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An Evaluation Taxonomy For Congestion Pricing

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ABSTRACT

This paper formulated an evaluation taxonomy to identify a broad range of factors that would be important for a comprehensive assessment. The evaluation taxonomy consists of three dimensions: road pricing strategies, impacted groups and impacts. We classified road pricing strategies by seven elements, and defined three types of impacted groups, and eleven impact types. Projects with different objectives will likely emphasize the impact types and impacted groups differently. This evaluation taxonomy is intended to be sufficiently broad so that a wide variety of road pricing schemes can be discussed and compared in one framework.

The paper also included a literature review of previous research in road pricing, especially regarding modeling tools and methods for conducting evaluation. The review indicated that there was a substantial body of work published in this area, containing many scattered ideas and approaches. It seems like a coordinated effort is needed to streamline and in some cases calibrate existing models so that they may be used for evaluation purposes. Finally, we also identified two areas where previous research especially lacked--the impact of road pricing on commercial vehicle operations, and on transit operations. Being important users and service providers of the transportation system, we recommend that the impact of road pricing on them should be included as part of the evaluation as well.

Keywords: **Congestion Pricing, Pricing, Transportation Management, Transportation Economy, Evaluation**

EXECUTIVE SUMMARY

Over the past few years, there has been a resurgence of interest in the topic of road pricing, particularly in the form known as congestion pricing. It is believed that recent advances in road pricing technology, and the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 that authorized $25 million to fund congestion pricing demonstration projects have contributed to its cause. In California, there are now three different projects that are intended to demonstrate some benefits from congestion pricing.

However, in reviewing the considerable literature on the topic of congestion pricing, there has been very little discussion of the needs in evaluating such demonstrations. Even a cursory review of the literature suggests that there are many dimensions to consider in evaluating the need for and impacts from congestion pricing. Responding to this need, this paper presents an evaluation framework that may guide evaluation efforts for these demonstration projects, considering the many possible dimensions of congestion pricing.

In this paper, we formulated an evaluation taxonomy to identify a broad range of factors that would be important for a comprehensive assessment. The evaluation taxonomy consists of three dimensions: road pricing strategies, impacted groups and impacts. We classified road pricing strategies by seven elements, and defined three types of impacted groups, and eleven impact types. Projects with different objectives will likely emphasize the impact types and impacted groups differently. This evaluation taxonomy is intended to be sufficiently broad so that a wide variety of road pricing schemes can be discussed and compared in one framework.

The paper also included a literature review of previous research in road pricing, especially regarding modeling tools and methods for conducting evaluation. The review indicated that there was a substantial body of work published in this area, containing many scattered ideas and approaches. It seems like a coordinated effort is needed to streamline and in some cases calibrate existing models so that they may be used for evaluation purposes. Finally, we also identified two areas where previous research especially lacked--the impact of road pricing on commercial vehicle operations, and on transit operations. Being important users and service providers of the transportation system, we recommend that the impact of road pricing on them should be included as part of the evaluation as well.

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1. INTRODUCTION

Over the past several years, there has been a resurgence of interest in the topic of road pricing, particularly in the form known as congestion pricing. Traditional road pricing involves pricing road use either directly as a flat fee for road use (as is currently done on many bridges, tunnels, tollways and turnpikes) or indirectly through licensing or other vehicle-based fees. For congestion pricing, however, road use may be priced in a manner that is somewhat related to the level of demand for the facility, and hence the level of traffic congestion on a certain facility or network. For many reasons, the concept of congestion pricing has received increased attention from both the academic and the transportation policy and planning communities. Recent reports by the World Bank (Hau 1992a) and the Transportation Research Board (1994) have been widely distributed; a great many other reports and articles have also been published in this area.

As suggested by the TRB report, some of the recent interest in congestion pricing is due to recent advances in road pricing technology. The recent research, development and implementation experiences in the realm of Intelligent Transportation Systems (ITS) have led to new electronics to collect fees for road use. There are a number of operational systems in the US that can collect tolls and other fees directly, electronically, without requiring the driver to stop or even slow down. In general, a stationary reader at a fixed collection point can communicate with some type of transponder on board the vehicle. When the vehicle passes the collection point (even at highway speeds), messages are shared between the transponder and the fixed reader, allowing efficient, fast and secure transactions.

Additional interest in congestion pricing has been fueled by recent federal legislation and funding for congestion pricing demonstrations. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 authorized $25 million over a 6-year period to fund planning and implementation of up to five congestion pricing demonstration projects. Initially, a single project, the San Francisco-Oakland Bay Bridge, was chosen. Other areas are now receiving some of this funding to determine the feasibility and begin planning for such projects.

In California, there are now three different projects that are intended to demonstrate some benefits from congestion pricing. The Bay Bridge project, involving a differential peak/off-peak toll structure for the bridge, is currently on hold pending support from the California State Legislature. A second project, coming on line in the fall of 1996, involves allowing single-occupancy vehicles (SOVs) the opportunity to pay a toll to use a high-occupancy lane on I-15 near San Diego. This so-called high-occupancy/toll (HOT) lane would require pricing based on the level of congestion in the HOV lane, as the operator is required to maintain level of service B in the HOV lanes. A third project, which began operation in December 1995, involves the pricing of a new privately-financed toll road in the median on State Route 91 (SR 91) in Orange County. The private operator may use differential pricing schemes, based on the time of day and/or the level of traffic congestion on the facility.

These demonstration projects offer a unique opportunity for the transportation research, planning, and policy communities to observe the mechanisms and results of congestion pricing in the US directly. To date, the applications of congestion pricing have occurred overseas, and many researchers have questioned the extent to which such experiences could be transferable to the US. Rather, much of the debate in this country has focused on the political acceptability, potential economic implications, and hypothetical transportation system impacts that might occur if congestion pricing were applied. Finally, it seems that years of speculation and theoretical study of the effects of congestion pricing may finally be borne out in these demonstration projects.

This evolution from theory to practice naturally raises the question of what information can be learned from such a demonstration project. The congestion pricing demonstration itself may only prove the feasibility of the concept. More fundamentally, however, there are many unresolved questions about congestion pricing that could be asked empirically through the course of a demonstration. As in all research, a structured approach is necessary to collect and analyze data in determining answers to these questions. Transportation, demographic, social and economic data, when properly analyzed and digested, should support credible answers to these questions. Thus, anticipating the importance of the results of a demonstration, it is vital that any US experience with congestion pricing undergo a thorough and objective evaluation.

However, in reviewing the considerable literature on this topic, there has been very little discussion of the needs in evaluating such demonstrations. Even a cursory review of the literature suggests that there are many dimensions to consider in evaluating the need for and impacts from congestion pricing. However, these have largely been considered in the theoretical; with these demonstration projects, we are now moving into the practical. To get meaningful information about the potential impacts from congestion pricing, a more detailed structure is needed to guide the evaluation of these demonstrations.

This paper presents an evaluation framework that may guide evaluation efforts for these demonstration projects, considering the many possible dimensions of congestion pricing. At the highest level, an assessment must consider the underlying objectives and goals of the pricing project; a structure for these objectives is presented in Section 2. Section 3 then presents a more detailed taxonomy of factors to consider in the evaluation: the set of impacts, the impacted individuals and groups, and the available technologies. With this taxonomy, Section 4 identifies the range of relevant literature that addresses these factors, and identifies tools that may be required to perform the needed evaluations of these demonstration projects. Conclusions about this evaluation approach are given in Section 5.

2. OBJECTIVES OF ROAD PRICING

At the highest level, an evaluation of a road pricing project must begin by examining the underlying goals and objectives of the project. The evaluation of specific factors and potential impacts from congestion pricing must be logically connected to the goals of the project (e.g., May 1992). Several broad goals have been mentioned in the literature that provide the most persuasive arguments for congestion pricing, including:

1. Cost recovery for planning, construction, operation and maintenance
2. Pricing of social costs / externalities
3. Effective management of transportation demand

In essence, the objective(s) of a congestion pricing project may be expected to influence the relative importance of various factors in the evaluation. For example, if the motivation for congestion pricing is to provide transportation-related revenues, one must be careful how much weight is put on its value for the impact of reducing congestion. Below, we discuss each of these three objectives and its resulting impacts on the evaluation.

2.1. Cost recovery

Perhaps the most well-accepted practice of road pricing is to charge user fees to recover capital, operations and maintenance costs of a given facility. This type of objective has been the primary motivation for the pricing of toll roads, turnpikes, bridges, tunnels, etc., as has been practiced for a very long time. The operating agency (public, quasi-public, or private) typically issues bonds to pay for the infrastructure and its upkeep, and relies on user fees to cover these bonds. Depending on the degree to which different user groups can then be uniquely identified, the operating agency may then choose to charge different tolls to different user groups, depending on some quantitative measure of their “use” of the facility. For example, it is common practice to charge tolls on these facilities that differ based on the type of vehicle (e.g. automobiles, light trucks and heavy trucks) or on some proxy for wear and tear of the roadway (e.g. number of axles).

In the context of congestion pricing, an operating agency may instead seek to recover costs from users based on segmenting users by the degree to which they cause congestion (slower speeds, delays, longer travel times, etc.) on the facility. With the overarching goal of cost recovery and return on investment, the private company constructing and operating the toll road along SR 91 in Orange County has chosen a congestion-based toll structure. In this way, the price charged during peak periods of congestion will differ from that charged at off-peak times. The user segmentation can be achieved through electronic toll collection technology and real-time announcements of tolls to drivers approaching the facility.

