Road Pricing: An Economic Analysis

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Niall Jones and Sarah Meredith examine the economics of road pricing. They begin by outlining how congestion pricing increases efficiency and can help maximise welfare. They then examine in depth several different attempts at road pricing throughout the world and conclude that by using economic analysis and congestion pricing, it is possible to make the best use of scarce road space and increase efficiency.

Introduction

'If all economists were laid end to end, they would not reach a conclusion.'
George Bernard Shaw

Tolling, as one of the best mechanisms for congestion management, will be investigated in this research paper. By looking at the specific methodologies and available pricing techniques for traffic management, it is hoped to highlight the merits inherent in tolling as an effective contemporary policy tool. Freight and passenger traffic forecasts will be considered separately, as will the important distinction between shadow and the more traditional forms of real tolling. Empirical evidence shall be utilised to reinforce these policy recommendations. The case study has an atypical payment schedule linked to congestion, based on traffic flows and average speeds. A number of novel tolling approaches, which include elements of new technology to alleviate congestion problems, will be looked at, namely smart cards and hot-lanes.

Road pricing is the best instrument to internalise the cost of congestion. Initial installation costs are high, though these may be recouped over the lifetime of the road in the form of efficiency gains. Economists strive to set incentives so that the resources are allocated as efficiently as possible. Baumol observed that radical changes in transport policies came along at the beginning of the 1980's and were largely supported on a theoretical basis by the concept of contestable markets (Baumol, Panzar and Willig, 1982). Newberry (1990), noted that *'road space is a valuable and scarce resource'*, we believe it ought to be rationed by a price mechanism, and it is this price mechanism which is the central thrust of our argument.

What is Congestion Pricing?

Transportation policy makers and economists view congestion pricing as an important part of the solution to growing highway congestion in urban areas. In many sectors of the economy - telephone services, public utilities, and air travel businesses use something akin to congestion pricing as a solution to congestion problems in urban areas, it allocates scarce capital assets in peak demand periods, but its use for road congestion is a very recent practice. It was originally introduced in Singapore in 1975, other countries did not follow suit until the 1990s. Currently, Norway and France are using congestion pricing and other countries around the globe are also considering its use. In the USA, a variable-priced toll road opened in late 1995 in California.

Many forces have caused transportation authorities to consider congestion pricing. These include:

- Continuing growth in urban travel demand.
- Realisation that construction of additional road capacity may not always be possible or desirable.
- The advent of new electronic tolling technologies that greatly reduce implementation costs.
- A desire for cost-effective strategies to reduce mobile-source air emissions and energy consumption.
- The need for new revenue sources for infrastructure investment.

The full cost of a trip on a congested road includes not just a traveller's own time and vehicle operating costs but also the costs that each traveller imposes on all other travellers by adding to the level of congestion. Market prices do not internalise externalities, which spill over. To maximise welfare, it is imperative to account for these neighbourhood effects.

A congestion price is a user charge based on a user's perceived cost when entering the traffic stream and the actual congestion cost created by the traveller's entry onto the system. It results in more efficient use of limited road capacity by encouraging those who value their trips at less than their full cost to shift to off-peak periods, mass transit or car-pooling, and/or to less congested routes. Determining optimal congestion prices is difficult. Estimates can be based on the traffic-engineering literature that deals with the relationship between travel delays and traffic volume. Analysts have derived estimates of "optimal" congestion prices on the order of $0.15 to $0.25 per vehicle mile of travel on congested expressways in the US and about twice that amount on congested arterials. These are only approximate averages. Actual optimal prices must be estimated for each local context. Although congestion pricing holds great promise as a way of rationalising the use of scarce urban road space, many cities have been reluctant to implement it because of institutional barriers and the lack of political acceptance. Critical political and institutional issues include public opposition to any new taxes or fees, geographic and economic equity concerns, lack of regional transportation co-ordination, and the lack of alternatives to driving alone during peak periods.

Methods of Payment

Having read the report *'A Matter of Congestion: An Initial Report to the Environmental Task Force of the City of Toronto'* by Joseph Dadson from the University of Toronto, pragmatic solutions aimed at curbing personal car travel into Toronto are offered and we intend to generalise the findings of this report and detail other international examples. The report examines the various economic disincentive mechanisms that are currently in use in many other parts of the world.

