Economic Aspects of Public-Private Partnerships for the Provision of Roadway Services

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Abstract

Road pricing is an old and, theoretically, an effective approach to traffic congestion relief, but has problems of political acceptability. This paper reviews the basic concept and recent developments in road pricing, and develops a theoretical framework for the broader issue of public-private partnerships for the provision of roadway services. Within this framework the basic concept of road pricing may be implemented in an innovative bundling of private intelligent vehicle-highway systems (IVHS) services with economic incentives for traffic diversion. Future research is suggested for building basic economic models of excludable public goods that would include congestibility. An operational field test is suggested to try out the idea of bundling private services to trucks; economic incentives would be offered by public authorities for the trucks to divert from congested routes.

1. Introduction

Forming partnerships between the public and private sectors appears to offer promise in the delivery of a menu of IVHS functions for users of the roadways to choose, in the improvement of travel efficiency, and in the provision of needed financial sources for intelligent vehicle-highway systems (IVHS) infrastructure [Chen and Stafford, 1992]. Key elements underlying the viability of these partnerships are user fees for newly developed services, ranging from in-vehicle delivery of timely and relevant traffic information to nonstop toll collection for access to bridges, special lanes, or use of roads during peak traffic periods.

The idea of any type of fees for the use of *free roads* or freeways is likely to be met with public skepticism. Yet, two motivating factors for a closer examination of options in this area are 1) Existing traffic patterns are clearly ineffective; and 2) New highway technologies may allow the public collection of road-use fees in conjunction with private services — services that may be purchased on a voluntary basis from private suppliers. A key illustration of the latter, discussed below, is what has been referred to as the *bundling* of public and private road services.

The need for some new approach is highlighted by the fact that during peak traffic times, Los Angeles freeways handle a far smaller volume of cars per hour than in off-peak hours [Cameron, 1992]! Evidently, free access to roads can and does create a result that is far below what can be regarded as system optimal. Even simple access limits, such as entry ramp metering, could improve overall traffic flow.

2. Road Pricing — Concept and Recent Developments

Basically, road pricing works through the provision of economic incentive or disincentive to influence drivers' behavior, *i.e.*, demand management. The concept is not new, as it dates back to the 1920s [Pigou, 1920], but it has been reassessed and improved at different times [Walters, 1961; Small *et al.*, 1990]. The concept has been attractive to economists who argue that excessive congestion is a phenomenon of inefficient allocation of scarce resources. An efficient way to reduce congestion is thus to introduce a market mechanism to road transport. Without road pricing, increasing highway capacity through road building or automation would simply attract more traffic to the new roads, and the previous level of congestion would return as the system finds a new equilibrium. In the long run, the only way to reduce congestion is by charging the less urgent users — some critics would say the less affluent users — sufficiently to keep them off of the congested routes. While this concept does not require IVHS to be implemented, electronic toll collection technology has made road pricing practical and has given the concept a new life [Small *et al.*, 1990].

Compared with the incremental approach to congestion relief through traveler information and route guidance, road pricing may be considered a radical approach [Chen, 1992]. Its impact on urban traffic congestion in Singapore has been dramatic. Interestingly, IVHS was not used in Singapore to set up its current road pricing scheme although some form of electronic toll collection is expected to be installed there soon. The toll collection system will facilitate the future expansion and management of that country's road-pricing scheme. In Singapore, a manually-operated road pricing system (an Area Licensing Scheme) to keep most of the motor traffic from its central business district has been in operation since the mid-1980s. The scheme was dramatically successful in reducing traffic congestion in the central business district. In fact, it was overly successful to the extent that the roads became highly underutilized in the district, and the price was reduced from $3 to less than $2 for any vehicle to enter the restricted zone during peak hours [Field, 1991]. Those who used to drive to the central district now either ride the subway or drive to the periphery of the central district and walk or take a taxi in.

