CWARUM**: Conceptual proposal developed by Daniel Malick,
- **Iowa**: "New Approach" proposal developed at the University of Iowa,
- **Oregon**: Road User Fee Taskforce pilot program, and
- **Puget Sound**: Distance-based congestion pricing pilot program.

Distance-Based User Fees (international)

- **ARMAS**: Pan-European road tolling project,
- **PRoGRESS**: Pan-European urban road pricing consortium,
- **Copenhagen (Denmark)**: Cordon and distance pricing pilot test,
- **Gothenburg (Sweden)**: Distance and congestion pricing pilot test,
- **Helsinki (Finland)**: Cordon and distance pricing modeling study,
- **Netherlands**: "Mobimiles" distance-based user fee proposal, and
- **Newcastle on Tyne (United Kingdom)**: Distance-based congestion pricing study.

Cost Variabilization Studies (United States)

- **Atlanta**: variable cost study at Georgia Institute of Technology,
- **Minnesota**: "PAYD" variable cost study, and
- **Progressive Insurance**: variable insurance cost study.

Note that references for each of these projects are listed along with the summary reviews in the following section. In addition to web references and journal articles, for certain case studies key individuals involved with the project were contacted via telephone to gather additional background data. The set of individuals contacted includes

- Ken Buckeye: Minnesota Department of Transportation, program manager for the current Minnesota variable cost study;
- Randy Guensler: Associate Professor at the Georgia Institute of Technology, leader of the Atlanta variable price study efforts;
- Matthew Kitchen: Puget Sound Regional Council, principal planner involved with the Puget Sound distance-based congestion toll project;
- David Levinson: assistant professor at the University of Minnesota, participant in the early Minnesota value pricing feasibility studies; and
- James Whitty: Oregon Department of Transportation, administrator of the Road User Fee Task Force.

CASE STUDY SUMMARIES

This section provides a brief overview of each of the case studies listed above. For the most relevant projects, more detailed reviews are provided in Appendixes G through R.

Weight-Distance Truck Tolls (international)

Australia: Austroads "IAP" for Freight Monitoring

Austroads, a consortium of national, state, and territory transport authorities in Australia, has developed a proposal termed the Intelligent Access Program (IAP). The primary purpose of the IAP is to provide for voluntary monitoring of freight vehicles, via on-board units equipped with GPS and DSRC, to ensure compliance with agreed conditions of operation (i.e., how, where, and when they operate). In return for their participation, transport operators will be granted permission for expanded access to various applications (e.g., larger loads operating on an expanded network). According to the IAP scheme, the government will establish basic system requirements as well as a certification and auditing regime; individual companies will in turn develop technical solutions and offer these to transport operators for a monthly fee. Following a yearlong feasibility study, the Australian Transport Council endorsed the results of the project and recommended implementation in May of 2003. Subsequently, a steering committee was convened to develop and manage the implementation schedule. For a more detailed review, refer to Appendix G. For references, see Koniditsiotis (2003).

Austria: "GO" Weight-Distance Truck Toll Program

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

Bristol (United Kingdom): Combined Truck Toll/Cordon Toll Demonstration

The City of Bristol is a member of the Pan-European PROGRESS Project investigating alternate road pricing strategies in urban areas (see below for more details). The city recently conducted a trial study integrating distance charges and cordon congestion tolls for heavy goods vehicles. The primary purposes of the test were to investigate (1) the potential for integrating a national distance-based charging program with local cordon congestion tolls using on-board units equipped with satellite positioning technology and (2) the feasibility of ANPR for enforcing congestion tolls. Though technical feasibility of these two objectives was demonstrated successfully, the final evaluation results have not yet been published. For a more detailed review, see Appendix H. For references, see City of Bristol (2001), European Transport Pricing Initiative (2004), and PRoGRESS (2003, 2004).

Germany: "Toll Collect" Weight-Distance-Emissions Truck Toll Program

The German Toll Collect truck toll system was targeted initially for implementation in the fall of 2003, but because of technical and contractual difficulties the launch was delayed until January of 2005. Per European Union directive, the fee system applies only to vehicles over 12 tons and only to use of motorways—other roads are exempt. The price varies by distance traveled, by the number of axles (as a perhaps problematic surrogate for weight), and by the emissions class of the vehicle. The overall fee structure is designed to recoup direct capital and operating costs to the motorway system imposed by truck traffic. The technology supporting Toll Collect involves an on-board unit equipped with GPS (to determine both entry to and exit from the motorway network and distance traveled[2]) and GSM (to communicate billing data to the central computer system). Toll Collect is administered by a private consortium that collects the tolls on behalf of the German government. The government then spends most of the revenue on road maintenance and improvement projects that reflect government priorities. For a more detailed review, see Appendix I. For references, see Kossak (2003), Rothengatter (2004), Rothengatter and Doll (2002), Ruidisch (2004), and Reason Public Policy Institute (2004).

Switzerland: "HVF" Weight-Distance-Emissions Truck Toll Program

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

United Kingdom: Proposed Weight-Distance-Emissions Truck Toll

The United Kingdom plans to institute a heavy goods vehicle toll scheme in the next three to four years that will vary according to distance traveled, type of vehicle (weight, number of axles, and emissions class), and type of road. In subsequent years, the fee basis may be expanded to include time of day (to reflect congestion costs) and geographic area (to reflect, for example, the high costs that trucks can impose on residential areas) as well. The technology to support the new toll will be based on an on-board unit that includes GPS (to determine both distance and road type), GSM (to communicate with the central billing authority), and a link to the vehicle's tachograph (to provide a backup check on distance traveled). The primary purpose of the fee is to ensure that foreign haulers who purchase their fuel abroad before arriving in the United Kingdom are forced to pay their fair share for road use. Because the focus of the new program is not on increasing fees on domestic truckers, the proposal enjoys a significant degree of political popularity in the United Kingdom. The proposed system has been studied heavily, and the

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[2] Distance traveled is not measured directly with GPS in the German system. Instead, highway segments are recognized by the on-board units and matched with segment length and toll rate data stored in the OBU memory.

procurement process should begin this year. For a more detailed review, see Appendix K. For references, see Worsley (2004).

Distance-Based User Fees (United States)

CWARUM Proposal

Daniel Malick, a consultant in the field of policy, financial, and administrative system development for public infrastructure, has introduced a technical and institutional model for a system capable of administering distance-based road use charges, termed the Certified Wide Area Road Use Monitoring (CWARUM). Under CWARUM, public jurisdictions would specify pricing criteria (e.g., charges by distance and by type of road traveled) and private companies would develop and implement technologies capable of administering the charges. Specifically, the systems would be designed around on-board units featuring GPS, digital maps, and cellular communications. Private firms would then compete for users based on both the price of the service (i.e., the monthly subscription rate) and on additional services offered above and beyond implementing the road user charges. For example, companies could provide value-added services such as navigation and incident response. The CWARUM proposal was evaluated initially for possible implementation in New Zealand, though that project subsequently was aborted. More recently, CWARUM has served as the underlying model for the planned Austroads IAP truck monitoring application. For reference, see Malick (1998).

Iowa: "New Approach" Proposal Developed at the University of Iowa

Researchers at the University of Iowa, with pooled funding from fifteen state departments of transportation and the Federal Highway Administration, have developed a proposal for a mileage-based fee system operating across multiple jurisdictions that would serve as a long-term replacement to the fuels tax for both automobiles and trucks. The proposal includes the use of on-board units equipped with GPS and GIS maps for determining distance traveled by jurisdiction, as well as smart cards for data transfer to a billing center. In its simplest form, the proposed fee structure for automobiles would be based on the number of miles driven in each state, while for trucks it would be based on the number of miles driven by road class by state. At their discretion, individual jurisdictions also could choose to include additional fee criteria, such as congestion tolls, per-mile charges based on emissions class, and per-mile adjustments based on weight and axle configuration (for trucks). The initial feasibility study was completed and published in 2002, and efforts to develop a field trial of the proposed technology are currently underway. For a more detailed review, see Appendix L. For reference, see Forkenbrock and Kuhl (2002).

Oregon: Road User Fee Taskforce Pilot Program

Under a mandate from the state legislature, the Oregon Department of Transportation has organized a Road User Fee Taskforce conducting a pilot study of mileage-based user fees and areawide congestion tolls, facilitated by on-board units featuring GPS receivers and short wave radio communications. The technology platform was demonstrated successfully in May of 2004. In early 2005, 20 vehicles were to have been equipped with the on-board technology for an initial trial run of six months, and in late summer 2005, an additional 250 users in the Eugene area were to have been added to the study. The pilot test will last approximately one year; during this time, one portion of the study group will pay distance charges only, while the remainder will pay both mileage fees (albeit at a reduced rate) as well as congestion tolls. To compensate for these fees, all participants will receive rebates on the standard fuels tax at the time of purchase. Depending on the results of the study, legislation to enact the mileage fee (and potentially introduce congestion tolls) on a statewide basis may be considered as early as 2007. For a more detailed review, see Appendix M. For references, see Whitty (2003).

Puget Sound (Washington): Distance-Based Congestion Pricing Pilot Program

The Puget Sound Regional Council is conducting a test of network-wide congestion tolls. Approximately 350 households, collectively owning close to 500 vehicles, will participate in the study. Each vehicle owned by a participating household will be equipped with an on-board unit, complete with cellular communications and a GPS receiver. The on-board unit is capable of detecting when the vehicle travels on a link that is subject to congestion tolls, calculating the ensuing charge, and periodically uploading the data to a central computer center. The study does not include time-dependent distance-based user fees, but instead is designed to evaluate the behavioral response of drivers to congestion-adjusted distance pricing (the study includes a built-in mechanism to provide a financial reward for drivers who reduce their level of travel during peak congestion periods). A prototype for the on-board unit was demonstrated successfully during the summer of 2004, and the study was scheduled to commence in early 2005 and last for one year. For a more detailed review, see Appendix N. For references, see Puget Sound Regional Council (2002).

Distance-Based User Fees (international)

ARMAS: Pan-European Road Tolling Project

On behalf of the European Union, the European Space Agency has initiated the Active Road Management Assisted by Satellite (ARMAS) program. ARMAS involves the use of on-board vehicle equipment incorporating satellite based positioning information and cellular communications. Initial trial applications focus on electronic road tolling, which may be implemented across all of Europe as early as 2010. Additional applications envisioned for the technology include improved safety (obstacle detection and avoidance, incident warnings, etc.), increased traffic management capabilities (e.g., electronic speed advisory and enforcement), fleet management support, and dynamic route guidance services. The preliminary feasibility study for ARMAS was completed successfully in November 2003; initial trial projects were to have been demonstrated in May 2005. For a more detailed review, see Appendix O. For references, see *Innovation Reports* (2003) and *RedNova News* (2003).

PRoGRESS: Pan-European Urban Road Pricing Consortium

The PRoGRESS (Pricing Road Use for Greater Responsibility, Efficiency, and Sustainability in Cities) project, launched in May 2000 and completed in May 2004, was developed in response to the mandate for “competitive and sustainable growth” in the European Commission’s Fifth

Framework Program. The objective of the program was to demonstrate and then evaluate the effectiveness and acceptance of integrated urban transport pricing schemes to achieve both transport goals and raise revenue. The project involved a consortium of eight European cities: Bristol, Copenhagen, Edinburgh, Genoa, Gothenburg, Helsinki, Rome, and Trondheim. Several different tolling schemes and road pricing technologies were investigated, as follows (Table 4):

Of the eight cities, Rome and Trondheim developed the only full-scale implementations, but officials in Bristol, Edinburgh, and Genoa have announced the intention to move in that direction. In contrast, the future of projects in Copenhagen, Gothenburg, and Helsinki are unclear. Additional details on the individual projects in Bristol, Copenhagen, Gothenburg, and Helsinki are discussed separately. For references, see PRoGRESS (2003, 2004).

Copenhagen (Denmark): Cordon and Distance Pricing Pilot Test

Copenhagen, Denmark, as part of the PRoGRESS Project consortium, recently completed a study to determine whether road user taxes are an effective means of changing the travel behavior of motorists. In other words, can road pricing motivate motorists to drive less and use other means of transport more? The study involved three different road-charging scenarios: multizone charges, a low per-kilometer charge, and a high per-kilometer charge. Approximately 500 households, divided into three trial periods (200 each in the first two trials, conducted between mid-2001 and mid-2002, and 100 in the final trial, conducted between late 2002 and mid-2003), participated in the study. During each trial, there was an initial control period during which base travel behavior was recorded. Subsequently, participants were given the opportunity to “earn” money by reducing their travel; specifically, they were paid an amount equal to the distance or zonal charges that would have applied to the foregone trips. To record and report mileage and zonal charges, each vehicle was equipped with an on-board unit incorporating GPS and cellular communication. The on-board unit included a display that alerted drivers to charges as they were accrued, thereby presenting the opportunity for users to gain familiarity with the concept and alter their behavior over time. On the whole, the study resulted in mixed findings. Many of the participants reported that they didn’t really understand the experiment, and thus made little effort to alter their travel patterns. Among those who did fully comprehend the financial consequences of the program, many did try to earn money by traveling less or using alternate modes of transportation. Regardless of the outcome, there are no present plans for a

TABLE 4 PRoGRESS Projects Overview

Pricing Scheme	Road Pricing Technology		
	DSRC	ANPR	GPS
Cordon (per trip)	Rome Helsinki	Bristol (trucks) Genoa Rome	Bristol (trucks)
Cordon (per day)		Edinburgh	
Multi-Zone (per trip)	Trondheim Helsinki		Copenhagen
Distance-based			Bristol (trucks) Copenhagen Gothenburg Helsinki

larger-scale implementation of the program because road pricing is not a priority of the current national government. As a result, regional and local governments have found it difficult to proceed with their own initiatives towards road pricing. For references, see PRoGRESS (2003, 2004).

Gothenburg (Sweden): Distance and Congestion Pricing Pilot Test

Gothenburg, Sweden, a member city in the PRoGRESS Project consortium, recently completed a trial study of distance-based user fees. Two distinct pricing scenarios were considered. The first studied the potential for reducing travel during congested periods through a distance-based congestion toll during specified hours along specified corridors. The second evaluated reductions in automobile travel and associated environmental effects in response to a base distance charge applied to all travel, regardless of time or location. The study included approximately 260 participants divided into five trial periods that were conducted from April 2002 through June 2003. During the first two weeks of each trial period, the base travel of each participant was recorded, leading to the establishment of an endowment account. For the following nine weeks, distance and congestion charges were deducted from the account. Any funds remaining in the account at the end of the trial were given to the participant. Thus, drivers had the opportunity to earn money by changing their travel behavior—either by driving less overall (in the case of base distance charges) or by altering the time or mode of their trips (in the case of congestion tolls). To record and report travel behavior, each participating vehicle was equipped with an on-board unit (essentially, a modified Palm Pilot) that incorporated a GPS receiver and GSM cellular communications. Drivers also could check the status of their accounts and determine charge information through the Internet. In addition to the Gothenburg study, the Swedish government also has begun a trial of cordon congestion tolls in Stockholm; future Swedish policy decisions on the subject of road pricing will likely depend on the collective findings of these two studies. For references, see PRoGRESS (2003, 2004).

Helsinki (Finland): Cordon and Distance Pricing Modeling Study

Helsinki, Finland, another member of the PRoGRESS Project consortium, has recently completed an extensive modeling exercise to estimate the potential of zone-based tolls and distance charges as a demand management tool. Thus far, the analysis has been entirely computer-based; no actual physical trials have been attempted. As part of this effort, the city also performed a stated preference survey and interviews with key stakeholders in order to evaluate both the acceptability of road pricing and the expected behavioral impacts. The study was conducted against the backdrop of a recently approved Helsinki Metropolitan Area Council transport strategy for the year 2020, the major goals of which are to develop denser patterns of land use, to improve options for transit, biking, and walking, to reduce levels of pollution, and to maintain (rather than improve) existing access conditions for automobiles and commercial traffic. Road pricing is viewed as a key tool in supporting many of these objectives. At present, the Council has not yet endorsed specific road pricing schemes for implementation, but instead is carefully watching the outcomes of many other trials from around Europe in order to determine the best strategies to implement in Helsinki. For references, see PRoGRESS (2003, 2004).

The Netherlands: Dutch "Mobimiles" Distance-Based User Fee Proposal

In 2001 the Dutch Ministry of Transport, Public Works, and Water Management introduced the "Mobimiles" plan—a proposal for distance-based road pricing that accounts for both vehicle weight and emissions class. As originally envisioned, the plan required the installation of "mobimeters," on-board units equipped with GPS receivers and cellular or short wave radio communications, on each Dutch vehicle to monitor and report applicable distance charges. The program involved joint public and private participation; the government would be responsible for developing standards for the mobimeter, setting toll rates, supervising the collection of tolls, and imposing sanctions for fraud and default, while the public sector would develop and install the devices and offer additional value-added services (e.g., way-finding, emergency alerts, stolen vehicle location, etc.). Though technically promising, and despite a fair degree of public support, the program was cancelled in 2002 after the May election of a new, more conservative government. For a more detailed review, see Appendix P. For references, see Crawford (2002), Dalbert (2002), and Imprint-Europe (2001).

Newcastle on Tyne (United Kingdom): Distance-Based Congestion Pricing Study

Researchers in the engineering department at Newcastle University recently completed a study of behavioral response to cordon-style and distance-based congestion charges that featured in-vehicle computers equipped with GPS receivers to monitor driving activity. More specifically, the test evaluated the price level required to induce drivers either (1) to divert from their primary commute route to a longer secondary or tertiary commute option or (2) to shift their morning departure time at least 30 minutes earlier or their afternoon return time at least 30 minutes later. The study included approximately 30 university staff members and lasted for two weeks. To simulate the financial incentives, individual participants were granted an initial endowment account against which congestion tolls were debited; participants kept any money remaining in the account at the conclusion of the test (because of participants switching to different routes or times of day). One interesting feature of the test was that the level of the toll for a given participant was allowed to increase from one day to the next (based on an algorithm stored in the on-board computer) until a participant was motivated to change his or her driving behavior. This allowed researchers to evaluate the ranges of values of time among different participants. For reference, see Thorpe and Hills (2003).

Cost Variabilization Studies (United States)

Atlanta (Georgia): Variable Cost Study at Georgia Institute of Technology

Supported by a grant from the Federal Highway Administration's Value Pricing Pilot Program, researchers at the Georgia Institute of Technology are studying driver response to various road use pricing schemes. The research design includes a technically advanced in-vehicle unit that features GPS, cellular communications, a Linux-based computer with ample memory and processing power, and connections to many of the vehicle's electronic systems. The first year of baseline travel data collection for 275 households and approximately 460 vehicles will be completed in November, and second-by-second location observations for around 800,000 individual trips already have been collected. Pending the award of follow-on funding, researchers plan to investigate the feasibility of distance-based user charges in place of the motor fuels tax as well as the per-mile pricing of currently fixed costs such as vehicle registration and insurance. The Georgia Institute of Technology researchers also plan to evaluate time- and distance-based congestion tolling schemes the following year. For a more detailed review, see Appendix Q. For references, see Guensler, Ogle et al. (2004); Guensler, Dunning et al. (2004); and Li, Guensler et al. (2004).

Minnesota: "PAYD" Variable Cost Study

The Minnesota Department of Transportation, with support from the Federal Highway Administration's Variable Pricing Pilot Program, is currently conducting a pilot test to measure behavioral responses to distance-based pricing for currently fixed costs such as registration fees, vehicle leasing fees, and insurance fees. The program is referred to as *Pay As You Drive* (PAYD). In the initial study proposal, the researchers intended to measure travel behavior based on in-vehicle GPS and cellular technologies. After revising the scope midway through, however, they instead decided to install a less expensive car chip technology that measures time, speed, and distance of travel but is unable to track location. The field trial began in the months of April and May of 2004, during which the car chips were installed in the vehicles of 130 participants and baseline travel behavior data were recorded. The pricing phase then began in June, when 100 of the participants were presented with the opportunity to earn money by reducing the number of miles driven in comparison to the baseline behavior (the remaining 30 participants continued to serve as a control group). The field test concluded in November, and a summary evaluation of the results was slated to have been completed in early 2005. For a more detailed review, see Appendix R. For references, see U.S. Department of Transportation Federal Highway Administration (2004).

Progressive Insurance: Variable Insurance Cost Study

Progressive Insurance is currently conducting a field trial involving 5,000 customers in Minnesota for an insurance program that would offer discounts to drivers based on their driving behavior. A small chip installed in each participant's vehicle and connected to various vehicle electronic systems measures driving patterns. Although the device does not track vehicle location (there is no GPS receiver on the chip), it does record a wide range of other factors, such as distance traveled, time of travel, speed of travel, rates of acceleration and deceleration, etc. When the chip is disconnected from the car and hooked up to a personal computer, the information is relayed to Progressive, who in turn offers discounts for safer driving habits (e.g., less miles traveled, lower average travel speeds, etc.). Progressive has indicated that it will not, on the other hand, use such information to raise rates. The current study follows on the heels of an earlier Progressive pilot test in Texas from 1998 to 2001 that used vehicle-mounted GPS units to evaluate the potential for distance- and location-based auto-insurance rates. Although the technology in the Texas test worked as planned, in the end the per-vehicle cost of acquiring and installing the equipment was considered prohibitive and the program was cancelled. In August of 2003, the United Kingdom's largest auto insurer, Norwich Union, announced a partnership agreement with Progressive to test a "pay as you drive" program involving 5,000 customers in the United Kingdom. Like the earlier Progressive trial in Texas, the United Kingdom study will also involve satellite tracking. For reference, see Fordahl (2004).

3

Policy and Pricing Issues

Road pricing can be configured in a variety of ways to address a wide range of policy goals. Therefore, researchers began by developing a taxonomy of the many policy and pricing issues gleaned from the case studies conducted in this research. Highlights include

- The general pricing applications pursued in each of the cases studied;
- The policy goals motivating the programs and proposals;
- The characteristics of travel subject to monitoring or pricing, or both; and
- The dedication of resulting revenues.

Following this, researchers synthesize the factors that appear to have contributed to the success or failure of the pricing schemes studied with respect to their stated policy goals. Given that many of the cases studied have yet to be implemented, included, where relevant, is evidence from other recent pricing efforts such as facility congestion tolls and cordon pricing schemes. In these assessments, the following were examined:

- A general description of the program or proposal,
- Success with respect to revenue goals,
- Success with respect to transportation management goals,
- Success with respect to environmental goals, and
- Unintended consequences.

GENERAL APPLICATIONS

Within the case studies reviewed, four distinct pricing and monitoring applications have been addressed: (1) distance-based fees (which may be modified based on vehicle-specific factors such as weight, number of axles, and emissions class), (2) congestion tolls (based on location and time of travel, usually layered on top of distance-based tolls), (3) variable cost applications (such as charging by-the-mile for normally fixed costs such as leasing fees, registration fees, or insurance), and (4) monitoring travel behavior (including speed, weight, and route enforcement, factors primarily relevant to the trucking industry). Table 5 provides an overview of the different applications pursued within each of the cases studied (note that cells with a value of "Opt" indicate that the application represents a potential future extension).

TABLE 5 Applications Overview

Case Study	Users	Distance Fee	Congestion Tolls	Variable Cost	Monitoring
Truck Tolls - International					
Australia	Trucks				X
Austria	Trucks	X			
Bristol	Trucks/cars	X	X		
Germany	Trucks	X			
Switzerland	Trucks	X			
United Kingdom	Trucks	X			
Distance Charges - US					
CWARUM	Trucks/cars	X	Opt		
Iowa	Trucks/cars	X	Opt		
Oregon	Cars	X	Opt		
Puget Sound	Cars		X		
Distance Charges - International					
ARMAS	Trucks/cars	X	Opt		
Copenhagen	Cars	X	X		
Gothenburg	Cars	X	X		
Helsinki	Cars	X	X		
Netherlands	Trucks/cars	X	Opt		
Newcastle on Tyne	Cars	X	X		
Variabilization - US					
Atlanta	Cars	X	X	X	
Minnesota	Cars			X	
Progressive Insurance	Cars			X	

POLICY GOALS

A wide array of policy goals influences the various approaches to pricing summarized in Table 4. Broadly, however, two families of goals motivate the programs and proposals examined: raising revenue and managing traffic. With respect to revenue, specific objectives include (1) preserving the existing revenue base against future erosion (e.g., protect against eroding fuels tax revenues), (2) capturing full user costs (which also may be viewed as achieving an equitable distribution of prices, which might either raise or lower individual user fees depending on circumstances), and (3) charging external (out-of-state or foreign) users. Goals related to managing traffic include (1) improving enforcement and compliance, (2) streamlining regulatory processes (e.g., automating toll collection), (3) reducing road wear, (4) improving safety, (5) optimizing use of capacity, (6) reducing demand (by reducing trips, changing trip times, or changing trip modes), and (7) reducing environmental impacts. These goals are in many cases complementary. For example, reducing peak demand may also reduce road wear and tear, improve safety, and reduce environmental externalities. Similarly, charging trucks more precisely for the costs that they impose on the road system could substantially reduce heavy truck travel on light duty roads, thereby significantly reducing road maintenance costs. Table 6 lists the explicitly stated policy goals for each of the cases studied here.

TABLE 6 Policy Goals

	Revenue			TSM / TDM						
Case Study	Preserve Revenue	Charge Full Costs	Charge External Users	Enforcement	Efficient Regulation	Reduce Road Wear	Improve Safety	Optimize Capacity	Reduce Demand	Improve Environment
Truck Tolls - International										
Australia				X	X	X	X			
Austria		X	X							
Bristol		X							X	
Germany		X								X
Switzerland			X						X	
United Kingdom		X	X							X
Distance Charges - US										
Iowa	X	X	X							
Oregon	X	X						X	X	
Puget Sound								X	X	
Distance Charges - International										
ARMAS		X					X		X	
Copenhagen									X	
Gothenburg									X	
Helsinki									X	
Netherlands									X	X
Newcastle on Tyne									X	
Variabilization - US										
Atlanta	X	X						X	X	
Minnesota		X							X	
Progressive Insurance		X							X	

PRICING AND MONITORING STRATEGIES

To achieve their stated goals, the programs and proposals studied here all involve charging for the use of a given facility (as in HOT lanes or bridge congestion tolls), charging for travel within a specified zone (as in cordon or zone congestion tolls), or charging for distance traveled. The applications most relevant to this research are distance-based: distance-based user fees, weight-distance truck tolls, and distance-based cost variabilization studies.

Beyond distance, however, many pricing strategies include additional criteria depending on the policy goals and the limits of the technology base. These additional factors are of three types: time of travel (which may be relevant to congestion pricing or enforcement activities), individual vehicle characteristics (including vehicle weight class, maximum laden weight, axle configuration, axle loads, and emissions class), and location of travel (including geographic sub-region, road class, and specific road segment). Table 7 provides an overview of the factors monitored or priced within each of the case studies for which information was available (note again that cells containing “Opt” represent optional future extensions).

TABLE 7 Travel Characteristics Monitored or Priced

	Time		Vehicle				Location		
Case Study	Congestion	Enforcement	Weight Class	Actual Weight	Axle Configuration	Emissions Class	Geographic Area	Road Class	Specific Road Link
Truck Tolls - International									
Australia		X	X	Opt				X	
Austria			X		X			X	
Bristol	X		X			X	X	X	
Germany					X	X		X	
Switzerland			X			X			
United Kingdom			X			X		X	
Distance Charges - US									
CWARUM	Opt							Opt	Opt
Iowa				Opt	Opt	Opt	X	X	Opt
Oregon	Opt					Opt	Opt		
Puget Sound	X								X
Distance Charges - International									
Copenhagen	X						X		
Gothenburg	X						X		
Helsinki	X						X		
Netherlands	Opt		X			X	Opt		
Newcastle on Tyne	X								X
Variabilization - US									
Atlanta	X								X

USE OF REVENUES

The political acceptability of new pricing schemes often hinges on the proposed distribution of revenues. Within the larger set of road pricing applications reviewed in the first phase of this research—facility congestion tolls, cordon congestion tolls, and distance-based user fees—four options have been vetted: (1) augmenting the general fund, (2) maintaining and improving the road network, (3) subsidizing alternate models of travel (e.g., transit or rail freight), and (4) returning the funds to various groups to offset equity concerns (e.g., offering credits to allow drivers who normally use the standard lanes to make periodic use of HOT lanes, as in the FAIR lanes proposal of DeCorla-Souza, 2001). The subset of case studies focused on here includes two of these—funding road system maintenance and improvements and subsidizing alternative modes of travel. Table 8 summarizes the actual or proposed revenue distribution policies for the cases when revenue distribution is discussed explicitly.

TABLE 8 Revenue Distribution

Case Study	Road Network	Subsidizing Alternatives	
		Transit	Rail
Truck Tolls - International			
Austria	X		
Bristol	X	X	
Germany	X		
Switzerland	X		X
United Kingdom	X		
Distance Charges - US			
Iowa	X		
Oregon	X		
Distance Charges - International			
ARMAS	X		
Netherlands	X		
Variabilization - US			

LESSONS AND OBSERVATIONS

Even though the road pricing programs and proposals examined here—facility congestion tolls, cordon tolls, and distance-based fees—are all either relatively new or still in the planning stages, and their effectiveness with respect to stated policy goals can be evaluated. First, make several general observations, and then focus on specific results related to revenue goals, traffic management goals, and environmental goals. Finally, there is discussion on several potential unintended consequences that have emerged from some of the cases studied.

General Observations

Coordinated Efforts

The implementation of novel road pricing strategies often is linked to complementary programs that support the same ends. For example, the London cordon congestion toll program's goal of reducing central city traffic congestion was explicitly linked to funding public transit improvements, expanding rideshare programs, enhancing pedestrian and cycling facilities, and coordinating parking policies (Short, 2004).

Clarity and Substance of Objectives

Road pricing can be designed to meet a wide variety of objectives, as enumerated above. However, the prospects for implementation appear to be correlated with the clarity as well as the substance of the goals. Notably, those projects that voters view as behavior manipulation tend to be voted down, whereas those that permit new and better options in exchange for payment tend to go forward. Given the sometimes-significant political constraints on new pricing schemes, stated objectives frequently address specific political concerns in addition to general welfare maximization goals. For example, the German weight-distance truck toll system excludes, per European Union directive, all vehicles with laden weights below twelve tons. As Short concludes, "Do not let the perfect be the enemy of the good" (2004, p. 3).