Understanding this objective, there seem to be at least two factors of highest importance in the evaluation. First, the agency that operates the facility is concerned about the effectiveness of the pricing strategy to ensure adequate cost recovery. Second, both the operator and the users of the facility will need to determine whether the pricing policy is equitable. In this case, equity may be measured by the extent to which those who pay receive the benefits, perhaps in some proportion to their payment. Other factors in the evaluation, such as the level of traffic congestion or changes in system-wide travel demand patterns, are of secondary concern relative to these elements.

2.2. Pricing of marginal social costs or externalities

A second objective of road pricing is to charge the user a cost equal to the *tofu2* costs of his/her travel, including many externalities. Following a common line of argument in the literature (see, for example, Hau 199213 and Decorla-Souza et al. 1992), the traveler experiences a cost in travel that is borne directly by him/her, such as gasoline costs, travel time, automobile use, etc. However, there may also be costs that this traveler imposes on others that are not captured in these direct, “out-of-pocket” costs. Such external costs could include additional congestion and travel delay for other drivers, air pollution, accidents, etc. This pricing objective seeks to improve market efficiency by reducing the activities that produce these external costs. Following this argument, it is believed that a clear market inefficiency exists due to ineffective pricing of road use, and that this inefficiency can be offset by charging a fee equal to the FUZZ external costs.

This type of pricing scheme has been advocated by a number of transportation economists, primarily based on arguments of system efficiency. However, the practical difficulties of implementing this objective are considerable, primarily because it is difficult for analysts and decision-makers to come to an agreement on (i) the magnitude of external costs, (ii) the range of impacted user groups, and (iii) an efficient toll collection and revenue allocation methodology. Moreover, any assessment of such a congestion pricing program would need to examine both the effectiveness of recovering these marginal costs as well as the equity of collection and allocation of toll revenues. Given these practical problems with designing and implementing marginal social cost pricing, very few projects explicitly mention this objective.

2.3. Demand management

A third objective of road pricing is to manage the supply of network capacity in a market-driven manner. That is, it may be the case that the use of transportation resources is not efficient: available capacity in one part of the network is under-utilized while it is over-utilized to the point of congestion in another part. Through a market-based pricing approach, demand in the network can be enticed to use the under-utilized capacity and perhaps reduce the congestion in the remainder of the network. Thus, pricing may serve to balance the level of supply and demand through the transportation system as a whole (see Vickrey, 1963 and 1965). Road pricing under this objective captures the marginal costs of traffic congestion, effectively charging road users for the marginal travel delay they cause to other users. One may consider this objective as a special case of the second objective described above--the external cost includes only the additional congestion and travel delay incurred on other drivers. Due to its prominence and that many existing pricing schemes follow this principle, we separately it as the third objective.

A number of congestion pricing demonstration projects rely on just such an objective. Perhaps most obviously, the San Diego HOT lanes demonstration project has identified under-utilized capacity in the HOV lanes, while there is significant congestion on the main freeway lanes. Rather than maintaining the restriction to keep SOVs from the HOV lane, the project seeks to develop a market for lane capacity by opening the HOV lanes to SOVs, at a price. The price charged for that available capacity may directly affect the number of SOVs switching to the HOV lane and the resulting level of congestion relief in the main freeway lanes.

A somewhat different perspective on transportation system capacity is evidenced in the Bay Bridge demonstration project. In this case, there is clear evidence that the road capacity in the corridor is highly over-utilized, and the primary motivation for implementing congestion pricing is to reduce this congestion through a higher toll during peak periods. At a secondary level, though, the alternatives in the corridor (primarily public transit bus, subway, and ferry) are under-utilized at current prices. So, the pricing strategy may have the direct effect of reducing the level of congestion on the main roadway, as well as a secondary effect of increasing the use of public transit capacity.

In this class of demonstration projects, the primary objective is to introduce a pricing mechanism into the transportation market that will more efficiently manage the existing capacity. For this reason, the primary focus of the assessment should be on the system performance under the pricing scheme. Measures such as the travel volumes on different facilities, total network throughput, and levels of congestion on selected facilities are likely to be of greatest concern to the evaluator.

2.4. Summary

In this section we have briefly reviewed three objectives for congestion pricing that seem to dominate the literature in road and congestion pricing. However, this list is not intended to be comprehensive; nor does it address the subtleties associated with each of the different objectives. Rather, this review suggests that there may be many reasons for implementing congestion pricing on a particular facility or across a road network. The conclusion we can draw from these examples, however, is that the goals and objectives of a given application of congestion pricing will affect the emphasis and design of the program's evaluation. Thus, the evaluator should consider the underlying goals of congestion pricing in valuing particular impacts and impacted groups.

3. EVALUATION TAXONOMY

To establish a broad perspective for this evaluation, we develop a road pricing evaluation taxonomy, as illustrated in Figure 1. The evaluation taxonomy consists of three dimensions: Pricing *Strategies, Impacted* Groups, and *Impacts.* Based on the objectives defined in Section 2, we set up a structure to frame road pricing schemes so that they can be discussed and compared on common ground. In this taxonomy, we also define the impact types and the impacted groups. This provides a framework to expose the distribution of costs (in a generalized sense) and benefits. The impacted groups and impact types are discussed in Sections 3.2 and 3.3, respectively.

The contribution of this paper is not on developing this evaluation taxonomy. Rather, the taxonomy is used as a platform to study the literature so that ideas can be generalized and assimilated. This taxonomy is also used to survey and classify state-of-the-art evaluation approaches, so that available modeling tools as well as missing ones can be identified. The results of this survey study are reported in Section 4.

3.1. Road Pricing Strategies

Various aspects of designing road pricing strategies have been proposed in the past. Gomez-Ibanez and Small (NCHRP Synthesis 210, 1994) contended that congestion pricing could take seven basic forms: (i) point pricing; (ii) cordon pricing; (iii) zone pricing; (iv) parking charges; (v) charges for distance traveled; (vi) charges for time spent in an area; and (vii) charges for both time spent and distance traveled.

A report by Federal Highway Administration (FHWA) (1994, page 11) suggested a similar approach, classifying pricing strategies according to mainly geographical scope, such as spot, facility, corridor, area, and regional. Armstrong-Wright (1986) proposed pricing strategies emphasizing implementation instruments, such as area licensing, parking restraints, user taxes, and vehicle ownership restraints. Hau (1992a) structured road pricing implementation schemes according to two methods: (i) indirect methods, such as vehicle ownership purchase tax, and (ii) direct methods, such as manual charging via tollgates. On the technology side, Halloran (1992), Hudders (1992), and Fleming (1992) discussed approaches for electronic toll collection (ETC), mostly through Automatic Vehicle Identification (AVI) technologies. Finally, Fielding and Klein (1994) discussed the procedures of implementing pricing projects.

There is a large volume of literature discussing implementation aspects. These articles each described road pricing strategies in their unique ways and covered part of the spectrum. Assimilating these previous work, we propose to categorize road pricing strategies by eight elements:

1. Geographical scope: Both FHWA (1994, page 11) and Gomez-Ibanez and Small (NCHRP Synthesis 210,1994) provided a good summary in this aspect, including (i) spot, (ii) facility, (iii) corridor, (iv) area, and (v) regional pricing mechanisms. An example of facility or link specific project will include the Bay Bridge in California. The ongoing project in Singapore represents an example of a region-wide implementation.

2. Right-of-way: Whether the proposed tolled facility is located at public or private right-of-way implies very different acquisition and perhaps even operation and revenue distribution consequences. This aspect has generally been ignored in the literature.

3. Rate variation over time: Toll rates can be fixed, or varied by time or day and/or traffic volume. This is possible with the advent of AVI technologies and data processing capabilities. For example, in California, the SR-91 and San Diego HOT projects will both adjust their rates based on traffic volumes on their facilities.

4. Basis for Charge: Tolls can be charged according to, for example, duration of stay in a congested area, annual mileage driven, or entrance/exit to a cordoned area or a facility, etc. The charge base should be closely related to the objective of the pricing project; for example, the impact of annual mileage-based fees will be very different from facility tolls. Hau (1992a) and Armstrong-Wright (1986) provided a good summary of this aspect of road pricing.

5. Target market: Tolls can be charged or exempted according to specific vehicle types. For instance, during morning and evening rush hours, high occupancy vehicles or HOVs (of three of more passengers) are exempted from paying the toll on the Bay Bridge. Also, single occupancy vehicles (SOV) will be allowed to use the HOV lane (on I-15) by paying a toll.

6. Implementation agency: This should be closely related to the objective and motivation of the pricing program, the institutional and organizational requirements for its operations, and finally, responsibility and accountability. For example, SR-91 in Orange County is built and operated by a private company for primarily business reasons. The Bay Bridge project, however, will likely be implemented by the Metropolitan Transportation Commission, with the goal to reduce peak hour congestion.