It is recommended to:

- Introduce congestion pricing for Toronto.
- Integrate this congestion pricing mechanism with a combination of other initiatives.
- Use the revenues for investment into public transit.

Cars accounted for 72% of all trips undertaken by Toronto residents within a 24-hour period in 1991. In the last few years, a significant amount of effort has been put towards investigating various options for reducing personal car usage in Toronto.

Surveying different economic disincentives for car use can be problematic if no criteria are defined to properly ascertain the effectiveness of any one initiative. Thus, we shall examine the criteria published in the report *'Road Pricing: The Economic and Technical Possibilities'*, otherwise known as the *'Smeed Report'* criteria, this provides a useful starting point for evaluating different car-usage disincentives. The 18 operational requirements of a "road pricing" scheme are as follows:

- Charges should be closely related to the amount of road use.
- It should be possible to vary prices for different roads at different times of the day, week, or year, and for different classes of vehicle.
- Prices should be stable and readily ascertainable by road users in advance of their journeys.
- Payment in advance should be possible.
- The system should be regarded as fair.
- The method should be simple for road users to understand.
- Equipment used should be highly reliable.
- Payment should be difficult to evade.
- Systems must be able to handle real-time volumes of vehicles.
- Payment in small amounts should be possible.
- Drivers in high-cost areas should be aware of their payment rates.
- Drivers should not be "unduly" distracted from their driving activities.
- The method should be able to accommodate users from other areas.
- Enforcement should lie within the capacities of non-police staff.
- The method could be used to charge for street parking.
- The method should indicate to planners the strength of demand for road space.

- The method should be amenable to gradual introduction.

- The payment process should not necessarily identify payers or vehicles, as privacy is an important issue.

Licensing Schemes

Licensing schemes are simple, cost-effective and versatile and can be implemented in a variety of different ways. For example, daily licenses could be sold in books, with refunds obtainable for tickets not used. Different prices may be charged in different zones depending on traffic intensity. Time-of-day variations are also possible, with weekend and/or "off-peak" licenses made available for a cheaper cost than "on-peak" licenses.

It is important, for the sake of balance, to note the disadvantages of such schemes. Due to the discrete delineation of licensing boundaries, injustices can develop due to the fact that areas just inside charged zones are treated quite differently from areas that lie just outside the boundary. Secondly, because a licensing scheme would amount to a flat rate charge for vehicle use, road users travelling long distances within the priced zone would pay no more than those travelling only short distances, thereby encouraging drivers to "make the most" of a licensing expenditure by driving longer distances within the charged zone.

We shall now briefly mention Singapore as a pioneer in licensing disincentives. It's Area Licensing Scheme (ALS), is by far the most established and extensively studied example of the use of supplementary licenses as an indirect charge for road use. It was originally implemented in June 1975, the original scheme required drivers entering the downtown core in the morning peak period (approximately 7:30 am - 10:15 am), to display a daily or monthly license. Buses, motorcycles, service and military vehicles and cars carrying four or more passengers were exempted from payment; taxis were required to pay half of the regular fee. Since 1975, the ALS has undergone several revisions in response to changing traffic patterns. For example, in 1994, Singapore traffic authorities instituted similar restrictions on afternoon peak traffic, due to surprisingly heavy afternoon volume despite restrictions in morning flow. From a technological standpoint, the ALS is very simple, yet effective. Licenses are obtained either via mail order or from booths away from zone entrances; enforcement is performed by police personnel, and involves visual inspection, the use of tape recorders to note the license-plate numbers of violating vehicles, and billing vehicle owners the appropriate fines.

The next brief example was derived in 1991 in when the city of Trondheim (pop. 140,000) in Norway launched an electronic cordon-pricing scheme. A fee of 11 Kroner is levied for automobiles crossing a "toll ring" surrounding the city centre. The system includes time-differentiated tolls (a slightly higher fee during the morning peak hours, with free passage after 5:00 p.m. and on weekends.) Unlike Singapore, the Trondheim initiative does not require the purchase of monthly licenses; approximately 80% of the automobiles using the system are tracked by electronic tag. Motorists are levied for each inbound crossing (a maximum of 1 passing per hour and 75 crossings per month for cars with a tag.) The Trondheim example also takes vehicle weight into account, with heavy cars (above 3500 kg), incurring twice the normal fee.