Revenue Effects

Facility Congestion Toll Projects May—or May Not—Pay for Themselves

In addition to meeting goals related to traffic management, congestion tolls can generate a moderate amount of revenue. In cases where existing lanes are converted to charged lanes, revenues may exceed costs by a fair amount. For example, the I-15 HOT lanes near San Diego, California, cost approximately $500,000 per year to operate and gross close to $1.2 million per year, with net revenues dedicated to enhancing public transit service along the corridor (Ward, 2001). Where new capacity must be constructed from scratch, in contrast, it appears difficult to cover the full cost of building and maintaining HOT lanes from toll revenues alone (R. Poole, personal communication, February 4, 2005).

Cordon Congestion Tolls Can Raise a Lot of Money

Whereas facility congestion tolls, and especially HOT lanes, tend to collect tolls from smaller groups of users, cordon tolls effect nearly all travelers living or working near a cordon area and thus have significant revenue-generating potential (even if that is not their primary aim). To illustrate, after the first six months of operation, officials for London’s cordon toll estimated that the project would net £68 million in first year and between £80 million and £100 million in subsequent years (Transport for London, 2003).

Distance-Pricing Schemes Can Be Cost-Effective

Even with a relatively expensive technology base that includes on-board GPS equipment, the annual cost (including capital and operations) of the Swiss truck toll program is approximately €40 million per year, which represents just 8 percent of gross revenues. With planned fee increases in the coming years, the cost percentage will drop to just 5 to 6 percent of gross revenues (Balmer, 2004).

Traffic Management Effects

Traffic Effects Depend on the Structure of the Program

Road pricing strategies can have significant but varying influences on the transportation system. Depending on their design, pricing programs can have minor to significant effects on road system performance, vehicle occupancy rates, time of travel, and use of other modes (Ward, 2001).

Results Are Context-Specific

In Lee County, Florida, which has a rudimentary cordon-pricing scheme in which bridge tolls are reduced during shoulder hours before and after peak periods, approximately 300 vehicle trips per day have shifted from the peak to the shoulder periods. In contrast, after HOT lanes were introduced on the Katy Freeway in Texas and on SR-91 in California, vehicle trips shifted from the shoulder to the peak periods in response to increased capacity and reduced congestion brought about by the HOT lanes (Ward, 2001).

Cordon Tolls Can Alter Peak Period Travel Dramatically

During its first six months of operation, the London congestion toll program has eliminated approximately 60,000 vehicle trips per day in the city center. Officials have estimated that between 50 to 60 percent of this reduction is because of a mode shift to public transit, 20 to 30 percent is because of traffic diversions around the toll zone, and 15 to 25 percent is because of shifts to carpools, motorcycles, or bicycles, to traveling outside of the peak, priced hours, or to making fewer trips to the city (Transport for London, 2003).

Congestion Tolls Can Reduce Congestion Significantly

Both facility and cordon congestion tolls can lead to significant travel time improvements, for users and nonusers alike. To illustrate, the SR- 91 HOT lanes in Southern California save users approximately 12 to 13 minutes per trip on normal traffic days (Ward, 2001). Similarly, the London cordon toll has reduced traffic delays within the cordon zone by about 30 percent, reduced journey times to and from the zone by approximately 14 percent, and increased trip time reliability by about 30 percent (Transport for London, 2003). Such dramatic benefits can obviously spill over to nondrivers as well. For example, the decrease in congestion in the London cordon zone has reduced bus delays by about one third (Transport for London, 2003).

Distance-Based Fees Can Also Dramatically Alter Travel Demand

Distance-based user fees also can alter travel demand, even absent congestion pricing. For example, the heavy goods vehicle fees in Switzerland were set deliberately to discourage truck traffic and induce a freight mode shift to rail. In the three years since the inauguration of the toll, the number of truck trips traveling through Switzerland, which had been growing at an annual rate of 7 percent, decreased by about 4 percent in 2001, by another 3 percent in 2002, and has remained stable since. However, the anticipated growth in rail freight traffic has not materialized. Instead, the principal effects appear to have been because of changes in truck configuration and delivery logistics. Specifically, larger trucks are chaining more pick-ups and deliveries together. These unintended effects are likely because of inherent logistical advantages of trucks for many shipment types and delays in rail freight improvements, such as a proposed streamlining of transnational shipping logistics (Balmer, 2004).

Environmental Effects

Environmental Effects of Congestion Tolls Vary

The environmental effects of congestion tolls depend on the design of the toll. For HOT lanes, such as I-15 near San Diego, California, a primary objective was to optimize the use of a congested freeway by reducing delay and increasing the throughput of vehicles. Ward (2001) notes that increased traffic volumes may lead to an increase in I-15 corridor emissions, though this remains an open, testable question. In contrast, cordon congestion tolls tend to reduce delay and traffic volumes, making the emissions benefits far less speculative. As noted earlier, the London congestion toll reduced daily vehicle trips in the city center by 60,000, with most of these trips shifting to public transit and carpooling (Transport for London, 2003).

Emissions Incentives Can Yield Dramatic Results

To encourage emissions reductions, most of the European truck toll programs (e.g., Switzerland, Germany, and the United Kingdom) have incorporated considerable fee offsets based on the emissions class of the vehicle. In Switzerland, current estimates developed by forecasting models suggest this type of price signal will lead to a 30 percent reduction in the emissions of NO_2 and CO_2 in coming years (Balmer, 2004).

Unintended Consequences

Effects on Businesses Vary

Business interests seldom initiate innovative road pricing schemes. This is likely because of the uncertain effects of new road pricing regimes on trade and commerce. Given that so many of the programs discussed here are relatively new or still in development, the magnitude and distribution of effects on businesses remain uncertain.

Generally speaking, congestion tolls on individual facilities intended to improve traffic flows are viewed by most analysts as being of net benefit to businesses, especially for those firms dependant on time-sensitive movements of goods and labor. Though, as with emissions, this remains a situation-specific, testable question.

Cordon tolls, on the other hand, which typically reduce vehicle trips in congested areas, often are viewed with skepticism by inner city retailers. Such concerns have been raised frequently, such as in London (Transport for London, 2003), Edinburgh, and Rome (PRoGRESS, 2004). Whether reduced vehicle trips and reduced congestion are good or bad for retailers is unclear and likely varies from block to block. In the first year of the London congestion toll, inner city retailers reported a 7 percent drop in economic activity from the previous year, though the implementation of central city congestion tolling was coincident with extensive London Underground subway closures for maintenance and repair work. Given the reported shifts in central city person travel in London to public transit following the implementation of cordon tolls, it's likely that retail activity shifted to shops adjacent to transit stops and stations, creating winners and losers in the process. In a contrast, the City of Durham, well north of London in the United Kingdom, instituted a congestion charge of £2 for vehicle travel along the main commercial row, the revenues of which were used to subsidize bus transit service to and from outlying areas. Although vehicle traffic along the row decreased by 85 percent after the institution of the charge, both pedestrian and retail activity along the row increased (Short, 2004).

If the Entire Road Network Is Not Priced, Traffic Diversion Is Likely

Per EU directive, the tolls in both Austria and Germany charge trucks for travel on highways, but not on smaller surface streets. Forecasts of the effects of this policy suggested that significant levels of truck traffic would divert from highways to parallel streets and roads. Truck tolls were implemented a few months ago in Austria, and preliminary analyses suggest that truck traffic is being diverted onto streets and roads (Rothengatter, 2004). In contrast, truck tolls are applied to the entire Swiss road network and, as one would expect, no diversions from highways have been observed (Balmer, 2004). Like Switzerland, the proposed U.K. truck tolling system will apply to the entire road system, and forecasts project no route diversions of truck traffic (Worsley, 2004).

Hastily Conceived Standards and Thresholds Can Produce Individually Rational But Undesired Responses

In Germany, the planned lower weight limit for pricing truck tolls is 12 tons. In response, several truck manufacturers are planning to introduce 11.9-ton models to circumvent charges (Rothengatter, 2004). In contrast, in Switzerland, the lower limit on vehicles subject to truck tolls is 3.5 tons (the size of large U.S.-style SUVs) and no plans for new, small 3.4-ton trucks are in the works (Balmer, 2004).

4

Technology Issues

This section begins with a brief overview of the various tasks associated with the implementation of road pricing strategies identified in the literature, as well as the technologies that are commonly used to address those tasks. The focus is on weight-distance truck tolls and general-purpose distance-based user fees, because they are more technically challenging than facility- or cordon-based congestion tolls. Next, this section identifies the specific technologies used within the case studies reviewed, focusing in particular on

- Methods for measuring distance traveled,
- Methods for communicating billing data,
- Methods for maintaining privacy, and
- Methods for enforcement.

After discussing the technologies used in the various case studies, observations on the utility of different technological approaches are offered.

WIDE RANGE OF TASKS AND TECHNOLOGIES

In designing a road pricing system, there are numerous tasks that must be addressed. Depending on the exact specifications of the program, these tasks may include

- Detecting entry to, exit from, or presence within a geographic area;
- Detecting entry to, exit from, or presence along a specified road link;
- Determining location on the road network;
- Determining time of travel;
- Determining distance of travel;
- Identifying vehicle specific information, such as vehicle identification, vehicle class, vehicle weight, or vehicle configuration;
- Recording travel data and calculating charges owed;
- Communicating travel data or billing data; and
- Issuing bills and collecting payment.

To accomplish these tasks, the most commonly employed technologies include the following.

- **On-Board Unit**: The on-board unit is a computer module (of varying complexity, depending on the scheme) that provides memory storage, computational power, and a framework for integrating other necessary on-board technologies such as GPS, cellular communications, or DSRC. The on-board unit typically is used to record usage data and calculate charges owed. It also may store vehicle-specific information such as unique identification, vehicle class, vehicle weight, or vehicle configuration.

- **DSRC (Dedicated Short-Range Communications)**: Relying on short-range microwave communications between vehicles and roadside receivers and transponders, DSRC is used commonly to determine when vehicles enter or exit specific road segments or geographic areas. DSRC also may be used to assist in enforcement, for instance by verifying that a passing vehicle has a functioning on-board unit that is registering charges owed or by communicating travel data or billing data.
- **GSM (Global System for Mobile communications)**: As an alternative to DSRC, GSM (essentially, satellite based cellular communications) also may be used to communicate travel data or billing data. Although typically more costly than DSRC, GSM does not require the installation of roadside communications devices, and furthermore it permits real time communications (which may be particularly useful, for example, in value-added features such as route guidance and emergency distress signals). With DSRC, in contrast, communications are only possible when a vehicle happens to be passing by a roadside receiver.
- **Chip Cards**: A chip card is a small, credit card-sized device with an embedded computer chip or memory module. The most common use of chip cards within road pricing applications is to store and transfer billing data from the on-board unit to a card reader that can relay the information to the collections agency. For example, card readers might be set up at fueling stations, or alternatively they could be attached to a home computer with Internet access.
- **GPS**: GPS is a satellite-based system, devised by the U.S. military, for determining latitude and longitude on the surface of the earth. GPS receivers (integrated with the on-board unit) can be used to determine location within the road network, speed of travel, time of travel, and distance of travel. It is worth noting that in 2008, the European Union intends to launch a similar satellite-based positioning system called Galileo, which ultimately may be used within the various European projects. For the sake of simplicity, however, the term GPS is used generically to refer to any satellite-based location technology.
- **GIS**: In order to translate latitude and longitude data into a position on the road network, it is necessary to rely on a digital road network map, stored and accessed via GIS. Any road pricing strategy that relies on GPS, therefore, must include GIS functionality and suitable maps as well. Typically these will be stored within the on-board unit, though it also would be possible for a vehicle to transmit raw latitude and longitude data directly to the billing center, which could then use GIS maps to determine the travel history and in turn the amount of the fee owed.
- **Odometer**: The odometer (or in the case of trucks the tachograph, which includes a link to the odometer) can be used to measure distance traveled. This may serve as a backup to GPS, in cases where the signal goes down, or it may be the sole or primary means for recording distance.
- **Dead-Reckoning**: Dead-reckoning, usually based on mechanical devices such as gyroscopes, is a technique for tracking the location of traveling vehicles (given a known starting point). Though prone to accumulated error over time, it may be used as a suitable backup to GPS during short intervals when the signal is lost.
- **Automated Number Plate Recognition (ANPR)**: ANPR uses digital photography and optical character recognition (OCR) algorithms to identify vehicles that pass by a particular location. This technology is most commonly used for enforcement purposes in facility and cordon toll schemes (as, for example, in London; see Transport for London, 2003), but it has been at least considered for distance-based schemes as well.

- **Internet and On-Line Billing**: These technologies often are used to automate the billing and collections process.

METHODS OF MEASURING DISTANCE TRAVELED

Based on the technologies discussed above, there have been a variety of schemes devised to measure distance traveled in order to determine the appropriate fee. Specific examples include

- Measuring distance traveled based solely on odometer reading, as in the Minnesota variable pricing study and inthe Progressive Insurance variable pricing study (K. Buckeye, personal communication, September 13, 2004; Fordahl, 2004);
- Using DSRC to measure distance traveled on specific links in the road network, as in the Austrian truck toll (Schwarz-Herda, 2004);
- Using DSRC or GPS, or both, to determine entry to and exit from a geographic region, then using the odometer to measure travel within the region, as in the Swiss truck toll or the Oregon mileage-charge (Balmer, 2004; J. Whitty, personal communication, August 18, 2004);
- Using GPS to determine road types and distance traveled, with the odometer as a backup for distance traveled, as in the proposed United Kingdom truck toll (Worsley, 2004)
- Using GPS to determine road types and distance traveled, with the odometer as a backup for distance traveled and dead-reckoning as a backup for location (and hence road type and jurisdiction) of travel, as in the proposal developed at the University of Iowa (Forkenbrock and Kuhl, 2002)

Table 9 indicates the specific technologies used to measure distance traveled in each of the different case studies considered.

METHODS OF COMMUNICATING TRAVEL AND BILLING DATA

Within the case studies reviewed, three distinct technologies for communicating travel behavior and billing data to the central processing center have been proposed. These include GSM (cellular), DSRC, and chip cards. Table 10 provides an overview of these technology options. Note that in the case of the Netherlands Mobimiles proposal, the “?” entries indicates the technologies that were still under consideration at the time that the project was shelved.

METHODS OF MAINTAINING PRIVACY

In the case studies reviewed here, privacy has not been raised as a concern for truck tolls. For general-purpose distance-based pricing programs, in contrast, privacy in most cases has been raised as a significant concern. To address the privacy concerns, two approaches typically have been proposed. The first is to perform all travel analysis and fee calculations on the on-board unit

TABLE 9 Measuring Distance Traveled

Case Study	Odometer	GPS	Dead Reckoning	DSRC
Truck Tolls - International				
Australia		X		
Austria				X
Bristol		X		
Germany		X		
Switzerland	X	X		X
United Kingdom	X	X		
Distance Charges - US				
CWARUM		X		
Iowa	X	X	X	
Oregon	X	X		
Puget Sound		X		
Distance Charges - International				
ARMAS		X		
Copenhagen		X		
Gothenburg		X		
Netherlands		X		
Newcastle on Tyne		X		
Variabilization - US				
Atlanta	X	X		
Minnesota	X			
Progressive Insurance	X			

TABLE 10 Communications Technologies

Case Study	GSM	DSRC	Chip Card
Truck Tolls - International			
Australia		X	
Austria		X	
Bristol	X		
Germany	X		
Switzerland		X	
United Kingdom	X		
Distance Charges - US			
CWARUM	X		
Iowa			X
Oregon		X	
Puget Sound	X		
Distance Charges - International			
ARMAS	X		
Copenhagen	X		
Gothenburg	X		
Netherlands	?	?	
Newcastle on Tyne			X
Variabilization - US			
Atlanta	X		
Minnesota			X
Progressive Insurance			X

and then communicate only aggregate data, such as the total bill owed. The second is to transfer raw travel data to a central data analysis agency, which is under legal or contractual obligation to keep the data confidential.

It should be noted that many of the research-oriented trials reviewed have opted for the latter approach, which facilitates a detailed analysis of traveler responses to various price signals. In such cases, however, the confidentiality of test participants' data usually is protected under some type of privacy agreement that allows the researchers to use the data in the course of their investigations and prohibits the researchers from sharing the raw data with third parties.

Table 11 indicates the privacy strategy that has been adopted or advocated in each of the case studies reviewed.

METHODS OF ENFORCEMENT

With any system that attempts to monitor road usage over wide areas and across the entire road network, enforcement is a major issue. In particular, the monitoring equipment must remain operational (specifically, that it is both active and functioning properly) at all times while vehicles are operating within the charged area (PRoGRESS, 2004).

Although there have been numerous strategies proposed to prevent toll evasion, they can generally be grouped into two categories: (1) designing the on-board unit in such a manner as to prevent tampering or disabling and (2) observing the vehicle from fixed or mobile check points to ensure that charges are being recorded. The two are not mutually exclusive, however, and can be employed in parallel for the sake of redundancy.

TABLE 11 Privacy Strategies

Case Study	Non-Issue	OBU	Privacy Agreement	
			Study	3rd Party
Truck Tolls - International				
Australia	X			
Austria	X			
Bristol			X	
Germany	X			
Switzerland	X			
United Kingdom	X			
Distance Charges - US				
CWARUM				X
Iowa		X		
Oregon		X		
Puget Sound			X	
Distance Charges - International				
Copenhagen			X	
Gothenburg			X	
Netherlands		X		
Newcastle on Tyne			X	
Variabilization - US				
Atlanta			X	
Minnesota			X	
Progressive Insurance			X	

NOTE: OBU = on-board unit

Strategies proposed to prevent tampering with the on-board unit include the following:

- Disabling the engine unless the on-board unit also is activated;
- Ensuring that the components of the on-board unit can be accessed only by certified professionals; and
- Checking the on-board unit's distance monitoring records against the odometer reading each time the unit is turned on, and flagging any discrepancies.

Strategies for observing the vehicle from fixed or mobile checkpoints, in turn, can be based on either DSRC or ANPR:

- DSRC can be used to transmit queries to passing vehicles to ensure that their on-board units are in fact operating as intended.
- ANPR can identify vehicles that have passed a given check point; this information can later be crossed-referenced against billing records to ensure all identified vehicles did in fact pay the corresponding tolls.

Table 12 provides an overview of the approaches used in the various case studies. Note that many of the research-oriented pilot tests did not address the issue of enforcement and as such do not appear in the table.

LESSONS AND OBSERVATIONS

Applications of ANPR

From the standpoint of distance-based charging schemes, ANPR is of limited use.

TABLE 12 Enforcement Strategies

Case Study	OBU	DSRC	ANPR
Truck Tolls - Intl			
Australia		X	
Austria		X	
Bristol (UK)			X
Germany	X		
Switzerland		X	
UK	X		
Distance Charges - US			
CWARUM			
Iowa	X		
Oregon	X		
Puget Sound			
Distance Charges - Intl			
Netherlands	X	X	
Variabilization - US			

ANPR Is Better Suited to Enforcement for Facility or Cordon Tolls

ANPR can be used to identify vehicles that have passed a specific point, and this information can be used subsequently to verify that all such vehicles have paid the toll owed. This approach is used, for example, in the London cordon toll (Transport for London, 2003) and for enforcement on the SR-91 HOT lanes near Los Angeles. On the other hand, ANPR cannot determine whether a vehicle's on-board unit is operational and thus is of limited applicability for true distance-based charging schemes.

ANPR Is Not Highly Accurate

It is perhaps fortunate that ANPR has limited relevance to distance-based pricing schemes, given reported problems related to accuracy. For example, the PRoGRESS demonstration trials in Genoa and Rome, each of which involved the use of ANPR, reported nonrecognition rates (i.e., the software failed to resolve the license plate number) of 7 percent and 15 percent, respectively. On the other hand, ANPR has been used successfully in many toll road projects—such as Highway 407 in Toronto, the Melbourne CityLink in Australia, and the Cross-Israel Highway—and accuracy does not appear to be a major problem in these cases (R. Poole, personal communication, February 4, 2005).

Applications of DSRC

In contrast to ANPR, DSRC can be quite useful for distance charging schemes:

DSRC Has Many Potential Applications

DSRC can be used to measure distance traveled across a limited road network equipped with gantries or road-side beacons, as in the case of the Austrian truck toll (Schwarz-Herda, 2004); to toggle the status of the on-board unit between on and off when entering or leaving a charging area, as in the case of the Swiss truck toll (Balmer, 2004); to verify that an on-board unit is functioning as required, as in the case of the Dutch Mobimiles proposal (Imprint-Europe, 2001); or to communicate billing data, as in the case of the Oregon distance-based user fee strategy (J. Whitty, personal communication, August 18, 2004).

DSRC Is Proven Technology

To date, DSRC has been used successfully in facility tolls such as the I-15 HOT lanes (Supernak et al., 2002), in cordon tolls such as Singapore (Phang and Toh, 2003), and in weight-distance truck tolls such as Austria and Switzerland (Schwarz-Herda, 2004; Balmer, 2004). Furthermore, it is relatively standardized, opening the door to interoperability among adjacent systems (PRoGRESS, 2004).

Applications of GSM

GSM holds great promise as a communications technology for distance-based pricing programs, but there are some caveats:

GSM Opens New Communications Options

With DSRC, communications can occur only when the vehicle is within a short distance of a receiver or transponder. With chip cards, in turn, communications can take place only when the user manually removes the card from the on-board unit and inserts it into a card reader. With GSM, in contrast, communications can occur at any time from any location on the road network. This opens up new options for value-added features such as real-time routing and emergency distress signals.

GSM Is More Expensive

With GSM it is necessary to pay for air time, which can add to the expense of operating a system that relies on GSM for communications.

GSM Raises Privacy Issues

In contrast to chip cards and DSRC, GSM communications are transmitted over much longer distances, and thus the data transmitted may be more susceptible to unauthorized interception.

GSM Poses Integration Challenges

To date, GSM has been used successfully in demonstration projects, such as the PRoGRESS projects in Gothenburg and Copenhagen (PRoGRESS, 2003) and the Atlanta cost variabilization study (R. Guensler, personal communication, September 14, 2004). It also has been used successfully in the German weight-distance truck toll, but this project was beset by significant technical integration challenges at least partially related to the use of GSM (Rothengatter, 2004) that delayed the implementation for more than a year.

Applications of Chip Cards

Chip cards appear to be a relatively robust option for communicating data. The technology is well established and quite inexpensive. Perhaps the only disadvantage is that it requires manual intervention on the part of the user, who periodically must remove the card and insert it into a card reader in order to transmit billing data. On the other hand, some users may favor this, in that it gives them some control over how and when their data is transmitted.

Applications of GPS

GPS is essential to virtually any area-wide road-pricing scheme that must distinguish between different charging zones (or between areas subject to charge and areas not subject to charge) or that distinguishes between different road types. In fact, of the case studies evaluated here, only four did not rely on GPS: the Minnesota Department of Transportation variable pricing study and the Progressive Insurance variable pricing study, neither of which distinguished between charging zones and charge free zones (R. Guensler, personal communication, September 14, 2004; K. Buckeye, personal communication, September 13, 2004); the Austrian truck toll, which applies only to highways (Schwarz-Herda, 2004); and the Helsinki modeling study, which was strictly computer based (PRoGRESS, 2003).

Given the clear importance of GPS in road pricing schemes, it is appropriate to evaluate both current capabilities as well as potential weaknesses.

Generally GPS Systems Work

GPS already is employed in the Swiss truck tolling program (Balmer, 2004), and it has been demonstrated successfully in the PRoGRESS test cases in Bristol, Copenhagen, and Gothenburg (PRoGRESS, 2004); in the research trial in Newcastle on Tyne (Thorpe and Hills, 2003); in the Atlanta variable pricing study (R. Guensler, personal communication, September 14, 2004); in the Puget Sound congestion toll study (M. Kitchen, personal communication, August 18, 2004); and in the Oregon mileage-based user fee pilot (J. Whitty, personal communication, August 18, 2004).

GPS Can Be Applied at Various Resolutions

At the broadest level, GPS can be used to measure whether a vehicle is within or without a given geographic region, as in the Swiss truck toll (Balmer, 2004) or in the Oregon pilot study (J. Whitty, personal communication, August 18, 2004). At the intermediate level, it can be used to identify whether a vehicle is on a specific link (or, by extension, on a particular class of road), such as in the German truck toll (Rothengatter, 2004), the Puget Sound study (M. Kitchen, personal communication, August 18, 2004), or the Bristol project (PRoGRESS, 2003). Finally, at the finest grain level, GPS potentially can be used to detect the presence of vehicles within specific lanes on a given road (for example, to implement HOT lane pricing), though this type of application has yet to be proposed, primarily given accuracy limitations (as discussed below).

The Effectiveness of GPS Depends on the Level of Required Accuracy

The degree to which GPS yields accurate measurements is related to the scale of the data being represented. If the goal is to determine merely whether the vehicle is in one charging zone (e.g., a state) or another, current applications of GIS are easily adequate. If the goal is to discern one road from another, as in truck tolls, accuracy is a much larger issue. For example, to distinguish between a freeway and a parallel frontage road, accurate position measurements to within roughly 20 meters are required. With differential correction, GPS can typically measure location to within one or two meters, which is quite sufficient to meet the task. Unfortunately, to correctly match a geographic position to a segment of the road network, it is also necessary to have accurate digital road network maps, and this is where the problem lies.

Researchers at the University of Minnesota (Nelson, 2003) have demonstrated that most commercially available digital road maps fail to provide 40 meter accuracy with consistency, and this makes it difficult to distinguish between closely situated parallel roads. The implication is that in any program that seeks to differentiate pricing based on road segment or road class, great care (and possibly great expense) must be devoted to constructing sufficiently accurate road network maps.

GPS Does Not Always Work Properly and Thus Should Be Supplemented

GPS can suffer a variety of problems, including loss of battery power (PRoGRESS, 2004) and intermittent loss of signal due to tall buildings, tunnels, or the roof of the car (J. Whitty, personal communication, August 18, 2004). It is therefore appropriate to build in some type of backup strategies for measuring distance and location during times when the GPS is not available. In particular, the odometer can be used as a backup for measuring distance traveled (J. Whitty, personal communication, August 18, 2004), while dead-reckoning can be used to track (at least roughly) position on the road network between GPS signals (Forkenbrock and Kuhl, 2002).

General Technology Lessons

The Simpler, The Better

The probability that a system is delivered on time and within budget appears to be inversely related to its technological complexity. The use of tried-and-true solutions was considered integral, for example, to the success of the Swiss truck toll (Balmer, 2004) and Austrian truck toll (Schwarz-Herda, 2004) programs, each of which relies primarily on standard DSRC communications to register vehicles as they pass specified points (Balmer, 2004).

Most Simple Systems Can Be Upgraded Later

It is nearly always possible to start with a very basic level of technology and then upgrade to a more complex system later (Short, 2004). For example, congestion pricing in Singapore (Phang and Toh, 2003) began with a manually implemented cordon toll in 1975, which was later upgraded to the world’s first electronic cordon pricing scheme in 1998. Such an upgrade strategy may apply to distance-based pricing programs as well. For instance, it may be possible to begin by pricing all roads equally (excluding, of course, pre-existing toll roads with legally enforceable bond covenants)—requiring a coarser grain of GPS accuracy—and then add price gradations based on road type at a later date.

Greater Complexity Increases the Potential for Technical Difficulties

In contrast to the parsimonious Swiss and Austrian programs, the German truck toll project was more ambitious, seeking to integrate GPS and GSM on the on-board unit. Unfortunately, technical difficulties, on the hardware and software fronts, were encountered during the development phase, and this has led to a budget overrun in excess of $875 million and delayed implementation by more than a year. The German experience is not isolated; similar technical difficulties were encountered during the field trial projects in Copenhagen and Gothenburg, each of which also incorporated both GSM and GPS (PRoGRESS, 2003).

Fallback Plans Facilitate Implementation

In Germany, the prior vignette toll system was discontinued as of fall 2003 in anticipation of the launch of the Toll Collect system. Because of the technical difficulties, however, the implementation of Toll Collect was delayed until January 2005. This delay, in the absence of backup plan, left Germany with no trucking road revenues for more than a year (Rothengatter, 2004).

Standardization Has Yet to Be Achieved

Three European nations have developed (or are nearing completion, in the case of Germany) automated distance-based truck tolling programs, and each has used a different technology base (Short, 2004). To facilitate future interoperability between adjacent jurisdictions, some effort is needed to develop common standards. It is likely, however, that a movement toward standards will occur only after the different approaches have been in operation for some time, and their relative advantages and disadvantages have become more apparent.

5

Institutional Governance Issues

This section addresses the issue of governance and focuses on two key distinctions in program structure: (1) single versus multi-jurisdiction programs and (2) the respective roles of public and private entities within the scheme. With regard to the issue of public and private interactions, three questions are considered:

- Who oversees the program (public versus private)?
- Who administers the program (public versus private)?
- Who provides the technology (sole provider versus market competition)?

After introducing these issues and categorizing the various case studies by governance structure, some conclusions are offered on the relative advantages of alternate structures of governance and administration.

SINGLE VERSUS MULTIJURISDICTIONAL PROGRAMS

Road pricing policies and programs function in both single and multijurisdictional settings. Multijurisdictional programs can apply to peer-level jurisdictions (such as multiple adjacent states or countries) or to hierarchically ordered jurisdictions (such as counties within a single state). From an implementation standpoint, the differences between single-jurisdiction and multijurisdiction systems do not appear to be significant, though incorporating more than one jurisdiction does add several complicating factors. Multijurisdictional systems typically record the charges owed to each jurisdiction separately and establish an independent agency that collects charges from each user by jurisdiction and then appropriates revenues to the member jurisdictions according to some agreed-upon formula.

Table 13 shows, where such information was available, the breakdown of jurisdictional structure among the cases studied.

PUBLIC AND PRIVATE ROLES

A major governance issue for most of the programs studied was the relative roles of public agencies and private companies. Here, researchers draw three distinctions: (1) who oversees the program, (2) who administers the program, and (3) who supplies the technologies (usually either a sole private provider or competitively procured system of multiple private providers).

The question—who oversees the program (i.e., who initiates it and is ultimately responsible for its implementation and management)—depends entirely on the type of pricing application in question. Most notably, pricing applications designed to raise road revenues or to influence demand, such as distance-based road user fees or congestion tolls, fall squarely within the public realm (with the exception of toll road projects carried out by private firms under long-term franchise or concession arrangements). In contrast, some of the programs that seek to

TABLE 13 Single- versus Multiple-Jurisdiction Applications

Case Study	Single Jurisdiction	Multi-Jurisdictional
Truck Tolls - International		
Australia		X
Austria	X	
Bristol		X
Germany	X	
Switzerland	X	
United Kingdom	X	
Distance Charges - US		
CWARUM		X
Iowa		X
Oregon	X	
Puget Sound	X	
Distance Charges - International		
ARMAS		X
Copenhagen	X	
Gothenburg	X	
Helsinki	X	
Netherlands	X	
Newcastle on Tyne	X	
Variabilization - US		
Minnesota	X	

"variabilize" formerly fixed costs associated with automobile ownership and usage, such as distance-based leasing fees or insurance, lie within the private realm.