7. Toll collection approach/Technologv: This includes traditional toll booths for facility pricing, or the daily license scheme used in Singapore. The advent of AVI and in-vehicle display technologies permits innovative ways of collecting tolls and targeting specific markets. For example, Van Vuren and Malcolm (1990), Ghali and Smith (1993a), and El Sanhouri and Bernstein (1994) discussed ways of combining route guidance (AVI) and road pricing to achieve the goal of effective traffic management.

8. Use of revenue: Given that distributional issues are of particular concern to the public and many interest groups, we include the uses of road pricing revenue as one of the distinctive features. For privately financed toll facilities, the goal of pricing is clear--to recover investment. In other cases when pricing is used to manage traffic demand or ration travel externalities such as air emissions, the possible uses of the revenue is less definite. Small (1992) proposed a simple tri-partite rule: one third as monetary reimbursement to travelers, one third as a substitute for general taxes used to pay for transportation services, and one third for new public services including transportation. FHWA (1992, Section 2) provided a more detailed review of different ways of using the revenues from road pricing.

These eight elements are devised to be independent and comprehensive, and can be combined in different ways to achieve various pricing objectives. One aspect of particular importance is the development of AVI and Advanced Transportation Management and Information Systems (ATMIS) technologies. They offer flexibility and precision for designing innovative pricing systems. For example, if controlling air emissions is an objective, a toll can be set and charged according to a vehicle's air emission levels and the ambient conditions, with both being measured in real-time. Alternatively, tolls can be determined from real-time traffic conditions to effectively manage traffic.

3.2. Impacted Groups

The second dimension delineates the recipients of the impacts, so that the allocation of cost and benefit can be exposed. The ultimate **goal** is to allow an evaluator to assess whether the scheme is efficient for the entire system as a whole, and on a per group basis. Assessing system efficiency is critical since it is, the motivation for implementing congestion pricing in the first place. On the other hand, assessing the allocation of cost-benefit per impacted group answers questions regarding the distributional effects of achieving such system efficiency.

Distributional effects of road pricing have been a topic of constant discussion in the literature (see for example, TRB (1994, Vol. 1, pp. 66); FHWA (1994, Section 4); Cameron (1994)). As identified in Gomez-Ibanez (1992), Bhatt (1993) and others, objections based on inequitable distribution of benefits and costs of road pricing are among the most difficult barriers to overcome. It is, therefore, important to identify the winners and losers and the extent they are impacted. As pointed out in Bhatt (1993), subsequently, appropriate compensatory measures can be determined to mitigate adverse impacts for particular groups.

For evaluation purposes, we identify three types of impacted groups:

1. Users of the transportation system
2. Providers of the transportation services
3. Society as a whole

1. <u>User Groups</u>

The eventual goal of this classification is to differentiate the user groups so that the benefit and cost distribution can be illuminated. At the highest level, we divide users into two big categories: travelers and commercial vehicles. These two categories cover the movements of people and goods on the transportation system. Each of them is subject to different cost and travel time considerations, and hence is appropriately separated for evaluation purposes.

The distribution of costs and benefits among different traveler groups has been a topic of considerable discussion in the past. Most of the discussions pivot on the underlying concept of equity. The most commonly adopted view of equity considers the distributional effects according to income classes (see for example Cameron (1994)). Therefore one way of classifying travelers is by income quartiles. This is a convenient classification, especially for an evaluation of the impacts on low-income travelers.

There are other notions of equity that need to be addressed as well. Bhatt (1993) defines three other dimensions of equity: (i) Gender equity--congestion may have a disproportionately more adverse impact on women road users compared to men. (ii) Geographic equity--congestion pricing spill traffic to unpriced facilities; therefore, an assessment of impacts on users of priced versus unpriced facilities in the vicinity is necessary. (iii) Causal equity--this notion attempts to match those who create the congestion and related problems with those who should pay for the solution (i.e. equating those who benefit with those who pay).

In addition, there is the equity between different modes of travel: high occupancy vehicles (HOV), single occupancy vehicles (SOV) and transit riders. Finally, different trip purposes may have different cost and time tradeoffs; we include them as a final user group category. With this classification scheme, a trip may be classified in multiple categories. This is fine since the intention is to create categories that can highlight potential tradeoffs for a given road pricing scheme.

In summary, this notion of equity requires an analysis of the distribution of costs and benefits. Six possible classifications for user groups include:

1. Income
2. Mode
3. Gender
4. Geography
5. Trip purpose
6. Cause

Some of cost and benefit analyses across these user groups are difficult and expensive to conduct. Moreover, the existing literature seems to indicate that there is very little conclusive investigation of these kind of assessment approaches. Dependent on the project's objectives, given limited resources for evaluation, prioritization of these user group analyses should be defined. From the existing literature, it appears that analyses for the first three categories are more developed than the latter three.

Regarding the impacts of road pricing on commercial vehicles, there is very little information ever gathered for this purpose. We could not identify a single framework set up to examine this question, which supports a similar conclusion by TRB (1994, page 91). Given the potentially large impacts of road pricing schemes on commercial vehicles, we retain it as an important user category in the evaluation taxonomy.

2. Transportation Service Providers

One aspect of road pricing that is rarely addressed in the literature is the impact of road pricing implementation on transportation service providers. They in general include two broad categories: transit agencies and traffic management agencies.

A simplistic view of road traffic considers mode shifts from SOVs to transit as "disappeared" trips. How the transit system accommodates these additional demands is external to the traffic analysis. This is a safe assumption if the transit system has spare capacity. In this case, the additional revenue generated should be documented as part of the positive impacts of road pricing. For situations where the transit system must change service patterns to cope with new demands (e.g. by increasing schedule frequency or adding new routes), changes in transit revenues and costs should be evaluated and documented. Except in (TRB 1994, Vol. II, paper by Kain), there is very little we can find in the existing literature that discussed the magnitude of impact of road pricing on transit services.

Traffic management agencies is the second group that would be impacted by road pricing. On the positive side, they may receive some revenues *from* road pricing to expand their functions, such as build more roads, have better traffic control systems, or disseminate more accurate traffic information. The benefits of having these expanded capabilities should be documented as part of the impact of road pricing. On the requirement side, if the traffic management agencies are also the implementors of the road pricing scheme, one ought to evaluate, given their current regulatory and enforcement style of traffic management, whether they can adapt to this new market-based approach for traffic demand management. These types of impacts are captured in Section 3.3.

3. Society

Society as a whole, without differentiating the specific users groups, may be evaluated as a separate group. This group may be conceived as the government in general or the "system". Its purpose is to illuminate impacts that individual user groups would not be as concerned about, such as environmental impacts, overall network travel conditions, or government tax revenues. This was actually the argument that motivated economists to develop road pricing concepts in the first place (see, for example, Vickrey 1963). The concept of congestion pricing has been aptly summarized by Mohring and Anderson (1994), "Urban travelers both experience congestion and contribute to it. Inducing the operator of a vehicle--any vehicle--to remove it from a traffic stream would save not just its occupants' own time but also the time cost they would otherwise impose on other travelers by adding to the road's congestion level." It was the achievement of system-level objectives that motivated this concept.

However, the concept does not imply that any road pricing scheme will automatically result in an increase in social welfare. Recent evidence shows that the Singapore road pricing program--Area Licensing Scheme--may result in a decrease in social welfare, despite a drop in peak hour traffic. Wilson (1988) reported that after implementing the road pricing program in Singapore, peak hour traffic reduced by 65%, bus ridership increased from 35.9 to 43.9%; however, 44.1% of peak hour commuters experienced longer travel time, and only 36.1% experienced shorter travel time. This was because higher transit speed due to lower peak hour traffic was more than balanced by greater bus ridership and hence more and longer stops (Wilson, 1988). The net effect appeared to be longer travel times for the transit users. This result seemed discouraging since the policy was supposed to alleviate congestion and reduced travel time. This example also illustrates the importance of assessing the effects from multiple criteria.

Selecting society as an impacted group will also facilitate the evaluation and summarization of impacts such as financial viability of a project, and other longer term impacts such as land use changes. These impacts will be discussed in Section 3.3.

3.3. Impacts

Much of the literature in road pricing focuses on two type of impacts: time and money. Despite these are two very important attributes, they do not capture the entire scope of impacts for evaluation. Based on the objective of the pricing program, evaluation should include measures that address the level of attainment of that objective and possible side effects, such as changes in emissions, accident rates, etc. More recent thinking in road pricing has widened the scope of evaluation substantially. For example, FHWA (1994, Section V) recommended eight aspects for evaluation: (i) transportation and traffic, (ii) high occupancy vehicle use; (iii) air quality, (iv) violation and enforcement, (v) traffic accidents, (vi) public information and community response, (vii) pricing system technical performance, (viii) financial, economic, and distributional results.

The UK Department of Transport has identified eight major areas for evaluation (Richards, 1992): (i) travel choice impacts--encompassing demand impacts on both personal and commercial vehicle travel, (ii) transportation network impacts--encompassing network responses to different levels of demand, (iii) urban economy impacts--including effects on commercial vehicle operating costs and practices, and other consequential costs, (iv) social and equity impacts, (v) environmental and safety impacts, (vi) technology--including the technology of enforcement, (vii) administration--including the administration of enforcement, (viii) social and public acceptability.

The above two impact structures share much common ground. Along this same line of thinking, Richards (1992) proposed another eight ways of framing impacts. In the following, building on Richards' ideas, we establish a comprehensive list of eleven impact areas:

1. Demand-side impacts: How does a particular user group change their travel behavior, in terms of departure time choice, mode choice, route choice, destination choice, and decision to travel? What are the demand shifts?