While road pricing has been successful in Singapore, it has not been accepted in other congested cities. In fact, the first attempt at electronic road pricing was actually made by Hong Kong in the mid-1980s, when motor-traffic congestion and pollution in the central business district became intolerable. However, even after money and effort had been spent to install such a system, it was never put to use, due to political unacceptability. In a recent interview, the Hong Kong authorities attributed the public rejection to the unfortunate timing in the road pricing installation. The Hong Kong authorities did not anticipate that, shortly after the installation, the United Kingdom and China would sign the treaty to have Hong Kong reverted back to China in 1997. The Hong Kong populace became highly suspicious that the road pricing system might be the beginning of Big Brother watching the residents' movement. Thus, although road pricing is still an official policy in Hong Kong, the authorities resorted to an increase of car ownership taxes as the more practical means to achieve a marked, though perhaps temporary, traffic reduction in Hong Kong.

In Europe, there is a joint manual and automatic toll cordon for Oslo, Norway, and similar plans are under consideration for Stockholm, Sweden. The Dutch Government initiated the now-tabled *Rekening Rijden* (traveling accounting) project, which was due to implement the first part of a road pricing system by 1992, with complete coverage of the Randstat (Rotterdam, Amsterdam, and the Hague) by 1996. In the United Kingdom, serious consideration for road pricing has been coupled with innovative ideas for its implementation. For example, a *Timezone* concept has been proposed for London, which would be ringed with roughly concentric circles representing progressively more expensive tolls as one approached the center [Green, 1990]. This approach would prevent traffic diversion at zone boundaries as has happened around the central business district of Singapore, causing congestion around its boundaries. It was reported that GEC, a UK firm, would begin a pilot test of this concept in early 1992 in the southwest London borough of Richmond upon Thames, using a radio frequency communications link that activates an in-vehicle meter [*Inside IVHS*, 1991]. An even more radical concept, known as *congestion metering*, has been under consideration by the City of Cambridge [Oldridge, 1990]. Unlike the usual road pricing scheme (as in Hong Kong), where a congested zone is predetermined and a fixed fee for entry is charged whether the zone turns out to be congested or not, congestion metering will levy a charge only when a vehicle experiences actual congestion (defined by a threshold of vehicle speed and/or numbers of stops per unit distance). It is believed that such a scheme will induce a more economically rational behavior from the driver and will result in more effective relief of congestion. Because of the unpopularity of road pricing, the Cambridge term, *congestion metering*, has apparently been adopted in place of road pricing to represent the generic concept of demand management through economic incentives.

The rejection of, or hesitancy in, adopting the radical solution of road pricing has led to a number of analyses of its political unacceptability. Road pricing has many opponents. Besides the impression that road pricing favors the rich, the strongest public sentiment against road pricing is its appearance as another tax. The general public feels that it has already paid too many taxes. Moreover, the gasoline taxes at both the national and the state levels have not been used entirely for road construction and maintenance. Why not use some of those taxes for roads instead of charging more for road use?! Most of the highway users are against road pricing, which is considered as a deterrent for automobile travel and another potential imposition that favors public transit versus car use. As has happened in Hong Kong, the privacy issue has also been raised elsewhere as a negative factor by the opponents of road pricing when it is implemented with automatic vehicle identification (AVI) technology.

On a rational basis, the proponents of road pricing seem to have answers to all the objections that have been mentioned [Green, 1990]. For example, reduced rates may be charged to the poor; privacy may be protected by the use of anonymously prepaid smart cards; *etc.* Depending on the economic assumptions made, no net increase in taxes or costs would result from road pricing; families would be induced to own multiple vehicles; and therefore the automotive industry might even get a 13% increase in market [Karlsson, 1990]! Perhaps the best conclusion to the political controversy of road pricing is that although the net social benefit is maximized by the introduction of road pricing, the realistic distribution of this benefit will leave some of the interested parties (including those who cannot afford to pay) worse off than the status quo, and strong opposition from these parties has usually succeeded in blocking the implementation of road pricing [Nemoto and Jansson, 1991]. Any realistic introduction of road pricing must consider some sort of innovative compensation arrangement so that all major interested parties will be better off than the status quo. While this debate continues, resolution of the key issues and consensus forming will be difficult without field tests of the basic concept of congestion pricing. Interestingly, the recent U.S. legislation [ISTEA, 1991] has provided $25 million per year for six years to support such field tests.