The next question—who administers the program—usually centers on questions of ease and efficiency. In certain cases, the public agency in charge of a pricing program chooses to directly perform most administrative duties (e.g., overseeing implementation, issuing bills, and collecting and distributing revenue); this usually occurs when the agency already is equipped with the necessary personnel and infrastructure for such roles. In other cases, the government organization procures such services from private service providers.

The final question—who provides the technology—depends largely on the incentives used to spur development by system integration firms. In certain cases, the agency in charge chooses to contract with a single firm (or a single consortium of firms) to provide a technology solution that meets all specified requirements. The primary advantage in this case is that the firm or consortium selected is obliged contractually to deliver. In other cases, however, the agency in charge simply provides a set of specifications to be met and then allows multiple firms to develop solutions and compete for business with one another on the basis of price as well as value-added features. For example, a device intended to record travel throughout the road network could include optional user features such as dynamic routing or emergency roadside assistance distress calls.

Table 14 lists the actual or intended governance structure for each of the case studies reviewed, distinguishing between the roles of oversight, administration, and technology provision.

TABLE 14 Structure of Governance

Case Study	Oversight		Administration		Technology	
	Public	Private	Public	Private	Sole Provider	Free Market
Truck Tolls - International						
Australia	X			X		X
Austria	X			X	X	
Bristol	X		X		X	
Germany	X			X	X	
Switzerland	X		X		X	
United Kingdom	X		X		X	
Distance Charges - US						
CWARUM	X			X		X
Iowa	X			X	X	
Oregon	X		X		X	
Puget Sound	X		X			
Distance Charges - International						
ARMAS	X					
Copenhagen	X					
Gothenburg	X					
Helsinki	X					
Netherlands	X			X		X
Newcastle on Tyne	X					
Variabilization - US						
Atlanta	X	X	X	X		
Minnesota	X	X	X	X		
Progressive Insurance		X		X		

LESSONS AND OBSERVATIONS

Single versus Multijurisdictional Programs

The review of the case studies suggests, not surprisingly, that single jurisdiction programs are marginally easier to establish than multiple jurisdiction programs. On the other hand, it is possible, or even likely, that the flexibility to handle multiple jurisdictions will be desired at some point in the future for many of the initially single-jurisdiction programs. For example, the distance-based pricing proposal in Oregon (Whitty, 2003) might begin with just a single jurisdiction (the state of Oregon) with a single toll rate based on miles traveled. In the future, however, the system might be extended to include multiple jurisdictions with pricing for similar mileage tolls in adjacent states or congestion charges within urban areas.

Public versus Private Administration

Public agencies equipped to administer pricing programs often choose to do so. The Swiss heavy goods vehicle fee, for example, is administered by the Swiss Customs Agency (Balmer, 2004), an organization already involved in the collection of fees on freight shipments.

Private contract management is more common among multiple-jurisdiction programs. For example, the proposed Australian truck monitoring program (Koniditsiotis, 2003) and the multi-state road-pricing proposal developed at the University of Iowa (Forkenbrock and Kuhl, 2002) both call for private contract administration. Private program administration can take advantage of companies with this expertise, realize gains in efficiency (PRoGRESS, 2004), mobilize capital and recruit operators quickly (Short, 2004), and more easily assuage privacy concerns (if members of the public are more willing to trust a private firm under contractual obligations to hold data in confidence; Malick, 1998).

Sole Technology Provider versus Market Competition

There is no consensus on the best approach to procure the pricing technologies. Selecting a sole provider eliminates the need to provide incentives for multiple companies to participate, and the sole provider chosen is contractually obligated to deliver. Further, the contracting agency is guaranteed to get what it pays for, although the technical delays that have beset the German truck tolling program make it clear that contracts cannot guarantee that the delivery will occur in the specified timeframe (Rothengatter, 2004).

Free market provision, on the other hand, can spur innovation among private competitors and drive down prices (Malick, 1998). In addition, profits from value-added services can help defray development costs. The risk to this approach is that absent sufficient incentives a sufficient number of firms may not enter the market.

Our scan of various program proposals suggests that for pricing systems in which participation is or would be mandatory (such as most of the truck tolling programs as well as the distance-based user fee proposals), there is a tendency to go with the single provider to ensure that the required technology is in fact delivered. Where participation is strictly optional (such as in the Australian truck monitoring program), on the other hand, the free market approach is more often favored as a way to reduce implementation costs and encourage more widespread adoption through the provision of value-added services.

6

Implementation Issues

This section touches briefly on two questions related to system implementation. First, is the proposed system mandatory or optional? Second, for mandatory participation, what is the proposed rollout strategy—one-time conversion or phased-in conversion?

PARTICIPATION REQUIREMENTS AND ROLLOUT APPROACH

In systems that aim to generate transportation revenues from user fees, participation is generally mandatory. This includes general-purpose distance-based fee programs as well as weight-distance tolls for trucks. Where participation is mandatory, experience suggests that there are two general approaches to rollout.

- **Immediate rollout**: This is the approach used in the Swiss and Austrian truck toll programs in which all domestic users are required to install the on-board equipment at the onset of the program.
- **Phase-in over time**: In this approach, envisioned for general purpose distance tolls such as that developed for Oregon (J. Whitty, personal communication, August 18, 2004) and that proposed by researchers at the University of Iowa (Forkenbrock and Kuhl, 2002), the necessary equipment will be phased-in over time with the purchase of new vehicles; both the old and new charging systems operate in parallel throughout a lengthy period of transition.

For many other programs and proposals, participation is optional, such as with the distance-based variable insurance and leasing cost programs, as well as with the proposed truck monitoring program in Australia. In a sense, participation is optional in certain cases with the weight distance truck tolls. Within the Swiss and Austrian programs, for example, foreign truckers have the option of installing on-board equipment to pay their tolls automatically or continuing to rely on the older, more cumbersome manual payment methods. In the German program, the on-board equipment is optional for foreign and domestic truckers alike, but those who choose not to use the on-board equipment must still manually pay their fees.

Where participation is optional, it is typically necessary to offer some type of incentive encourage users to enroll. To wit:

- For the Minnesota (K. Buckeye, personal communication, September 13, 2004) and Atlanta, Georgia, (R. Guensler, personal communication, September 14, 2004) variabilized cost programs, participants can receive financial bonuses for reducing travel.
- For the Australian truck monitoring program (Koniditsiotis, 2003), truck operators are offered expanded road access privileges in return for agreeing to allow their travel patterns to be monitored, and they are given the opportunity to purchase value-added services, such as fleet management, from the certified technology providers.

- For the Swiss (Balmer, 2004), Austrian (Schwarz-Herda, 2004), and German (Rothengatter, 2004) truck tolls, drivers who install the equipment are able to avoid the time-consuming hassles of manually paying tolls.

Table 15 identifies which of the case studies involve manual participation and which offer optional enrollment. For those in which participation is mandatory (and for which the information is available), the table also shows whether the intended rollout strategy is immediate or instead involves a prolonged phase-in period.

PHASE-IN STRATEGIES

As shown in the table, the two case studies that require mandatory participation and envision a prolonged phase-in approach are the distance-pricing proposal in Oregon (J. Whitty, personal communication, August 18, 2004) and the distance-pricing proposal developed by researchers at the University of Iowa (Forkenbrock and Kuhl, 2002), both of which envision a similar phase-in strategy. In each case, all new vehicles would be required to have on-board equipment installed, while for existing vehicles (for which retrofitting would be more costly) it would remain optional. During the phase-in period, both the existing fuels tax and the distance-based user fee systems would operate in parallel; cars without the on-board equipment would continue to pay the fuels tax as always, while cars with the equipment would pay the mileage fee instead.

In order to prevent double taxation (given that the fuels tax is built into the retail purchase price for gas), users of the mileage-based fee system would receive a rebate on any amount of gas tax paid. Within the Oregon proposal, the rebate would occur simultaneously with the purchase of fuel (with each purchase the mileage fee would be added to the bill, and the gas tax would be subtracted; J. Whitty, personal communication, August 18, 2004). For the Iowa proposal, in contrast, the gas taxes would be subtracted from the total bill owed when the vehicle owner sent billing data to the collections agency through use of a smart card reader (D. Forkenbrock, personal communication, March 3, 2005).

TABLE 15 Participation Requirements and Rollout Approach

Case Study	Adoption		Roll-out	
	Required	Optional	Immediate	Phase-In
Truck Tolls - International				
Australia		X		
Austria			X	
Bristol	X			
Germany		X	X	
Switzerland	X		X	
United Kingdom	X		X	
Distance Charges - US				
Iowa	X			X
Oregon	X			X
Distance Charges - International				
Netherlands	X		X	
Variabilization - US				
Atlanta		X		
Minnesota		X		
Progressive Insurance		X		

LESSONS AND OBSERVATIONS

For Truck Tolls, Immediate Rollouts Appear Feasible and Reasonable

Immediate rollout requires that all vehicles install on-board equipment from the outset, and this can represent a considerable expense (either on the part of truckers or the government, depending on the financial structure of the program). In comparison to noncommercial vehicles, however, the magnitude of weight-distance fees applied to trucks is quite large, so the expense of the on-board equipment represents a small fraction of the overall revenue generated. Furthermore, when prices rise for all trucks, the costs generally are shifted onto customers.

For Private Vehicles, Immediate Rollout Is Not a Realistic Option

On-board units for passenger vehicles represent a larger share of the vehicle purchase price and would need to be installed in many more vehicles. And unlike trucks, passenger vehicle units would not be viewed as a cost of doing business. For these reasons, political resistance to required installation of $200 units is much more likely (J. Whitty, personal communication, August 18, 2004). Therefore, prolonged phase-in of passenger vehicle units is the most likely strategy for general-purpose distance-based user fees.

Parallel Operation of Pricing Systems Is Likely Necessary

Given the need for a prolonged phase-in period, it is likely necessary to develop a strategy for operating the fuels tax and distance-based user fee system in parallel. The experiences in Oregon and Iowa suggest that this can be accomplished rather seamlessly (J. Whitty, personal communication, August 18, 2004; D. Forkenbrock, personal communication, March 3, 2005).

7

Political and Public Acceptance Issues

This section begins with an evaluation of the two largest political issues that confront innovative pricing schemes—concerns pertaining to *equity* and *privacy*. Next, it highlights a range of additional programmatic factors that may affect the degree to which politicians and the public are willing to accept road pricing; these include the following:

- The severity of the problem to be confronted;
- The anticipated level of effectiveness of the proposed pricing solution;
- The degree to which the program is integrated with complementary policies;
- The size and scope of the project;
- The use of resulting revenues;
- The manner in which different stakeholders are compensated;
- The degree of choice offered, or precluded, by the program;
- The transparency and user-friendliness of the program;
- The nature of the enforcement strategy; and
- The legal context in which the program is to be enacted.

After the various elements of a proposed program that can contribute to its success or failure are outlined, lessons regarding the *process* of securing public and political buy-in are discussed, with a particular focus on the following:

- What to expect in terms of initial support and opposition,
- How pricing has been presented most effectively to decision makers, and
- Techniques and strategies that have been used to enlist and build popular and political support for pricing.

EQUITY

Equity often is in the eye of the beholder. Even though analysts and researchers typically define equity in terms of income, ability to pay, or sociodemographics, political debates over equity in transportation finance more often center on the distribution of winners and losers among jurisdictions or modal interests. Important to this research, questions of equity often weigh heavily when debating *any* new transportation finance or pricing schema, while the fairness of the *status quo* system of finance is given far less scrutiny. For example, congestion-pricing proposals are challenged frequently on fairness grounds, while the now commonplace practice of dedicating local sales taxes for transportation—which is regressive with respect to both income and road system use—is subject to fewer challenges on equity grounds. Thus, the road pricing proposals considered here may in many cases be challenged on equity grounds simply because they rearrange the current distribution of winners and losers, not because they are less equitable than current systems of transportation finance.

In the case studies analyzed for this paper, the degree to which equity concerns were raised depended, not surprisingly, on the specifics of the program. For weight-distance truck tolls, distance-based road user charges, and the variabilization of fixed costs such as insurance based on miles driven, equity has proven less of an issue. Each of these approaches embodies, to some extent, the pay-as-you-go principle, which many analysts and stakeholders would argue is a way to increase equity. To illustrate, consider a new weight-distance toll for trucks that includes a surcharge for travel on local roads. Such a fee could capture more proportionally the costs imposed by trucks traveling on surface streets engineered to lower standards. Such a toll could lead to either reduced volume of trucks driving on local streets and roads, and in turn reduced maintenance costs, or increased funding for local road maintenance. In either case, the prices charged to trucks and the road costs they occasion are brought into line.

Despite the fact that one could argue that congestion tolls increase equity by bringing costs imposed and prices paid more in line, equity concerns have arisen more frequently with this form of pricing. Two characteristics of congestion tolls appear to motivate equity concerns. First, while any pay-as-you-go scheme involves some sort of link between the level of benefits received and prices paid, this nexus is brought into especially sharp relief with congestion tolls. With HOT lanes, for example, concerns are voiced frequently that wealthy drivers can simply "buy their way out of congestion," while poorer drivers remain stuck in the congested free lanes. Second, weight-distance truck tolls, distance-based road user charges, and the variabilization of fixed costs, such as insurance based on miles driven, are all reformulations of existing charges. Congestion tolls, by contrast, are seen by many as an entirely new form of user fees. As such, they appear to be held to a higher standard of scrutiny in political debates. As noted above, while other tax instruments, such as property taxes or sales taxes, may also be challenged on equity grounds, they enjoy the benefits of incumbency.

Based on the review of the implementation of congestion pricing schemes, the following observations regarding public and political concerns over equity are offered.

Equity Concerns Can Kill a Project

In 1997, former Minnesota Governor Arne Carlson decided to rule out the idea of HOT lanes in future Minnesota transportation plans based, at least in part, on equity concerns (D. Levinson, personal communication, September 9, 2004). In 2001 former Maryland Governor Parris Glendening made a similar decision, and equity again was cited as one of the difficulties (U.S. Department of Transportation Federal Highway Administration, 2004). It should be noted in each of these cases, the decision against HOT lanes was reversed subsequently by the next governor. Minnesota's first HOT lane was to have been operational by summer 2005, while the Maryland DOT is now fully committed to Express Toll Lanes (R. Poole, personal communication, February 4, 2005).

Equity Outcomes Appear to Vary by Project

There is conflicting evidence as to whether congestion tolls favor higher income groups, especially in comparison to current instruments of transportation finance. On both the Katy Freeway HOT lanes in Texas and the I-15 HOT lanes, for example, the average user is a professional with an annual income in excess of $100,000 (Ward, 2001). On the SR-91 HOT lanes near Los Angeles, by contrast, one-third of the corridor travelers from households with annual incomes below $40,000 use the HOT lanes at least occasionally (Sullivan, 2002).

Despite Equity Concerns, Congestion Pricing Is on the Rise

Despite enduring equity concerns with congestion pricing, the implementation of congestion tolls is waxing. Notable examples include the I-15 HOT lanes near San Diego (Supernak et al., 2002), the SR-91 HOT lanes near Los Angeles (Sullivan, 2002), the Katy Freeway HOT lanes in Houston (Stockton, 2002), the Singapore cordon congestion toll (Fabian, 2003), and the London cordon congestion toll (Transport for London, 2003). Given the success of these pioneering efforts with respect to the intended policy goals—most notably optimizing use of limited capacity, reducing congestion, and raising revenue—congestion tolls in fact appear to be gaining political momentum. To illustrate, the state of Minnesota, which originally rejected the idea of HOT lanes in 1997, was to have opened its first HOT lane facility on I-394 beginning in spring 2005 (D. Levinson, personal communication, September 9, 2004).

Proper Use of Revenues Can Mitigate Equity Concerns

Congestion tolls on individual facilities can raise a significant amount of revenue, while the revenue raised by cordon congestion tolls that apply to entire districts or cities can be far greater. By devoting at least a share of the proceeds to subsidizing lower-income travelers or alternative transportation options, equity concerns have been somewhat mitigated. One approach, used in both the I-15 HOT lanes project near San Diego (Ward, 2001) and the London cordon congestion toll (Transport for London, 2003), is to use the revenues collected to subsidize the public transit system. Another option, based on the FAIR lanes concept introduced by DeCorla-Souza (2001), is to use a portion of net revenues to offer credits for occasional use to those who usually travel in the congested free lanes.

PRIVACY

Like equity, the level of privacy concerns depends very much on the nature of the proposed pricing scheme. With respect to weight-distance truck tolls, privacy concerns have centered on preventing public disclosure of proprietary information regarding the identity of customers, prices charged to various customers, and the location and timing of particular shipments. However, since commercial trucking already is subject to regulation and scrutiny, such concerns have in most cases proven manageable.

Most congestion tolls don't involve tracking the location of a given vehicle in time and space (above and beyond noting that the vehicle used a particular facility or traveled within a given cordon at a particular time), which limits privacy concerns. For those systems that track the movement of vehicles in time and space, policies similar to those applied to telephone records have been put into place. And, in a few cases, customers have been allowed to purchase numbered accounts to allow concerned customers to insure the highest levels of anonymity.

With general-purpose distance-based user fees, privacy concerns are paramount. In fact, the preservation of reasonable standards of privacy was cited as a major design consideration in all of the case studies that involved distance-based tolling schemes. The reason that privacy is such a significant concern with distance-based pricing schemes is that the proposed technical solution usually incorporates an on-board unit equipped with a GPS receiver, which in theory could be used to track and record time, location, and speed of travel. This raises at least three important issues. First, there is the general concern that people will resist any new technology that may enable the government to monitor their movements. As noted by Forkenbrock and Kuhl (2002), people tend to be more protective about their privacy in terms of others knowing where and when they travel than they are about many other aspects of their lives. Second, there is a concern that travel data—in particular data pertaining to speed of travel—could be used by insurance companies as a basis for raising insurance rates (R. Guensler, personal communication, September 14, 2004). Third, there is concern that travel data—again, especially data related to speed of travel—could be used against a driver in court in the case of an accident (R. Guensler, personal communication, September 14, 2004).

Given the care and attention that has been devoted to the issue of privacy within the various case studies, it appears that these potential concerns can be addressed successfully. The following observations, drawn from the experience of researchers involved in the design of distance-based pricing schemes, are of particular relevance:

Privacy Concerns Are Not a Legal Issue

Legal research reported in Forkenbrock and Kuhl (2002) indicates that even if extensive data were collected, distance-based charging schemes would not constitute a legal infringement of users' privacy. As such, the primary hurdles pertain to public and private acceptance rather than legal prohibitions.

Public Concerns for Privacy May Be Over-Estimated

Politicians and policy analysts commonly have assumed that concerns over privacy represent a significant barrier to achieving public acceptance of distance-based pricing schemes. This assumption, however, may in fact be somewhat overblown. In the Copenhagen and Gothenburg distance-pricing demonstration projects, for example, surveillance was not considered by participants to be a major issue. This may be due to the fact that many people have become accustomed to using technology platforms where, in principle, it is possible for their activities to be tracked, such as with credit cards, cell phones, and the Internet (PRoGRESS, 2004). In addition, in those places where anonymous toll accounts have been offered (such as the Dallas North Toll Road, Highway 407 in Toronto, and the SR-91 Express Lanes), the fraction of users choosing this option has been well below one percent (R. Poole, personal communication, February 4, 2005).

Privacy Can Be Protected on Two Levels

Even if public concerns over privacy are not as great as some politicians and planners suspect, it is still important to protect the privacy of users. In the various case studies examined, two general (and potentially complementary) approaches to protecting privacy have been offered. The first of these is to perform detailed calculations of charges owed on the on-board unit itself (which requires, of course, that the on-board unit includes information on the toll rate for various road classes and jurisdictions) and to then only transmit the final bill to the collections authority (see, for example, Forkenbrock and Kuhl, 2002; Whitty, 2003). In this way, detailed location, time, and speed information never leave the vehicle, and in fact could be purged from memory after being used to calculate the bill. The second approach is to set up iron-clad agreements with the collections agents (which may be private firms under contract, as suggested by Malick, 1998) that guarantee that the data will never be released or used for any purposes other than billing without a court order.

OTHER PROGRAMMATIC FACTORS

In addition to the primary concerns of equity and privacy, there are other programmatic factors that have influenced the degree to which politicians and the public embraced pricing proposals.

The Problems Addressed Are Viewed as Pressing

To garner sufficient public acceptance and political willpower for change, successful implementations of pricing strategies have in all cases addressed clear and widely recognized problems that are considered important by a majority of voters and elected officials and that have not been solved through existing remedies (Ward, 2001). To illustrate, in Switzerland, the heavy goods vehicle fee was motivated in part by a concern for the increasing levels of truck traffic on the motorways, as well as the adverse environmental impacts, especially in the alpine regions (Balmer, 2004). In Oregon, the proposed vehicle mileage fee has been designed to address the waning ability of the fuels tax to raise sufficient funds to maintain and expand the state highway system. Many of the roads in Oregon are in poor repair, and congestion along heavily traveled routes is on the rise; both of these problems are widely recognized among Oregonians and their elected officials (J. Whitty, personal communication, August 18, 2004).

The Pricing Solutions Produce Demonstrable Benefits

As few are happy to pay new taxes or fees, explicitly linking new transportation tolls with transportation benefits has proven critical. Road pricing strategies are more likely to be embraced if they are directly linked to widely desired benefits, such as better roads and bridges, improved transit service, or reduced congestion delays (Loveland, 2003). For example, the I-15 HOT lanes toll near San Diego (Supernak, 2002) and the London cordon toll (Transport for London, 2003) have relieved congestion and provided funds to enhance public transit; the Swiss heavy goods vehicle fee has reduced the number of trucks traveling on the highway system, providing both safety and environmental benefits to the population (Balmer, 2004); and distance-based user fees such as those proposed in Oregon (Whitty, 2003) and by Forkenbrock and Kuhl (2002) promise to provide sorely needed revenues to maintain and enhance road networks.

The Pricing Solutions Are Integrated with Complementary Measures

As noted in the review of the PRoGRESS demonstration project in Gothenburg, support for road pricing as a sole means for mitigating congestion can be weak (PRoGRESS, 2004). On the other hand, congestion-pricing proposals tend to be viewed much more favorably if they are part of an integrated package that includes other measures (such as improved transit service) to address the problem as well. For example, the existing cordon charge in London (Transport for London, 2003) and the proposed cordon charge in Bristol (PRoGRESS, 2003) include major improvements to public transportation as key elements within the overall strategy.

Incremental Projects and Programs Are More Likely to Be Implemented Than Sweeping, Universal Proposals

Even though the case study review strongly suggests the benefits of integrating pricing proposals with complementary measures, such as improved transit service, most favorably received pricing projects have been incremental and tightly focused. Experience suggests that if the scope of the project grows too large, it becomes very difficult to gain and sustain political support. Specifically, the accumulated opposition of multiple interest groups opposing specific—and different—aspects of the proposal ultimately has shelved several very large-scale proposals. For example, a proposed "coordinated transport policy" in Switzerland, which included weight-distance tolls for trucks and numerous other user-related fees and pricing programs, was defeated in a 1988 vote. Several years later, however, Switzerland successfully passed separate bills to improve the rail transport network and to institute the weight-distance truck tolls (Balmer, 2004).

Successful Programs Typically Dedicate Revenues to Transportation Projects

Public acceptance for transportation user fees clearly is enhanced by explicitly dedicating the funds collected to related transportation projects. Interestingly, opposition to using revenues collected from one mode to subsidize another is frequently voiced by modal stakeholders but far less by elected officials or the general public. For example, net revenues from the I-15 HOT lanes near San Diego (Supernak et al., 2002) and from the London congestion toll (Transport for London, 2003) are used to support public transit, while revenues from the Swiss truck-tolling project are devoted to enhancements to the rail network (Balmer, 2004).

Successful Programs Tend to Mitigate "Losers" at Least Partially

As noted previously, most road pricing programs reallocate the distribution of winners and losers, usually with an eye toward bringing prices paid in line with costs occasioned. While there may be sound reasons for ending the "free (or substantially discounted) rides" enjoyed by some classes of road users, some efforts to soften the blow of new pricing regimes often are politically necessary. For instance, the heavy goods vehicle fee in Switzerland, set at a level designed to encourage a mode shift to rail freight, resulted in a significant increase in charges to the trucking industry as compared to the prior flat fee. The trucking industry generally was supportive of the measure, however, because the new program also allowed a higher maximum vehicle weight that enabled trucking companies to increase efficiency by lowering unit costs (Balmer, 2004).

The Most Popular Programs Enhance Choice Rather Than Diminish It

Citizens in democratic societies are conditioned to resist restrictions on choices. Accordingly, pricing strategies that enhance choices have proven more marketable (Loveland, 2003). One of the reasons that HOT lanes have proven successful is that they add a new option: users can continue to travel for free in the congested lanes, or they can pay a toll to enjoy free-flow HOT lane travel. Likewise, cordon tolls and distance-based user fees can each be structured to increase the range of transportation alternatives as well. With cordon tolls, if the revenues are used to enhance the public transit system, new (or at least improved) commute options become possible. With distance-based charges, in turn, when revenues are devoted to improving and expanding the road network, the result will be to increase the range of route options available to travelers.

Successful Road Pricing Systems Tend to Be User-Friendly: Easy, Reliable, and Unobtrusive

Popular pricing programs typically provide a range of easy payment channel options (PRoGRESS, 2004), including payment by the Internet, by telephone, by automated debits, or by automated inclusion in the price of fuel (this last has been demonstrated successfully in the Oregon project, as noted by J. Whitty, personal communication, August 18, 2004). In addition, given that many drivers feel strongly about vehicle aesthetics, system designers have had to ensure in-vehicle equipment can be mounted unobtrusively (R. Guensler, personal communication, September 14, 2004). Finally, the reliability of the technology employed plays a critical role in the level of popular support, as new equipment often may be blamed (rightly or wrongly) for car malfunctions. In the Copenhagen pricing demonstration project, for example, a significant number of participants claimed that the on-board unit had drained their battery flat (PRoGRESS, 2004).

The implications of this last finding are twofold. First, extensive field testing of equipment before implementation often has been necessary to ensure that problems like those reported by the Copenhagen demonstration program participants are not caused by the new technologies. Second, even if the system does work as intended, experience suggests that its administrators should be prepared for people and interests to blame a wide array of problems on the new equipment.

Successful Programs Have Effective and Transparent Enforcement Strategies

Clever users quickly find loopholes and enforcement weaknesses in any program. Successful programs require widespread belief among the participants that cheaters are rare and will eventually be caught (Short, 2004).

The Legal Framework for the Charge Needs to Be Clear and Well-Established

A murky legal framework for road pricing can complicate debates over the merits of pricing proposals and lead to delays in implementation. Unresolved legal questions were cited as problems with the cordon pricing demonstration project in Edinburgh (PRoGRESS, 2004) and with the truck-tolling program in Switzerland (Balmer, 2004).

THE PROCESS OF BUILDING SUPPORT

The successful implementation of road pricing strategies in recent years, including facility congestion tolls, cordon congestion tolls, and weight-distance trucking tolls, all overcame barriers to public and political acceptance. Here are lessons from the successful implementation of road pricing projects and programs, focusing in particular on the following:

- Likely sources of support and opposition,
- Approaches to framing and presenting proposals, and
- Efforts to build public and political support.

Initial Expectations: Likely Sources of Support and Opposition

Road pricing schemes typically represent a radical departure from traditional forms of transportation tolling and taxation. As such, significant effort, sometimes lasting many years, preceded most implemented programs. Below is a summary of the collective lessons of road pricing implementation:

The Efforts Are Staffed and Sustained

Public and political debates on new forms of transportation pricing are typically painstaking and slow. Elected officials in particular are often wary of adopting a new financing scheme that has not been successfully tried in some other jurisdiction. The growing cache of successfully implemented road pricing programs has helped in this regard. But during this period of experimentation with alternative forms of tolling, no standard or widely accepted model has emerged. As a result, development of new programs typically proceeds cautiously and incrementally, pushed along by a few enthusiastic leaders and support staff. Experience suggests that if the community and political outreach efforts are not sustained over time, proposals are likely to be shelved (Loveland, 2003).

The Initial Level of Support Is Likely to Be Low

Even where innovative pricing schemes have been implemented and are viewed widely as successes, popular support in advance of program implementation has seldom exceeded 50 percent, suggesting the need for sustained commitment and some risk-taking on the part of the project leadership (Short, 2004).

Initial Support Frequently Erodes as Detailed Plans Are Vetted

In the earliest phases of many of the projects examined for this study, planners and policy makers tended to focus on the potential benefits of the proposed new pricing scheme. As the plans are fleshed out in greater detail, however, the exact nature of the costs and who would likely bear them become more apparent; this frequently leads to public criticism of the proposals and an erosion of public support. This effect was observed in many cases including, for example, the planning process for the cordon toll demonstration project in Edinburgh (PRoGRESS, 2004).

Support for Innovative Tolling Tends to Increase after Implementation

Among the projects eventually implemented, popular and political support tends to increase following implementation. For example, 75 percent of those polled prior to the implementation of the cordon congestion toll demonstration project in Trondheim held a negative opinion of the proposal. The percentage of area residents who viewed the project negatively two months after implementation dropped to about 50 percent. Two years after implementation, just 30 percent of those polled held negative views of the project (PRoGRESS, 2004).

Approaches to Framing and Presenting the Proposals

All of the successful projects reviewed here were accompanied by sustained communication efforts. The observations about these efforts are as follows:

Focus Groups Are Frequently Used to Structure and Sell New Proposals

Many of those responsible for implementing new pricing programs report using focus groups for input on the formulation of a project, helping to gauge public opinion of program components and identifying key fears and sources of resistance (such as concerns related to equity or the potential for increased prices). And later, feedback from focus groups often has been used to shape the marketing message in campaigns for implementation (Ward 2001).

Aggressive, Comprehensive Outreach Efforts Are Common

Public outreach and education have proven effective in gaining support for innovative pricing projects and creating an understanding of the concept. Members of the public are frequently uncertain of the logic behind new pricing proposals, and skeptical of their benefits. To achieve the desired level of awareness, support, and understanding, most implemented programs were accompanied by sustained efforts to explain the need for and objectives of the new program. Ward (2001) reports that such efforts typically involve a clear communication of the problem, the role that the proposed pricing strategy will play in solving the problem, and the ultimate benefits that will result.

Complicated Schemes Require More Communication

In comparing the experience of the PRoGRESS pricing demonstration projects in various European cities, it was noted that the most complicated schemes—typically those involving distance-based charges monitored through the use of GPS—required a significantly higher level of communication in order to facilitate understanding on the part of the demonstration participants (PRoGRESS, 2004).