2. Supply-side impacts: How does the transportation system perform, as a function of time of day, on the priced and unpriced facilities and on the alternate modes? Can the supply side cope with the demand shifts?

3. Impacts on urban economy: How will commercial operations, businesses within, outside or in the vicinity of the priced facilities, and the selection of residential location be affected? This impact measure covers the shorter term impacts on business operations as well as the longer term impact of land use changes.

4. Equity: How will different user groups defined in Section 3.2 be affected? An analysis of the incidence of costs and benefits according to the different classes of users (see Section 3.2) will provide useful information to identify the winners and losers.

5. Environment and Safetv: How will air quality, noise levels and accident rates change?

6. Financial: How will costs and revenues of the pricing program affect the financial status of implementing agencies, transit agencies, traffic management agencies, etc.? Is the program financially viable?

7. Enforcement and Compliance: How effective is the enforcement approach? How much does its cost? What is the rate of compliance/number of violations?

8. Technologv: To gauge future choices, we recommend technology as a separate category for evaluation, even though it is tilted more toward the operational rather than the impact

aspect of pricing programs. This is because the performance of many of these new technologies, such as AVI, are still relatively untested. The early demonstration programs should provide data on the performance of the concept as well as its apparatus.

9. Public acceptance: Road pricing is an untested but rather old concept. Public acceptance is clearly an area that evaluation must address. Do people gradually accept road pricing projects over time? Or do they remain skeptical and object to their implementation? Guiliano (1992) suggested some helpful hints in public acceptance based on some case studies. As TRB (1994, Vol. I, page 102) pointed out, the early congestion projects, given their small scale, are not likely to impact regional air pollution and travel time reductions, but they will provide unique opportunities to evaluate, among other things, the political sensitivity to pricing as a transportation policy option.

10. Impacts on institutions: In the case of the implementor being public traffic management agencies, can they adapt from a regulatory and enforcement environment to a market-based management approach? How will the various institutions with different cultures and practices work smoothly together to implement road pricing projects?

11. Organizational changes: For the implementing agency, a road pricing program may significantly alter its operations and network management practices. What changes in operating procedures are required? What are the changes in job skills or workforce requirements for those involved with the road pricing project?

These eleven impact areas form a comprehensive set. It does not mean that every program evaluation must cover them equally. Depending on the objective of the program, given limited resources, some prioritization is required. As a minimum, it appears that the evaluation should cover impact types l., 2., 4., 6., 7., and 9. to some degree.

4. STATE-OF-THE-ART EVALUATION TOOLS

Based on the evaluation taxonomy defined in Section 3 as a framework, this section identifies state-of-the-art approaches and modeling tools for evaluating road pricing projects. From a detailed literature review, we were able to identify about 190 published articles, reports, or books related to road or congestion pricing. The detailed references are listed in the Appendix. There was a substantial number of articles discussing road pricing as a policy option. Relatively few articles addressed directly the evaluation of road pricing projects (less than 30). Yet fewer articles discussed or proposed modeling tools or approaches for their evaluation (less than 15). This is not surprising, since evaluation was only recently recognized as an important part of road pricing projects (TRB 1994; FHWA 1994). And actual proposals for road pricing projects were initiated after ISTEA in 1991. In short, although the theory behind road pricing is fairly well developed in the literature, the modeling approaches and tools that support its evaluation lag behind.

To illustrate the coverage of previous literature, we classify those that are relevant to evaluation by the taxonomy developed in Section 3. Table 1 illustrates the results of this classification--cells with bold lines represent instances where a meaningful relationship exists. Without going through the detailed references, we use three levels of shades to indicate the amount of published articles for each meaningful incidence. Blank cells, and cells with light shades and heavy shades represent, respectively, no article, less than 5 articles, equal to or more than 5 articles found. Although this is a subjective assessment, the results do indicate some interesting patterns. In the following, we discuss the results of this literature review by impacted groups.

<u>Societv and Traveler Groups</u>

Modeling tools to determine demand-side impacts are reasonably developed (see for example: Harvey 1979 and 1994; Cameron 1991; Saccomanno 1984; Harrison et al 1986). They can be used to estimate measures such as mode shifts from SOVs to HOVs or transit ridership. However, the existing literature seems to indicate that there was rarely any validation of results produced. We believe that these models will be benefited significantly if data collected from road pricing projects can be used for their calibration.

Supply-side impacts (e.g. transportation system performance) require good dynamic traffic models to derive the resultant traffic performance. Since traffic simulation models have been improving significantly over the past decade (such as TRAF-NETSIM family, INTEGRATION, etc.), such ability should be available. However, there were few paper that addressed the linkage of these traffic simulation models with demand models to simulate the impact of congestion pricing.

Also in reviewing the literature, most of the quantitative and analytical results were based on applying simplistic speed-density-flow relationships such as variations of the BPR function on a single link. Generalizing these results to network performance in the presence of realistic conditions, such as traffic control, queuing, stochastic distribution of vehicle or traveler preferences, discrete step-wise toll structures, etc. are largely new aspects that need to be addressed. A closely related but unresolved question of this is the determination of tolls that achieve the coveted objective. Along these needs, these are some samples of recent work: Ghali and Smith (1993b) included traffic control in the consideration, Ran and Boyce (1994, Chapter 15) discussed a mathematical platform to relate dynamic system optimal characteristics with congestion pricing, Smith et al. (1994) proposed the existence of optimal road tolls under stochastic user-equilibrium, Bernstein and Smith (1994) examined the impact of having step-wise toll structure, Yang and Lam (1995) examined the optimal road tolls under conditions of queuing and congestion, and Yang and Huang (1995) investigated the appropriateness of the principle of marginal-cost pricing in a general road network.

The evaluation of dynamic tolls in a network often involves the so called dynamic traffic assignment models. Examples of these models include: Cascetta (1989), Drissi-Kaitouni and Hameda-Benchekroun (1992), Berstein et al. (1993), Friez et al. (1993), Chang and Mahmassani (1988), Mahmassani and Peeta (1992), Janson (1991), and Ran et al. (1993), Ran and Boyce (1994), and Ran, Lo, and Boyce (1996). In summary, this is a dynamic area with many active studies in progress. Most of these studies looks at the problem from an analytical, yet independent perspective. Adapting these approaches to evaluation would require a good effort of assimilation.

On the contrary, the impact of urban economy (such as longer term land use changes, and impact on businesses in the vicinity of a tolled facility) is largely unexamined (Deakin, 1994). The lack of a credible modeling tool is the major reason.

Distributional impacts or equity has been contended in a number of articles (for example: Dawson and Brown 1985; Bhatt 1993; Giuliano 1994). The evaluation approach is mainly through surveys and focus groups. This is another area that will be benefited from the demonstration programs. With actual data, one can improve these contentions by establishing the magnitude of this impact, hence allowing the design of fairer compensatory measures.

There is also a relatively large number of articles discussing the financial aspects of road pricing projects (See for example: Hau 1992a, 1992b; Ramjerdi 1993; Fielding and Klein, 1994). This is not surprising since finance is one of the crucial aspects of road pricing schemes. Finally, the tool to evaluate public acceptance has also been reasonably addressed, which is primarily based on stated preference survey methods or focus groups (for example, see Petrakis 1991). In summary the tools for evaluating impacts on society and traveler groups are essentially available. Most of these modeling tools focus on shorter-term impacts, however. The research on longer term impacts such as land use and urban economy changes (e.g. productivity) is still undecided to date . It is also important to note that the available models are mostly unvalidated, and sometimes they may be inconsistent with each other. Data collected from earlier road pricing projects can be helpful for their calibration, so that they may be used for subsequent and later evaluation activities.

Commercial Vehicle Operations

Unlike the first two impacted groups, very little is ever published on the impact of road pricing on commercial vehicle operations, or transit agencies. For commercial vehicle operations, how would road pricing programs affect their business operations, financial status, and eventually business practices are largely undetermined. Bhatt (1993) argued generically that, due to their higher value of time than private autos, commercial operations should benefit from road pricing. However, there was never a study framework set up to investigate the impact of road pricing on them. The lack and need of such research for a comprehensive assessment of road pricing programs are apparent.

Transit Agencies

Similarly, there was very little published work on the impact of road pricing on transit. On the demand-side impacts, a number of models can estimate the shifts from SOVs to transit, as mentioned earlier (for example, see: Harvey 1979, Cameron 1991). Kain in (TRB, 1994) proposed a general framework to examine the impact of road pricing on the transit system. However, Kain could not collect sufficient data to establish results.

For transit systems that must be expanded, short-term cash flow problems need to be resolved, and an eventual cost-benefit analysis need to be assessed. The Singapore road pricing programs produced some insights of the financial impact on the transit system (Hau 1992a). However, since the transit or bus system in Singapore had a high level of ridership even before the road pricing program (about 39%), the transferability of results is questionable. In short, research and data are definitely needed for assessing the impact on transit agencies.