3. Road Pricing — Theoretical Issues

In this section is an assessment of issues in the theory of road pricing and suggestions of how these issues may be dealt with in the context of emerging IVHS technologies and the potential for public-private partnerships. There are six features (marked by numbers in parentheses throughout the paper) of such partnerships, which shape a new perspective on road pricing:

(1) IVHS technologies offer a large potential set of *new services* which can be offered on a fee-for-service basis through

electronic pricing. A precondition is a significant willingness to pay for these services. The rapidly spreading electronic toll and traffic management (ETTM) applications in the U.S. and the privately operated TrafficMaster system in the U.K., which provide traffic conditions to fee-paying subscribers [Martell, 1990], are encouraging indications of the existence of this precondition.

(2) Delivery of these services creates a potential for new relationships between public agencies and private firms. Traditionally, the public sector has contracted on a one-time basis with private firms for delivery of new roadways built according to a design and specifications of the highway department. The new partnership is more likely to be established on a *continuing basis* with need for revisions in the relationship as new ideas flow from the learning experience. Contracting must take place with a new emphasis on functional outcome rather than on the basis of predetermined design features

(3) The private sector is assumed to be better equipped to develop pricing and compensation relationships with *more flexibility* across user groups and more flexibility through time. In other words, for IVHS functions to be fully deployed, there should be the flexibility of unbundling any package of services [Robertson and Roberts, 1992] as well as the possibility of bundling public and private services, as suggested below in Section 4(F).

(4) More options will be needed. The *fee-for-service* approach might start with a fee for basic services *and* then offer *options* for those who are interested and willing to pay [Ristenbatt, 1991].

(5) The baseline of fees for users opens up new public sector opportunities. As an important possibility, *public sector user fees* can be offered *in the form of discounts* or *negative prices* (subsidies and discounts) to system users [Chen and Ervin, 1990].

(6) In developing such systems it is important to offer the user the *status quo as an option.* In this way citizens will not be forced to accept new technologies, which they may see as experimental. Only far in the future will it be necessary to create mandatory participation in some elements, which may achieve consensus as important for safety or provide benefits for the traffic system as a whole, such as in the mandatory installation and use of the seat belt.

We now turn to application of these features to fee-for-service partnerships. Recent studies have shown that, from the public perspective, the idea of road pricing or fee-for-service has a negative connotation. As stated previously, while the basic idea of road pricing goes back to the 1920s, and has been reassessed and improved at different times, proposals to implement pricing systems have met with resistance. To counter public resistance, added efforts wil be required to present a clear and well-reasoned plan if there is to be any hope of achieving a consensus of support.

It could be argued that the implementation of the theory has been naive; issues of redistribution among different groups have been ignored; explanations to the public about the purposes have been inadequate; and cumbersome or unreliable procedures have been used in collecting fees. We now turn to the discussion of six topics in the area of fee-for-service. We will refer to these as A to F throughout this paper to keep the identification separate from the six features (numbered in parentheses) outlined above.

4. Fee-for-Service Systems

A. Why Fees Fail to Gain Public Support

The road pricing controversy has been assessed recently in a working paper [Nemoto and Jansson, 1991]. It is easy to see from the basic theory of road congestion where opposition can arise. As shown in the Appendix, Figure A1, the net benefits to road users are reduced by congestion, but the fee used to "correct" the problem makes them still worse off *unless* they see the revenues from the fee going to their benefit in some other way.

Some users, notably those who value their time highly, will be better off even if the revenues are not returned through lower taxes or in-kind travel related benefits. Since these users are apt to be a minority, there is widespread resistance to user fees by road user associations, leading to the political demise of naively formulated proposals to charge for the use of what are regarded as "free" roads. Moreover, some of the losers in a road pricing scheme may feel strongly about the loss and organize highly vocal opposition to user fees.