The Marketing of New Programs Is Often Elaborate, With Messages Customized for Different Decision Makers

The value pricing programs reviewed here have been sold as environmental tools, traffic management tools, financing tools, and transit tools. Furthermore, they can be positioned ideologically as conservative, liberal, or both. Experience suggests that road pricing advocates often spend a lot of time arguing over the single most important reason to support, and sell, pricing programs. However, given that it often is necessary to enroll support from broad coalitions in order to implement innovative tolling programs, the architects of many of the programs reviewed here found it useful to customize messages for a diverse set of potentially supportive interest groups, messages focusing on benefits related to finance, to public transit, to the environment, to equity concerns, etc. (Loveland, 2003).

In Building Support, Program Advocates Have Found It Useful to Shift the Debate from an Overly Simplistic Choice Between Free-Ways and Toll-Ways

Experience suggests that as decision makers make their calculations about the likely levels of public acceptance, they often believe that changing free lanes into tolled lanes will be exceedingly unpopular with their constituents. Numerous survey and focus group results suggest that, if the issue is framed in such a light, tolling proposals are indeed unpopular. As a result, program advocates frequently have sought to reframe the issues to focus on out-of-control versus mitigating congestion, deteriorating versus improving roads, or cutting versus expanding public transit. Shifting the focus to problem solving appears to be a common feature of successfully implemented pricing programs (Loveland, 2003).

Innovative Pricing Programs Are Presented Frequently as a Response to Some Crisis

Bold policy initiatives are most often implemented as a response to crisis (Kelman, 1987). Despite a growing number of pricing programs around the globe, road pricing in almost any form is still widely viewed as unorthodox, and even radical. As such, many of the pricing programs reviewed as part of this study were presented as a response to some looming crisis, such as out-of-control congestion or a steadily deteriorating road or transit stock due to revenue shortfalls (Loveland, 2003). The London cordon-pricing program, for example, was presented explicitly as a response to both debilitating congestion and a fiscal crisis at the London Underground subway system (Transport for London, 2003).

The Selling of Pricing Programs Often Continues Long After Implementation

Pricing program managers frequently report a need to continue selling the innovative programs to claim credit for the direct and indirect benefits of the programs and to challenge unsubstantiated claims of problems caused by the programs (Short, 2004). Vehicle owners, for example, sometimes claim that on-board tracking and pricing equipment is responsible for obviously unrelated mechanical problems. In addition, former free riders often continue to chafe at the new charges, and the changes in behavior that they motivate, long after initial program implementation.

Efforts to Build Popular and Political Support

Beyond marketing, pricing program advocates frequently have engaged in a wide array of other efforts to build popular and political support for pricing programs. The following observations are most relevant.

The Technical Details of the Programs Tend to Be Settled Early

Pricing strategies usually are more complex and technical than the policies and programs they replace. As such, both potential supporters and opponents of new programs often are concerned about analytic details—such as the technology to be employed, the level of costs and revenues anticipated, the strategy for dealing with out-of-area users, and the techniques of enforcement. Experience suggests that until such important questions are addressed, pricing proposals rarely move forward. Even though many programmatic details are negotiated just before implementation, the basic technical elements of proposed programs are established early to frame the proposed program as technically feasible (Loveland, 2003; Short, 2004).

Implemented Programs Tend to Have Engaged Stakeholders—Supportive and Hostile—Early

Extensive and ongoing stakeholder involvement was common to nearly every successful program reviewed. For example, planning for the I-15 HOT lanes project near San Diego included an extensive and elaborate program to involve community groups, commuters, and the media in educational forums and focus groups. The project sponsors also worked to involve regional, state, and federal planning authorities, and thus broaden the base of project sponsors. In contrast, a road pricing study effort in Boulder, Colorado, failed to develop stakeholder group involvement, which made it difficult to achieve project buy-in at the grassroots level (Ward, 2001).

Innovative Pricing Programs Are Often Supported by Delicate, Tenuous Coalitions

Nearly all of the implemented programs reviewed here were supported by coalitions of strange bedfellows. Such coalitions often included business interests, environmental groups, transit advocates, road builders, suburban leaders, and central city interests. Pricing program proponents report that building and maintaining such coalitions consumed significant time and resources but were seen as necessary to overcome opposition from entrenched opponents (Loveland, 2003).

Nearly All Implemented Programs Had One or More Political Champions

Most of the projects reviewed here benefited by the ongoing support of a highly visible political champion. For example, the Mayor of suburban Poway was an active political advocate for the I-15 HOT lanes project near San Diego, and the Mayor of Houston played an active behind-the-scenes role in supporting the Katy Freeway HOT lanes project in Texas. In contrast, the failed value pricing efforts in Boulder, Colorado, and the Twin Cities region of Minnesota lacked political champions (Ward, 2001). Pricing program managers report that although the support of low- and mid-level decision makers is helpful at least one high-profile supporter in the "bully pulpit" is essential to build public acceptance for something as novel and controversial as road user fees (Loveland, 2003). These lower-level decision maker influencers, however, are usually behind every political champion, providing strong analytical and engineering support for pricing proposals (Short, 2004).

Implemented Programs Typically Addressed Early Concerns and Questions with Hard Evidence

The materials reviewed for this study suggest that the biggest concern that elected officials have about road pricing schemes usually is related to public acceptance—and most politicians are predisposed to believe that the public strongly opposes any type of tolling. In response to such important concerns, many pricing program supporters have turned to local public opinion data from a credible source to develop a more nuanced picture of public attitudes toward the costs and benefits of pricing proposals. In addition, many pricing proposals cite public surveys from established value pricing projects, such as the I-15 HOT lanes in San Diego, to show that public support for innovative road pricing measures tends to wax following implementation (Loveland, 2003).

The Steady Growth in Pricing Examples Is Reducing Perceived Risk

Any form of road pricing tends to look counterproductive and risky to those unfamiliar with it. Political scientists argue that the incentives faced by most elected officials encourage risk-aversive behavior and a fear of programmatic failures. As noted briefly earlier, the growing number of road pricing experiments worldwide often are chronicled, and touted, in new proposals for innovative toll finance. Champions and managers of road pricing programs are frequent speakers in jurisdictions contemplating some form of road pricing. For example, the PRoGRESS demonstration projects in the European cities of Edinburgh, Genoa, and Rome have all touted the success of the London cordon toll program, frequently including testimony from its administrators, to help make the case for their road pricing projects (PRoGRESS, 2004).

The Attitudes of Local Media Toward Pricing Proposals Can Strongly Influence Public Opinion

It goes without saying that local media can influence public perceptions of local plans, road pricing proposals and otherwise. Many of the case studies conducted for this paper noted positive and negative media coverage as influencing project implementation. In several cases, project proponents actively sought to educate the media on the logic and potential benefits of pricing in an attempt to influence reporting on the topic (Ward, 2001; Loveland, 2003).

8

Summary

As noted in the introduction, the motor fuels tax has served for many years as an effective tool for highway finance, and it has many advantages. The fuels tax is based roughly on the "user pays" principle, it encourages motorists to use fuel-efficient vehicles, and it has very low costs of administration. Despite these many assets, however, the fuels tax is saddled with a significant political liability: without regular increases to account for both inflation and increasing fuel efficiency, it gradually "sunsets" over time. Such increases have grown more politically contentious in recent years as they have become increasingly rare. As a result, the buying power of the motor fuels tax is waning over time.

Even as concerns have been raised for a decade or more that alternative fuel vehicles pose a significant threat to the long-term viability of the motor fuels tax as the backbone of transportation finance, the more immediate threat to the fuels tax is the reluctance of voters or their elected officials to regularly raise the levy to keep pace with rising costs and travel. It is this political liability of the fuels tax, rather than any immediate threat from alternative fuels vehicles, that has heightened and hastened interest in proposals to replace the fuels tax with some form of a distance-based user fee. Such a new fee would be immune to the effects of increasing fuel efficiency in conventional or alternative fuel vehicles, would allow variable pricing to increase system efficiency, and, importantly, would be a *tabula rasa* on which political debates over the appropriate tax levels could begin anew.

This paper has reviewed a number of implemented projects, proposals, and studies related to the concept of distance-based user fees. In particular, it has shared the evaluations of the case studies with respect to policy and pricing issues, technical implementation issues, structures of governance, implementation and rollout strategies, and public and political acceptance issues.

This report does not compare and contrast the motors fuels tax with the new mileage-based programs reviewed here. As such, no judgment as to whether the fuels tax should be replaced by some form of a mileage fee in the near term is offered. Instead, the findings are summarized with respect to the fuels tax alternatives to inform such a debate over the future of the fuels tax. These findings are summarized below in three categories:

- Policy and pricing issues,
- Technology issues, and
- Political and public acceptance issues.

SUMMARY OF FINDINGS RELATED TO POLICY AND PRICING ISSUES

- If the goal were solely transportation revenue preservation or enhancement, the costs of converting to a distance-based scheme from the current system of motor fuels taxes would appear to be quite high.
- If shifting to a distance-based charging scheme were determined to be the best political path to preserving or enhancing transportation revenues, the case studies reviewed here suggest that a mileage-base fee is feasible and could be implemented in a cost-efficient manner.

- If the goal were also to mitigate congestion and optimize use of the road system, a distance-based scheme paves the way for congestion tolls to be implemented on individual facilities, which have proven to be very successful where implemented.
- If the goal were also to encourage mode shifts to carpooling, public transit, walking, and biking, distance-based tolls would allow the application of area-wide congestion tolls in congested urban areas.
- If the goal were also to reduce mobile-source emissions, a distance-based scheme can include per-mile fee offsets based on vehicle emissions class.
- Collectively, the case studies suggest that business interests often fear the uncertain effects of new road pricing schemes and can organize effectively in opposition to them. However, the risk and uncertainty of road pricing is likely to diminish over time as additional projects and programs come online, which may gradually diminish opposition from business interests.
- Partial network pricing schemes greatly increase the likelihood of traffic diversion to unpriced roads; full-network pricing programs have avoided such problems.
- To reduce circumvention of tolls, it is necessary to carefully craft standards and thresholds to produce rational, efficient responses.

SUMMARY OF FINDINGS RELATED TO TECHNOLOGY ISSUES

Specific Technical Options

- Given the potential for signal interruption, GPS cannot be used in a stand-alone manner; the odometer can be used as a backup for measuring distance traveled, while dead-reckoning can provide a means of determining position while the GPS signal is down.
- If the system only needs to distinguish between different jurisdictions, then current GPS and GIS capabilities are easily sufficient; if it is necessary to distinguish between different road segments, however, differential GPS corrections are needed, and the digital road network map must be highly accurate as well.
- For communications, GSM, DSRC, and chip cards are all feasible options; GSM provides the greatest flexibility (albeit at the highest cost), DSRC supports additional capabilities (such as enforcement), and chip cards offer the greatest degree of user control.
- Strategies for preventing users from tampering with on-board units appear to offer reliable prevention of toll evasion, though additional checks from DSRC readers mounted on overhead gantries may be needed as well.

General Technical Approach

- Simple systems relying on tried-and-true technologies pose the fewest barriers to implementation.
- Experience suggests that established systems are amenable to subsequent upgrades.
- The cases reviewed here suggest that development, integration, and testing of technology configurations are frequently more time consuming than expected.
- Problems arise when existing tolling and finance systems are abandoned before new road pricing schemes are fully operational.

SUMMARY OF FINDINGS RELATED TO POLITICAL AND PUBLIC ACCEPTANCE ISSUES

- Recent road pricing programs appear to be motivated by a variety of factors. First, and perhaps foremost, many of the distance-based user fee programs (including weight-distance truck tolls) have been motivated largely by transportation revenue shortfalls, combined with general political reluctance to raise motor fuels taxes. Second, many of the congestion pricing projects—particularly those in Europe and Asia—appear also to be strongly driven by a desire to mitigate traffic congestion. Third, many of the European truck toll programs have been designed to ensure that foreign truckers pay their fair share of road use costs and, more generally, to bring user fees in line with the costs that such vehicles impose on the system.
- Congestion pricing proposals tend to stir more controversy, especially with respect to equity, than distance-based user fee proposals.
- Objections to pricing on privacy grounds are common as well, though in most cases such concerns have been addressed satisfactorily in program design.
- Every pricing program currently in place was motivated by a problem, or crisis, that had not been adequately addressed by more conventional means.
- Most implemented pricing programs have clearly defined and widely recognized scopes and scales.
- Most programs also have been crafted as part of a larger set of policy and planning actions—often, it appears, to ameliorate the concerns of various interest groups.
- Most programs include some provisions for compensating “losers” under the new pricing regime, even when those losers were “free (or heavily subsidized) riders” under the pre-existing finance structure.
- Most of the implemented programs were marketed and are generally perceived as increasing transportation choices rather than diminishing them.
- Nearly every system reviewed aggressively enforces compliance to keep cheating, and perceptions of widespread cheating, to a minimum.
- Most implemented and proposed road pricing proposals include sophisticated (for the public sector) marketing efforts, including focus groups, targeted messaging, and coordinated issue framing (away from a toll roads versus free roads debate).
- In most though not all of the programs examined, the basic technical details of the pricing program were established early.
- Most current and proposed programs include extensive stakeholder involvement and are supported by political champions.
- Finally, in most cases the media were courted actively, often with references to and testimony from leaders of implemented pricing programs elsewhere.

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APPENDIX A

Terminology and Acronyms

ANPR:	Automated Number Plate Recognition—a technique for analyzing digital photographs of vehicles and identifying the license plate number through the use of optical character recognition algorithms.
Chip cards:	Small plastic cards with embedded computer chips or memory modules that can be used for transferring data to and from the on-board unit.
DSRC:	Dedicated Short Range Communications—a type of communications based on microwave frequencies over short distances.
GIS:	Geographic information systems—a type of database for storing and manipulating spatial data such as digital road maps.
GPS:	Global Positioning System—a series of geo-synchronous satellites that provide signals through which it is possible to triangulate a relatively accurate (within a couple of meters) position on the surface of the earth.
GSM:	Global System for Mobile communications—essentially satellite-based cellular communications.
OBU:	On-board unit—a vehicle mounted computer which may integrate GPS, GIS, DSRC, GSM, chip cards, or other technology.
Tachograph:	A tamper-proof device commonly installed in trucks that can be configured to sense and track a variety of data, including speed, time, distance traveled, etc.
VPS:	Vehicle Positioning Satellites, a generic term to refer to systems such as the U.S. GPS or the forthcoming European Galileo system.

APPENDIX B

Facility Congestion Toll Projects Reviewed

Location	Name	Status
US - Operational		
California (Orange County)	SR-73 Congestion Toll	Operational 2002
California (Orange County)	SR-91 HOT Lanes	Operational 1995
California (San Diego)	I-15 HOT Lanes	Operational 1999
New Jersey	New Jersey Turnpike Congestion Toll	Operational 2000
New Jersey / New York	Hudson River Congestion Tolls	Operational 2001
Texas (Houston)	I-10 / Katy Freeway HOT Lanes	Operational 1998
Texas (Houston)	US 290 HOT Lanes	Operational 2000
US - Studied / Planned		
California (Alameda)	I-680 HOT Lanes	Recommended
California (Alameda)	I-580 / I-680 FAIR Lanes	Study Ongoing
California (Alameda)	I-880 HOT Lanes	Not Recommended
California (Los Angeles)	SR-14 HOT Lanes	Studied
California (Orange County)	SR-57 HOT Lanes	Not Recommended
California (San Diego)	I-15 HOT Lanes Extension	Planning Phase
California (San Francisco)	Bay Bridge Congestion Toll	Studied
California (San Francisco)	Golden Gate Congestion Toll	Studied
California (Santa Cruz)	SR-1 HOT Lanes	Not Recommended
California (Sonoma)	SR-101 HOT Lanes	Studied
Colorado (Denver)	1-25 / US 36 HOT Lanes	Planning Phase
Colorado (Denver)	C-470 HOT Lanes	Study Ongoing
Florida (Broward)	Sawgrass Expressway Congestion Toll	Study Ongoing
Florida (Miami-Dade)	Florida Turnpike Congestion Toll	Recommended
Florida (Miami-Dade)	I-95 HOT Lanes	Planning Phase
Georgia (Atlanta)	GA-400 FAIR Lanes	Study Ongoing
Illinois (Chicago)	I-90 Congestion Toll	Study Ongoing
Maryland	Maryland HOT/FAIR Lanes	Not Recommended
Maine	Maine Turnpike Congestion Toll	Not Recommended
Minnesota (Twin Cities)	I-394 HOT Lanes	Plannning Phase
North Carolina (Raleigh)	I-40 HOT Lanes	Study Ongoing
Oregon (Portland)	Highway 217 HOT / FAIR Lanes	Study Ongoing
Pennsylvania	Pennsylvania Turnpike Congestion Toll	Study Ongoing
Texas (Dallas)	I-635 / LBJ Freeway HOT Lanes	Study Ongoing
Texas (Dallas)	Dallas Regional HOT Lanes	Study Ongoing
Texas (Dallas)	I-10 / Katy Freeway HOT Lanes Expansion	Study Ongoing
Texas (San Antonio)	I-35 HOT / FAIR / Congestion Toll	Study Ongoing
Virginia	I-495 HOT Lanes	Study Ongoing
International - Operational		
Canada (Toronto)	407 ETR Congestion Toll	Operational 1997
France (Paris)	A1 Lille-Paris Congestion Toll	Operational 1997
France (Paris)	A14 Congestion Toll	Operational 1996
Korea (Seoul)	Namsen Tunnel Congestion Toll	Operational 1998
International - Studied / Planned		
Argentina	Toll Road Congestion Pricing	Study Ongoing
France (Paris)	Highway Network Congestion Tolls	Recommended
France (Paris)	A10-A11 Congestion Toll	Studied
France (Paris)	A1-A26 Congestion Toll	Studied
France (Paris)	A5-A6 Congestion Toll	Studied
Korea	Highway Network Congestion Tolls	Study Ongoing

APPENDIX C

Cordon Toll Projects Reviewed

Location	Name	Status
US - Operational		
Florida (Lee County)	Fort Myers Cordon Toll	Operational 1998
Florida (Lee County)	Fort Myers Cordon Toll for Trucks	Operational 2003
US - Planned / Studied		
New York	East / Harlem Rivers Cordon Toll	Study Ongoing
International - Operational		
Norway (Bergen)	Bergen Toll Rings	Operational 1986
Norway (Oslo)	Oslo Toll Rings	Operational 1990
Norway (Trondheim)	Trondheim Toll Rings	Upgraded 1998
Singapore	Singapore Cordon Toll	Upgraded 1998
United Kingdom (Durham)	Durham Cordon Toll	Operational 2002
United Kingdom (London)	London Cordon Toll	Operational 2003
International - Studied / Planned		
Hong Kong	Cordon Toll	Study Ongoing
Indonesia (Jakarta)	Cordon Toll	Studied
Ireland (Dublin)	Cordon Toll	Studied
Italy (Genoa)	Cordon Toll	Study Ongoing
Italy (Rome)	Cordon Toll	Study Ongoing
Sweden (Stockholm)	Cordon Toll	Study Ongoing
United Kingdom (Cambridge)	Cordon Toll	Not Recommended
United Kingdom (Edinburgh)	Cordon Toll	Study Ongoing
United Kingdom (Leicester)	Cordon Toll	Studied

APPENDIX D

Truck Toll Projects Reviewed

Location	Name	Status
International - Operational		
Austria	"GO" Truck Tolling Program	Operational 2004
Switzerland	"HVF" Truck Tolling Program	Operational 2001
International - Planned / Studied		
Australia	Austroads "IAP" Truck Monitoring Proposal	Planning Phase
Germany	"Toll Collect" Truck Tolling Progam	Delayed until 2005
Hungary	Distance / Time Based Truck Tolls	Ongoing Study
United Kingdom (Bristol)	Truck Toll / Cordon Toll Combined Study	Results Pending
United Kingdom	Weight-Distance Truck Toll	Planning Phase

APPENDIX E

Distance-Based User Fee Projects Reviewed

Location	Name	Status
US - Planned / Studied		
United States	CWARUM Conceptual Proposal	Published
United States (Iowa)	New Approach to Assessing Road User Charges	Pilot Planned
Maryland	"SmartMeter" Proposal	Canceled
Minnesota	GIS/GPS Accuracy Study	Study Ongoing
Oregon	Oregon Road User Fee Taskforce Study	Pilot Planned
Washington (Puget Sound)	Distance-based Congestion Toll Study	Pilot Planned
International - Planned / Studied		
Pan-European	ARMAS Road Tolling Project	Study Ongoing
Pan-European	PRoGRESS Project Consortium	Studied
Denmark (Copenhagen)	Cordon and Distance Pricing Pilot Test	Study Ongoing
Finland (Helsinki)	Cordon and Distance Pricing Modeling Study	Study Ongoing
Netherlands	Mobimiles Distance-Based User Fee Program	Canceled
Sweden (Gothenburg)	Distance and Congestion Pricing Pilot Test	Study Ongoing
United Kingdom (Newcastle)	Distance-Based Congestion Pricing Study	Studied

APPENDIX F

Distance-Based Variable Cost Projects Reviewed

Location	Name	Status
US - Planned / Studied		
California (San Francisco)	Car Sharing Study	Study Ongoing
Georgia (Atlanta)	Variable Cost Study at Georgia Tech	Study Ongoing
Massachusetts (Boston)	Variable Insurance Study	Study Ongoing
Minnesota	PAYD Variable Cost Study	Study Ongoing
Minnesota	Progressive Insurance Variable Cost Study	Study Ongoing

APPENDIX G

Australian Austroads "IAP" for Freight Monitoring[3]

OBJECTIVES OF THE SYSTEM

Austroads, an Australian-based governmental coalition (consisting of six state and two territory road transport and traffic authorities, the Australia Commonwealth Department of Transport and Regional Services, the Australian Local Government Association, and Transit New Zealand), has completed a feasibility study for the *Intelligent Access Program*, or IAP. The proposed IAP system incorporates on-board equipment featuring GPS and DSRC (collectively referred to as telematics) to monitor freight vehicles and ensure that they are complying with operations and access conditions specified within different jurisdictions.

Explicitly, the IAP is designed to provide alternatives to better manage the existing road transport compliance and enforcement task. Implicitly, however, the program has the potential to offer a variety of new ways in which to pursue important policy issues. The scheme has been generally well received, particularly in that it offers a compelling mix of private and public benefits.

From the perspective of government jurisdictions, the IAP is designed to provide the following advantages:

- More efficient use of the road network;
- Reduction in infrastructure wear;
- Improved road safety;
- Assorted environmental benefits;
- An equitable, user-pays approach;
- Optimization of road freight policy and operations tasks, including road enforcement activities; and
- Better management of public perceptions and expectations of heavy vehicle movements.

From the perspective of the transport industry, the IAP offers

- Improved productivity, and
- Reduced regulatory burden.

The institutional model for the IAP is similar to the CWARUM proposal of Daniel Malick. Government agencies are responsible for setting freight access rules and policies as well as for establishing technical specifications for on-board equipment and communications necessary to monitor compliance. Private IAP service providers, in turn, develop technical implementations (appropriately certified) that are offered to transport operators on a fee-for-service basis. In addition to basic monitoring capabilities, service providers also may offer additional value-added services such as fleet monitoring and routing.

[3] The information covered in this review is based primarily on material from Koniditsiotis (2003).

The primary purpose of the IAP feasibility study conducted by Austroads was to

- Identify the specific applications to which jurisdictions would apply the IAP (in the short and long term), and
- Demonstrate the technical and institutional feasibility of the IAP within the context of the identified applications.

In conducting the feasibility study, Austroads addressed four distinct areas of concern:

- Intended applications and business feasibility;
- Regulatory feasibility and implications for jurisdictions;
- Technical feasibility and standards; and
- Proof of concepts, pilot demonstrations, and other research efforts.

Based on the results of the feasibility study, Austroads has recommended a two-stage approach to the implementation of IAP. Stage 1 consists of a set of applications that can be delivered easily now, given currently available technical solutions. Stage 2, to be broached only after successful completion of Stage 1, entails a fully implemented IAP (i.e., consisting of a wider range of applications), which may itself be rolled out over time in a series of sub-stages.

The applications targeted for Stage 1 include three of a general nature (applying to all relevant vehicles across all jurisdictions) and three niche programs (applying to a limited subset of vehicles in a limited number of jurisdictions.

The general-purpose applications include the following:

- Dangerous goods vehicles—focusing on route compliance, freight consignment identification, gross speed violation, and possible driver identification for security purposes—providing access to a wider network and enabling an early warning system for incidents involving these vehicles;
- Specialized rigid vehicles (cranes, controlled access buses, agricultural equipment, etc.)—focusing on route compliance—providing the ability to access a wider network, operate at higher mass, or both; and
- Low loaders—focusing on route compliance and gross speed violation—providing the ability to access a wider network and to reduce the number of trip-based permits required.

The niche level applications include the following:

- Mass concession scheme—focusing on route compliance, mass management accreditation, and gross speed violation—allowing operation of over-mass vehicles on an approved network;
- Higher mass limits—focusing on route compliance, mass management accreditation, and gross speed violation—allowing operation of higher mass limits over an expanded network; and
- Performance based standards and innovative vehicles—focusing on route compliance, mass management accreditation, and gross speed violation—ability to operate tailored vehicles on approved routes and networks.

Anticipated jurisdictional benefits from the Stage 1 applications include

- Provision of an efficient means of responding to operator demand for operator route access and an efficient and effective means of controlling that improved access;
- Improved confidence for jurisdictions in the granting of more permissive and flexible route access;
- Improved community confidence in the compliance of freight vehicles to access conditions;
- Encouragement of further adoption by the transport industry of technology solutions for enhanced fleet, vehicle, and compliance management; and
- Provision of an opportunity for jurisdictions to test the IAP concept through a set of applications that generally are expected to be of relatively low risk and that should be attractive to transport operators in terms of the benefits offered.

On May 23, 2003, the Australian Transport Council endorsed the results of the project and recommended implementation. Subsequently, a steering committee was convened to develop and manage the implementation schedule.

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

The technical solution advocated in the feasibility study involves on-board equipment that incorporates GPS and digital road networks (for determining time and location) as well as DSRC for communicating with roadside monitoring devices. This technical combination provides the ability to track, within an acceptable level of accuracy and tamper-resistance, the following data:

- Vehicle identification (prime mover and rigid vehicle),
- Vehicle location,
- Vehicle time,
- Vehicle distance traveled,
- Vehicle speed, and
- Store and forward communications (e.g., allowing post-processing but not real-time monitoring).

The feasibility study team is still evaluating technical solutions for the following desirable, though not critical, system attributes:

- Driver identification (this is currently feasible, but there is no guarantee that the person driving the vehicle is the same person that has identified himself or herself via the system);
- Unique trailer identification; and
- On-board vehicle mass sensors.

Having identified a feasible technology configuration that will meet the needs of the IAP, the next logical task is to enumerate a set of system specifications that will enable individual service providers to develop compliant solutions that can be offered for a fee to transport operators. In determining the exact set of specifications, the general goal is to establish a relatively low level of prescription, including just those aspects that are considered to be essential to the operation of a coordinated, interoperable, and credible system. This low prescription approach provides the following advantages:

- Offers the best balance between standardization required for interoperability and the flexibility needed for innovation and meaningful competition;
- Allows industry the flexibility to innovate and take appropriate development risks; and
- Minimizes the standards and technology development timeframes, costs, and risks for jurisdictions.

The minimum set of capabilities to be specified (in a cooperative effort between jurisdictions and service providers, thus ensuring interoperability) includes the following:

- GIS map information and updating required for maps;
- Location and other parameter solutions, relying on GPS;
- Local communication links between in-vehicle units and enforcement monitoring sites, relying on DSRC;
- Message formats for fetching common data calls from in-vehicle equipment; and
- Functional specification development with cooperation between jurisdictions and service providers ensuring interoperability.

PRICING POLICY

The primary purpose of the IAP is to monitor compliance by freight vehicles rather than to generate revenue. Thus, pricing policies are not discussed explicitly within the proposal. Even so, it should be noted that the technology base for the IAP provides the potential for the future introduction of pricing schemes such as congestion tolls, weight-distance fees, etc.

GOVERNANCE

As noted above, the general institutional model for the IAP is one of public–private partnership. The government sets up specifications, requirements, and a certification regime, while service providers develop actual solutions and vend these to transport operators. Compared with the alternatives—direct government provision or monopolistic outsourcing to a single provider—this approach leads to significant benefits in terms of efficiency, effectiveness, and the potential for innovation. In particular, the IAP approach

- Avoids barriers to entry and market dominance,
- Promotes competition,
- Reduces barriers to market innovation,
- Avoids the creation of tradable property rights, and
- Assigns control of information assets.

Public participants in the IAP would include representatives of jurisdictions who would be responsible for determining access rules and regulations within their own road networks. It also would be necessary to establish a central body for the purpose of setting up and administering the IAP, a role that would include the certification and auditing of service providers. This body likely would be attached to an existing national organization such as Austroads or the National Road Transport Commission. Private participants in the IAP would include third-party certifiers, IAP service providers, and the transport industry itself.

A summary of the responsibilities for the different public and private participants is given as follows:

Administrative Body

- Administer the IAP on behalf of jurisdictions, providing the focus and consistency necessary to ensure that adequate measures to deliver the IAP services are put in place on a timely basis and that core requirements are met.
- Provide a consistent and efficient line of communication among all stakeholders involved in the system.
- Ensure that jurisdictions are kept abreast of advances in telematics, business issues, legislative changes, and how they affect the IAP.
- Establish certification rules.
- Coordinate certification and auditing regime.
- Oversee IAP operating model structure and rule architecture.

Individual Jurisdictions

- Set access rights and concessions for transport operators,
- Provide GIS maps of jurisdictions to be used by IAP service providers, and
- Penalize noncompliance.

Third-Party Certifiers

- Certify and audit IAP service providers.

IAP Service Providers

- Provide fleet management services for transport operators,
- Monitor compliance of transport operators, and
- Provide noncompliance reports and other data to jurisdictions.

Transport Operators

- Pay IAP service provider for services rendered;
- Benefit from expanded, though more carefully monitored, access rights; and
- Operate according to access rights or be penalized accordingly.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

Over last few years, there has been a growing interest in possible public sector applications and associated benefits that may be offered through the use of telematics for the purpose of monitoring freight vehicle road access compliance. In particular

- Transport operators are interested in gaining improved access and concession rights from jurisdictions in the use of the road network (and in turn are willing to agree to tighter monitoring to ensure compliance).
- Jurisdictions are faced with challenges in providing smarter compliance mechanisms and in allowing the introduction of alternative freight vehicle types and weight capacities.
- Given that the movement of freight trucks in Australia is expected to double over the next 15 to 20 years, the government as a whole is interested in the development for innovative mechanisms to better manage the road network asset and its associated uses.