Case study: Congestion Charging in London

Central London suffers the worst congestion in the UK, costing people and businesses both time and money, adversely affecting quality of life. The proposed congestion-charging scheme, part of Ken Livingstone's *'Draft Transport Strategy'*, is designed to discourage unnecessary car journeys into central London. Studies show that congestion charging would reduce traffic in the central area by 10-15% and reduce queuing delays by about 20-30%. It would also help to reduce congestion beyond the charging area. The proposed scheme suggests that the charge for driving in central London should be a flat fee of Stg.£5 per day for all vehicles. There would be 100% discounts for emergency vehicles, London buses, licensed taxis, certain vehicles used by disabled people and vehicles, which use alternative fuel, as well as a 90% discount for residents who live within the charging zone. Motorcycles would be exempt from charges. The charges would apply from 7am to 7pm from Monday to Friday.

Drivers would purchase a daily, weekly, monthly or annual license linked to the registration of their vehicle. Payment could be made by post, telephone, retail outlets or the Internet. The scheme would be enforced via vehicle registration numbers being monitored by fixed and mobile cameras linked to automatic number plate recognition technology as well as street patrols. There would be a Stg.£80 penalty charge for non-compliance, reduced to Stg.£40 for early payment. The proposed charging scheme will have the added benefit of producing substantial net revenues of around Stg.£190 million per year, which by law must be spent on improving transport within Greater London for a minimum of ten years. Priorities for spending in the short term include making radical improvements to London bus operations, including an expansion of the network, improved journey times and reliability. Time has been spent working with the Greater London Authority to consult key groups and businesses, as well as all Londoners, about the proposed congestion-charging scheme for central London. This has included an initial discussion paper in July 2000, to key stakeholders in the capital and the Draft Transport Strategy. On the technical front, TFL Street Management has developed an experienced project team to study the feasibility and potential impact of the proposed scheme to aid the Mayor's decision-making process on whether to progress or not. Should the Mayor decide to include the scheme within his final Transport Strategy, TFL Street Management would prepare scheme and traffic orders to bring the proposals into operation. These would set out in detail how the scheme would operate, for example, giving a precise definition of the charging area, street by street. There would be separate consultations on these orders. The target date for the start of the proposed scheme would be early 2003.

Political Issues in Congestion Pricing

Fred Salvucci of MIT highlights the contemporary political issues which arise in the implementation of congestion pricing mechanisms. The odds are against convincing the public that a tax is good for them. But a tax on congestion is unique in that it improves economic efficiency. Ways to improve its chances for success include:

- Provide choices.
- Use revenues to benefit those most hurt by the fees. Access is a unique good; we must ensure that we are not denying people access by pricing them off the road.
- Target congestion pricing in other areas like aviation (runway pricing). This is very compelling with virtually no equity issues. If we cannot make congestion pricing work at airports, we should abandon the whole thing. If we show some dramatic gains in that area we may be more successful on the surface transportation front.

There are three groups to consider when thinking about congestion pricing:

The "tolled" are the people who stay on the road and pay the toll. In principle, their choice to remain on the road suggests that they are benefiting more in time than they are losing in money.

The "tolled off" are the people who shift off the facility to avoid the toll. They are worse off than they were before the toll was established, and are likely to be unhappy about it.

The "untolled" are the people on parallel facilities, who are adversely affected by the tolled-off group. If they are passengers, they may actually benefit from the higher services implemented to meet this additional demand. But if they are drivers, they may lose if their roads become more congested. They are generally outside the calculus of modelers studying the costs and benefits of pricing.

When politicians oppose congestion pricing, they know something that we should be thinking about: it would create many losers. In Cost Benefit Analysis terms, congestion pricing is attractive if social benefits exceed the social costs, in this case if the benefits that accrue to the tolled groups exceed the costs to the tolled-off and untolled groups, the project should be adopted.

The idea that tolls must be revenue-neutral is a mistake. If we are serious about equity, we need to use the revenues to address the needs of the tolled off and the untolled. Among the tolled-off, we should not be looking strictly at the distribution of income. It would be better to recognize the degree to which congestion pricing may be limiting people's access in ways that are more significant than simple income differentials might indicate. Offering choices would make this more palatable. People have a high value of time at particular times, and would value the choice to be able to pay to take a faster route when they want it. In Boston's western end (where there is a choice), there is greater support for tolls than on Boston's eastern end (where these is not a choice). In trying to balance environmental concerns with equity, deeper subsidies for everybody are needed.