Traffic Management Agencies

For traffic management agencies, (in many cases they are also the implementor of road pricing projects), the demand-side and supply-side impacts are related together. Changes in demand due to road pricing, such as higher demand for HOV lanes, should translate into longer term supply-side actions, such as providing more HOV lanes. However, most of the modeling activities stop at analyzing the resultant traffic system performance due to road pricing. Longer term impacts are generally not included as part of the modeling activity (see for example: Harrison et al 1986). Realizing this lack of a broader modeling system for analyzing road pricing and other transportation policy options, the UK Department of Transport has undertaken development of a transport model system. The model system consists of three tiers: (i) the upper tier is a strategy model relating demand and capacity changes of the transport system, (ii) the middle tier is a model assessing impacts on highways and public transport as a result of the demand and capacity changes, (iii) the third tier consists of a series of local area case studies to obtain detailed impacts (Richards 1992).

Since most of the recently proposed toll projects rely on new technologies such as electronic toll tags or AVI, technology assessment of toll collection approaches is an important item. Bhatt (1974), Catling and Harbord (1985), and Hau (1992a) would provide sufficient background to establish a scheme for technology assessment. Inter-institutional coordination issues within a region, and intra-organizational adaptation to handle road pricing programs are aspects that should be assessed too, and have generally been ignored in the past. Two articles would provide some insights on developing appropriate evaluation approaches: Olson (1994), Giuliano and Wachs (1992). Other than those, the demonstration projects would provide substantial hands-on experience to investigate these institutional and organizational issues.

In summary, there is a large volume of work published in the past, discussing a wide spectrum of issues. However, most of them did not aim at providing methods to evaluate road pricing projects. It appears that a coordinated effort is much needed to consolidate previous efforts, streamline and calibrate existing models so that they may be used for evaluating road pricing projects.

5. CONCLUSIONS

TRB (1994, vol. I, Section 5) aptly summarized the importance of having a reliable evaluation for early road pricing projects: it will enhance the discussions with reliable information about how the traffic system is impacted, how the benefits and costs are distributed, and how the public perceive before and after the change. All this information will only be available if a comprehensive evaluation is planned and executed for each of the limited number of early pricing projects.

This paper presents an evaluation taxonomy to identify a broad range of factors that should be considered for a comprehensive assessment. We formulated **the** taxonomy with three dimensions: road pricing strategies, impacted groups and impacts. We classified road pricing strategies by eight elements, and defined three types of impacted groups, and eleven impact types. Arguably, this is one of the most comprehensive framework set up for evaluating congestion pricing programs, with most of the previous work assimilated in this framework.

Subsequently, the taxonomy is used as a platform to study the literature so that ideas can be generalized and assimilated. State-of-the-art evaluation approaches and available modeling tools as well as missing ones were identified. This literature review indicated that there was a substantial body or work published in this area, containing many scattered ideas and approaches. It appears that a coordinated effort is needed to streamline and in some cases calibrate existing models so that they may be used for evaluation purposes. Finally, we also identified two areas where previous research especially lacked--the impact of road pricing on commercial vehicle operations, and on transit operations. We recommend that the impact of road pricing on these two operations should be included as part of the evaluation.

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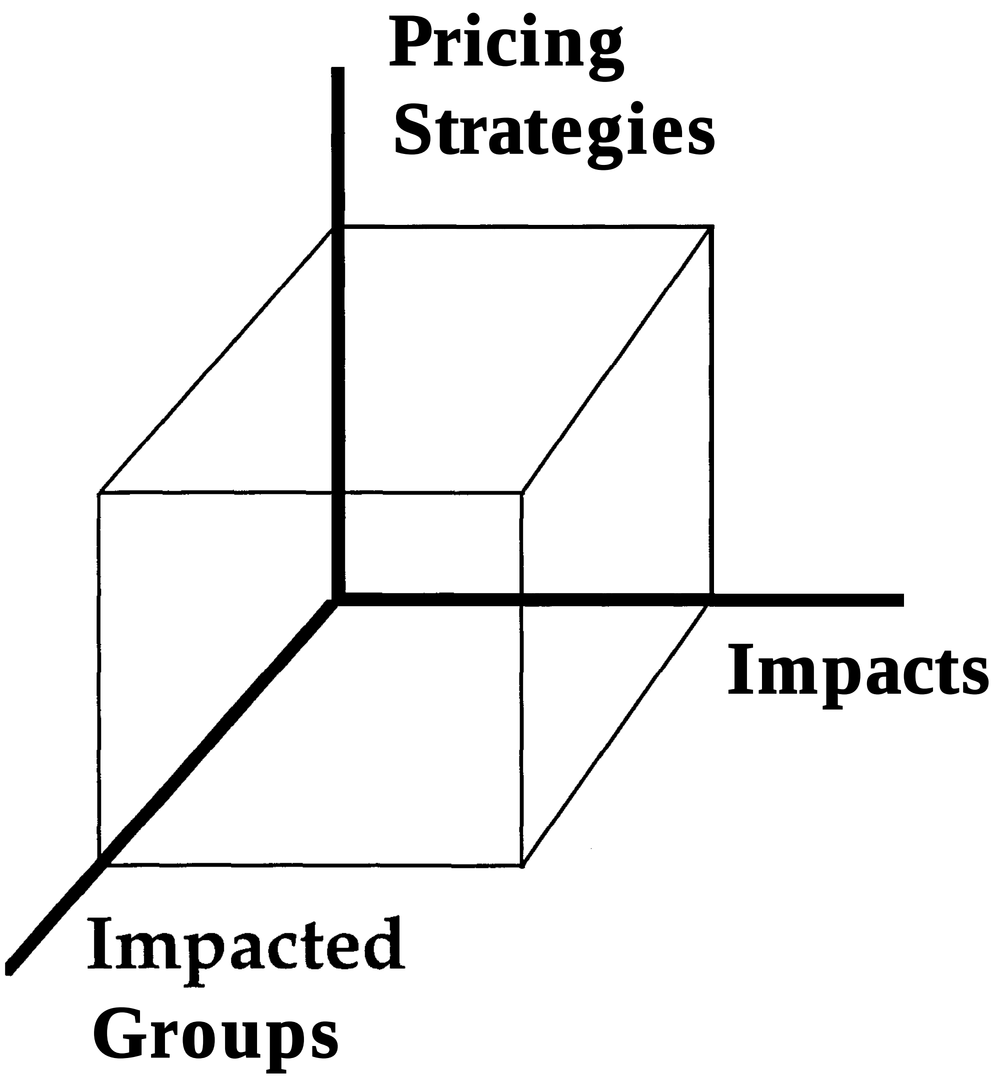

Figure 1 An evaluation taxonomy for road pricing

Table 1 Coverage of existence literature: blanks, light shades, heavy shades represent no article, less than 5 articles, and greater than or equal to 5 articles found, respectively.

Impacts	Society	User Groups		Transportation Service Providers	
		Traveler groups	Commercial vehicles	Transit agencies	Traffic man. agencies / Implementor
Demand-side impacts					
Supply-side: Sys. Performance					
Urban economy					
Equity					
Environment & Safety					
Financial					
Enforcement & compliance					
Technology					
Public acceptance					
Institutional impacts					
Organizational changes					

7. APPENDIX: DETAILED LITERATURE SEARCH RESULTS

(1) Author: Armstrong-Wright, Alan, 1929-
Title: Road pricing and user restraint : opportunities and constraints in developing countries / A.T. Armstrong-Wright.
Found in: Transportation research. Part A, General. Vol. 20A, no. 2 (Mar. 1986)
Description: p. 123-127 ; 28 cm.

(2) Author: Arrillaga, Bert.
Title: U.S. experience with congestion pricing / by Bert Arrillaga.
Found in: ITE journal. Vol. 63, no. 12 (Dec. 1993)
Description: p. 39-43 ; 28 cm.

(3) Author: Banister, David.
Title: Congestion : market pricing for parking / David Banister.
Found in: Built environment. Vol. 15, no. 3/4 (1989)
Description: p. 251-256 : ill. ; 25 cm.

(4) Author: Banister, David.
Title: Toll road pricing on inter urban highways in developing countries. London : University College London, Bartlett School of Architecture and Planning, 1986.
Description: 1 v.
Series: Town planning discussion papers ISSN: 02642093 ; no. 46.

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Title: Toll road pricing on inter urban highways in developing countries / David Banister. London : Bartlett School of Architecture and Planning, (1986)
Description: (28) p. : maps ; 30 cm.
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(6) Author: Bayliss, David.
Title: British views on road pricing / David Bayliss.
Found in: Proceedings (Chartered Institute of Transport). Proceedings. Vol. 1, no. 4 (autumn 1992)
Description: p. 3-13 ; 21 cm.

(7) Title: Behavioural responses to electronic road pricing : case study, Athens / Kostas Petrakis . . . iet a1.u ; prepared as part of the contribution of the Organisation for Planning and Environmental Protection of Athens to the Euronett project. (Oxford,England : Transport Studies Unit, Oxford University, 1991)
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Title: Financing road capacity and returns to scale under marginal cost pricing : a note / by J. Berechman and D. Pines.
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Description: p. 145-151 : ill. ; 22 cm.

(11) Author: Bernstein, David.
Title: Understanding the competing short-run objectives of peak period road pricing / David Bernstein and Jerome Muller.
Found in: Transportation research record. No. 1395 (1993)
Description: p. 122-128 : ill. ; 28 cm.