As will be seen in Section 4(F) below, if road users are paying a fee for service to a private firm (4), then instead of a fee for using the road at peak congestion times, they may be offered a credit to their monthly statement for diverting off the congested roadway (5) or for the condition that the roadway was not used at all on peak times during the billing period. While in theory, as shown in Appendix A, paying a fee to travel a congested road should have identical incentives to receiving a subsidy for not traveling a congested road, the user reaction to the latter may be far more favorable. This is analogous to the traveling public reacting negatively to designating an existing lane for HOV while being neutral to designating a newly constructed lane for the same purpose. Moreover, it is the public partner that should have a predominant interest in system benefits from diversion of travelers rather than the market response of a minority of individuals seeking a specific service option, and this division of responsibility creates a motivation for a public-private partnership. Using the concept of the status quo as an option (6) means that no one has to divert or pay to continue their planned route. This seems to necessarily mean that they will not be worse off.

B. <u>IVHS as a Congestion or Loss Reducing Strategy</u>

The fee for service provision of IVHS technology, such as traveler information and route guidance, can be thought of as shifting out the point (point D in Figure A1) at which added flow of traffic begins to congest a roadway or roadway network or reducing the congestion functions. Another dimension to IVHS benefits can be in the area of predictability of trip times rather than reductions in average duration of trip. Some of the congestion on a given road can be predicted by users, but an unexpectedly high level of congestion, discovered only after the trip is in progress, may be unavoidable since the commitment to the trip has already been made: there may be no turning back.

Congestion with long delays has been argued to have a particularly acute cost if, as seems highly plausible, there is rising marginal cost of added delay in trip time or loss function convexity [Chen, 1990; Stafford, 1990]. A classic and extreme example of this would be the speed-flow curve, wherein at high levels of traffic flow it is possible to achieve either a high speed and low trip time <u>or</u> near gridlock with lengthy trip time. If travelers are averse to the risk of lengthy delays, then some type of public-private partnership seems essential for offering users an optional fee-for-service (4) advisory information system, which would allow the users to avoid unexpectedly long delays from congestion. Again those not interested can have the status quo (6) with the added plus that some of the diversion of participants can facilitate their trips. Here too is a partnership role. If diverters provide benefits to *others,* but little or none to themselves, it is in the system interest to find a way to compensate them.

If participation in the advisory system is on a voluntary subscription basis, then those who are advised to divert or postpone a trip over a congested segment will presumably save time for themselves or avoid the risk of near gridlock. By not adding to or reducing the trip time of others not diverting, subscribers will provide benefits to non-subscribers as well. These system benefits, particularly to the non-subscribers, should motivate a continuing (2) public sector commitment to traveler advisory systems offered through private contractors. These public benefits can be seen as a rationale for some public cooperation or financial support for the provision of infrastructure.

C. <u>Multiple Routes - Existing or Newly Created?</u>

In the modeling of multiroute congestion [Walters, 1961], the approach is to represent congestion of a road *network* rather than a single road. In the simple case that he examined, there are two routes connecting point Y to point Z, with different functions for congestibility on the two routes. In this case the user fee on one route needs to be set, taking into account the effect of diversion on the traffic pattern and congestion on the other route. Two messages from this network approach to public-private partnerships are: a) In setting a user fee on a given (private) route in a road network, there is a need to factor in the possible cost of excessive diversion onto the (public) alternative routes. This supports a continuing relationship (2). b) The newly constructed private tollways or bridges create benefits on the publicly held routes by relieving congestion there. Here the status quo user (6) of public routes is better off. In this sense new private roadways partially solve the problem of public road congestion just as public transportation systems ease commuting delays, thereby eliciting an endorsement by resolute auto commuters.

D. Excludable Public Goods offered by a Sole Seller

There is a literature on private provision of excludable public goods [Oakland and Brito, 1981]. Excludable public goods are those from which a potential user can be prevented access, such as a museum, a road, an airport, a park. Excludable public goods are distinct from weather forecasts or other pure public goods (from which users cannot be easily excluded). This excludable public good literature indicates a potential conflict between the private interest of the supplier and user benefits: the supplier offers too little of the public good at too high a price — a situation parallel to the main result of monopolies.

These existing models have not incorporated overuse and consequent congestion. If there is congestibility, the supplier will factor in the interest of users, insofar as congestion will diminish the user community's willingness to pay. There is an element of fortuitous circumstance in that the incentive of the sole seller to undersupply coincides with a social benefit from restricting use below the free access equilibrium. The formal model for this has not yet been worked out in the literature but seems to be a useful project given the range of circumstances that coincide with these conditions.