Another place to start experimenting with congestion pricing would be the use of airport runways. The case for congestion pricing at airports is extremely compelling. It presents no equity problems, since most users are passengers (general aviation is a small but vocal minority). There is a place for people to go to save runway time: larger aircraft. This could be the place to demonstrate dramatic efficiency gains without creating equity problems, and could change the policy landscape for congestion pricing elsewhere. But, if we cannot make congestion pricing work at airports, we should stop talking about implementing it on roads.

Case Study - Review of Payment Mechanism and Traffic Projections

This case study comprises the operation and maintenance of 53 km of the A1 (M) trunk road in the UK, which includes a new build of 21.75 km of dual 3-lane motorway, in respect of the A1 (M) Wetherby to Walshford and the A1 (M) Ferrybridge to Hook Moor schemes. The project itself, currently under tender, has been structured largely along the lines of the previous Highways Agency DBFO road projects, except for the introduction of a new payment mechanism linked to congestion, measured with reference to traffic flows and average speeds, thus our focus on this particular scheme. The tender documents envisage a concession period of thirty years.

This Active Management Payment Mechanism scheme is a particular type of shadow tolling. DBFO will design, build, finance and operate the road and undertake maintenance under the scheme. Payment will be made not on the traditional volume basis, but rather on a fixed rate system depending on certain average speeds and traffic flow thresholds on each carriageway section for each hour of each day.

Deductions to this payment will be made if these thresholds are not met and a corresponding bonus is awarded for superseding these targets. No hourly congestion management payment will be made for any particular carriageway section if for any part of the hour the carriageway section fails to meet any of the set condition criteria. Reduced payments will occur for a particular carriageway section if during an hour both the target speed is not achieved and the vehicle flow for that hour is less than the deemed capacity for that carriageway section. No payment will be made for a particular carriageway section if both the section average speed achieved for that carriageway section drops below 2/3 of the target speed (90 kph or approximately 56 mph), and the vehicle flow during the hour is less than 80% of the deemed capacity. A bonus will be added to the payment for a carriageway section if its vehicle flow for that hour exceeds 110% of its deemed capacity, and section average speed for that hour exceeds 2/3 of the target speed. The bonus is subject to a cap equal to 20% of the payment for that carriageway section. This cap is reached when the vehicle flow exceeds 120% of the deemed capacity for the carriageway section and section average speed exceeds the target speed. Between these two extremes, the amount of the bonus will vary linearly with both flow and speed.

It is envisaged that there will be 50 carriageway sections, covering the north and southbound A1 (M), each being about 2km in length. Tender submissions will bid a

Base Annual Gross Congestion Management Payment, a proportion of which will be subject to annual indexation. The overall payment for a given Contract Year is then divided into equal weekly amounts and from that an amount for each individual hour on each Carriageway Section is determined.

The weekly amount will be divided into hourly amounts on the basis of the vehicle kilometres on each Carriageway Section as a proportion of the total weekly vehicle kilometres on the entire Project Road, for the corresponding hour of the day, averaged over the previous four-week period. It should be noted that when vehicle kilometres or vehicle flow are referred to, vehicles will be measured in units with 1 unit for a car and 2.5 units for larger road vehicles. The factor of 2.5 reflects the different characteristics and road space requirements of long vehicles. While the payment for each hour and for each Carriageway Section will vary from week to week, at the start of each week the gross payments (i.e. before deductions and bonus payments) allocated to each Carriageway Section for each hour of the day can be pre-determined.

For instance, at a speed of 10km/h, and a traffic flow of 110% of deemed capacity – the full payment will be made, with no bonus and no deduction. At a speed of 90km/h, and a traffic flow of only 5% of deemed capacity on the stretch, full payment will also be made. While with a speed of 90km/h and a flow of 110% of deemed capacity, a bonus will be paid along with the full payment.

We believe that although this method of shadow tolling is untried and, therefore, carries perhaps an extra element of risk, the congestion projections are not prohibitively high so as to jeopardise the necessary cash flows, for the life of the concession.

As payments to the DBFO will be linked primarily to the management of congestion, we will look at the Consortium's traffic estimates for the new route. MVA were engaged on behalf of the Consortium to advise on traffic-related matters and produce traffic forecasts for use in developing the bid structure.