(12) Author: Bhatt, Kiran.
Title: Implementing congestion pricing : winners and losers / by Kiran Bhatt.
Found in: ITE journal. Vol. 63, no. 12 (Dec. 1993)
Description: p. 33-37 ; 28 cm.

(13) Author: Bhatt, Kiran.
Title: Road and parking pricing : issues and research needs / Kiran Bhatt and Thomas J. Higgins (K.T. Analytics, Inc.). (Washington, D.C. : Transportation Research Board, National Research Council, 1992)
Description: 14 p. ; 28 cm.

(14) Author: Bhatt, Kiran.
Title: Transportation improvement and road pricing: a demonstration program / by Kiran Bhatt, Ronald Kirby and Michael Beesley. Washington : Urban Institute, 1976.
Description: vii, 12 p. ; 28 cm.
Series: An Urban Institute paper.

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Title: Road pricing technologies : a survey / Kiran Bhatt. Washington, D.C. : Urban Institute, 1974.
Description: v, 45 p. ; 28 cm.
Series: Urban Institute paper ; no. 1212-11.

(16) Author: Bhatt, Kiran U.
Title: What can we do about urban traffic congestion? : a pricing approach / by Kiran U. Bhatt. Washington, D.C. : Urban Institute, (1975).
Description: viii, 47 leaves ; 28 cm.
Series: Working paper (Urban Institute) ; 5032-03-l.

(17) Author: Bhatt, Kiran U.
Title: What can we do about urban traffic congestion? : a pricing approach / Kiran U. Bhatt. Washington, D. C. : Urban Institute, 1976.
Description: vi, 41 p. ; 28 cm.
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(18) Author: Bhatta, Kiran U.
Title: Road and parking pricing : issues and research needs / Kiran U. Bhatta and Thomas J. Higgins.
Found in: Transportation research record. No. 1346 (1992)
Description: p. 68-73 : 28 cm.

(19) Author: Blythe, Philip T.

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Found in: World Conference on Transport Research (1986 : Vancouver, B.C.) Research for tomorrow's transport requirements. Vancouver, Canada : Centre for Transportation Studies, University of British Columbia, 1986.
Description: p. 1367-1378 ; 23 cm.

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Title: Electronic road pricing : an idea whose time may never come / Sandford F. Borins.
Found in: Transportation research. Part A, General. Vol. 22A, no. 1 (Jan. 1988)
Description: p. 37-44 ; 28 cm.

(23) Author: Brett, A. C.
Title: Electronic route-guidance to electronic road-pricing : the next step? / A.C. Brett & J.R. Estlea (Wootton Jeffreys Consultants Ltd.).
Found in: Planning and Transport Research and Computation (International) Co. Meeting. Proceedings of Seminar A held at the PTRC summer annual meeting. 17th (1989)
Description: p. 85-92 ; 30 cm.

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Title: Electronic route-guidance to electronic road-pricing : the next step? / A.C. Brett & J.R. Estlea.
Found in: Planning and Transport Research and Computation (International) Co. Meeting. Proceedings of Seminar H held at the PTRC summer annual meeting. Vol. P323 (1989)
Description: p. 245-252 ; 30 cm.

(25) Author: Burke, R. H.
Title: A road construction price index / R. H. Burke. Canberra : Australian Govt. Pub. Service, 1978.
Description: ix, 30 p. ; 25 cm.
Series: Occasional paper - Bureau of Transport Economics ; 27.

(26) Author: Castillo, William A.
Title: Analysis of road pricing, metering and the priority treatment of high occupancy vehicles using system dynamics / by William A. Castillo. Wright-Patterson AFB, OH : Air Force Institute of Technology, í1992ù
Description: vi, 87 leaves : ill. ; 28 cm.
Doc Numbers: Report No.: AFIT/CI/CIA-93-009
Stock No.: AD-A268 080 NTIS

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Title: Electronic road pricing in Hong Kong : 2., the technology / by Ian Catling and Brian J. Harbord.
Found in: Traffic engineering & control. Vol. 26, no. 12 (Dec. 1985)
Description: p. 608-615 : ill. ; 30 cm.

(28) Author: Catling, Ian.
Title: Electronic road pricing in Hong Kong : an opportunity for road privatization? / Ian Catling and Gabriel Roth.
Found in: Transportation research record. No. 1107 (1987)
Description: p. 51-55 : ill., chart ; 28 cm.

(29) Author: Cervero, Robert.
Title: Transportation alternatives in a congestion pricing environment / Robert Cervero. Berkeley, Calif. : University of California at Berkeley, Institute of Urban and Regional Development, National Transit Access Center í1992ù
Description: íviù, 29 p. ; 28 cm.
Series: Working paper ; 583

(30) Author: Chan, C. C.
Title: Area traffic control systems and electronic road pricing in Hong Kong / C.C. Chan and I. Catling.
Found in: International Conference on Road Traffic Control (1986). Second International Conference on Road Traffic Control, 15-18 April 1986. London : Institution of Electrical Engineers, c1986.
Description: p. 68-76 : ill., maps ; 30 cm.

(31) Author: Cheslow, Melvyn D.
Title: A road pricing and transit improvement program : a preliminary analysis for Berkeley, California / Melvyn D. Cheslow ; DHR, Incorporated. 1981.
Description: i, 39, A-5 leaves ; 28 cm.

(32) Author: Cheslow, Melvyn D.
Title: A road pricing and transit improvement program in Berkeley, California : a preliminary analysis / Melvyn D. Cheslow. Washington, D.C. : Urban Institute, 1978.
Description: xii, 80 p. : ill. ; 28 cm.
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(33) Title: Congestion pricing for Southern California : using market pricing to reduce congestion and emissions / The Reason Foundation.
Found in: Symposium on the Transportation Land Use Air Quality Connection : the Role of Pricing and Market-based Strategies (1992 : Lake Arrowhead, Calif.) The transportation land use air quality connection : the role of pricing and market-based strategies,

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(34) Title: Congestion pricing for Southern California : using market pricing to reduce congestion and emissions / The Reason Foundation. Los Angeles : The Reason Foundation, í1992ù
Description: 1 v.(various pagings) : ill. ; 28 cm.
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(35) Title: Congestion pricing for Southern California : using market pricing to reduce congestion and emissions / The Reason Foundation. Los Angeles : The Reason Foundation, í1992ù
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(36) Title: Congestion pricing : special issue / guest editor: Kenneth A. Small. Dordrecht, the Netherlands ; Norwell, MA : Kluwer Academic, 1992.
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(37) Title: Congestion pricing study : final report / prepared by the Urban Institute íandù KT Analytics ; prepared for Southern California Association of Governments. íLos Angeles, Calif. : Southern California Association of Governments, 1991ù
Description: vii, 65 leaves ; 28 cm.

(38) Author: Daniel, Joseph Irvine.
Title: Peak-load-congestion pricing and optimal capacity of large hub airports : with application to the Minneapolis-St. Paul Airport / by Joseph Irvine Daniel. 1992.
Description: í6ù, 127 leaves : ill. ; 28 cm.
Doc Numbers: Stock No.: 92-31026 University Microfilms International

(39) Author: Dawson, J. A. L.
Title: Electronic road pricing in Hong Kong / J.A.L. Dawson and I. Catling.
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Description: p. 129-134 : ill. ; 28 cm.

(40) Author: Dawson, J. A. L.
Title: Electronic road pricing in Hong Kong : 1. a fair way to go? / by J.A.L. Dawson and Fred N. Brown.
Found in: Traffic engineering & control. Vol. 26, no. 11 (Nov. 1985)
Description: p. 522-529 : charts, map ; 30 cm.

(41) Author: Dawson, J. A. L.
Title: Electronic road pricing in Hong Kong : 4, conclusion / by J.A.L. Dawson.
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Description: p. 79-83 ; 30 cm.

(42) Author: deCorla-Souza, Patrick.
Title: Congestion pricing : issues and opportunities / by Patrick Decorla-Souza.
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(43) Author: Edelstein, Robert.
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Description: p. 15-18 : ill. ; 28 cm.

(44) Title: The Effects of road pricing in London : an assessment of monitoring requirements / A.D. May . . . iet al.ù.
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Description: p. 43-54 ; 30 cm.

(45) Author: El Sanhouri, Ibrahim.
Title: Integrating driver information and congestion pricing systems / Ibrahim El Sanhouri and David Bernstein. íWashington, D.C. : Transportation Research Board, 1994ù
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(46) Title: Electronic road pricing in Hong Kong / M.J. Clancy . . . iet al.ù.
Found in: Planning and Transport Research and Computation (International) Company. Meeting. Proceedings of Seminar L held at the PTRC summer annual meeting. 13th (1985)
Description: p. 221-234 : ill. ; 30 cm.

(47) Author: Elliott, Ward.
Title: Fumbling toward the edge of history : California's quest for a road-pricing experiment / Ward Elliot.
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Description: p. 151-156 ; 28 cm.

(48) Author: Evans, Andrew W.
Title: Road congestion pricing : when is it a good policy? / Andrew W. Evans.
Found in: Journal of transport economics and policy. Vol. 26, no. 3 (Sept. 1992)
Description: p. 213-243 : ill. ; 25 cm.

(49) Author: Evmolpidis, Vassilis.
Title: Road pricing and its application in Berkeley / Vassilis Evmolpidis. í1977ù
Description: 50 leaves : ill., maps ; 28 cm.