In light of these considerations in 1999 the Tasmanian Department of Infrastructure, Energy, and Resources approached other jurisdictions to initiate a national project to investigate the use of telematics in this role. At the time, Tasmania had just completed its Intelligent Vehicle Trial, which demonstrated the basic feasibility of monitoring the movements of freight vehicles. A number of jurisdictions subsequently joined Tasmania in this project, contributing both staff and funds to the effort. In November of 2001, to enable further progress, the project was brought under the auspices of Austroads, where it received its official name, the Intelligent Access Program.

Throughout the course of the IAP feasibility study, the project team has conducted detailed consultation with a suite of stakeholder groups, including government road and transport jurisdictions (individually and through Austroads); the transport industry (individual operators and industry bodies); private sector providers of telematics and communication services; privacy commissions of New South Wales and Victoria; and interested research, consultancy, and academic organizations. Generally speaking, feedback has been positive and interest strong, assuming that reasonable expectations are met.

Feedback from potential IAP service providers indicated that in order to ensure their participation, there are several key tasks that would need to be addressed by the government in setting up the IAP. These included

- Providing a clear, concise, and consistent certification and auditing regime;
- Providing standards for accuracy and evidence of tampering;
- Providing government GIS map data;
- Ensuring a stable regulatory environment, where all relevant issues have been tested in court;
- Ensuring that any overhanging public policy issues are capable of being settled; and
- Setting up clear communication arrangements and well-defined roles between jurisdictions and service providers.

Likewise, feedback from the transport industry indicated a number of important issues that would be necessary to facilitate system adoption. The following are among them:

- Ensuring the security and protection of commercial-in-confidence information held by IAP service providers;
- Ensuring consistency in the approach for application and enforcement of IAP operators across participating jurisdictions;
- Ensuring that jurisdictions continued to target non-IAP operators through enforcement and didn't treat IAP operators as "easy enforcement targets;" and
- Ensuring that the IAP would not be treated as a revenue raiser through enforcement of minor breaches that would be more readily detectable.

FINANCIAL STRUCTURE

As noted, the IAP is designed primarily as a means of monitoring freight vehicle movement, not for the purpose of raising revenue. As such, the financial structure is relatively simple, and can be summarized as follows:

- IAP service providers develop solutions and vend these to transport operators on a monthly fee basis.
- Transport operators choose whether or not to pay for IAP services; although this involves additional expense, transport operators that opt into the system will enjoy expanded access privileges.
- IAP service providers monitor the movement of subscribing transport operators and report any violations to the relevant jurisdiction.
- Jurisdictions impose fees on any participating operators who violate their access rules (they also continue to monitor violations and impose access violation fees on nonparticipating operators through existing methods).

SUMMARY OF EVALUATIONS

In the course of the feasibility study, the IAP project team evaluated technology approaches and implementation experience from other countries as well as from within Australia itself. Prior Australian trials relevant to various aspects of the study included

- VicRoads Category 3 Cranes—route compliance;
- RTA Mobile Crane Concessional Benefit—route and time compliance, testing of draft auditing regime;
- Queensland Fisheries VMS—zone, time, and speed compliance;
- Western Australia Department of Environment Protection Liquid Waste Vehicle Tracking System—location and liquid volume compliance;
- Western Australia Department of Transport Central Area Tracking (CAT) system—location tracking;

- Queensland Quad Axle Semi-Trailer Trial—route and on-board mass compliance; and
- Victoria-based Australia Post trailer and combination identification—trailer identification validation experiment.

Based on the insight gleaned through these studies, the project team focused on regulatory feasibility, financial feasibility from the perspective of jurisdictions, financial feasibility from the perspective of IAP service providers, and financial feasibility from the perspective of the transport industry. Across the board, the project team concluded that the IAP was both feasible and desirable.

Regulatory Feasibility and Implications for Jurisdictions

Based on an analysis of existing federal and jurisdictional regulatory apparatus, the feasibility team concluded that

- There are no significant regulatory obstacles to the implementation of the IAP; Queensland Fisheries legally proved the approach in their VMS program and by the Western Australia Department of Environment in their Liquid Waste Vehicle Tracking system.
- To facilitate a nationally consistent IAP, jurisdictions must commit to provisions in the model laws that facilitate mutual recognition of certificates and other documentary evidence validly made and obtained in another jurisdiction. Foremost this will require a solid legislative basis for the program and robust certification for jurisdictional maps.
- The IAP can manage privacy policy issues. Consultation with both the New South Wales and Victorian Privacy Commissions have identified the driver identification parameter as being the most sensitive but still manageable. Effectively, IAP service providers and jurisdictions need to ensure that the collection, storage, and security of information is protected against loss, unauthorized access, use, modification, disclosure, or misuse.
- A clear and unambiguous legislative head of power must support the regulatory concessions proposed under the IAP.

Business Feasibility from the Perspective of Jurisdictions

In evaluating the business feasibility from the perspective of jurisdictions, the project team estimated that the financial benefits per year (across all jurisdictions, given 100 percent participation in the program) would total between $118 and $212 million. These estimates were broken down as follows:

- Infrastructure—$20 to $30 million,
- Safety—$90 to $170 million, and
- Environment—$8 to $12 million.

The benefit–cost ratio was estimated to vary between 3.5:1 and 5.0:1, depending on assumptions regarding the level of enforcement pursued.

In addition to quantifiable benefits, the team also noted a variety of additional, subjective advantages offered by the IAP, including

- Providing unparalleled confidence in terms of compliance to access conditions,
- Providing a tool for jurisdictions to address risks in dealing with access requests from transport operators, and
- Providing a way to manage community concerns associated with the movement of heavy vehicles.

Business Feasibility from the Perspective of Service Providers

In analyzing business feasibility from the standpoint of IAP service providers, the project team began by surveying the capabilities of companies that could potentially fulfill this role. Focusing on issues such as current customer base, number of employers, geographic presence across multiple jurisdictions, and technical sophistication, the team identified at least five firms that could currently qualify to become certified providers.

The team also estimated that in order to entice a desired minimum of three IAP providers to enter the market, at least 2,500 vehicles would have to opt into the system over a three-year period. Given the current fleet size of more than 60,000 vehicles throughout Australia, this goal appears easily attainable.

Business Feasibility from the Perspective of the Road Transport Industry

In discussing business feasibility from the perspective of the road transport industry, the project team noted the following:

- When IAP was presented to road transport industry representatives, the response was favorable in light of the potential commercial and productivity benefits that the industry envisioned.
- Response was one of willingness to participate, provided that the benefits from any incentive or concession was greater than the cost of the IAP services.

The estimated cost of the IAP services depended on whether or not a given transport operator already had installed telematics equipment. For vehicles already using telematics, the additional cost was expected to be $30 to $50 per month; for those not yet using such technology, the cost would be $110 to $190 per month. Even with this price tag, however, the benefit cost ratio still appears quite desirable. For the six applications identified for the first phase of the IAP, the estimated ratio ranged from 1.9:1 to 10.1:1.

APPENDIX H

Bristol Truck/Cordon Toll Demonstration[4]

OBJECTIVES OF THE SYSTEM

Following numerous successful studies and trials throughout the 1990s, the Bristol City Council decided to institute a cordon congestion toll in order to achieve a reduction in traffic congestion, thus improving the city environment and making it more attractive to residents, visitors, and businesses. Specific goals for the program included

- Reducing the impact of excess car use,
- Maintaining economic vitality, and
- Raising revenue for transport alternatives.

As one of the eight city members of the PRoGRESS Project consortium, Bristol initially planned to implement the project by the year 2004, the end of the PRoGRESS grant. Unfortunately, there were unforeseen delays in the development of the city's light rapid transit system. Since the light rail project (as the embodiment of a more robust transit system) was seen as a necessary complement to congestion pricing, planners determined that it would not be possible to implement the cordon toll during the timeframe of PRoGRESS. Around the same time, however, the United Kingdom government adopted a new policy for a national distance-based charging scheme for heavy goods vehicles, one that is likely to rely on satellite positioning technology as well as microwave detection. With the institution of this new policy, the Bristol City Council recognized an ideal opportunity for studying the possible synergy between a national charging system and local congestion pricing. Toward this end, Bristol has worked with the United Kingdom Government Department for Transport (DfT) to establish a join technology demonstration, rather than a full scheme implementation, as part of both national United Kingdom research and the PRoGRESS Project.

Bristol City Council sees the new government policy as an opportunity for tidying the synergy between a national charging system and the local congestion-charging scheme, as proposed by the city council. To this end, Bristol has worked with the United Kingdom Government DfT to establish a joint technology demonstration, rather than a full scheme implementation, as part of both national United Kingdom research and as part of the PRoGRESS project. At the most general level, the goals for the study are two-fold: first, to evaluate the potential for various technologies in the implementation and enforcement of distance charges and congestion tolls; and second, to analyze various behavioral and pricing issues relevant to cordon congestion tolls.

In terms of technology, the specific goals of the project are as follows:

[4] The information covered in this review is based primarily on material from City of Bristol (2001), European Transport Pricing Initiative (2002), and PRoGRESS (2003, 2004).

- Evaluate the technical reliability and accuracy of satellite-based metering equipment with respect to both a cordon charging scheme and a distance-based scheme; and
- Evaluate enforcement issues and potential solutions using ANPR.

As background, the City of Bristol had intended initially to implement its cordon-pricing scheme through DSRC. Given that the national government plans to use satellite positioning for its distance-based heavy goods vehicle charges, however, the city wished to investigate the potential for implementing cordon charges using satellite-based systems as well. At the same time, the national government, following the lead of the German truck-tolling program, had initially intended to use DSRC for enforcement operations (essentially, road-side devices would communicate via DSRC with on-board units to ensure that the units are loaded and functioning properly). The national Driver and Vehicle Licensing Agency (DVLA, a division of DfT), however, already is already using ANPR technology for other types of enforcement activities (e.g., identifying and citing non-registered vehicles on the road) and is interested in determining whether ANPR also would be suitable for enforcing distance tolling applications. Toward this end, the City of Bristol has agreed to install several fixed and mobile ANPR stations for use in the trial.

On the behavioral and pricing side of the equation, the primary goals are as follows:

- Track commercial vehicle operating patterns in order to evaluate the potential costs that commercial operators will incur in relation to various pricing schemes,
- Measure the acceptance and understanding of the technology among the commercial vehicle operators, and
- Track general traffic flow patterns in order to evaluate the potential costs that private drivers will incur in relation to various pricing schemes.

To evaluate the full spectrum of commercial activities, the study will include approximately 50 vehicles representing different commercial sectors: own-account freight operators, hire and reward freight operators, courier and delivery services, service vehicles, municipal vehicles, and local bus service operators. Each of the participating vehicles will have on-board units equipped with satellite receivers, allowing researchers to track the movement of the vehicles within the city throughout the day, recording data such as the number of times that each vehicle crosses the cordon line and the times of day at which the crossings occur. Based on this information, it will be possible to determine the likely financial impacts for different types of commercial operations based on different pricing scenarios.

To measure acceptance and understanding of the technology among commercial operators, pre- and post-trial surveys for both drivers and fleet managers also will be conducted.

To evaluate intra-urban driving patterns among the general population, the ANPR technology used within the trial will register cordon crossings not only for participating commercial vehicles but for general traffic as well. For each successful license plate identification, the researchers will link in information from the DVLA regarding the type and age of the vehicle. Overall, the goal is to ascertain various characteristics of the general traffic flow that will be relevant to the pricing of the cordon charge, such as

- The types of vehicles are entering the cordon—car, van, HGV, etc.;
- The age and fuel type of these vehicles;

- How the entry times are distributed over the day;
- How many vehicles cross the cordon repeatedly; and
- The percentages of local, national, or international vehicles.

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

The primary technical component in the trial is an on-board unit equipped with a GPS receiver as well as with cellular communications to transfer transaction information to the central computer system and to download map and tariff table updates. The GPS signal, along with map and tariff information, will be used to calculate a series of charges associated with: (1) entry into the city center cordon, which includes the central retail and business area in Bristol, based on the charging scenario in operation at the time (e.g., peak, shoulder, off-peak); and (2) distance-based charging along portions of the motorway. Given accuracy considerations with the GPS signal, the distance-based component of the scheme will not be true distance charging but rather will work on the concept of segment charging, in which each road is broken down into a series of segments of known length, and a distance-based fee is attached to each segment.

Technical assessment of the on-board equipment will include evaluation of

- The percentage of OBUs that function consistently after installation,
- The number of known occasions when the presence of an equipped vehicle within a charged zone is not correctly registered (using ANPR as a comparison source), and
- The accuracy of bills generated by the on-board charges.

The demonstration also will use ANPR technology to simulate enforcement of the in-vehicle satellite-based charging system. In practice, this scheme would involve a list of vehicles that have traveled in the cordon during a given period, as identified by the ANPR units, which could be cross-listed against all vehicles that have paid a toll for that period based on use of the in-vehicle equipment. For any vehicles identified by the ANPR that have not paid a toll, it would be presumed that either the on-board equipment was malfunctioning, in which case it would be necessary to perform repairs, or that the vehicle did not have in-vehicle equipment installed (and likewise did not pay the toll manually), and thus would be subject to a penalty fine.

Technical assessment of ANPR as a potential enforcement tool will focus on

- The percentage of license plates accurately read (cross checked by human inspection), and
- The percentage of known cordon crossings successfully registered by the ANPR system (using on-board equipment records as a comparison source).

PRICING POLICY

The distance-based charging scheme will aim to demonstrate some of the principles proposed for the United Kingdom government’s heavy commercial vehicle charging. In particular, the scheme demonstrated will

- Charge over a 24 hour period, and
- Have differentiated charges dependant on vehicle size and weight.

The cordon-tolling scheme will evaluate several different charging scenarios based on time of day:

- Charge all day from 7:00 a.m. to 7:00 p.m.,
- Charge at a.m. peak and p.m. peak, and
- Charge at a.m. peak with shoulders.

Although the main cordon scheme for Bristol eventually will levy charges on a wider range of vehicles, the demonstration will focus solely on commercial vehicles. The main categories include

- HGVs over 17 tons (large articulated vehicles),
- HGVs between 7.5 and 17 tons (mostly rigid),
- Vans between 3.5 and 7.5 tons,
- Commercial cars and car-derived vans, and
- Buses and coaches.

Within the trial, there is no explicit goal of influencing the behavior of drivers. Rather, the main goal is to evaluate the technical feasibility of the proposed system. As such, all prices will be nominal. The use of different pricing scenarios is primarily to indicate the technical feasibility of applying these in practice not to measure driver response to the different schemes.

GOVERNANCE

Within the context of the demonstration, the Bristol City Council will be working in partnership with the United Kingdom DfT and the DVLA. The work will involve

- The procurement of satellite-based charging technology through the DfT's DIRECTS (Demonstration of Interoperable Road user End-to-end Charing and Telematics Systems) program,
- Cooperation on policy development with respect to local road user charging and the United Kingdom government's proposals for truck charging, and
- Use of the DVLA's existing ANPR technology for enforcement activities.

Key benefits of the cooperative effort include

- Cost-effective use of existing technology and procurement processes;
- Integrating United Kingdom-supported research and EC-supported research (PRoGRESS) on charging technology to provide a wider range of results;
- Development of both local and national road pricing policy, through a real life demonstration; and

- Exploring the use of existing ANPR-based enforcement technology for other uses.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

Even before its involvement with the PRoGRESS Project, Bristol has been involved intensely with research efforts around the issue of road pricing. Notable studies in recent years include

- Bristol Integrated Transport and Environmental Study, or BRITES (1991);
- Bristol Traffic Restraint Study, Stage 1 (1993);
- Avon Traffic Restraint Study, Stage 2 (1995–1997);
- Environmental Led Guidance and Restraint, or ELGAR (1996–1998);
- Trafficflow Project (1999);
- Road User Charging Scheme Definition (1999);
- Intermodal Concepts in European Passenger Transport, or INTERCEPT (1998–2000); and
- EUROPRICE Project (starting in 1998).

As a result of these studies, the Bristol City Council decided that it would both advisable, in terms of environmental and transportation goals, and feasible, in terms of technical, social, and political considerations, to develop a cordon congestion toll program. This was planned initially for implementation in conjunction with the PRoGRESS Project, which would conclude in 2004. As noted above, however, delays in the completion of the light rapid transit system resulted in a postponement of the full cordon-charging scheme, so the city instead decided to pursue the joint demonstration project involving both distance charges and cordon charges for heavy goods vehicles.

From the prior studies listed previously, the City of Bristol already had developed a good understanding of political and public acceptance issues relevant to its cordon toll scheme. Given this context, the primary focus selected for the joint demonstration project was one of technical feasibility, with social and economic issues relegated to secondary importance. Even so, it is expected that the results of the trial will inevitably influence any future decisions on road pricing in Bristol. In particular

- The component of the study that addresses the distribution and timing of intra-urban traffic flows, both commercial and general, within Bristol will have bearing on the economic impacts of the pricing scheme ultimately adopted.
- The results of the pre- and post-trial surveys of commercial drivers and operators will indicate the appropriate level of outreach and education necessary prior to rolling out any full-fledged implementation of cordon- or distance-based pricing.

Given the significance of this project with respect to future road pricing efforts in the United Kingdom, there will be a marketing campaign involved, linked in part to the marketing strategy for DIRECTS being developed by the DfT. This will include brochures, links to websites, and press coverage.

FINANCIAL STRUCTURE

The test project is being supported in part by the Economic Union, through the PRoGRESS project, and in part by the DfT, in association with the DIRECTS program.

In any future implementation, it may be presumed that the national government, and in particular the DfT, would have jurisdiction over funds from distance-based truck tolls, as the City of Bristol would control revenues generated through the cordon congestion toll.

SUMMARY OF EVALUATIONS

The demonstration planning and technology specification was completed at the end of 2002. The full system was installed and tested by the end of July 2003, at which point data collection began. The ANPR systems were installed in August 2003. The test was scheduled to be completed in December 2003. Final results have not been published yet.

APPENDIX I

German “Toll Collect” Truck Toll Program[5]

OBJECTIVES OF THE SYSTEM

The Toll Collect truck-tolling program in Germany was launched successfully in January of 2005. It was originally scheduled for release in late 2003 but was delayed because of a variety of contractual and technical integration issues.

The structure of the Toll Collect charge is subject to an EU directive that limits the toll on trucks to vehicles over 12 tons, limits the toll to motorways only (other roads are free[6]), and limits the aggregate charge to direct capital and operating costs imposed by truck traffic on the motorway network. Within these constraints, the charge is allowed to vary by distance, by vehicle category (weight and environmental emissions) and by time of day (for congestion purposes). Of these, the Toll Collect charge factors in distance and vehicle category but does not include time of day. Accordingly, the main objectives of the system are to

- Recover system costs associated with truck use of motorways in order to finance ongoing maintenance, repair, and improvements;
- Promote environmental improvements by sending price signals that encourage a shift to lower emissions vehicles and a mode shift from road to rail; and
- Reduce deadheading thereby encouraging more efficient use of vehicle stock.

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

The Toll Collect system includes two distinct payment options. For infrequent users, there is a manual declaration and payment method that can be accessed via roadside toll stations or the Internet. For frequent users, in turn, there is an automated electronic system based on the use of on-board equipment, which includes GPS and GSM. The GPS receiver is used to determine when a vehicle enters or exits the motorway as well as the route and distance traveled.[7] The on-board unit then calculates the charges owed based on the kilometers driven and the vehicle type (which is pre-coded in the on-board unit) and transmits the information via GSM to the Toll Collect center, which sends out a corresponding invoice on a periodic basis.

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[5] The information covered in this review is based primarily on material from Kossak (2003), Rothengatter (2004), Rothengatter & Doll (2002), Ruidisch (2004), and Reason Public Policy Institute (2004).

[6] The Toll Collect system has been designed to allow for charges on other major roads (termed “Bundesstrassen,” meaning major highways that are not “Autobahns”) in order to discourage truckers from deviating off of tolled highways to avoid paying charges. If, in monitoring the program, analysts observe frequent deviation off of Toll Collect truck routes onto parallel routes not intended to handle heavy truck traffic, then the toll system will be extended to include these routes.

[7] Distance traveled is not directly measured with GPS in the German system. Instead, highway segment are recognized by the on-board units and matched with segment length and toll rate data stored in the OBU memory.

Given that the toll only covers the motorway, it would have been possible in theory to develop a charging methodology based on DSRC and overhead gantries at entry and exit points to the network. Eventually, however, the European directive governing the permissible structure of truck tolls is likely to be expanded to include secondary roads as well as the motorway, and at that point Germany envisions expanding its own toll program correspondingly. The planned technology using GPS will allow this future expansion, whereas a DSRC-based solution would not make this possible.

The German Toll Collect technical strategy (similar to that proposed for the United Kingdom) is more sophisticated than that implemented in Switzerland or Austria, involving the integration of GPS and GSM technology. It was developed under an aggressive schedule and suffered from a series of hardware and software problems at the beginning. These problems were eventually solved, however, and the system is now up and performing as intended.

It is interesting to note that the first three European nations to develop distance-based truck tolls—Switzerland (not a member of the European Union), Austria, and Germany—have all relied on different technical configurations that are not interoperable. This disparity has motivated the European Commission to launch an Interoperability Directive to promote unified standards for combined GSM–GPS technology (under the assumption that GPS will be either supplemented or replaced by the new European Galileo satellite system around the year 2008). In the future, then, it is to be expected that the technology base for tolling projects in the European Union, including that of Germany, will move to a greater level of uniformity.

PRICING POLICY

The pricing policy for the German Toll Collect program is governed by EU Directive 62/1999, which determines the economic basis for heavy goods vehicle tolls throughout the European Union. According to this directive, the fee can vary according to several criteria such as distance traveled, category of vehicle, and time of day. At the same time, however, the toll can be applied only to motorways (the remainder of the road network is explicitly excluded, except in specific cases where a high level of traffic diversion would otherwise be expected), and the overall level of the fee must be proportional to the total capital costs (including interest and depreciation) and operational costs (including maintenance and repair, administration, enforcement, traffic control, and administration of the toll collection program) associated with truck use of the motorways. These costs are allocated to different user categories (e.g., to different vehicle types and to users across a multiyear horizon) according to the following principles:

- **Causality**: measured on the basis of operational parameters (e.g., axle loads);
- **Specificity**: measured by the typical requirements of user categories with respect to the design of roads (e.g., thickness of layers, curvature, width of lanes); and
- **Fairness**: minimizes cross subsidization between user categories for the fair allocation of pure common costs (based on game theoretical concepts).

The calculation of total costs and the allocation of costs to different user groups are difficult analytical tasks requiring extensive modeling and forecasting activities. In the end, however, the output is a set of per-kilometer charges for travel on the motorway system differentiated according to

- **Number of axles**: up to three axles versus four or more axles; and
- **Environmental categories**: A (the best), B, and C (the worst).

Generally speaking, the per-kilometer charge is about 20 percent higher for vehicles with four or more axles, and is 50 percent higher for environmental category C variables than for category A vehicles.

GOVERNANCE

The Toll Collect program represents a public-private partnership. Legislation for the program was passed by the German government, and overall authority for the policy and pricing of the Toll Collect system remains with the Ministry of Transport. As shown in Figure 2 below, Toll Collect collects user charges and transfers them to the Ministry of Transport (via the Ministry of Finance). Toll Collect then gets direct reimbursements for its services from the Ministry of Transport.

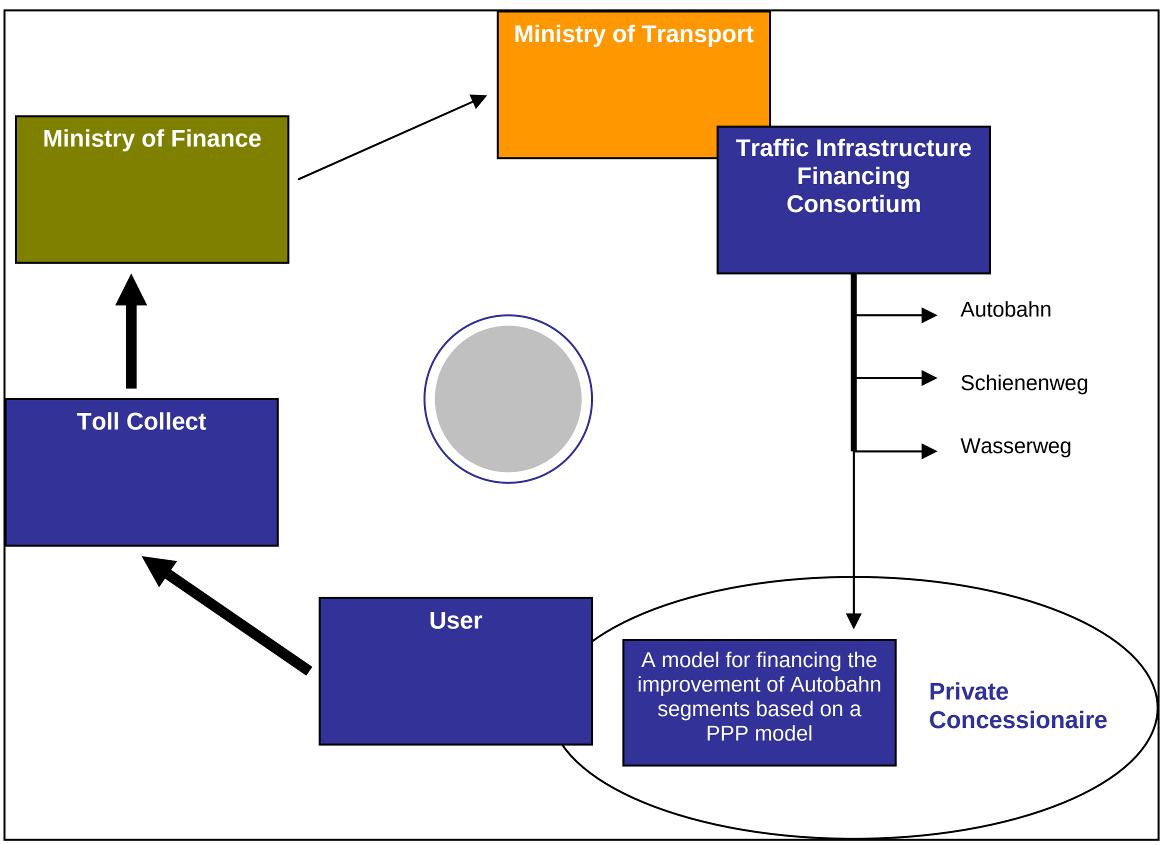

FIGURE 2 Diagram of the revenue path in the German Toll Collect Program.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

In 1995, countries within the European Union that had not already introduced general charging systems for their motorways agreed to start with the Euro-Vignette system for heavy goods vehicles (HGV), a program that applied to vehicles with a gross weight ranging from 12 to 40 tons (the upper end of the spectrum corresponding to the maximum weight limit allowed on European roads).

In 1999 the European Union introduced Directive 62/1999, which allowed distance-based truck tolls on the motorway for vehicles over 12 tons. The toll structure is subject to various constraints, including

- The toll applies primarily to the motorway network; other roads can be included only if the potential for traffic diversion would create significant safety issues.
- Only costs directly related to the provision and operation of road infrastructure can be included in the fee; external costs are explicitly excluded.
- The charge for a given vehicle category has to be based on the average infrastructure cost that can be reasonably allocated to the category.
- It is possible to differentiate the charges according to two criteria: the time of day (peak/off peak), where the maximum difference between the highest and the lowest cost cannot exceed 100 percent; and environmental performance, measured by the EURO-standard for vehicle emissions, where the maximum difference between the highest and the lowest charge cannot exceed 50 percent.

The new German Law for Motorway Charging of HGV, based on the European directive, includes distance and emissions categories, but does not currently factor in the time of day. In anticipation of the original implementation schedule, the new law replaced the previous Euro-Vignette law in September 2003. The new kilometer-charge was not introduced until January 2005. During the intervening period, truck movements on German motorways were essentially free of any charge.

For the past two years, the EU Commission has been working on a revision of the heavy goods vehicle-tolling directive, which may include the following elements:

- Extension of the priced road network;
- Reduction in the weight limit from 12 to 3.5 tons;
- Earmarking of revenues;
- Consideration of environmental sensitivity, allowing for addition mark-ups for passes through the Alps and the Pyrenees;
- Consideration of accident costs; and
- Differentiated guidelines for calculating infrastructure costs, in particular the omission of capital costs for old infrastructure.

To date, there has been heavy debate on some of these proposed changes, and no consensus has emerged yet. When the new directive is finally agreed on, however, it may influence the future structure of the German truck toll.

FINANCIAL STRUCTURE

As noted above, a public company operating under private law, termed VIF, has been formed to implement and administer the Toll Collect program. VIF will receive revenues from Toll Collect and can spend them for road transport projects; the government will determine the overall investment plans, but the company is responsible for design, construction management, operation, and finance (in the case of loss making projects they negotiate with the government on public grants).

Under the current arrangement, trucking companies do not have to pay for the on-board unit, but they do have to pay for the installation. To encourage rapid adoption, operators qualified for a reduced installation price if they ordered before September 2004.

SUMMARY OF EVALUATIONS

Given that the system has been operational for such a short time, as of yet there are little real world data on which to evaluate the effects of the system on traffic and shipping. A number of forecasted evaluations have been conducted, however, including a study launched by the German Environmental Agency in 2002. This study looked at a variety of possible behavioral effects that would result from the new toll, including

- Diversion of traffic from the motorway to the secondary network;
- Diversion of freight from road to rail; and
- Strategic adjustment of logistics, round trips, loading factors, and fleet composition in the trucking industry.

To assess these issues, the study relied on a series of analytic and simulation models, including a road haulage cost model, a social cost model, a freight transport network model, a logistics model, and a vehicle fleet model, to evaluate demand-side reactions in the various segments of the trucking industry. To inform policy decisions (this work was performed prior to the establishment of the official charge structure), three different pricing scenarios were considered:

- Scenario 1 assumes that only motorways are priced, and the secondary network is free of charge; that the rate is differentiated by weight and emissions class; and that the rate remains constant (after adjustment for inflation) from 2003 through 2010.
- Scenario 2 assumes that road pricing applies to both motorways and primaries, that the charge is differentiated by weight and emissions class, that the toll increases (in real value) in a step-wise manner from 2003 through 2010, and that the level of service offered in the rail network remains constant over time.
- Scenario 3 is identical to scenario 2, with the exception that the level of rail service available is considerably improved in subsequent years (thus increasing the attractiveness of shipping by rail).