Two traffic models have been used to produce the traffic forecasts, a strategic TRIPS model and a detailed micro-simulation GETRAM model. The main function of the TRIPS model is to take account of the wider network and routing choices in order to determine how much traffic wishes to use the whole A1. It models a 12-hour average weekday period, 0700 to 1900 hours based on a variety of traffic count and origin-destination (O-D) surveys carried out over several years. It has successfully been calibrated and validated to the year 2000. The GETRAM model covers the A1 DBFO project area. Its network includes full details of mainline road sections, slip roads and intersections for the A1.

The main function of the model is to produce detailed forecasts of speed and flow by hour of day and road section and for this information to then be fed into the Financial Model. The model was developed for the Highways Agency for use in developing the Active Management Payment Mechanism (AMPM), and the model is based on a combination of traffic count, O-D and journey time data. It has been successfully calibrated and validated to the year 1999. The approach adopted has been to take these two existing models and to use them as tools for producing future year traffic forecasts. Forecasts for future years have been produced, by applying growth factors to the base year traffic models. The TEMPRO database takes account of projections of future land use and economic growth for all regions of the country. It then produces projected increases in vehicle usage based on this data together with projections of population, employment and car ownership. NRTF produces one set of national projections for all vehicle types. These have been used for all non-car traffic, mainly goods vehicles and bus/coaches.

The occurrence of accidents and incidents is relevant to the project, as it will affect levels of "congestion" on the A1, leading to possible deductions in payment in accordance with the AMPM. These traffic accidents and incidents could in some instances result in the road being blocked and/or lanes being closed by the emergency services attending to the problem. MVA have made some estimates of the number of likely accidents based on a combination of data, information and assumptions. These include actual personal injury accident data for the A1, personal injury accident rates from the Design Manual for Roads and Bridges, discussions with various traffic police authorities in Yorkshire and its own professional judgement. However, the conclusions drawn do not seem to make the project overly risky. Accidents/incidents could cause around one to two days of "congestion" in any given year leading to deductions in payment, according to MVA. These have been modelled and sensitised in the financial model for the project.

Highway maintenance may also result in some deductions in payment, but these are not expected to be significant. Routine maintenance in certain situations will make it necessary to impose temporary speed limits, which will be either 50mph or 40mph. Both of these are below the 56mph (90kph) target speed of the AMPM and therefore deductions could occur under these scenarios. Major maintenance could involve lane closures for periods upon certain road sections. Together with temporary speed limits necessary for the works, this could also lead to deductions. Emergency maintenance will be required on an ad hoc basis. The frequency of such maintenance will be relatively low and its impact on congestion and resulting deductions also low. Winter maintenance includes activities such as road gritting and as such is not expected to hinder traffic flows, but any unexpected and prolonged freak weather conditions could lower road use, but to a lesser extent than under a system of traditional tolls. These are being fed into the GETRAM model in order to assess the impact on traffic conditions under various scenarios, and for the results of these tests to be used in estimating the effect on deductions in payment.

The Tender Documents and discussions with the Highways Agency indicate that traffic/congestion management measures may be required. These measures should lower the probability of DBFO not reaching its targets and therefore, make the present values of its future cash flows more certain. One such method, ramp metering, involves controlling the volume of traffic entering a motorway system during critical peak hours. Traffic lights are installed on the slip roads leading to the motorway. When the mainline motorway traffic conditions are approaching capacity and "congestion" is predicted to occur, the algorithm changes the traffic lights to red in order to prevent further slip road traffic from entering with the aim of averting the predicted "congestion". In relation to the A1, this would equate to around a 200 vehicle per hour increase over the sections with 6,600 vehicles per hour deemed capacity.

Dynamic or variable speed control is another option. Information on speed and flow is collected and an algorithm determines the optimal speed for vehicles to travel based on the objectives of smoothing the flow and maintaining journey time reliability. Mandatory speed limits of 60mph, 50mph or 40mph are displayed on regularly spaced overhead gantries where speed cameras are also installed to deter vehicles from travelling faster. Additional signs tell drivers to keep in lane. By reducing the average speed of traffic and by discouraging lane changing, a smoother flow of traffic is promoted, as vehicles tend to drive with reduced headways. Such measures could possibly be of benefit to the A1 although the lower speed limits of 50mph and 40mph would be below the target speed of the AMPM and hence, deductions in payment would occur.