(50) Title: Examining congestion pricing implementation issues : summary of proceedings, Congestion Pricing Symposium, June 10-12, 1992. Washington, D.C. : Federal Highway Administration, í1992ù
Description: xiii, 43, A-7, B-2 p. ; 28 cm.
Series: Searching for solutions. A policy discussion series ; no. 6.
Doc Numbers: Report No.: FHWA-PL-93-008

(51) Title: Exploring the role of pricing as a congestion management tool : summary of proceedings : Seminar on the Application of Pricing Principles to Congestion Management / sponsored by the Federal Highway Administration and the Federal Transit Administration. íWashington, D.C.?ù : Federal Highway Administration, í1992ù
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(52) Title: Exploring the role of pricing as a congestion management tool : summary of proceeedings : Seminar on the Application of Pricing Principles to Congestion Management. íWashington, D.C.ù : Federal Highway Administration, í1991ù
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Doc Numbers: Report No.: FHWA-PL-92-012

(53) Author: Field, Brian G.
Title: From area licensing to electronic road pricing : a case study in vehicle restraint / Brian G. Field.
Found in: IVHS and vehicle communications. Warrendale, PA : Society of Automotive Engineers, 1991.
Description: p. 49-59 ill. ; 28 cm.

(54) Author: Field, Brian G.
Title: Road pricing in practice / Brian G. Field.
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Description: p. í5ù-14 : ill. ; 26 cm.

(55) Author: Fielding, Gordon J.
Title: High occupancy / toll lanes : phasing in congestion pricing a lane at a time / Gordon J. Fielding, Daniel B. Klein. Berkeley, Calif. : University of California Transportation Center, í1993?ù
Description: 16, í1ù p. : ill. ; 28 cm.
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(56) Author: FitzRoy, Felix.
Title: Priority over pricing : lessons from Zurich on the redundancy of road pricing / by Felix FitzRoy and Ian Smith.
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(57) Author: Fleming, Daryl S.
Title: Integrated electronic toll collection and traffic management systems : the foundation for congestion pricing / Daryl S. Fleming.
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(58) Author: Fleming, Daryl S.
Title: Laying the foundation for congestion pricing / by Daryl S. Fleming (HNTB, Irvine, California).
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Description: p. 94-103 : ill. ; 28 cm.

(59) Author: Fong, Peter K. W.
Title: The electronic road pricing system in Hong Kong / Peter K.W.

Fong.
Found in: Innovative strategies to improve urban transportation performance : proceedings of a specialty conference. New York, N.Y. : American Society of Civil Engineers, 1985.
Description: p. 245-262 : ill., maps ; 22 cm.

(60) Author: Fong, Peter K. W.
Title: An evaluative analysis of the Hong Kong electronic road pricing system / by Peter K. W. Fong. Hong Kong : University of Hong Kong, Centre of Urban Studies & Urban Planning, 1985.
Description: 27 p. : ill.
Series: Working paper / University of Hong Kong, Centre of Urban Studies & Urban Planning 12.

(61) Author: Fong, Peter K. W.
Title: Issues of the electronic road pricing system in Hong Kong / Peter K.W. Fong. Hong Kong : University of Hong Kong, Centre of Urban Studies & Urban Planning, 1985.
Description: 27 p. ; 30 cm.
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(62) Author: Fong, Peter K. W.
Title: Issues of the electronic road pricing system in Hong Kong / Peter K.W. Fong.
Found in: Transportation planning and technology. Vol. 10, no. 1 (1985)
Description: p. 29-41 : chart ; 25 cm.

(63) Author: Fourie, S. A.
Title: Road pricing and supplementary licensing : the current position / S.A. Fourie, P.N.W. Freeman. Pretoria : National Institute for Transport and Road Research, 1980.
Description: 29 p. : map, chart ; 30 cm.
Series: Technical report / National Institute for Transport and Road Research ; RT/9/80.

(64) Author: Ghali, M. 0.
Title: Road pricing : a new model for assessing the many options / by M.O. Ghali and M.J. Smith.
Found in: Traffic engineering & control. Vol. 33, no. 3 (Apr. 1992)
Description: p. 156-157 : charts ; 30 cm.

(65) Author: Ghali, M. 0.
Title: Traffic assignment, traffic control and road pricing / M.O. Ghali and M.J. Smith.
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(66) Author: Gillen, David W.
Title: Effects of changes in parking prices and parking restrictions on urban transport demands and congestion levels / by David W. Gillen. íToronto : University of Toronto-York University Joint Program in Transportationti, 1975.
Description: 49 leaves : ill. ; 28 cm.
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(67) Author: Gillen, David W.
Title: A pricing paradigm : one economist's view of what it will take to put road pricing into effect / by David Gillen.
Found in: ITS review. Vol. 15, no. 3 (May 1992)
Description: p. 2-3, 8 ; 28 cm.

(68) Author: Giuliano, Genevieve.
Title: An assessment of the political acceptability of congestion pricing / by Genevieve Giuliano.
Found in: Transportation. Vol. 19, no. 4 (1992)
Description: p. í335ù-358 : ill. ; 24 cm.

(69) Author: Goldsack, Paul.
Title: Cambridge road pricing plans come under expert scrutiny / Paul Goldsack.
Found in: Highways (Croydon, London, England). Highways. Vol. 58, no. 1967 (Nov. 1990)
Description: p. 16-17 : ill. ; 30 cm.

(70) Author: Gomez-Ibanez, Jose A., 1948-
Title: The political economy of highway tolls and congestion pricing / Jose A. Gomez-Ibanez.
Found in: Transportation quarterly. Vol. 38, no. 3 (July 1984)
Description: p. 343-360 ; 26 cm.

(71) Author: Goodwin, P. B.
Title: Road pricing : the political and strategic possibilities / P.B. Goodwin and P.M. Jones. Oxford : University of Oxford, Transport Studies Unit, í1989ù
Description: 53 p. : ill. ; 28 cm.
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(72) Author: Goodwin, P. B.
Title: The "Rule of Three" : a possible solution to the political problem of competing objectives for road pricing / P.B. Goodwin.
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(73) Author: Great Britain. Ministry of Transport.
Title: Road pricing: the economic and technical possibilities; report of a panel set up by the Ministry of Transport. London, H.M. Stationery Off., 1964.
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(74) Author: Haritos, Z.
Title: Rational road pricing policies in Canada íbyù Z. Haritos. Ottawa, Canadian Transport Commission í1973ù
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(75) Author: Harrison, Bil.
Title: Electronic road pricing in Hong Kong : 3. estimating and evaluating the effects / by Bil Harrison.
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(76) Author: Harvey, Greig.

Title: Applying pricing principles to congestion management : summary and comment / by Greig Harvey and Elizabeth Deakin. Berkeley, CA : Deakin, Harvey, Skabardonis, Inc., í1991ù
Description: 21 leaves : charts ; 28 cm.

(77) Author: Hau, Timothy D.
Title: Electronic road pricing : developments in Hong Kong 1983-1989 / by Timothy D. Hau.
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(78) Author: Hau, Timothy D.
Title: Road pricing in Hong Kong : a viable proposal / Timothy D. Hau.
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(79) Author: Hau, Timothy D. (Timothy Doe-Kwong)
Title: Economic fundamentals of road pricing : a diagrammatic analysis / by Timothy D. Hau. Washington, DC (1818 H St. NW Washington 20433) : Transport Division, Infrastucture and Urban Development Dept., the World Bank, í1992ù
Description: vi, 96 p. : ill. ; 28 cm.
Series: Policy research working papers ; WPS 1070.

(80) Author: Hewitt, Patricia.
Title: A cleaner, faster London : road pricing, transport policy and the environment. London : Institute for Public Policy Research, c1989.
Description: 44 p. ; 30 cm.
Series: Green paper ; no. 1.

(81) Author: Higgins, Thomas J., 1944-
Title: Comparing strategies for reducing traffic-related problems : the potential for road pricing / Thomas Higgins. Washington, D.C. : Urban Institute, 1978.
Description: viii, 36 p. ; 28 cm.
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(82) Author: Higgins, Thomas J., 1944-
Title: Road pricing : a clash of analysis and politics / Thomas J. Higgins.
Found in: Policy analysis. Vol. 7, no. 1, (Winter 1981)
Description: p. í71ù-89 p. ; 23 cm.

(83) Author: Higgins, Thomas J., 1944-
Title: Road-pricing attempts in the United States / Thomas J. Higgins.
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(84) Author: Higgins, Thomas J., 1944-
Title: Road pricing : managing the risks / Tom Higgins.
Found in: Policy analysis. Vol. 3, no. 4 (Fall 1977)
Description: p. í579ù-582 ; 23 cm.

(85) Author: Hills, P.
Title: The automation of toll-collection and road-use pricing systems /

P. Hills and P.T. Blythe.
Found in: International Conference on Road Traffic Monitoring (1989 : London, England). Second International Conference on Road Traffic Monitoring. London : Institution of Electrical Engineers, c1989.
Description: p. 118-122 : ill. ; 30 cm.