From the perspective of public-private partnerships, one could think of a case where it could be effective to charge a relatively high user fee on the toll road to limit excessive congestion. This could be combined with a sharing formula for revenues (2). The public sector share of revenues could be used to fund a diversity of transportation activities.

E. Highways as Public Utilities?

A review of legal dialogue [Syverud, 1992] on the recent innovations providing authorization for private toll roads indicates wide differences across jurisdictions in the extent to which private toll roads are regarded as being subject to public utility (cost plus normal profit) rate regulation. In some cases it is as though it were a forgone conclusion that the public utility rate commission is applicable and in others it is as if this were not even a question.

This lack of clarity concerning rate regulation could create a situation parallel to that with cable television. There, suppliers were granted exemption from public rate regulation as a condition for investment in the systems. Now that the systems are in place and subscription rates have been rising, various groups have asked for some type of limitation or review of cable rates through mechanisms similar to public utility rate regulation. These issues are bound to arise in road pricing.

F. Bundling of Public and Private Services

An asserted advantage of public-private partnerships has been the possible augmentation of resources for transportation outside the traditional tax revenue sources [Gomez-Ibanez *et al.*, 1990]. Here the idea is a bit different: the partnership revenue could give the public sector not only added revenue but an opportunity to set incentives for users (5). This idea arose in the context of a particular application, but seems to have a wider applicability. The specific context was the issue of a privately provided service to truck fleets on I-75 in Michigan [Stafford and Chen, 1992]. For a subscription fee and a per-use-of-service fee, trucks would have the benefit of electronic weigh-in, messages from the private fleet controller, travel advisory messages, and other new services (1).

The public sector interest would be the longer-term (2) savings from reduced weigh-station personnel, reduced stop-and-start pollution and, in addition, the possible use of economic incentives as a means of diverting traffic. Specifically, at certain points along the route that are subject to periods of congestion, the public partner could offer financial incentives for trucks to divert (5) or possibly postpone trips to a less congested time. Note that truck drivers so inclined could stick with the status quo (6). The assumption here is that there are alternate routes which are below capacity or that trip timing could be set for non-peak times (l).

The incentive could be in the form of a reduced monthly charge for each diversion, or *frequent diverter* credits, for those with no trips at peak times. This, of course, assumes some longer-term sharing (2) of the subscription revenues between the public and private partners. The important point here is that the private partner would not be expected to have a long-term interest in creating incentives out of its revenue share for trucks to divert, since a good part of the benefits would accrue to vehicles outside the system (private passenger cars in this case). Here we can see a division of interest and responsibility within the partnership which creates real possibilities for a complementary relationship between the public and the private partners.

5. Suggestions for Future Research and Field Test

The key ideas in the area of public-private partnerships, from the perspective of economics as have been developed and summarized in this paper, constitute a framework for future research, which can range from basic investigations to operational field tests.

At the fundamental level, we would suggest the development of formal models for studying the concept of congestibility in excludable public goods. Such models can be used as a basis for legal and economic policy analysts to debate and develop rate regulations to resolve conflicts between, and to protect the interests of, users and suppliers of excludable public goods such as toll roads and IVHS infrastructures. These models can also provide a more solid ground for estimating the private versus external benefits/costs in a total system, so that the optimal share of public versus private financing (for IVHS infrastructures) can be determined on a more rational basis.

The institutional issue of public-private financing is intertwined with technical issues and requires a sociotechnological approach to consider both types of issues simultaneously [Chen and Stafford, 1992]. For example, for IVHS infrastructures, a key prior issue is what type of standard should be used regardless of how it is financed. The whole issue of standards is a subject unto itself and highlights questions such as early commitment to what turns out to be a poor standard (consider the issue of analog or digital standards in HDTV) on the one hand, and procrastination, which prohibits anything from starting, on the other [Gifford, 1992]. Suppose the question of infrastructure type is settled. One could argue that the public could pay for infrastructure and charge a user fee to suppliers, who would, in turn, pass this cost on to users. This has a parallel in the payment of landing fees by airlines to a publicly financed airport authority. If an infrastructure were privately financed and the private firm charged a user fee based on use of services, the issue of public regulation of the fee structure could arise here, too.