Finally, another tool, incident detection is used on many motorway systems. This largely involves monitoring the speed and flow of traffic by loop detectors. Monitoring systems then identify any unusual situations. Such systems speed up the detection of problems so that the appropriate actions can then be taken as quickly as possible to alleviate the problem. The AMPM requires speed and flow to be measured at several points within each of the twenty-five 2km sections. An incident detection system will therefore be in place for the A1 in order to identify any problems as they occur. This should therefore promote a swift response and necessary actions.

Preliminary forecasts of "congestion" have been made based on traffic demand. These have been converted to equivalent passenger car unit kilometres according to the AMPM. The conclusions so far indicate deductions in the early years of the concession will be small. They will increase throughout the period of the concession as traffic demands increase but annual deductions will still be less than 5% even by 2032. It is extremely probable that some form of payment will therefore occur for every hour throughout the concession period. The risk on deductions increases as congestion spreads both linearly along the A1 and through time with peak spreading.

The A1 currently has traffic volumes well within its deemed capacity, and speeds are well above target speeds. Based upon the above analysis the expected reductions due to congestion have been modelled and valued for the central traffic case as follows.

Table. 2.

Date	Central Traffic Case	High Traffic Case
2006	0.00%	0.00%
2021	0.70%	1.90%
2032	3.11%	7.62%

This project exemplifies the merits of the techniques available to control congestion. It is expected to be financially viable as deductions made at the beginning are expected to be small but set to rise as traffic demand increases. By focusing on speeds and flows it makes economic sense. It is more sensible in economic terms to do this rather than solely relying on volume, which can induce severe traffic congestion.

The Future of Tolling

According to the International Bridge, Tunnel, and Turnpike Association (IBTTA), there are currently over 400 toll facilities operated by their members. Of these, about one third are in the US and most of the remainder in Western Europe, Japan, and

Mexico. Conventional tolling facilities consist of booths set up at the entrance to a roadway or bridge, and require the manual collection of road fees. Road users are required to pay a set fee for traversing the distance of the bridge or the roadway. There are several drawbacks to conventional tolling mechanisms. By requiring vehicles to stop or to slow down, manual toll collection can actually add to congestion, wasting time and raising vehicle-operating costs. Furthermore, the costs of collection (i.e., hiring staff to collect tolls) absorb revenues.

Electronic tolling is seen as the solution to the drawbacks incurred with conventional tolling procedures. The Greater Toronto Area is viewed as a world leader in the field of electronic tolling, as the newly opened Highway 407 Express Toll Route (ETR), is the world's first all-electronic open road toll highway. A multi-lane 67-kilometre stretch of highway, which traverses across the top of Toronto, has an average traffic volume on the highway of over 200,000 trips per weekday and is climbing monthly.

Any car joining the motorway is required to pass under an electronic gantry. Electronic sensors located on the gantry automatically record the beginning of the road user's trip. Upon leaving the motorway, another gantry located on the exit ramp will log the vehicle off the motorway.

Electronic detection is done in one of two ways. For frequent users, a transponder unit - a small electronic device that attaches to the interior windshield behind the rear view mirror - can be obtained to communicate with the highway gantries. Such units are mandatory for vehicles weighing over 5 tonnes. Non-frequent users, or those who do not register for transponders are tallied via a digital image recognition system that captures video images of vehicle license plates. These images are then transmitted to a central processing computer, which then bills the owner of the vehicle for the distance travelled on the motorway. A CDN$2.00 account fee is levied for each 30-day period, an individual without a transponder drives on the motorway on top of an additional toll charge of CDN$1.00 per trip for this option to cover additional cost.

Highway 407 toll-fees for passenger vehicles range from CDN$0.07 per kilometre for off-peak periods to CDN$0.10 per kilometre for peak periods. Like the Trondheim mechanism mentioned above, vehicle weight is factored into the levy system, with heavy vehicles incurring a CDN$0.14 - CDN$0.20 fee per kilometre, depending on the time of the week. One important feature to the 407 tolling mechanism is that the transponders are transferable between vehicles of the same weight class, thereby providing road users with anonymity.