(86) Author: Hills, Peter J.
Title: Road congestion pricing : when is it a good policy? : a comment / by Peter Hills.
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(87) Author: Hoven, Tore.
Title: Electronic city access and road pricing : political and technical aspects. Part B, The Trondheim Toll Ring System / T. Hoven (County of Sor-Trondelag, Norway).
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Description: p. 355-359 : ill. ; 21 cm.

(88) Author: Howie, Don.
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(89) Author: Howie, Donald J.
Title: Pricing road use to manage peak demand / Donald J. Howie.
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Description: p. 321-324 : ill. ; 28 cm.

(90) Author: Hudders, Neal A.
Title: Strategies for implementing automatic vehicle identification for congestion pricing / by Neal A. Hudders.
Found in: Graduate student papers on advanced traffic management systems. College Station, Tex. : Texas Transportation Institute, í1992ù
Description: p. íD-iù - D-21 : ill. ; 28 cm.

(91) Author: Hurdle, David.
Title: Road pricing for London : an LBA policy report / David Hurdle. London : London Boroughs Association, 1990.
Description: 29 p. ; 30 cm.

(92) Author: Ingham, M. W.
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Description: xi, 128 p. ; 25 cm.
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(93) Author: Jabez, Alan.
Title: Paying the price : beloved of politicians but suspected by the public, road pricing has yet to become an ongoing reality / Alan Jabez.
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Description: p. 31-33 : col. ill. ; 30 cm.

(94) Author: Jara-Diaz, Sergio R.
Title: Congestion pricing of public transport / Sergio R. Jara-Dias and Franciso Martinez.
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Description: p. 209-220 : ill. ; 30 cm.

(95) Author: Jimenez Mazario, Juan I.
Title: A framework for road pricing in the European communities / Juan I. Jimenez Mazario.
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Description: p. 244-247 ; 28 cm.

(96) Author: Jones, Peter.
Title: Gaining public support for road pricing through a package approach / by Peter Jones.
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(97) Author: Jones, Peter.
Title: Restraining car traffic in European cities : an emerging role for road pricing / Peter Jones and Arild Hervik.
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(98) Author: Jones, Peter.
Title: Urban road pricing : dealing with the issue of public acceptability, a U.K. perspective / by Peter Jones, Susan Harvey.
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Description: p. í296ù-316 ; ill. ; 24 cm.

(99) Author: Jones, Peter M.
Title: The relevance of road pricing to urban transport problems : an assessment / Peter M. Jones. Oxford : University of Oxford, Transport Studies Unit, í1986ù
Description: i, 26 p. : ill. ; 28 cm.
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(100) Author: Jones, Philip C.
Title: On the equivalence of competitive transportation markets and congestion in spatial price equilibrium models / Philip C. Jones and Eric S. Theise.
Found in: Transportation science. Vol. 23, no. 2 (May 1989)
Description: p. 112-117 : ill. ; 28 cm.

(101) Author: Karhula, Mervi.
Title: Pricing of traffic noise in road planning / Mervi Karhula, Antero Honkasalo.
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Description: p. 617-620 : ill. ; 22 cm.

(102) uthor: Kim, Sung Soo.
Title: Congestion pricing in Seoul : a simulation of the effects of CBD cordon charges / Sung Soo Kim. c1993.
Description: xvi, 302 leaves : ill. ; 28 cm.
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(103) Author: Kulash, Damian Joseph.
Title: Congestion pricing : a research summary / Damian Kulash. Washington, D.C. : Urban Institute, í1974ù
Description: v, 33 p. ; 28 cm.
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(104) Author: Lam, William H. K.
Title: Effects of road pricing on system performance / by William H. K. Lam.
Found in: Traffic engineering & control. Vol. 29, no. 12 (Dec.1988)
Description: p. 631-635 : ill. ; 30 cm.

(105) Author: Lampe, Andrew J.
Title: Effects of road access pricing at the Los Angeles airport : a case study / by Andrew J. Lampe.
Found in: ITE journal. Vol. 63, no. 12 (Dec. 1993)
Description: p. 22-24 : ill. ; 28 cm.

(106) Author: Larsen, Odd I.
Title: Road pricing as a means of financing investments in transport infrastructure : the case of Oslo / Odd I. Larsen and Farideh Ramjerdi.
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Description: p. 19-30 : map ; 30 cm.

(107) Author: Lave, Charles.
Title: The demand curve under road-pricing, and the problem of political feasibility / Charles Lave. Berkeley : University of California Transportation Center, University of California, í1992ù
Description: 12 p. : ill. ; 28 cm.
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(108) Author: Lave, Charles A.
Title: The demand curve under road pricing and the problem of political feasibility / Charles Lave.
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(109) Author: Lee, Jae Choon.
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Description: vii, 144 leaves : ill. ; 28 cm.
Series: Dissertation series / Institute of Transportation Studies, University of California at Berkeley ISSN: 0192-4109 ; UCB-ITS-DS-91-3.

(110) Author: Lewis, Nigel C.
Title: Road pricing : theory and practice / Nigel C. Lewis. London : Thomas Telford, 1993.
Description: 122 p. : ill., maps ; 22 cm.

(111) Title: London congestion charging : a review of technology for road use pricing in London : a report / commissioned by the Department of Transport from the University of Newcastle upon Tyne. London : Dept. of Transport, 1993.
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(113) Author: Loong, K. Y.
Title: Road construction price indexes : 1977-78 to 1987-88. Canberra : Bureau of Transport and Communications Economics : Australian Government Pub. Service [distributor], c1989.
Description: xiii, 37 p. : charts ; 25 cm.
Series: Information paper ISSN: 0158-104X ; 32.

(114) Author: May, A. D. (Anthony D.)
Title: Road pricing : an international perspective / A.D. May.
Found in: Transportation. Vol. 19, no. 4 (1992)
Description: p. [313]-333 ; 24 cm.

(115) Author: May, Anthony D.
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(116) Author: McCarthy, Patrick.
Title: Road pricing in Singapore : too much of a good thing? / Patrick McCarthy, Richard Tay.
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(117) Author: McCarthy, Patrick S.
Title: Pricing road congestion : recent evidence from Singapore / Patrick S. McCarthy and Richard Tay.
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Description: p. 296-308 : ill. ; 23 cm.

(118) Author: McDonald, Michael B.
Title: Congestion pricing in an urban environment with heterogeneous incomes : a simulation approach / by Michael B. McDonald. 1988.
Description: 127 leaves : ill. ; 29 cm.
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(119) Author: McMullen, B. Starr, 1951-
Title: Congestion pricing and demand management : a discussion of the issues / B. Starr McMullen.
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Description: p. 285-295 : ill. ; 23 cm.

(120) Author: Menon, A. P. Gopinath.
Title: Singapore's road pricing system : its past, present and future / by A.P. Gopinath Menon, Soi-Hoi Lam and Henry S.L. Fan.
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(121) Title: A Model of departure time choice in the presence of road pricing surcharges / J.J. Bates . . . iet al.ù.
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Description: p. 227-246 : ill. ; 30 cm.

(122) Author: Mogridge, M. J. H.
Title: Road pricing : the right solution for the right problem? / M.J.H. Mogridge.
Found in: Transportation research. Part A, General. Vol. 20A, no. 2 (Mar. 1986)
Description: p. 157-167 ; 28 cm.

(123) Author: Morrison, Steven A., 1951-
Title: A survey of road pricing / Steven A. Morrison.
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(124) Author: Mwase, Ngila R. L.
Title: Road transport pricing in developing countries : the Tanzanian case / N.R.L. Mwase.
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(125) Author: Nevin, Michael.
Title: What price roads? : practical issues in the introduction of road-user charges in historic cities in the UK / Michael Nevin, Les Abbie.
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Description: p. 68-73 : ill. ; 28 cm.

(126) Author: Orski, C. Kenneth.
Title: Congestion pricing : promise and limitations / C. Kenneth Orski.

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(127) Author: Oum, Tae Hoon.
Title: Transportation infrastructure pricing : congestion tolls, lumpy investment and cost recovery / by Tae Hoon Oum and Yimin Zhang. Rev. Aug. 1989. Vancouver, B.C. : Faculty of Commerce and Business Administration, University of British Columbia, í1989ù
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Found in: TR news. No. 167 (July-Aug. 1993)
Description: p. 3-10 : ill. ; 28 cm.

(129) Author: Poole, Robert W.
Title: Introducing congestion pricing on a new toll road / Robert W. Poole, Jr. (Reason Foundation). íWashington, D.C. : Transportation Research Board, National Research Council, 1992ù
Description: 23 p. : chart ; 28 cm.

(130) Author: Poole, Robert W.
Title: Introducing congestion pricing on a new toll road / Robert W. Poole, Jr.
Found in: Symposium on the Transportation Land Use Air Quality Connection : the Role of Pricing and Market-based Strategies (1992 : Lake Arrowhead, Calif.) The transportation land use air quality connection : the role of pricing and market-based strategies, October 18-20, 1992. Los Angeles, Calif. : UCLA Extension, 1992.
Description: 16 p. : ill. ; 28 cm.

(131) Author: Poole, Robert W.
Title: Introducing congestion pricing on a new toll road / Robert W. Poole, Jr.
Found in: Transportation. Vol. 19, no. 4 (1992)
Description: p.í383ù-396 ; 24 cm.

(132) Author: Poole, Robert W.
Title: Introducing congestion pricing on a new toll road / by Robert W. Poole, Jr.
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