Notable findings from the simulation modeling exercises include the following:

- **Diversion to secondary network**: Generally speaking, diversion to the secondary network decreases with increasing distance of the trip, higher emissions standards (more environmentally efficient vehicles), and increasing vehicle weight; furthermore, diversion effects are substantially lower when the entire road network, as opposed to just the motorways, is priced. Given that the intended charging scheme for Germany (based on the current European Union directive) includes motorways only, significant diversion is to be expected.
- **Diversion of road to rail**: The results of this aspect of the study are not surprising. In scenario 1, where the charge rate remains constant and the rail network is not improved, little if any mode shift occurs. In scenario 2, where the road pricing increases over time but the rail network remains unchanged, there is a modest shift of 4 to 7 percent. Finally, in scenario 3, where the charge rate gradually increases and the rail network is improved over time, the mode shift ranges from 12 to 35 percent.
- **Logistics improvements**: Potential steps to improve efficiency in the face road pricing can include legal options, such as the optimization of round trip hours, the adjustment of warehouse locations, and the adjustment of the fleet composition, as well as nonlegal activities such as the employment of illegal immigrants, the overloading of vehicles, and the violation of other regulations. The results of the study indicate that the road haulage industry should be able to compensate for about 15 percent of the cost increase through legal internal adjustments alone, including an increased number of warehouse locations (for shorter average delivery distances), an increase in the percentage of environmentally efficient vehicles (to take advantage of lower corresponding charge rates), and a shift, especially pronounced at the lower end of the weight spectrum, to slightly smaller vehicles to get below the planned 12 ton lower weight limit (e.g., the truck manufacturing industry is already planning to introduced 11.9 ton trucks).

APPENDIX J

Swiss “HVF” Truck Toll Program[8]

OBJECTIVES OF THE SYSTEM

Against a backdrop of increasing truck traffic in prior years, the integrated Swiss freight transport policy is primarily intended to foster a mode shift from road to rail. This policy relies on three broad elements:

- A performance (weight/distance/emissions)-related HVF that allocates the cost of freight transport on roads according to the user–polluter pays principle;
- Modernization of the railway infrastructure, involving a voter-approved investment of €20 billion; and
- A railway reform act aimed at raising the productivity and improving the competitiveness of rail freight companies (e.g., increasing reliability and eliminating current lengthy delays associated with transnational shipments).

Introduced in January of 2001, the HVF can be considered the central pillar of the Swiss transport policy. Its main features are as follows:

- The fee is applied to heavy vehicles with a total weight of more than 3.5 tons on the entire road network in Switzerland;
- The rate of the fee depends on three factors: the distance driven, the maximum laden weight of the vehicle, and the emissions category of the vehicle;
- The average fee rate is currently one cent per ton-kilometer; this will increase incrementally to 1.8 cents per ton-kilometer by 2007; and
- The revenues of the fee are used primarily to finance the railway infrastructure program.

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

The primary technology for metering road use and storing billing data is an on-board unit that incorporates DSRC and a connection to the vehicle tachograph (which includes odometer information). For legal reasons, Switzerland cannot make installation of on board units mandatory for foreign vehicles. As such, they have had to institute two separate billing systems.

For vehicles equipped with the on-board unit, including all Swiss vehicles (for which installation is mandatory) as well as some foreign vehicles that frequently travel through Switzerland, the maximum laden weight of the vehicle and the emissions class are stored in the on-board unit. In order to record the kilometers driven, the on-board unit is coupled to the odometer (via the tachograph), enabling the unit to register the distance traveled within the country. To prevent charges for trips outside of Switzerland, microwave transmitters are

[8] The information covered in this review is based on material from Balmer (2004) and Werder (2004).

mounted on overhead gantries at all major border crossings. Each time a vehicle leaves Switzerland, a signal from the transmitter deactivates the on-board unit distance-tracking feature, and each time the vehicle re-enters, another signal reactivates the tracking feature. The GPS antenna serves as a backup for registering border crossings that occur on non-standard routes, such as minor roads or via motor rail (the GPS is also used as a backup check on the accuracy of the odometer readings). Once a month, the data stored in the on-board unit is registered on a chip card and forwarded to the federal authorities who use it to determine the fee and generate the appropriate monthly invoice. To prevent toll evasion, DSRC stations are distributed throughout the road network to verify the correct functioning of on board units.

Foreign vehicles not equipped with the on-board unit must register each trip (including weight and emissions class of the vehicle and the start miles and end miles) on entering and leaving the country, and the fee must be paid in full at the time of exit. The fee calculation is the same, but the overall process is much more cumbersome; as such, foreign vehicles that travel frequently in Switzerland will benefit, in terms of saving time on each trip, by having on-board units installed in their vehicles (which, incidentally, is free, both for domestic and foreign vehicles alike).

PRICING POLICY

Goals of the HVF include not only capturing direct costs and externalities but also encouraging a freight mode shift from trucks to rail. As such, in comparison to the prior flat toll, the introduction of the HVF led to not only a change in the structure of the fee system but also to the level of the fee. On average, the fee rate per truck is now five times higher (at around one cent per ton-kilometer) than it was before 1999, and by 2007, as a result of planned fee increases, it will be about nine times higher (at around 1.8 cents per ton-kilometer).

Fees are based on a combination of distance traveled, maximum laden weight of the vehicle in question (not actual weight of the current load), and emissions class. Three distinct emissions categories are recognized, corresponding similar distinctions adopted in the European Union.

GOVERNANCE

Initial work in developing the HVF was split between the Swiss Customs Authority (SCA), incorporated in the Swiss Ministry of Finance, and the General Secretariat of the Transport Ministry. The SCA, experienced in the administration and collection of taxes, was directed to prepare the implementation on the technical level, while the transport ministry was in charge of managing the political details, including the determination of the fee structure as well as the underlying scientific and economic research.

Currently, administration and toll collection for the HVF program is managed by the SCA, with support (e.g., enforcement activities) from the Swiss Cantons.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

The national referendum on the introduction of the HVF was one of the most controversial voter issues that Switzerland has ever seen. At first glance, it appears somewhat surprising that a clear majority of 57 percent voted in favor of the fee, given that the population is neither fond of new taxes nor known for being particularly progressive. The story behind the success of the fee is both long and complex.

In January 1972 the Swiss government set up a commission to elaborate an integral transport concept for Switzerland. This was motivated by the insight that the state's existing legal, financial, and organizational means could no longer cope with the strongly growing transport needs and the new major projects for rail, road, shipping, and air transport.

Five years later, in 1977, the commission presented its recommendations. One of the recommendations was that heavy road transport, which did not at the time cover the infrastructure costs that it imposed, should receive a new special tax linked to work performance (i.e., weight, distance, and emissions). In general, this concept was well received; however, in order to provide a legal basis for the fee, a voter approved constitutional amendment would be required, and this could take some time.

In 1983, the Swiss Parliament decided not to wait until the full set up recommendations of the 1972 commission could be implemented, but instead to introduce a performance-related heavy goods vehicle fee in advance of the other reforms. Given that the technology was not yet sufficient for a full performance-related fee, however, it decided to introduce a flat fee instead. At the same time, it also tacked on a flat user fee for automobiles using the motorway. In the following referendum, which was compulsory for both projects, both bills were accepted (57 percent in favor of the flat fee for heavy goods vehicles, and 53 percent in favor of the motorway user permit). The primary reason that voters accepted the heavy goods vehicle fee was that freight traffic did not cover its costs for use of infrastructure, and furthermore that it would serve as a catalyst for transferring more freight from road to rail. The motorway user fee, in turn, was favored primarily as a means of collecting compensation from foreigners for their use of the Swiss network. These were both implemented in 1984.

In 1982, two years earlier, the Swiss Association for Transport and Environment (a conservation group specialized in transport matters) had submitted a people's initiative requesting the introduction of a performance-related fee for heavy goods vehicles, one that not only compensated for the direct costs of road use, but also for the external costs of air pollution and other environment effects. Though the federal government basically agreed with the motives of the initiative, it finally rejected it in 1986, in part because it came at the wrong time (the vote took place just two years after the flat fee had been implemented) and in part because the government needed more time to establish a suitable fee system.

Two years later, in 1988, a vote was held on the bill for a "coordinated transport policy" based on many of the recommendations from the original commission study during the 1970s. The bill, which was approved by a large majority in Parliament, consisted of a variety of articles that provided the constitutional basis for the institution of performance-related fees, not just for heavy goods vehicles but for general traffic as well. Many voters were wary of the general scope of the amendment, however, viewing it as a mechanism for raising new taxes that would apply to all drivers, and ultimately the bill was refused by a majority of 54 percent of the electorate. This outcome demonstrates just how difficult it can be to gain sufficient political support for a global concept. Although a majority might accept the principle as correct, it is finally refused because of the accumulated opposition of interest groups, who oppose specific—and different—aspects of the bill.

With the rejection of the coordinated transport policy, Swiss transport problems continued to worsen, and as a result transport-related issues remained on the political agenda. One problem in particular continued to become more pressing: the increase in heavy goods vehicles transiting through the Alps, which had grown enormously following the opening of the St. Gotthard road tunnel in 1980. The fact that an increasing percentage of heavy goods vehicles came from abroad made the subject politically delicate, underscoring the need to find a solution that met Swiss requirements for better protection of the population along transit routes and the demand from the European Union to ensure sufficient transport capacity for transalpine traffic.

The suggested solution was to increase the percentage of freight traffic transported by rail across the Alps (a difficult goal, given that the rail already accounted for 80 percent of such traffic) by building two new rail links. Approximately 75 percent of the funding would be derived through loans (to be repaid based on rail freight user fees), with the remaining quarter coming from vehicle excise taxes (under the argument that it was also in the interest of car users to relieve the transit routes from heavy goods vehicles). The proposal was opposed by both some environmental groups, who argued that additional rail capacity only made sense if the use of rail would be mandatory for transport traffic, and some auto interest groups, who were afraid that the parliament might subsequently raise the share of revenues derived from fuel excise duties. Ultimately, however, the measure passed by a clear majority of 64 percent of the voters, who seemed to be convinced that the project would provide environmental benefits, support public transport, provide congestion relief benefits to road users, and be favorable to international integration.

The acceptance of the project for two new rail links across the Alps was not only a clear signal of the political appeal of transferring goods from road to rail but also a catalyst in favor of a performance-related fee as a means to push the policy forward. Given that the bill for a coordinated transport policy had been rejected, however, it was necessary to draft a separate bill to create the constitutional basis for a HVF. The vote for this initiative passed with a large majority in 1994, setting the stage for planning and implementation work to begin.

Work on the project was split between the SCA, incorporated in the Swiss Ministry of Finance, and the General Secretariat of the Transport Ministry. The SCA, experienced in the administration and collection of taxes, was directed to prepare the implementation on the technical level, while the transport ministry was in charge of managing the political details, including the determination of the fee structure as well as the underlying scientific and economic research. Immediately following the vote in 1994, the transport ministry began to draft the law to implement the fee. The following were among the key provisions in the initial draft:

- The fee was to depend on the distance driven and the laden weight.
- The fee was to be levied for all roads on Swiss territory.
- The fee was to be limited to the total costs caused by heavy goods vehicles.
- The Cantons were to receive some portion of the net income.
- The government was authorized to make exceptions.

Initial feedback to this draft was primarily negative. Primary arguments against the proposed legislation, offered by different interests, included the following:

- The fee should not be based on weight-distance but rather on diesel consumed.
- The fee should, additionally, depend on emissions.
- Because the fee only applied to vehicles with a laden weight of more than 3.5 tons, it would result in a shift to lighter vehicles.
- The scientific basis for the calculation of external costs was not sufficient.
- The proposed rate of two cents (Swiss) per ton-kilometer was too high.
- Reliable technology (e.g., an on-board unit) to implement the fee was not available.
- The Cantons should receive a higher share of the revenue.
- The fee should not be introduced prior to a solution on the European Union level (or should at least be compatible with a solution on a European Union level).

One of the first objections to address was the issue of the on-board unit, a clear prerequisite for implementing the performance-charge. Given that such technology was not yet commercially available, in 1996 the SCA started a call for tender for the development of this technology, which would require a budgetary allocation of approximately 7.9 million Swiss franks. Although this passed the first chamber of parliament to debate the issue, the Council of States, it was defeated in the second, the National Council. This failure, combined with the negative response to the initial draft discussed above, spelled trouble for the potential future of the heavy vehicle fee.

Despite these hurdles, however, a supporting motivation for the fee arose from an unexpected quarter. In 1992, the people of Switzerland had voted against joining the European Economic Area. Even as this left Switzerland free to development its own economic policy agenda, it also resulted in the need to set up bilateral treaties with the Economic Union, its most important trade partner. In 1996, Swiss industry representatives were interested in pursuing such a treaty. The EU, however, was reluctant to agree to Swiss requests unless the Switzerland was also willing to make various concessions. In particular, the EU was concerned with the issue of transalpine traffic passing through Switzerland. From a geographic perspective, Switzerland is located between three major members of the EU, France, Italy, and Germany, and thus has the potential to serve as a major conduit of trade between these nations. Yet in prior years, to protect the population living along alpine roadways, Switzerland had adopted legislation that hindered freight transport through the Alps, notably a maximum weight limit of 28 tons and a night ban prohibiting any trucks over 3.5 tons from traveling between the hours of 10 p.m. and 5 a.m. As a result of these regulations, much of the freight traffic passing between France, Germany, and Italy had to follow circuitous routes that skirted the Swiss Alps.

The EU demands to relax requirements for alpine freight travel could have led to a political deadlock, but the heavy goods vehicle fee provided a way to break the impasse. With the HVF, Switzerland could allow trucks up to 40 tons to travel through the Alps, thereby meeting EU demands in order to facilitate the treaty. At the same time, revenues from the fee would offset the costs imposed by heavier use, and the fee itself would continue to encourage a freight mode shift from road to rail. With this compromise in mind, progress on the heavy goods vehicle fee gained momentum once again. In late 1996, both houses of the parliament approved the budgetary allocation necessary to develop the required on-board technology. At the same time, the transport ministry organized a variety of changes to the proposed HVF legislation to address the earlier objections. These changes included

- Agreeing to provide one third of the net revenue of the fee to the Canons, thereby enlisting their support;
- Strengthening the scientific basis for the calculation of external costs factored into the fee; and
- Incorporating the level of emissions into the structure of the fee.

The amended bill was submitted to the parliament in 1997 and, despite opposition from the right wing of the political spectrum, was passed in both councils with a clear majority. Immediately following this success, opponents of the bill launched a referendum against it, arguing that it would lead to additional outlays (in the form of higher freight costs ultimately passed on to the consumer) per family and that it would not induce a substantial shift from road to rail. Concerned with securing the desired economic treaty concessions, however, and recognizing that the implementation of the HVF would be necessary in order to convince voters to approve an increase in the weight limit of trucks passing through the Alps, Swiss industry interest groups invested considerable time and money to lobby for the fee. In these efforts, they were ultimately successful, and in September of 1998 voters approved the fee with a 57 percent majority.

The system was ultimately launched in January of 2001, on time and within budget. The following factors contributed to the successful implementation:

- Both systems, the one for equipped vehicles and the one for unequipped vehicles, are technically and conceptually simple, leading to a quick installation process and a ready understanding of the nature of the charge on the part of users.
- The fact that the fee had been accepted in a popular vote increased its acceptance within the road transport industry, which certainly helped to facilitate the successful introduction.
- The fee was initiated at the beginning of January, a time of year during which heavy goods transport is relatively low. This provided the opportunity to ease into the operation and work out any issues before the system was subjected to peak loading.

FINANCIAL STRUCTURE

Approximately two thirds of the net revenues from the HVF are used to fund the Swiss rail improvement program. The remainder is disbursed to the individual Cantons, who use a share of the money for road repair and maintenance activities.

SUMMARY OF EVALUATIONS

The HVF system has been in operation since January of 2001, so there has been ample time to study its effects with respect to various goals. Preliminary findings include the following:

- **Economic productivity**: The higher weight limit allowed under the HVF has increased overall productivity (goods per vehicle) by about 18 percent. The increased level of the fee, which has raised transport costs by about 19 percent, roughly offsets this increase.

- **Changes in fleet composition**: Because part of the HVF is based on emissions class, the institution of the fee has led to a rapid upgrade of the trucking fleet. In terms of the type of vehicles purchased, there have been two distinct trends. On the one hand, haulers who in the past had routinely used oversized vehicles with excess capacity have now purchased smaller new vehicles in order to capitalize on the laden weight element of the charge. On the other hand, larger shippers have opted for even bigger trucks to take advantage of the new higher weight limit of 40 tons (as compared to the prior limit of 28 tons).
- **Changes in structure of the trucking industry**: The new system has led to a concentration in the trucking industry, either through acquisition of the closures of smaller companies. This appears to be due to the fact that larger companies can manage their trucks more efficiently, especially with respect to avoiding empty runs.
- **National trucking trends**: The new trucking fees have resulted in a break in the growth of truck traffic. In the years before the HVF, the average annual growth rate was around 7 percent. Since the institution of the fee, truck traffic dropped by 4 percent in 2001 and by 3 percent in 2002. In 2003 the rate remained more or less stable.
- **Transalpine trucking trends**: In transport traffic across the Alps, the new higher weight limit led to a significant increase in articulated trucks, which was offset by a corresponding decrease in lighter trucks. In aggregate, the number of trucks crossing the Alps has remained relatively stable since the institution of the fee, which represents an improvement over prior growth rate of up to 10 percent per year in the years preceding the fee.
- **Mode shift trends**: To date, there has been no apparent mode shift resulting from the HVF, even though this was clearly one of the stated aims. In part, this may be because of the fact that the dampening effect of the fee structure is offset by the productivity gains enabled by larger vehicle limits. For certain sectors unable to quickly adapt to the higher weight limits, such as the oil transport industry (for obvious safety reasons), however, there has indeed been an increase in rail share. In general, though, it is viewed that improvements in the efficiency of the rail network will be needed to spur a greater mode shift across all sectors, and efforts to that effect are already underway.
- **Environmental effects**: Given the rapid adoption of newer vehicles and the changes in fleet composition described above, estimates suggest that the new HVF fee will result in a 30 percent reduction in the emissions of NO_2 and CO_2.
- **Economic impacts**: Surprisingly, the new charging regime has had very little consequence on the cost of living; according to the federal office for statistics, the average increase per family was 0.1 percent at most.
- **Cost–benefit revenue analysis**: Total implementation and operational costs for the HVF (including research, investment, construction, replacement, and staff) are about €40 million per year, which is about 8 percent of gross revenues. When fees increase in the coming year, costs will represent just 5–6 percent of gross revenues. In other words, from a purely financial perspective, external benefits aside, the program is quite cost effective.

APPENDIX K

United Kingdom Truck Toll Proposal[9]

OBJECTIVES OF THE SYSTEM

Within a three-to-four-year time period, the United Kingdom government intends to implement a new truck toll for vehicles over 3.5 tons that will vary according to distance traveled, road type, and vehicle type (size, number of axles, emissions class, etc.). The toll will apply to all of the 415,000 goods vehicles registered in the United Kingdom as well as to all foreign registered vehicles operating on United Kingdom roads. There are two primary motivations behind this toll:

- To ensure fairness and efficiency, so that all users contribute equally and at a level that reflects the costs they impose on the road network; and
- To deliver environmental benefits by setting the rates to reflect the environmental performance of the vehicles paying the charge.

The first of these goals, fairness and efficiency, is motivated in particular by the current patterns of foreign truckers operating in the United Kingdom. At present, the diesel tax rate in the United Kingdom (representing a significant source of road revenue from the trucking industry) is higher than that in other surrounding nations. As a result, foreign trucks heading into the United Kingdom will refuel typically before entering the country and then not refuel again until they have left. As a result, foreign trucks both avoid paying their fair share of the costs of using United Kingdom roads and also enjoy a competitive advantage over the domestic shipping industry. By replacing the fuels tax with a distance tax, however, this inequity can be corrected. At the same time, layering in an element of the charge that is based on vehicle emissions can also result in significant environmental improvements as truckers upgrade their vehicles in response to the new price signal.

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

Implementation of the fee will be based on an on-board unit installed by authorized fitters, probably at the same garages as now install digital tachographs. The on-board unit will include a GPS receiver, a link to the vehicle’s tachograph (which includes odometer information), and GSM. The GPS receiver will record location (and hence road type) and distance traveled, while the tachograph will provide a secondary check on distance traveled (in cases, for example, where the GPS signal is temporarily interrupted). Finally, the cellular communications will provide a link to the data processing and payments center to which the charge is paid. All goods vehicles making regular use of United Kingdom roads would be required to register for the scheme and provide details of a bank account, which could be debited with the charge (special manual provisions will be instituted for occasional users).

[9] The information covered in this review is based primarily on material from Worsley (2004).

The decision to rely on this technical approach unfolded according to the following considerations. One of the initial policy questions addressed in early studies of the truck toll was whether to charge for the use of all roads in the United Kingdom or just for highways. In the former case, it would be necessary to rely on some device for tracking distance traveled across the entire road network, such as GPS or the odometer. In the latter case, however, it would be possible to opt for a DSRC solution, with overhead gantries distributed throughout the highway network.

Modeling efforts conducted by the DfT indicated that if highways alone were tolled, there would likely be a significant and undesirable shift of freight traffic from the interstate network to local surface streets. For this reason, the decision was made to charge for all road use within the United Kingdom, and this ruled out the DSRC option.

The next question to evaluate was the type of technology to use for tracking distance traveled across the entire network, which could be achieved via either satellite positioning or simple odometer. Given that the charge was intended to distinguish between road types, however, any odometer-based solution would be insufficient. Therefore the decision was made to rely on GPS instead (with odometer information relayed through the tachograph providing a secondary check on distance traveled).

PRICING POLICY

In designing the fee structure, the United Kingdom government is cognizant of the trade-off between simplicity and potential efficiency. Information from a earlier study entitled *Surface Transport Costs and Charges—Great Britain 1998* shows that the costs of road transport can vary significantly by time of day, road type, and area type (e.g., rural versus urban). From a theoretical standpoint, then, there would be good reason to structure the charge so as to reflect all of these differences. Unfortunately, however, there is little information available on how road users might respond to such a complex structure of charges, so it is unclear just how effective such a system would be.

Given this consideration, the United Kingdom government proposes to start with a relatively simple structure of charges designed to meet the primary objectives of the policy. In particular, the initial fee will vary based on

- Distance traveled,
- Vehicle type, and
- Road type.

Varying the fee by distance traveled within the United Kingdom ensures that all trucks contribute their fair share to road use costs, regardless of their country of origin or where they last purchased fuel. Distinguishing between vehicle types allows the toll to reflect both road damage factors and environment costs; generally speaking the oldest, heaviest vehicles with the fewest axles will pay the most, while newer, lighter vehicles with more environmentally friendly emissions standards will pay less. Along these lines, the charge will also encourage operators to upgrade their fleets and make more efficient use of their vehicles (e.g., less deadheading) to reduce unnecessary kilometers driven. Finally, varying the fee by road type helps to capture the significant differences in road costs between modern, high quality roads designed for freight traffic and older roads where road damage, environmental, and safety costs are much higher.

The proposed technical approach will also enable additional factors to be included in the future. For example, it is likely that the charge will eventually include a time of day factor so as to encourage operators to schedule their trips during times when the inter-urban network is least congested. In addition, the charge may include some variation by geographic area (e.g., industrial area vs. residential area) in order to reflect the higher costs that heavy vehicles typically impose when operating in close proximity to people and their homes. Neither of these options is likely to be included with the initial introduction of the fee, but the aim is to ensure that these can easily (from a technical perspective) be added subsequently.

GOVERNANCE

The truck toll will be administered at the national level by the Dft.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

In November 2001 the United Kingdom government issued a consultation document *Modernising the Taxation of the Road Haulage Industry*. The consultation was concerned with the implementation of fair and efficient pricing for all goods vehicles using United Kingdom roads.

One of the main motivations behind this proposal was related to the current patterns of foreign trucking within the United Kingdom. To put the issue in context, foreign haulers rather than domestic haulers carry most of the freight originating elsewhere in Europe that is bound for the United Kingdom. In part, this is because of the composition of United Kingdom exports and imports. Generally speaking, the United Kingdom imports a higher percentage of high bulk, perishable items such as food, which are typically carried by road, and exports a higher percentage of lighter refined goods and services, thus contributing to the imbalance in the road haulage sector.

This imbalance has significant financial consequences for road revenues in the United Kingdom. Given that diesel fuel taxes are higher in the United Kingdom than elsewhere in Europe, many inbound foreign truckers simply refuel before entering the country in order to avoid the high taxes. This not only leads to a revenue loss for the United Kingdom as a whole but also creates a competitive disadvantage to domestic shippers relative to foreign concerns.

Given the nature of this problem, there is broad support for the new fee structure within the United Kingdom. This support is further enhanced by the fact that from the perspective of domestic shippers, the changeover from a fuel tax to a distance charge will be more or less revenue neutral.

FINANCIAL STRUCTURE

The truck toll is not intended to increase the overall cost of road freight haulage for domestic carriers in the United Kingdom. As such, it is necessary to reduce other taxes on the industry so as to leave the aggregate fees more or less comparable. Two main options were considered: reduction of the vehicle excise duty (the annual ownership tax), and reduction of the diesel fuels tax.

The vehicle excise duty is already highly graduated to encourage the purchase of environmentally friendly vehicles; policy analysts consider this to be a desirable feature, so there was little flexibility to reduce this fee. Diesel fuel taxes, on the other hand, could certainly be reduced. The main danger in this latter option is that it would provide an unwarranted benefit to the owners of diesel-engine light goods vehicles and cars, resulting in turn in significant costs to the United Kingdom treasury. To circumvent this difficulty, the decision was made to retain the existing level of tax on diesel fuel but to offer a rebate on this tax to truckers when they purchased fuel in the United Kingdom (retailers would then claim a rebate from the tax authority).

SUMMARY OF EVALUATIONS

The government expects to implement the toll within the next three to four years. The timetable will partly depend on market response when the procurement process begins, which should occur in 2004.

APPENDIX L

University of Iowa "New Approach" Proposal[10]

OBJECTIVES OF THE SYSTEM

The Federal Highway Administration and 15 state departments funded jointly the study entitled *A New Approach to Assessing Road User Charges*. The central premise of the work is that the efficacy of the conventional fuels tax, long a primary source of road use revenues, will decrease significantly in the coming years. This is due not only to increasing fuel efficiency among current vehicle models (most notably the recently introduced hybrid designs) but also to the likely introduction of alternative fuel vehicles (for example, using hydrogen fuel cells) in the near future. As such, it was considered desirable to identify a replacement system that would be able to

- Raise sufficient revenues to replace the fuels tax;
- Charge users in a fair and equitable manner, proportional to their use of the road network;
- Span multiple jurisdictions, apportioning fees depending on the location of travel; and
- Apply to both passenger vehicles and freight trucks (though the specific nature of the charges would differ between the two).

The proposed solution involves the incorporation of on-board equipment that, at the most basic level, measures the miles driven in different jurisdictions and computes charges accordingly. This technology base has the potential to facilitate several important policy and research objectives, which can be ranked in importance as follows:

- The central, and by far the most important, objective is to provide a general basis for charging motorists for their use of roadways in a fair, reliable manner.
- A secondary objective is to enable jurisdictions to vary user charges by factors such as the time of day when a trip occurs.
- A tertiary objective is to collect detailed travel data to facilitate improved technical analyses, such as travel demand forecasting.

Two of the most potentially difficult challenges in securing public approval for this new form of charging relate to issues of equity and privacy. With respect to equity, the first of the goals listed above, that of charging motorists based on their level of use (i.e., by the mile), poses no real problems. In fact, it is quite similar (only more precise) than the existing fuels tax, which also varies by distance traveled. Introducing congestion charges (as in the second objective above), however, may raise real concerns, as has been demonstrated in recent controversies surrounding the issue of HOT lanes. As such, in order to avoid significant outcry over equity concerns, the study recommends that the new charging mechanism should, at least at first, only be used to capture mileage-based charges. Subsequently, once the new system is firmly

[10] The information covered in this review is based primarily on material from Forkenbrock and Kuhl (2002).

established, individual jurisdictions can decide whether to layer on congestion tolls in additional to the base mileage fees. More generally, then, the study envisions that there would be certain types of charges that would be built into the system from the onset, while there would be others that could be added later at the discretion of individual jurisdictions. The division is as follows:

Initial Charging Goals

- For autos: miles traveled by jurisdiction (specifically, by state); and
- For trucks: miles traveled by jurisdiction by road type (bearing in mind that heavy vehicles such as trucks may cause far more damage on local roads than on highly engineered highways).

Potential Future Charging Scenarios

- For autos and trucks: miles traveled by jurisdiction, where jurisdictions are measured at a finer grain; for example, local cities or counties may choose to layer on their own additional mileage charges, which could replace road finance funds currently drawn from property taxes;
- For autos and trucks: congestion tolls, based on time and location of travel; this could even be applied at the level of the individual lane (as in HOT lanes), though this latter would require a level of GPS and roadmap accuracy that is beyond currently available standards; and
- For autos and trucks: charge adjustments based on vehicle characteristics such as emissions class (in the case of autos) or weight and number of axles (in the case of trucks).

In the case of privacy concerns, the primary objective of the charging scheme—measuring miles driven by jurisdiction—again poses the least level of difficulty. In particular, the system can be structured such that it records nothing above and beyond the number of miles traveled in each jurisdiction and the corresponding charge level. To further enhance privacy, the only data reported to the billing agency that needs to be tied to a specific individual is the total amount of the bill owed (to facilitate billing, obviously); information about the division of the bill to different jurisdictions (which would imply where the user has traveled), in contrast, can be reported in a second, anonymous, transmission. As such, it is not necessary to keep track of where a given driver has traveled, even at the broadest level of the statewide jurisdiction.

In contrast, to meet the third possible objective, that of providing a rich data set to facilitate more accurate transportation analysis, it would be necessary to store a far more detailed record of transportation data, including origins, destinations, time of travel, and specific routes traveled. Within the context of the standard four-step demand modeling process, for example, this would allow

- Better trip generation data,
- Better trip distribution data, and
- Actual route selected data.

The data also would be useful in other common transportation management tasks, including

- Transportation system management, in which data on the exact volumes by vehicle class on individual links during specific time intervals would help to forecast and plan necessary maintenance schedules; and
- Signal timing activities, in which detailed traffic volume data would be used to determine the appropriate signal cycle lengths for different periods of the day.