One of the exciting ideas that has emerged from our work on this paper is the innovative implementation of congestion pricing through the bundling of public and private services (F). As mentioned previously, this idea has been discussed in the context of a privately provided service to truck fleets on I-75 in Michigan in conjunction with an economic incentive for the trucks to divert from congested routes. While the validity of the basic concept has been proven by our economic analysis, the practical problems in implementation will need further consideration. We would suggest a concerted effort among the interested parties to identify and resolve these practical problems. For example, how do we provide economic incentives according to the true intentions and not false reports by the truck drivers regarding their preferred routes given the current traffic information? Can we design the road network, including the access and egress control from freeways, to compel the truck drivers to reveal their true intentions? What about the conflicts between truck drivers and their fleet operators? How do we avoid some of the problems such as the potential oscillations between alternative routes as have been revealed by computer simulation [Halas, 1992]? How much is the ultimate benefit to the public authority to bring user optimum to system optimum in traffic assignment so that we can determine the maximum justifiable economic incentives for diversion?

Some of the above problems probably cannot be solved, and other related problems cannot be identified, unless the idea of bundling private services with congestion pricing is tested in the real traffic environment. Given the encouragement and substantial funding for congestion pricing field tests in the recent legislation [ISTEA, 1991], we would suggest an exploration of the feasibility of establishing a congestion pricing project on I-75 in Michigan with federal funding, augmented by private resources. Such a project will help to bring the interested parties together for a serious and concerted effort to test the exciting ideas of bundling and congestion pricing at the same time.

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Appendix A

A Model of Road Pricing

To understand this model of congestion, break the analysis into two parts. In the first part we have users of a roadway segment over a given time interval. The potential users are arrayed in terms of benefits as indexed by their willingness to pay. They may or may not need to pay. This is summarized in the curve JB (see Figure A1) ranking potential users from highest value of the trip to lowest value.

Now turn to the congestion side. We suppose that over some range of usage, there is no problem of road congestion. This range is from 0 to D users per hour. Beyond that point congestion sets in. Here the key distinction is between marginal congestion and average congestion. Average congestion shapes individual behavior. Marginal congestion describes system costs more accurately. Marginal congestion (MC) rises above average congestion (AC).

The idea may be illustrated numerically. Suppose that as the number of users rises from 14 to 15 per unit time, the trip is slowed by a few seconds for everyone. That is, average trip time rises by a few (3) seconds. The 15th traveler could possibly notice the slowdown. Here we assume, perhaps unrealistically, that the slowdown is noticed. This is not so critical to the argument. The critical point is that the 3-second slowdown applies not to just driver 15, but to all preexisting (14) drivers as well. This 45 second (15 x 3) slowdown, translated into congestion cost, is what defines marginal congestion cost (to the entire set of users). But individual behavior is shaped by average congestion costs. Added travelers are discouraged from driving only at point E, where average congestion equals the congestion-free benefit to the user from the JB schedule. Socially efficient congestion is back at G' travelers.

A commonly proposed remedy is a user fee of GF. The added user at G' would then face the cost of average congestion *plus* the user fee, and use would equilibrate to the level of G' travelers. A problem with this remedy is that the fee revenue of HGFI comes out of user pockets. This makes them worse off, and possibly more so than the original problem of congestion. In theory, this revenue should be used to reduce taxes or provide some offsetting benefit;

but motorists, like other taxpayers, are skeptical of government. A simple restriction on quantity of drivers to G' would seem to solve this question of the government getting the revenue. A drawback is that all drivers along the GB segment of the benefit curve would be interested and there would be a type of non-price rationing or roadway lottery. Some who value the trip very little would end up traveling at peak times and would displace those who value the peak trip time more highly.

A different approach is *negative pricing* or to pay for *not* using the road at peak times over some billing period. (This is paid to those who *do not* travel at peak times!) This has usually been only a theoretical possibility. With the idea of diverter discounts (administered through in-motion metering) in a joint public-private venture as discussed in Section 4(F), such an arrangement might be a practical possibility as well.