Despite the obvious utility of this enriched data set, it clearly raises significant privacy concerns. To address this, the study recommends that for automobiles, any data gathering above and beyond miles per jurisdiction should be purely optional (for commercial trucks, the issue of privacy is much less pressing). To encourage drivers to allow more detailed data collection, it might be possible to offer reductions in their registration fees or other incentives.

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

Technology Overview

In evaluating ways to charge vehicles based on miles driven across the road network, two options initially were considered: smart cars and smart roads. To be sure, some smart roads, in the form of toll facilities equipped with electronic gantries, already exist. To extend such technology to *all* roads, however, is simply cost prohibitive. For this reason, the natural option to focus upon was smart cars. In other words, the technology for registering mileage charges should reside within the vehicle itself.

For in-vehicle technology solutions, the simplest option would be to rely on the existing odometer, which would be checked on a periodic basis to determine appropriate user charges. Unfortunately, the odometer, in and of itself, offers no way to distinguish between different jurisdictions where the driver may have traveled. As such, there would be no way to apportion the resulting fees fairly on a state-by-state basis.

The need to distinguish between travel in one jurisdiction and another suggests a more complex technical solution, one that takes advantage, for example, of GPS and digital map technology. In order to ensure that such technology would be acceptable to the general public, study researcher place a strong emphasis on the issue of user-friendliness. More specifically, they sought to design a solution that

- Preserves the privacy of the road user;
- Is convenient and amenable to desirable features such as on-board navigation and emergency vehicle location;
- Is secure, robust, reliable, and sufficiently flexible to enable a variety of public policies to be supported; and
- Allows division of charges to different jurisdictions.

The resulting solution strategy involves an integrated on-board unit that consists of the following elements:

- A GPS receiver to position the vehicle and determine distance, with the odometer and a dead reckoning system to serve backups;

- A GIS file to indicate the road being traveled or the jurisdiction in which the travel has occurred;
- An on-board computer capable of storing road-use data and making simple computations, such as applying a given state's per-mile user charge rates to the relevant miles traveled;
- A display for informing the driver of accumulated user charges and indicating any past due amounts that may be subject to late payment penalties; and
- A smart-card system for transmitting the stored road-use data to a collection center and receiving information from the center.

The GPS and the GIS data file will be used collectively to record travel in different jurisdictions and optionally on different road types. For backup purposes, the number of miles traveled as measured by the odometer will be compared against the number determined by the GPS unit; in cases of significant discrepancy, the number identified on the odometer will be assumed correct. Such a circumstance, however, would indicate that the on-board unit might need maintenance or replacement, and a message to that effect would be shown in the on-board unit's display window. In cases where the GPS receiver loses its signal, dead-reckoning will be used to keep track of a vehicle's location (either within jurisdictions, in the case of cars, or by road type, in the case of trucks). If the GPS unit becomes disabled for a prolonged period, however, the positional accuracy offered by dead-reckoning will slowly degrade. In this case, the user will receive a message indicating that maintenance for the on board unit is required.

The on-board unit will include the basic information needed to compute charges by jurisdiction. At minimum, this will consist of a per-mile rate by jurisdiction (for autos) and a per-mile rate by jurisdiction by road type (for trucks). In addition, depending on the policies adopted, the on-board unit may store additional vehicle-specific information (such as emissions class, in the case of autos, or weight and axle configuration, in the case of trucks) used to determine per-mile charge offsets.

The on-board unit also will include a display panel, which indicates the current running total of charges owed since the most recent payment. The panel also will show if any of the charges are past due, which would result in the application of late payment penalties. Finally, the display will be capable of alerting the user to potential problems, such as the malfunction of any of the unit's components.

Data transfer will be accomplished using smart cards, small devices (approximately the size of a credit card) with an embedded computer chip. During use, the on-board computer will continuously update the smart card with information about the total user charges owed to each jurisdiction. Periodically, the user will then remove the smart card and insert it into a reader (potentially located at a fuel station) to transmit billing data. At the same time, the collection center can download new GIS files with updated boundaries or charging policies. When the smart card is reinserted into the dash, the new jurisdictional data will be uploaded into the on-board computer automatically.

To increase security, the smart card data transfer system will use an embedded security key for user authentication as well as data encryption for the transfer phase. To enhance the privacy of information even further, the system will first upload the total charge for each user (which will in turn be used to generate the bill), and then upload the division of charges by jurisdiction anonymously. The division of funds by jurisdiction is needed only to make sure that the funds are distributed appropriately, so there is not need to tie this information to each individual's charge record.

Above and beyond facilitating the basic per-mile charging scenarios already discussed, one important benefit of the technology scheme outlined above is that it has the potential to support numerous value-added features such as in-vehicle navigation. Another possibility is emergency location notification (in the case of accidents or breakdowns), which could be facilitated through the addition of cellular communications to the basic on-board configuration. The technology also offers several compelling advantages to the trucking industry, including the elimination of tollbooths, the automation of interstate permitting, and the potential for optimizing road user charges (for example, by adding axles and traveling on roads with higher engineering standards.

Autos versus Trucks

As already noted, the basic technology solution is designed to encompass both auto tolls and truck tolls. In practice, however, the requirements for these two distinct applications are slightly different. In particular

- Privacy is more an issue with private vehicles than with trucks, and
- Equity of payment is more pressing among trucks than with autos given that costs can vary tremendously based on the type of road traveled as well as the specific configuration of the vehicle.

These differences suggest that a much simpler approach is appropriate for autos than for trucks. In particular, the equipment could be configured to track and store different sets of information for autos and trucks, as follows:

For Autos

- GIS maps would store just state boundaries, not road segments, and the on-board unit would record just miles traveled per state.
- Optionally, the jurisdictional map could be enhanced considerably (i.e., at a finer grain of resolution than the state level) to allow for the collection of additional road user fees at the city or county level.
- Optionally, the on-board unit could track location and time to facilitate congestion charges.
- Optionally, the GIS map could include individual road segments and the on-board unit could track origins, destinations, time of travel, and route of travel to facilitate data collection for advanced transportation analysis (even if this were installed for all vehicles, however, it would always remain optional to the user).
- Optionally, the on-board unit could include information on the vehicle type to encourage the adoption of more environmentally friendly vehicles.

For Trucks

- GIS maps would store not just state boundaries but also individual road segments coded by class (e.g., highway versus nonhighway), and the on-board unit would record miles traveled by state by road category.
- Optionally, as with autos, the on-board unit could be configured to store jurisdictions at the local level, to record location and time for congestion tolls, and to record more detailed trip data to support subsequent transportation system analysis.
- Optionally, the on-board unit could keep track of the weight and axle configuration of the vehicle in order to capture the higher level of damage imparted by heavier trucks with fewer axles.

Phase-In Issues

Study researchers have determined that the goal of retrofitting existing vehicles would be cost prohibitive. This implies the need for a lengthy phase in period, which could easily stretch over 20 years (a time during which slightly more than 90 percent of the current vehicle stock will have been replaced). The suggested phase-in solution involves the following steps:

- Begin now to require the on-board equipment on all new vehicles.
- During the initial years of the program, apply the new mileage-based fees to alternate-fuel vehicles only; for gas- and diesel-powered vehicles, continue to apply the existing fuels tax (regardless of whether the vehicle in question has the on-board unit installed).
- At some point in the future, when a sufficient percentage of gas- and diesel-powered vehicles have been equipped with the on-board unit, eliminate the fuels tax and begin to apply the mileage-charge for all vehicles.
- At the time of the roll-over, any remaining older vehicles without on-board equipment can pay mileage fees based on periodic observations of the odometer; while this will not facilitate the necessary distribution by jurisdiction, the number of vehicles paying in this manner will be relatively small, so the overall magnitude of the problem will be minimal.

PRICING POLICY

For automobiles, the most basic pricing policy will be based on miles traveled per state, while for trucks it will be based on miles traveled by road type per state. Optional extensions could include

- For cars and trucks: per-mile surcharges at the local (neighborhood, city, or county) level;
- For cars and trucks: time- and location-based congestion charges;
- For cars: per-mile adjustments based on emissions class; and
- For trucks: per-mile adjustments based on weight and axle configuration.

GOVERNANCE

The system is, by design, multijurisdictional. As vehicles accrue miles, the on-board unit will determine the applicable jurisdiction and register the charge accordingly.

The study proposes that the collection facility responsible for billing and apportioning revenue to different jurisdictions should be managed under contract by a private firm. Under this arrangement, the firm would be subject to restrictive guidelines to ensure that any recorded user data would remain absolutely private.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

Currently, state and federal fuels taxes combine to account for nearly two-thirds of all road user charges, so there is clearly a huge amount of road financing capability at stake. In its defense, the existing structure of the fuels tax offers certain compelling advantages, most notably

- It roughly approximates the pay-as-you-go principle, thereby achieving a reasonable degree of equity; and
- It sends price signals to encourage more fuel efficient vehicles.

At the same time, however, the fuels tax suffers a number of problems that cast doubt upon its continued level of effectiveness in coming years. These include

- An increasing level of fuel efficiency in new cars (especially hybrids), which leads to lower tax receipts per mile traveled;
- A strong likelihood for the introduction of vehicles using hydrogen fuel cells or other alternative propulsions in the coming years, which would further undermine the ability of the fuels tax to generate sufficient revenue to maintain and improve roadways;
- A high rate of evasion, in the range of 10 to 15 percent, for the diesel fuel tax;
- A lack of any meaningful relationship to the type or cost of the facility being used and the level of service provided; and
- A weak relationship to the relative costs of particular trips such that some vehicle operators pay user charges that exceed the costs they impose, while others pay substantially less than their costs.

In considering potential replacements to the fuels tax, there are several inappropriate alternatives that can be ruled out immediately. These include

- Placing more emphasis on vehicle registration fees: these fees have no relationship to the amount of road use and thus the cost of serving the traveler; and
- Increasing property taxes: these fees also have no relationship to road use; furthermore, visitors to a jurisdiction pay no property taxes directly, and thus avoid user fees entirely.

In contrast, a user fee based on the number of miles driven does meet the user-pays principle, and in addition has the potential to address each of the problems that currently besets the fuels tax. Based on this consideration, the researchers set out to devise a technology base and institutional structure for mileage-based user charges that would eventually be able to replace the fuels tax. While recognizing that it may still be a number of years before the efficacy of the fuels tax becomes significantly degraded, it was none-the-less appropriate to begin this research now.

Given both the magnitude of the revenue involved as well as the potential resistance to change among the population, the researchers recognized that the new mileage-based user fee system would need to be extremely well designed. In particular, they identified the following key attributes:

- A low cost of collection for both agency and user,
- A stable revenue stream,
- An ability to assess higher charges for users who impose higher costs,
- A low evasion rate,
- An ability to offer incentives for users to travel on appropriate roads and to spread their trips across time periods,
- A procedure that is unaffected by the method of vehicle propulsion,
- An ability to accurately apportion user fees to different jurisdictions, and
- A strong level of protection for the privacy of road users.

Of these, the issue of privacy was considered the most likely to raise concerns on the part of the public. Based on a thorough review of legal precedents, it was determined that the proposed user-charging scheme would not violate user privacy from the legal perspective. Even so, however, it was noted that the mere perception of privacy issues might cause enough public outcry to prevent the program, even if it met all legal requirements. Given this potential, the proposed solution focused on privacy as a central issue, particularly with respect to private passenger vehicles. Most notably

- The on-board unit stores the minimum level of data necessary to calculate charges by jurisdiction.
- When reporting user charges to the collection center, the total charge is reported by user (for billing), while the charge per jurisdiction (for apportioning revenues) is reported anonymously.
- The smart card data transfer system includes both security-key authentication as well as data encryption.

FINANCIAL STRUCTURE

The research described herein was funded cooperatively by the FWHA as well as by the departments of transportation for fifteen different states (California, Connecticut, Iowa, Kansas, Michigan, Minnesota, Missouri, North Carolina, Ohio, Oregon, South Carolina, Texas, Utah, Washington, and Wisconsin). The Minnesota Department of Transportation led the study, while the research was organized by the University of Iowa’s Public Policy Center.

Under the proposed strategy, a collection agency, operated by a private firm, would collect fees from individual users and distribute them to jurisdictions as appropriate. Individual users would be offered multiple payment options, including

- Monthly billing: collect data periodically and send a bill each month;
- Smart card charging: add pre-payments to the smart card and debit as needed;
- Threshold billing: send a pre-payment to the billing center and then automatically send a new bill whenever the account balance falls below some threshold level; and
- Real time billing: tie the smart card to a credit card or debit card, which would be charged whenever mileage fees are uploaded.

SUMMARY OF EVALUATIONS

The study discussed herein evaluated technical and institutional options for a mileage-based user fee and developed a detailed proposal to implementation. The next step is to develop an extensive pilot test to evaluate the system in operation. Efforts to this effect are currently underway.

APPENDIX M

Oregon's Road User Fee Taskforce Pilot Program[11]

OBJECTIVES OF THE SYSTEM

Under a mandate from the Oregon State Legislature, the Oregon Department of Transportation (DOT) is conducting a test designed to demonstrate the feasibility of area-wide, distance-based road user fees as well as congestion tolls. This would apply primarily to passenger vehicles, as Oregon already has implemented weight-distance truck tolls.

The driving motivation behind this experiment is concern over the steadily eroding purchasing power of the fuels tax, a phenomenon resulting from: (1) the fact that the fuels tax is not indexed for inflation; (2) a general reluctance on the part of voters to approve periodic increases in the tax rate; and (3) continued increases in the fuel efficiency of new vehicles, especially hybrids and alternative-fuel vehicles. Given these issues, the Legislature asked Oregon DOT to evaluate the potential of alternate strategies to replace the fuels tax, focusing in particular on technical strategies for implementing a mileage-based charge. Oregon DOT also is investigating the possibility of using the same technology base to apply congestion tolls, due in part to a mandate from the Federal Highway Administration's Value Pricing Pilot Program, from which Oregon DOT is receiving some of its funding.

Before focusing in on the mileage charge and congestion tolls, Oregon DOT analyzed a wide range of other potential road revenue funding mechanisms. In evaluating whether any given alternative represented an appropriate and desirable source of revenue to replace the fuels tax, Oregon DOT established a checklist of important criteria that must be met:

- Users pay in proportion to road use;
- Strategy generates sufficient revenues to replace fuels tax;
- Funding source supports the entire road and highway system;
- Program doesn't usurp revenue sources from local governments;
- Program involves low administrative costs for government;
- Strategy is easily enforceable;
- Funding mechanism is transparent to the public, visible, and not confusing; and
- Program is perceived as fair and is acceptable to the public.

In total, Oregon DOT considered 28 different funding source alternatives, including a range of options such as general funds, property taxes, parking fees, battery taxes, and emissions fees. Of these, 24 failed to meet one or more of the criteria above. Four strategies, however, were considered likely candidates to fulfill specific funding roles:

- **Mileage fee.** Would serve as primary revenue source for Oregon's needs;

[11] The information covered in this review is based on material from James Whitty (2003; personal communication, August 18, 2004).

- **Congestion pricing.** Would work as a transportation demand management instrument (possibly implemented as a mileage fee adjustment for time of day in specific geographic areas or on specific facilities);
- **New facility tolling.** Would help pay for new facilities; and
- **Studded tire use fee.** Would offset disproportionate road damage caused by vehicles driving with studded snow tires.

After identifying these four potential sources, Oregon DOT next set out to design a pilot test to demonstrate the technical and administrative feasibility of implementing the first two of these: distance-based user fees and congestion tolls. With respect to distance pricing, the most substantive source of revenue, Oregon DOT identified a number of specific policy recommendations (above and beyond the general criteria listed above) that should be incorporated within the strategy:

- Should accurately determine distance traveled;
- Should be reliable, secure, and technically feasible;
- Should not charge for mileage outside of Oregon;
- Should impose minimal burden on private sector;
- Should not require expensive retrofitting for older vehicles;
- Should allow seamless transition with no more than incidental loss of fuel taxes; and
- Should not violate level of privacy expected by general public.

To date, Oregon DOT has developed successfully a technical strategy, encompassing both on-board equipment and supporting infrastructure that is capable of addressing these issues. The on-board technology was demonstrated in May 2004. According to the schedule, 20 trial vehicles were to have been equipped with the on-board devices in February and March 2005. In the summer of 2005, after verification of functionality, 280 trial participants in Eugene, Oregon, were to have had the on-board equipment added to their vehicles. For a period of one year, all participants will pay distance charges rather than the fuels tax (when they fill up at the station, the fuels tax will be deducted from the bill and the mileage charge will be added).

One portion of the study group will pay distance fees only, and not be subjected to congestion charges. The other group will pay slightly lower distance fees, but also have congestion charges added on. The purpose in establishing these two sub-sets is to evaluate the relative influence of congestion charging on driver behavior.

At the conclusion of the study, Oregon DOT expects to have demonstrated the feasibility of both distanced-based user fees and congestion tolls. They also will draft model legislation that will enable the Oregon State Legislature to consider adopting these programs on a statewide basis beginning in 2007.

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

In evaluating technical approaches to distance charging and congestion tolls, Oregon DOT began by identifying several key tasks to be supported. These included

- Calculation of distance traveled, by zone and by time (at the most general level, this would distinguish between travel within Oregon and travel outside of the state; in the case of congestion tolls, it would also distinguish between congestion zones and other areas of the road network);
- Calculation of fee owed;
- Data storage;
- Data transmission; and
- Data processing.

As potential solutions to these tasks, Oregon DOT investigated a number of potentially relevant technologies, including

- Global Positioning System,
- Odometer tag system,
- Automatic vehicle identification,
- Radio frequency transmission,
- Cellular transmission,
- Bar code identification,
- Electronic toll tags (transponders), and
- License plate recognition systems.

After much deliberation and experimentation, Oregon DOT researchers ultimately developed a technical design and implementation strategy consisting of the following key elements:

- **Measuring distance.** The on-board unit integrates both a GPS receiver as well as an electronic feed from the vehicle’s odometer. The GPS unit is used primarily to determine when the vehicle crosses from one zone to another (e.g., entering or leaving state borders, entering or leaving a congestion zone, etc.), while the odometer is used to measure travel distance within each zone. The primary reason for relying on the odometer feed to measure distance is that the GPS signal can be intermittent in mountainous areas or in cities with tall buildings; thus the odometer is considered more reliable.
- **Calculating fees.** To calculate charges owed, the on-board unit records the number of miles traveled and stores this information in different mileage “buckets”, each of which corresponds to a different charge category. At minimum, there will be at least two buckets: one for in-state travel (against which the base per-mile rate is charged) and one for out-of-state travel (for which no fee is charged). If congestion tolls are incorporated into the system, there will be additional buckets for different times of day (e.g., off-peak hours, shoulder hours, and peak hours) and different zones in which congestion tolls are applied.
- **Communications and billing.** The on-board unit will communicate via DSRC rather than by cellular (GSM). DSRC is generally cheaper to install and operate than GSM and poses fewer privacy concerns (DSRC works only over relatively short ranges, whereas cellular communications operate over much longer ranges). The on-board units will communicate billing data to radio receivers mounted at fuel stations.

- **Phase-in process.** When vehicles with on-board units purchase gas at a fuel station, the current mileage charge will be automatically added to the bill, while the built-in fuels tax will be deducted. For vehicles without an on-board unit, the fuel tax will be paid as always, and no mileage charge will be added. This parallel payment arrangement facilitates a prolonged phase-in period. Once the system is established, all new cars sold in Oregon will be equipped with on-board units. The equipment may also be required for newer vehicles imported into the state as well, provided that the on-board unit has been designed for easy installation within the model in question. Owners of older vehicles (both existing and imported) can also choose to install retrofitted on-board units, but this will be optional. Over time, as the current fleet of vehicles is replaced by newer models (a process that may take as long as 20 years), a greater share of Oregon drivers will come to rely on the distance charge instead of the fuels tax. In time, once most Oregon residents have converted to the distance charge, the fuels tax will be applied primarily to out-of-state drivers to make sure that they pay their fair share of road user charges.

PRICING POLICY

The primary aim of the task force is to demonstrate the technical feasibility of distance-based charges and congestion tolls implemented through the use of on-board units equipped with GPS receivers and digital road maps. It is not to advocate a particular pricing policy, which is viewed as lying in the purview of the state legislature.

Even so, the task force has estimated that the appropriate revenue neutral road pricing for distance (as a replacement for the fuel tax) would be approximately 1.22 cents per mile in 2002 costs. The task force also has discussed several pricing concepts that may be considered and possibly adopted by the legislature should a system of distance-based road pricing be implemented. These include

- **Indexing for inflation.** This would provide for automatic, as opposed to voter-approved, increases in the mileage charge to offset the pace of inflation.
- **Increasing the fees beyond revenue neutrality.** In part due to inflation and in part due to increasing fuel economy, fuel tax revenues per vehicle mile traveled in Oregon (as in most areas) have been declining for years. To compensate for this erosion, the Legislature may consider setting a cost per mile designed to raise revenues equivalent to a prior year benchmark, which would exceed strict revenue neutrality with respect to the system as it stands today.
- **Congestion tolls.** The pilot test is designed, in part, to demonstrate the feasibility of congestion pricing for heavily used urban road networks, primarily to manage demand but possibly to increase revenues as well (note that in the pilot test, the only goal considered is demand management; correspondingly, those participants forced to pay congestion tolls will also be subject to a lower per-mile base distance fee).
- **Fuel efficiency incentives.** The fuels tax has a built-in incentive for fuel efficient (hence lower emission) vehicles, whereas the mileage fee does not. To compensate, it may be appropriate to build in offsets (positive or negative) to the base distance fee to continue to encourage the use of environmentally friendly vehicles.
- **Geography factors.** Above and beyond congestion tolls, the legislature may consider variable pricing for distinct zones within the state to reflect differences in road construction and maintenance costs that vary with geographical characteristics. For example, mountain roads cost

more to construct and are subject to faster wear and tear based on the frequent use of snow removal equipment.

- **Studded snow tire fees.** The use of studded snow tires in snowy mountainous areas also causes significant road damage; to compensate, the task force has suggested the possible introduction of mileage fee surcharges applied to users of studded snow tires.

GOVERNANCE

Should the state legislature choose to implement a mileage-based user fee, the program would be administered at the state level, most likely by Oregon DOT.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

Currently, federal and state fuel taxes constitute approximately 60–70 percent of road revenues for Oregon. Yet because of increased fuel efficiency, continued inflation, and a general reluctance on the part of voters to increase the fuels tax, the purchasing power of this mechanism (in terms of inflation-adjusted revenue per VMT) has been steadily declining for decades. In response to this problem, in 2001 the Legislative Assembly passed House Bill 3946, which mandated the formation of the Road User Fee Task Force to establish a long-term vision for Oregon road finance.

Initial research findings of the task force quantified the recent erosion of the fuels tax and suggested that this trend was only likely to worsen in the coming years. The following were among the notable findings:

- Inflation is seriously eroding purchase power of fuel tax revenues.
- The rate of gasoline consumption per mile traveled is also dropping, from an average of 11.8 miles per gallon in 1970 up to 19.7 miles per gallon in 2002.
- With inflation and fuel efficiency combined, the cost per mile traveled is dropping.
- At the same time, economic and population growth have fostered a huge rise in VMT; from 1960 to 2000, VMT in Oregon has increased from 4.9 billion miles to 20.5 billion miles (about a 300 percent increase), while lane miles have increased from 18,478 to just 19,200 (about a 4 percent increase).
- Further fuel efficiency improvements are expected, including the current surge in hybrid vehicles, the likely introduction of fuel cell cars in the coming years, and the continued development of new composite materials that will lead to lighter and more efficient cars.
- Projected fuel price increases also will drive demand for more efficient cars; experts predict that by 2010, production of conventional oil will crest and reach permanent decline.
- Based on all these factors, total fuel tax revenues from the sale of gasoline are likely to level off then enter permanent decline over the next 10 years, a situation that will negatively impact the ability to maintain, preserve and modernize Oregon roads.

In response to these findings, the task force has developed the proposal for distance-based user fees and the pilot test discussed within this appendix. To help educate residents, politicians, and related stakeholders (e.g., auto manufacturers and fuel distributors) about the nature of this program, the task force has engaged in a concerted outreach process, including the following elements:

- The task force accommodated public testimony at each of its meetings.
- Addition comments were received at three public hearings held in Pendleton, Portland, and Coos Bay.
- Two stakeholder meetings were held.
- An interactive website was provided to allow residents to make comments.
- The work and findings of the task force were discussed in televised reports, news articles, editorials, and numerous radio interviews given by different task force members.

During the course of the public outreach, as well as the preparations for the pilot test, there has been a wide range of public, political, and institutional responses.

On the Public Front

- In general, there is a lack of angst about this proposal. Especially with the recent popularity of hybrids, many individuals see the utility of this type of program.
- The primary initial concern has been one of privacy. Once individuals understand that they system only transfers summary data and that it does not allow the government to track the movement of vehicles, this concern is quickly muted.
- An additional question that many residents ask is, "Why not just raise the fuels tax?" The position of the task force is that: (a) this has not proven to be popular with voters in recent years and (b) it becomes even more difficult with the introduction of hybrids and alternate-fuel vehicles. Once explained, most residents seem to buy in to this rationale.

On the Political Front

- There have been two common responses among politicians: excitement among those who have a reasonable understanding of road finance, and a quick reactionary dismissal among those unfamiliar with the current challenges facing the fuels tax. The task force has found, however, that when the issues and concepts are clearly explained, most politicians, even those initially hostile to the idea, tend to become supportive.
- The real political issue, it appears, is not whether the program is appropriate, but rather what the appropriate types and rates of charge would be. What is the base charge? Should congestion tolls be applied? Should environmental incentives be layered in? What are the social equity implications? These questions are likely to form the nexus around which political debate centers.

On the Institutional Front

- Among both automakers and fuel retailers, there has been some reluctance to this type of program, owing primarily to the additional work that would be required. Auto-manufactures, for example, would have to develop models that would include plug-in slots for the on-board equipment, while fuel retailers would have to develop technology for handling the traditional fuels tax and the new mileage tax interchangeably. These challenges are not viewed as insurmountable; still, it is clear that concerted effort and clear communication will be required to facilitate a cooperative partnership with these third parties.

FINANCIAL STRUCTURE

Current cost estimates for the on-board equipment are just over $200; when mass-produced, it is expected that the price may fall to below $100. Unfortunately, the cost of retrofitting existing vehicles not designed to house the on-board equipment adds an additional $200 to the price tag. As such, Oregon DOT does not consider it feasible to require that all existing vehicles be retrofitted with on board equipment. Instead, a lengthy phase-in process, one that could last as long as 20 years, is envisioned:

- Once the program is implemented, all new vehicles sold in Oregon would be equipped with appropriate on-board technology; installation would also be required for any vehicles imported into Oregon that are compatible (i.e., don't require costly retrofits) with the on-board equipment.
- Owners of existing vehicles (or older, incompatible imported vehicles) could choose to install on-board equipment as a retrofit, but this choice would be optional.
- When purchasing fuel, all vehicles equipped with the on-board technology would pay the mileage charge and receive an instantaneous rebate for the fuels tax. All vehicles not so equipped (including out-of-state travelers) would continue to pay the existing fuels tax.

With the current technical platform developed for the pilot test, mileage charges are paid each time a vehicle visits a fueling station and purchases fuel. Essentially, the on-board unit communicates via DSRC with a receiver mounted at the fuel station, and the resulting fees are automatically incorporated (adjusted for the rebate on the fuels tax) into the sale price. From an institutional perspective, this transaction would work as follows:

- Stations purchase fuel from distributors, paying an additional 24 cents per gallon in fuels taxes. Fuel distributors forward this tax to Oregon DOT.
- In serving its retail customers, stations will keep an aggregate count (across all customers) of the number of gallons sold, the fuel tax collected (for vehicles without the on-board equipment), and the mileage tax collected (for vehicles with the on-board equipment installed).
- Periodically, each station will send data to Oregon DOT on the total number of gallons sold as well as the total gas tax and mileage tax revenues collected.
- If the gas tax plus mileage tax revenues total less than 24 cents per gallon (the amount paid by the station to the fuel distributor), then Oregon DOT will remit the difference to the station.
- If the gas tax plus mileage tax revenues total more than 24 cents per gallon, then Oregon DOT will send the station a bill to collect the difference.

SUMMARY OF EVALUATIONS

Preliminary demonstrations of the technology to be used in the pilot test have been successful. The pilot test itself will be launched in 2005, and a detailed evaluation of the test will be performed in 2006. If the test is deemed successful, legislation to adopt mileage-based pricing throughout Oregon may be introduced as early as 2007.

APPENDIX N

Puget Sound Distance/Congestion Pricing Pilot[12]

OBJECTIVES OF THE SYSTEM

The Puget Sound Regional Council (PSRC) is developing a pilot test to evaluate behavioral response to time-dependent, network-wide congestion tolls charged according to distance traveled. The study does not include baseline distance charges (in other words, it is not intended to simulate the replacement of the fuels tax with a distance-based fee).

Approximately 350 volunteer households will participate in the study, including households with multiple vehicles and households with only a single vehicle. All vehicles for participating households will be equipped with on-board units that include GPS receivers and cellular communications. At the beginning of the study, there will be a two-month period during which baseline travel behavior will be monitored and recorded. Each household will then be set up with an endowment account of funds to be applied to congestion tolls, the size of which depends on the baseline travel behavior for each household. For the following ten months, the on-board unit will use coordinates from the GPS receiver, as well as time-of-day information, to determine the appropriate congestion tolls to apply to each segment of each trip (these charges will be displayed on the on-board unit, so that each driver is aware of the tolls in real time). Twice each day, the on-board unit will send, via cellular communications, detailed travel data for each vehicle to a central processing agency, which will debit the appropriate congestion tolls against the endowment accounts.

At the end of the ten months, each household is eligible to keep any funds that remain in the endowment account. If a household has reduced its level of travel during congested hours below the baseline level recorded during the initial two-month monitoring period, there will be a positive balance remaining in the account to reward the household for its travel choices. In contrast, if the household has maintained or exceeded its baseline travel behavior during peak hours, the account will be depleted and there will be no funds left to disburse at the end of the study. In this manner, the study provides an economic incentive that simulates the out-of-pocket costs that would be incurred under a fully operational congestion tolling system.

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

Each vehicle in the study is equipped with an on-board unit that includes a GPS receiver, a digital map of the road network, a table of applicable congestion tolls by road link by time of day, and a cellular communications device. During the course of each trip, the on-board unit will use the GPS receiver to obtain geographical coordinates, than compare these against the digital road map to determine the specific link on which the vehicle is traveling. Based on the time of day and the link in the network, the on-board unit will look up the corresponding congestion

[12] The information in this review is based primarily on material from M. Kitchen (personal communication, August 18, 2004) and Puget Sound Regional Council (2002).

charge for each segment of travel, display the information to the user, and record the information for subsequent transmission. Approximately twice each day, the on-board unit will contact the central processing center via cellular communications and upload detailed travel information for the most recent period (given that all participants in the study are volunteers, there will be no effort to summarize or mask the details of the travel in order to protect privacy). The central processing agency double checks the congestion toll calculations than debits the endowment accounts accordingly.