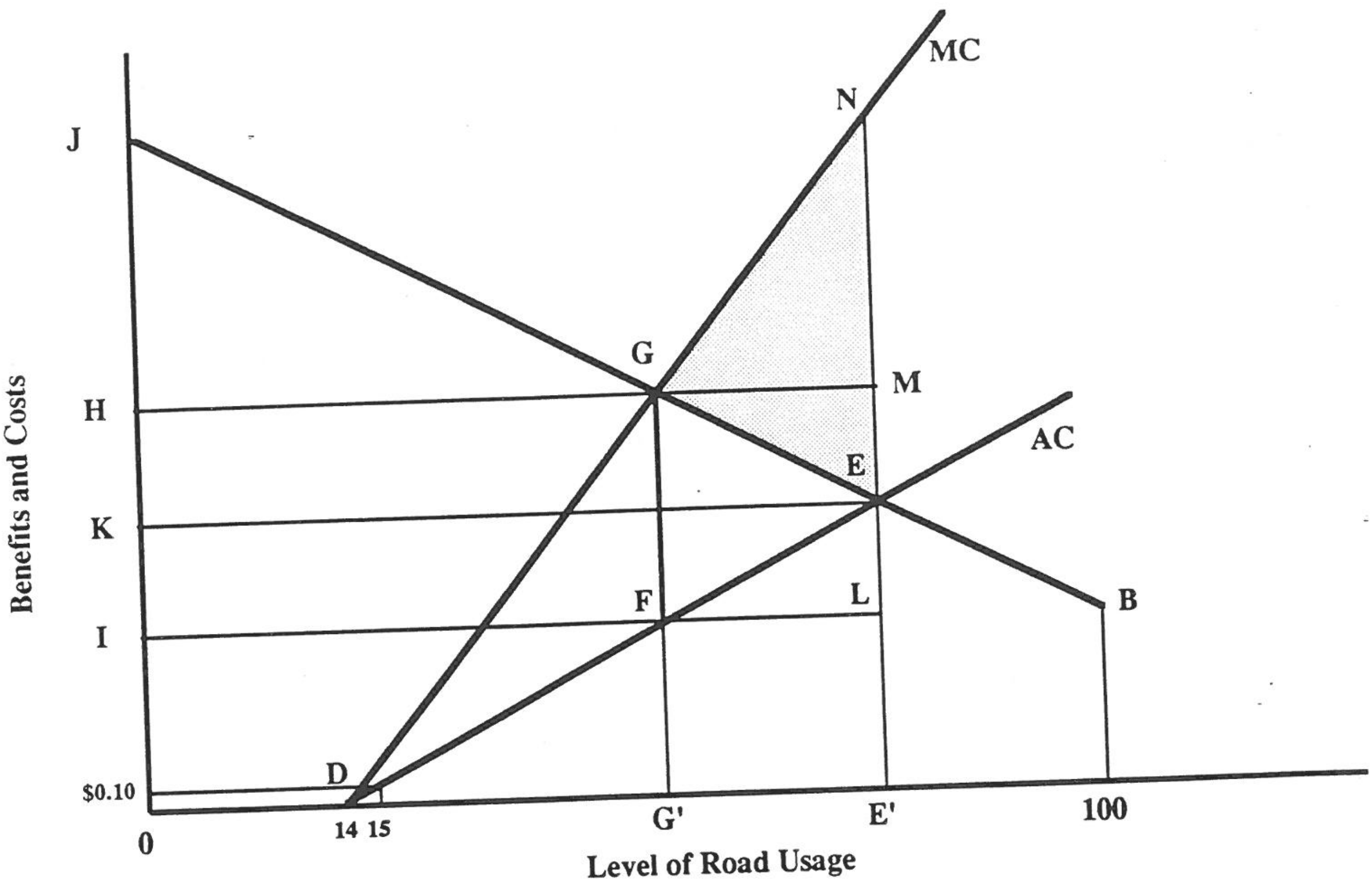

Figure A1. Road Congestion Fees and Payment to Diverters