PRICING POLICY

As noted, the pricing policy does not include a base charge for distance traveled. Rather, it focuses exclusively on congestion tolls.

The current plan is to distinguish between three different time periods: off-peak hours, during which no charges are applied; shoulder hours (periods between off-peak and peak hours), during which moderate congestion charges are applied; and peak hours, during which full congestion charges are applied. If this strategy proves to be too complex to manage, the agency may eliminate the concept of shoulder hours and only distinguish between peak and off-peak travel times.

Congestion tolls are applied on a link-by-link basis for each segment of the network. Initial calculations for the level of the congestion toll for each link will be based on (1) the physical characteristics of the link (e.g., length, design capacity, etc.) and (2) average peak loads on the link, as estimated by a regional transportation model. Generally speaking, the size of the toll on each link will be proportional to the length of the link and the extent to which peak loads exceed design capacity. Over time, there may be some effort to smooth out the level of charges from one link to the next to facilitate better understanding among users of the structure of the congestion tolls.

During the course of the study, the level of congestion tolls will not vary in real time (i.e., based on the current level of congestion, as in the case of the I-15 HOT lanes). Rather, the tolls will be based on historical averages as determined within the transportation model.

GOVERNANCE

The Puget Sound Regional Council is coordinating the pilot test. Currently there are no plans to develop a full system-wide program (though perhaps this will change, depending on the outcome of the program), and it is unclear who would take responsibility for such a task.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

Within the Puget Sound region, there has been a general recognition on the part of elected officials and transportation planners that traditional tax-based financing mechanisms are insufficient to meet the needs of maintaining and improving the area’s transportation network. For example, in May of 2001, the Puget Sound Regional Council’s General Assembly of members adopted a new regional transportation plan, *Destination 2030*, that includes $100 billion in planned transportation investments over the next 30 years. Yet current funding sources will only cover half of this amount, barely enough to maintain and preserve existing facilities.

Anticipating the likelihood of such a shortfall, in 1995 the Puget Sound Regional Council created a Transportation Task Force comprised of local elected officials, transportation professionals, area business representatives, and environmental and public interest groups. One of the primary purposes of this group has been to analyze options for reforming transportation finance through the introduction of more market-oriented finance tools with the potential to (1) ensure that public revenues are adequate to maintain, preserve, and improve the region's transportation system; and (2) manage demand for scarce road resources during chronically congested travel hours. As part of this research, the task force has evaluated a wide range of value pricing mechanisms and their potential impacts, both positive and negative. Based on the results of this survey, the Puget Sound Regional Council has decided to conduct the pilot test on network-wide congestion tolls.

In terms of public and political acceptance, to date there has been a fair degree of excitement, although this has been tempered by a healthy dose of skepticism as well. Given that the proposed effort is just a pilot test rather than a full-blown implementation, however, opposition to the project has been relatively muted. Future political and public support for this type of program will likely depend, at least in part, on the findings of the pilot test program, as well as the level of success in educating area residents about potential benefits (e.g., reduced congestion, more revenue for transportation system improvements) of congestion tolls.

FINANCIAL STRUCTURE

The Federal Highway Administration, under the Value Pricing Pilot Program, is providing financial assistance for the pilot test.

There are no revenues associated with the pilot test. If such a system were implemented on a region-wide basis, however, the revenues would presumably be devoted to the maintenance and improvement of the regions transportation network.

SUMMARY OF EVALUATIONS

The pilot study is scheduled to run from January 2005 through December 2005. Evaluations of the study should be available in early 2006.

On the technology front, though the system is not yet fully operational, all preliminary demonstrations have proven successful, and technical delays are not expected.

APPENDIX O

"ARMAS" Pan-European Road Tolling Project[13]

OBJECTIVES OF THE SYSTEM

In April 2003, the European Commission published a proposal that all vehicles traveling in Europe should pay road tolls electronically, with full implementation targeted for 2010. In support of this goal, the European Union commissioned the European Space Agency (ESA) to conduct a program entitled Active Road Management Assisted by Satellite, or ARMAS. The ARMAS program is designed around the use of in-vehicle equipment, including satellite-based positioning and cellular communications.

Overall goals of the proposed ARMAS system include

- Providing satellite-based tolling;
- Improving safety (e.g., obstacle detection and avoidance, incident warnings, etc.);
- Increasing traffic management capabilities (e.g., speed enforcement);
- Providing fleet management support; and
- Providing dynamic route guidance services.

Under contract from ESA, the ARMAS research and development effort is being led by the Portuguese firm Skysoft, working in a consortium that includes numerous other software vendors, hardware vendors, telecomm vendors, road infrastructure operators, and research institutions from around Europe. Phase I of the project, a six month initial feasibility analysis, was concluded in November 2003. Phase II, geared toward trial demonstrations, was to have been completed in May 2005.

Phase II includes initial trials, conducted in London and The Hague in mid-2004, to assess critical project issues such as positioning accuracy and fraud detection. These were to have been followed by application demonstration trials in Portugal, Ireland, and The Netherlands in May 2005. The Portuguese trial will involve satellite tolling on the Vasco Da Gama Bridge above the Targus, one of the longest bridges in Europe.

Assuming that the trials proceed successfully, the next step will be to plan for integration across all of Europe. Anticipated benefits of such a program include

- Fairer implementation of charging on a pay-for-use basis,
- Reduced road costs as the demand on physical infrastructure is decreased, and
- Reduced congestion.

[13] The information in this review is based primarily on material from Innovation Reports (2003) and RedNova News (2003).

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

With the ARMAS system, all participating vehicles will be installed with on-board equipment that tracks distance traveled, class of road traveled, and time of travel.

For positioning information, the system will initially rely on EGNOS, the European Geostationary Navigation Overlay Service. EGNOS enhances the data provided by the U.S. GPS system, offering greater precision and signal clarity, and was due for release in late 2004. In the future, EGNOS will be replaced with Galileo, a European system comparable to GPS. Due for release in 2008, the Galileo system will incorporate 30 satellites revolving in three circular medium earth orbits approximately 24,000 km above the earth, and will be capable of delivering two meter positional accuracy.

In terms of communication capabilities, the current plan is to rely on cellular. Although not strictly necessary for road tolling alone, cellular communications are convenient for many of the other intended applications that rely on real time data updates (e.g., distress signals for a vehicle traveling on a sparsely utilized road).

PRICING POLICY

At this early stage of the project, there has been little discussion about pricing policies. Given the anticipation of reduced wear and tear on the roads as well as the mitigation of congestion, however, it appears likely that pricing strategies will be used not merely to raise revenue, but also to manage demand.

GOVERNANCE

ARMAS is being funded by the European Union, which would presumably take a role in the overall administration of a fully integrated, pan-European tolling system. Individual countries, however, would likely set specific pricing policies and enforcement paradigms within their own jurisdictions.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

With the success of relatively recent pricing mechanisms in various European countries, ranging from cordon tolls in London and Norway to electronic weight-distance trucking tolls in Switzerland and Austria, there is growing interest in the use of new technologies to charge vehicles on a pay-for-use basis and to help manage demand. ARMAS certainly builds on this momentum.

To date, there has been little information published about public outreach efforts associated with the ARMAS program. Presumably, this would occur following the successful demonstration of trial projects in 2005 and before full system integration.

FINANCIAL STRUCTURE

Most of the effort thus far has focused on technical issues. The ultimate financial structure of the program has yet to be determined.

SUMMARY OF EVALUATIONS

The Phase I feasibility study was successfully completed in 2003, giving the green light to proceed with trial project demonstrations in Phase II. Detailed evaluations of the trial projects should be available in late 2005.

APPENDIX P

The Dutch "Mobimiles" Distance-Based User Fee Proposal[14]

OBJECTIVES OF THE SYSTEM

In 2001 the "Mobimiles" proposal for distance-based road pricing in the Netherlands was introduced as part of the Dutch National Traffic and Transport Plan. The intent of this proposal, which would apply to private automobiles as well as heavy goods vehicles, was to shift the basis of road charging from conventional fixed-cost methods such as vehicle fees to marginal-cost metrics based on distance traveled. Originally, the project was scheduled for research and development from 2002 and 2003, with implementation targeted for 2004. Although the proposal was promising from a technical standpoint and even enjoyed a fair degree of public acceptance, it ultimately was cancelled (or at least postponed indefinitely) with the election of a new, more conservative government in May of 2002.

The rationale for the Mobimiles plan was described as, "User pays, polluter pays, and scarcity has its price." Although the program was not intended to raise aggregate transportation revenues (the distance fee was designed to be revenue neutral with respect to the corresponding decrease in fixed vehicle fees), there were a number of other specific goals to be addressed:

- **Managing demand**. With a greater marginal cost per kilometer driven, aggregate distance traveled should decrease.
- **Improving the environment**. As the aggregate distance traveled decreases, the emission of pollutants should decline as well.
- **Improving safety**. As the aggregate distance traveled decreases, so too should the incidence of collisions.

The developers of the Mobimiles proposal also envisioned the eventual incorporation of congestion tolls, which would provide an additional mechanism to help manage demand for scarce resources. The introduction of congestion tolls, made possible by the same technology base used to support the basic distance charge, was originally targeted for 2006.

The Mobimiles proposal was based on the assumption that all vehicles would be required to install devices capable of tracking distance traveled and generating bills but that the required devices could be provided from different private entities. These private firms would have to comply with a variety of functional requirements, but could then compete for users on the basis of price (the cost of purchasing and installing the device) as well as additional value-added service offerings. For example, companies might offer services to private individuals such as traffic information, route guidance, advanced parking reservations, vehicle diagnostics, stolen vehicle location, and automatic emergency alerts. Services offered to businesses, in turn, might include fleet operation management, rental vehicle management, and tailored insurance

[14] The information in this review is based primarily on material from Crawford (2002), Dalbert (2002), and Imprint-Europe (2001).

packages. Such value-added services would make it possible to co-finance the distance-charging scheme, averaging the cost the necessary technology against a larger potential revenue base.

In order to ensure success, the authors of the Mobimiles proposal identified several key standards that the system would have to meet:

- **Guaranteed privacy for the user**. Neither the government nor private firms should be able to track the specific travel behavior of any user, unless the user has granted specific permission to do so (for example, to facilitate add-on features such as traffic information and route guidance). In general, the device should only report the total distance traveled (by zone or road type, if appropriate) and the total amount of the charge.
- **Reliable, fraud proof system**. In order to ensure public acceptance, users should know that the system is reliable, and that other users will not be able to cheat to avoid tolls.
- **Open standards to promote competition and lower prices**. Given that the goal was to encourage private companies to introduce the required devices, it was considered necessary to develop a set of open standards to level the playing field and ensure interoperability.

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

The framers of the Mobimiles proposal assumed that private firms would determine the specific technical configurations, so the specifications were left intentionally vague. In general, however, the following assumptions were made:

- Every Dutch vehicle would be equipped with a device for recording distance and calculating charges owed. This device would be referred to generically as a mobimeter.
- The mobimeter would be designed to transmit information related to the total amount payable and the total number of kilometers driven per charge class (e.g., base road charges, congestion road charges, etc.).
- Ultimately, submitting a declaration of charges would be the legal responsibility of each registered user. However, individual companies would have the ability to automate the declaration and payment process (e.g., via periodic cellular communication updates and on-line billing) for the convenience of the user.

The mobimeter most likely would be designed around an on-board unit with a built-in GPS receiver to record vehicle position coordinates. To facilitate the communication of billing data, the on-board unit could also be equipped with GSM (for cellular communications) or DSRC (for short-wave radio communications). To support the DSRC option, radio receivers could be mounted along the highway or at fueling stations.

Once billing data was transmitted to the service provider, it would next be forwarded to the tax office. The user would then receive two bills: one from the tax office, reflecting the actual distance charge; and one from the service provider, for any addition options selected by the user (e.g., traveler assistance and route guidance services).

To help prevent fraud, several different technical strategies were proposed. To begin with, the mobimeter could be designed to require the installation of a charge card. The charge card would be configured in such a way as to prevent the deletion or alteration of any data recorded, and the mobimeter would disable the operation of the vehicle unless a valid charge card was loaded. In addition, it would be possible to install fixed and mobile checkpoints that would verify (via short range radio communications) that an operational mobimeter was installed in each passing vehicle.

PRICING POLICY

As mentioned, the distance charge was designed to be revenue neutral. Given the planned decreases in other fixed taxes such as the vehicle ownership fee, as well as the average annual distance traveled per vehicle, the average break-even charge rate was estimated to be €3.3 cents per kilometer (in 2001 prices). At this rate, vehicle owners who traveled less than 18,000 kilometers per year would be better off than under the current system, while owners who traveled in excess of 18,000 kilometers per year would shoulder a heavier burden.

In addition to the goal of fiscal neutrality, the Mobimiles proposal was also designed to preserve existing incentives for the adoption of more environmentally friendly vehicles (under the current motor vehicle tax scheme, charges vary based on the weight and emissions class of the vehicle in question). Toward this end, it was envisioned that the per-kilometer charge would vary by vehicle class, with cheaper prices for lighter and more fuel-efficient models.

On the whole, the authors identified six key factors that collectively would determine pricing: distance, weight, fuel type, vehicle type, level of emissions, and province. Once congestion tolls were introduced, the factors of time and location would be incorporated into this list.

GOVERNANCE

According to its plan, Mobimiles was to be structured as a cooperative public-private engagement. On the public side, the Ministry of Finance and the Ministry of Transport, Public Works, and Water Management would assume joint responsibility for the program (this shared delegation reflects the fact that the program represents both a form of taxation and a traffic-related instrument). On the private side, implementation and operation of the system would for the most be conducted by competing market parties.

Key responsibilities of the public sector included

- Overseeing the development and implementation phase;
- Developing, validating, and demonstrating an open standards for the technology;
- Organizing pilot tests;
- Conducting a tendering procedure for service providers;
- Supervising market action;
- Stimulating the development of vehicle-related additional services;
- Certifying mobimeter providers;
- Establishing privacy guidelines;
- Determining rates and charges;
- Supervising collection; and
- Imposing sanctions for fraud and default.

Key private sector responsibilities included

- Developing and producing the mobimeter,
- Distributing and installing certified mobimeters, and
- Developing and providing value-added services.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

Before the Mobimiles proposal, several earlier Dutch road charging plans were abandoned, even after years of research and trials, because of objections from motoring organizations as well as local officials. To avoid a similar fate and gain additional adherents, the Mobimiles planners stressed two important goals: revenue neutrality and the preservation of existing incentives for environmentally friendly vehicles. Based on these characteristics, the Mobimiles program gained social approval from car owners clubs, employers and employee organizations, trade unions, and environmental coalitions, all of whom viewed the kilometer charge as a fair strategy for road pricing.

Somewhat surprisingly, it was the business aspects of the program, rather than the social implications, that created the most substantial hurdles. According to PA Consulting Group, a transportation and economics firm that analyzed the proposal, there were three significant problems that would hinder successful participation in Mobimiles on the part of private firms. First, wholesale costs for the on-board units, including GPS and communications devices, were estimated to be around €500–600 ($500–600) in 2002 prices, falling to €300–400 by 2012. This steep initial per-vehicle cost, combined with other capital and operational expenses, was unlikely to be supported by anticipated revenues, including those from proposed value-added driver services. Second, anticipated revenues from telematics services are notoriously uncertain and would likely take time to develop. To illustrate, in the year 2000, only 16 percent of purchasers of GMS vehicles with OnStar equipment actually subscribed to the service. This uncertainty contributed to an unacceptably high risk for road pricing service providers, who would face a total investment of close to €6 billion ($6 billion) over a 12-year concessions period. Third, the envisioned implementation timetable of two years would lead to impossible ramp-up demands on suppliers, thereby leading to inevitable delays in the deployment of the system.

To address these business issues, the PA Consulting Group suggested several adjustments to the program. To begin with, they proposed the addition of a low-tech “zonimeter”, costing less than €100 ($100), with a simplified tariff structure based on zones rather than individual roads. Trucks and high-volume car–light commercial vehicle users driving over 20,000 kilometers per year, largely on main roads, would enjoy low tariffs and install full-specification mobimeters, while low-volume users, less than 15,000 kilometers per year, could choose cheaper zonimeters but pay higher area-based tariffs. In addition, they suggested that road users be required to purchase (rather than borrow) in vehicle units from road pricing service providers, thereby setting up a marginal revenue stream. Finally, they suggested that total existing billing agencies (e.g., utilities) should be tapped to perform collection activities, thereby reducing back-office costs. Based on the proposed set of changes, PA Consulting Group estimated that the total capital expenditure required by road service providers could fall from €6 billion to around €500 million ($500 million).

Not surprisingly, the proposed changes engendered public resistance, particularly given the fact that each individual user would now be required to purchase the in-vehicle equipment. Responding to this public reaction, the new government elected in May 2002, a coalition of Christian Democrats, liberals, and the emergent right-wing LPF, decided to cancel Mobimiles.

FINANCIAL STRUCTURE

Current vehicle and user fees in the Netherlands include the annual motor vehicle tax (MRB), a purchase tax on private motor vehicles and motorcycles (BPM), and the euro vignette for heavy trucks, resulting in a total of €5.2 billion per year. Under the Mobimiles plan, the full MRB and a quarter of the BPM taxes would be converted to distance charges (supplemented by a proportion of duties), and the euro vignette for Dutch heavy trucks would be replaced by a weight-distance charge as well. In total, the budgetary shift involved in this transition would have been close to €4.5 billion, well over 80 percent of total road finance revenues.

SUMMARY OF EVALUATIONS

Preliminary modeling estimations suggested that by variabilizing the cost of travel (above and beyond the cost of fuel), Mobimiles would lead to a decrease in overall vehicle travel (and a corresponding decrease in emissions) of 7 percent by 2010 and of 10 percent by 2020. In addition, congestion would drop 20 percent by 2010 and 25 percent by 2020.

Based on the anticipated average price point of €3.3 cents per kilometer, anyone driving less than 18,000 kilometers per year would stand to gain from the program. Given that distance traveled tends to increase with income, this finding would tend to benefit the poor more than the wealth, a socially desirable outcome.

APPENDIX Q

Atlanta Variable Cost Study at Georgia Tech[15]

OBJECTIVES OF THE SYSTEM

Supported in part the Federal Highway Administration's Value Pricing Pilot Project, researchers at the Georgia Institute of Technology have launched a technically ambitious study of driving behavior and response to various road pricing strategies which relies on in-vehicle equipment featuring GPS and cellular communications. The project is currently near the completion the first year of data collection, measuring the baseline driving behavior of about 275 participating households. Pending the approval of follow on funding from the FHWA, the study will begin to examine the response to various pricing strategies over the next two years. More specifically, the project will evaluate

- Distance-based variabilization of fixed costs such as vehicle registration fees and insurance fees,
- Distance-based road user fees as a replacement to the fuels tax, and
- Time- and location-based congestion charges.

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

The on-board unit used within the test includes a Linux-based computer capable of running programs and processing data, a research-grade GPS unit with a high level of accuracy and a rapid sampling rate, cellular communications for transmitting results to the research computers, electronic connections to various engine inputs, and an open communications port that allows the potential for connecting to other devices on the vehicle (for example, if the researchers wish to gather more data on vehicle emissions, they can hook up an emissions analyzer to the vehicle exhaust system and then connect a link to the communications port).

During the initial baseline data collection effort, the on-board units have been set to record location and speed observations on a second-by-second basis. This data is then batched and sent to the research computers on a weekly basis. Summed across all participants, the by-second sampling rate results in a prodigious amount of data, on the order of two million observations per week. Not surprisingly, the data storage and analysis requirements are considerable.

PRICING POLICY

During the next phase of the pilot test, as researchers examine various time- and distance-related charging schemes, the pricing scenarios will be determined based on realistic estimates of the

[15] The information in this review is based primarily on material from Randy Guensler (personal communication, September 14, 2004).

corresponding costs. To illustrate, in determining the appropriate distance-based user fees as a replacement for the gas tax, researchers might first examine the current fuels tax cost per vehicle mile traveled (factoring in fleet composition and varying levels of fuel efficiency) and then use the average value to determine the per-mile user charge.

GOVERNANCE

As noted, the project is being funded through the Federal Highway Administration. Even though some of the pricing schemes to be evaluated (e.g., variabilization of registration fees, distance-based user fees in place of the fuels tax, and congestion tolls) would fall within the sphere of public implementation, others (e.g., variabilization of insurance costs) would need to be implemented by private firms.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

The first round of data collection for baseline driving behavior began in late July and early August of 2003 and includes 275 households and over 460 vehicles (the study began with 489 vehicles; the current number is 468). To date the researchers have collected extensive second-by-second data for around 800,000 trips. In addition to serving as a baseline for future pricing studies, this dataset also represents an incredibly valuable asset for analyzing general travel behavior.

A follow-on grant from the FWHA for the next phase of the research is currently pending, but the decision should be reached shortly. If granted, the next year of study will involve pricing incentives in the form of distance-based charges for costs such as registration, insurance, and the gas tax. In the following year, the research may factor in congestion charges as well.

Given the nature of the test, several private companies have become quite interested in following the results, but their identities are currently held in confidence.

On the public front, in contrast, there has been little weigh-in to date. One potential public acceptance issue that has been noted, however, is that related to privacy concerns. In particular, researchers have observed that once the in-vehicle equipment has been installed, it tends to become invisible to users. At the same time, however, the units record data that could be potentially damaging to individuals if it were made generally available. To illustrate, researchers have noted the virtually all test participants exceed the legal speed limit at least some of the time. Potentially, this data could be used against the drivers in a variety of ways, such as the following:

- Insurance company could use data about speed or other violations to raise a driver's rates.
- Following an accident, lawyers could review an individual's past driving behavior and use that information against the individual in court.

Within the context of this research project, all data are covered by a Certificate of Confidentiality issued by the National Institutes of Health, so privacy is not really an issue for current test participants. Even so, the potential for such privacy issues in future implementation efforts in either the public or private sphere has prompted researchers at Georgia Tech to prepare a manuscript detailing the most appropriate strategies for protecting the privacy of individuals whose vehicles have been equipped with in-vehicle equipment that includes location and speed information.

FINANCIAL STRUCTURE

As noted, the current research is being supported in part by the Federal Highway Administration. Private companies, however, have become interested in following the results of the study, and perhaps will someday choose to implement some of the pricing strategies evaluated as part of the research.

SUMMARY OF EVALUATIONS

The first year of baseline data collection will conclude in November, and preliminary evaluations are currently ongoing. Assuming that follow-on funding is provided by the FHWA, various pricing scenarios will then be tested over the next two years. Given this timeline, evaluations of user response to various pricing schemes will not be available for some time.

APPENDIX R

Minnesota "PAYD" Variable Cost Study[16]

OBJECTIVES OF THE SYSTEM

With support from the Federal Highway Administration's Value Pricing Pilot Program, the Minnesota Department of Transportation (DOT) is conducting a demonstration on distance-based variabilization of fixed costs associated with automobile ownership and use, such as registration fees, leasing fees, and insurance fees. The study is referred to as pay-as-you-drive (PAYD). The underlying motivation of the pilot test is to determine whether price signals, in the form of per-mile charges, can induce individuals to drive less or change driving habits or modes, thereby easing problems associated with congestion and harmful emissions.

TECHNIQUES OF METERING ROAD USE AND COLLECTING FEES

Originally the Minnesota PAYD project had hoped to enlist the participation of a car manufacturer or leasing company to try an actual PAYD product. Such a product might incorporate on-board equipment featuring GPS and cellular communications as a means to provide a simple hands-off market-based pricing experiment for consumers. The scope of the trial was altered, however, when the potential private partners declined to continue. Because of cost considerations, the researchers instead selected a technology referred to as the "CarChip" that plugs into the vehicle's on-board diagnostics (OBD II) port. The CarChip is able to record a variety of information such as time of travel, distance traveled, and speed of travel, but (lacking a GPS receiver) it is unable to determine location information.

During the pre-trial baseline data collection efforts, participants sent in their data chips to researchers for data collection on a monthly basis; during the actual test period, the frequency of data collection was increased to once every two weeks to allow for more frequent price signals.

PRICING POLICY

The pilot study offers drivers an incentive for reducing or altering their travel patterns under a variety of conditions with a payback rate that ranges between five and twenty-five cents per mile. By varying the incentive level among different participants, the test is designed to explore the elasticity of demand at different price points.

It is interesting to note that the price range selected, five to twenty-five cents per mile, does not correspond to the exact variabilization of a specific cost, such as insurance or vehicle depreciation. Rather, the range was determined based on the intensive market survey conducted during the first phase of the research effort, in which respondents indicated that they would be

[16] The information in this review is based primarily on material from Ken Buckeye (personal communication, September 13, 2004) and U.S. Department of Transportation Federal Highway Administration (2004).

willing to pay some form of variabilized cost that falls within that spectrum. In that sense, then, the study is generically applicable to any fixed price—registration, insurance, or leasing—which, when variabilized, would fall in a similar range. Both flat (per-mile) rates as well as rates that vary by time of day are being tested.

GOVERNANCE

The study represents a joint effort supported by both the Federal Highway Administration and the Minnesota DOT. This cooperative funding effort on the public front makes sense given that the ultimate goal is to examine the degree to which the variabilization of fixed costs can reduce or alter travel behavior, thereby fostering social goals such as the reduction of congestion and vehicle emissions.

At the same time, however, most of the intended applications, such as variabilizing lease prices and insurance prices, would have to be implemented by private parties. For this reason, there also has been a significant level of private interest in this demonstration, as discussed below.

HISTORY, POLITICAL SETTING, AND EXPERIENCE WITH PUBLIC ACCEPTANCE

The Minnesota DOT first became interested in value pricing during the mid 1990s and sought to develop a program of variable priced toll facilities including HOT lanes. These efforts were ultimately rejected by the public or cancelled by the governor based on opposition that was largely related to the perception of potential inequity. Public and community concerns focused on the fear of being singled out for toll roads and providing a disproportionate benefit to wealthy users.

Even so, interest in value pricing within the Minnesota DOT remained strong, particularly given mounting levels of congestion and a lack of revenue with which to respond to the problem. Recognizing that congestion is a multifaceted problem, Minnesota DOT, with the advice of an interagency committee, embarked on the PAYD project. Given the apparent political difficulties associated with HOT lanes at the time, the group decided to investigate other pricing mechanisms, especially those related to distance traveled. In particular, the group was intrigued by a pilot test conducted by Progressive Insurance in Texas from 1998 through 2001 that explored the idea of variabilizing insurance costs based on time, location, and distance of travel as measured by in-vehicle GPS units.

Inspired by the Progressive Insurance example, in May of 2001 the DOT applied for a value pricing demonstration project from the Federal Highway Administration to evaluate the variabilization of other fixed costs (above and beyond insurance) such as vehicle depreciation, leasing, registration, and parking. The proposed project, which would involve the use of GPS technology to record driver travel patterns, was accepted by FHWA in September of 2001. In early 2002, the DOT published an RFP to solicit technical assistance with the design and implementation of the demonstration; four responses were received, and ultimately Cambridge Systematics was selected as the lead project consultant, supported by GeoStats for technology applications and MarketLine Research to carry out focus groups and market research surveys.

The PAYD advisory committee overseeing the project recognized that in order to translate many of these pricing concepts from the theoretical level to real world implementation, it would ultimately be necessary to enlist the participation of private firms such as auto-manufacturers, auto-leasing agents, rental car companies, and insurance companies. Cambridge Systematics was able to bring several prospective partners to the table to explore areas of mutual interest and opportunity. General Motors (GM), in particular, was interested in the development of a program in which customers would purchase miles from the manufacturer rather than purchase vehicles.

The project team, along with GM, launched a significant market research effort to evaluate the potential for pay-as-you-drive applications within different market segments. GM, after considerable evaluation, determined that they could not (at least at that time) make a compelling business case for a mileage-based leasing program, and subsequently withdrew their participation in the PAYD demonstration.

To some extent, the departure of GM represented a blow to the project; especially given the fact that a significant portion of the budget had been devoted to enlisting their partnership to test variabilized leasing costs as one component of the larger PAYD project. Given the circumstances, the project team decided to restructure the remainder of the project given the amount of funding still available. In particular, they opted to conduct more quantitative market research and to evaluate a less expensive in-vehicle technology solution. Unlike GPS, the selected CarChip technology is unable to track vehicle location, but it provides a wealth of other useful information including both travel time and travel distance.

Under the revised scope of the study, the research team conducted a pre-trial market survey in January and February of 2004. This telephone survey of 400 randomly selected drivers in the Twin Cities area was structured to provide a sense of the overall market for PAYD leasing and insurance products. An additional 100 people that had prior specific experience with leasing were also recruited, because the research team found that a general understanding of leasing had a big impact on people’s willingness to consider PAYD leasing products. Survey respondents were also asked to participate in an additional mail-phone stated preference survey that further probed drivers’ willingness to choose PAYD options at different price structures.

In February–March of 2004, the team recruited 130 participants for the driving demonstration element of the project. This was an entirely separate group from those that participated in the telephone survey. The team installed the recording device in the participants’ vehicles and monitored baseline driving behavior during March and April. Beginning in May, a group of 100 participants was offered mileage-based incentives to reduce their driving or to drive outside of the peak period, while the remaining 30 participants continued to serve as a control group. For the 100 participants receiving mileage-based incentives, each was granted an endowment account (the size of which depended upon each individual’s baseline driving behavior) against which mileage fees would be deducted. At the end of the study, any remaining balance in the endowment account (which would only result from decreased travel behavior relative to the baseline measure) will be given to the participant as a bonus. In other words, each participant can make money by driving less or driving outside of the peak period. The incentive period will conclude this November, and final results were to have been available in early 2005.

Despite the departure of GM, one additional private partner, an insurance company, has subsequently expressed considerable interest in the test program. As of this time, the PAYD project team is considering appropriate means to engage this prospective partner.

To date, there has been little public or political weigh-in on this study. In part, this may be because of the fact that several of the key intended applications, such as mileage-based lease pricing and mileage-based insurance, would be offered by private firms and hence be entirely optional in nature.

FINANCIAL STRUCTURE

The Federal Highway Administration, under the Value Pricing Pilot Program, is funding 80 percent of the research, while Minnesota DOT is contributing the remaining 20 percent.

SUMMARY OF EVALUATIONS

As noted, the trial study period will conclude this November, and an evaluation of the results was to have been available in early 2005.