Integrated user-fee technology – Smart Cards

Multi-modal Access and Payment Systems (MAPS), or "Smart Card" technology are a major advance in electronic tolling mechanisms. These systems concentrate primarily on moving more people through an existing transportation structure. Smart card systems integrate motorway and transit facilities as complementary components of an integrated regional transportation network, a concept extremely attractive from a sustainable transportation stance. Through fare integration capability, MAPS provide seamless crossover flexibility to both motorway and transit users and allow them to take advantage of the entire transportation grid.

In relation to roadway usage, the Smart Card system is almost identical to the electronic tolling mechanisms detailed previously. A card with an embedded computer chip - providing logic and "intelligence" processing capabilities and the ability to store information - is inserted into a transponder unit. The transponder records all highway information data onto the smart card for billing purposes, and just like more conventional electronic tolling mechanisms road users are charged for each kilometre driven on a priced roadway.

The Smart Card system maximises the flexibility of choice available to commuters by eliminating many of the economic and operational barriers that now influence transportation mode use decisions. Within an inter-modal system, the Smart Card is used as a universal payment medium for both highway and public transit-related fares and fees. The card unit can be removed from a vehicle transponder, and used to access the transit system via electronic readers situated at the entrance to railway stations or on equipped surface vehicles such as buses or light-rail systems such as the LUAS.

With regard to the Toronto context, the use of a Smart Card system essentially eliminates the following aspects of the existing local transit system: tokens (as Smart Cards can be used to log existing trips and billed directly to the user); physical transfer slips (when users first access the transit system, the computer can keep track of transfers through the system); and rail passes (the Smart Card will become a universal payment medium, used by both frequent and infrequent users of public transit). Another important feature of the system, already realised with the current Metropass mechanism in Toronto is the convenience: users simply have to swipe their cards through automated readers instead of having to deal with the impracticality of depositing tokens or money, thereby speeding up the rate at which users can access the transit system.

The use of a Smart Card system is a preview to a full-length discussion of relating economic disincentives for car use to economic incentives for transit use. An inter-modal Smart Card system can charge car users for kilometres travelled on priced roads, with fees either raised or reduced depending on the time of day/day of the week travelled. This same system can be used to offer transit users discounts based on the number of trips logged into the transit system, essentially matching per-use discount rates now in place with the current Metropass system.

One downfall of the Smart Card system is its impact on individual privacy. With a system that can position an individual anywhere within a transportation grid, issues arise concerning the accumulation and the potential for distribution of information regarding the number of trips and destinations of these trips.

As mentioned in a Pollution Probe study of the environmental and social costs associated with private car use in Ontario, the term "automobile" is fast becoming an oxymoron. A growing dependence on the car is brought about through many inter-playing factors, many of which are essentially land-use issues. The mobility provided by a car allows for the decentralisation of activities from the downtown core; in turn, a decrease in core density makes public transit more expensive to finance. Though Toronto is often seen as a model for other cities in exemplifying how land use and transportation can be changed to reduce car dependence and urban sprawl, it is increasingly apparent that, as many factors in the lives of Toronto residents change, the city's favourable grid land use pattern and centrally oriented transit system has become less successful in combating the speed and convenience of the private automobile. As detailed herein, congestion-pricing mechanisms are now becoming technically viable initiatives to be implemented in Toronto. It is the desire of the City council, and that of City residents that will ultimately determine whether these approaches to diminishing private car use will become reality.

Electronic Tolling: Case studies

Single occupant cars equipped with transponders are now able to use the high-occupancy vehicle lane on Interstate 15, San Diego for a toll between US$0.50 and US$4.00 depending on traffic volumes. Electronic signs at the entrance to the High Occupancy Vehicles (HOV), lanes give solo drivers advance notice of the toll, which is collected electronically. Carpools and buses use the lanes free. Officials are using variable pricing to test the value commuter's place on the travel time saved, and to find better ways to manage the I-15 corridor. The demonstration project is being funded by a US$8 million grant from the Federal Highway Administration.

A contract has been awarded for the supply of 600,000 electronic transponders for the 22km Melbourne City Link. When the City link opened in 1999, transponders were distributed free of charge to motorists. Tolls are deducted automatically from pre-paid accounts as vehicles pass beneath a toll gantry. Frequent travellers were issued with a transponder and digital cameras capture the number plates of vehicles without a transponder.

The trial of the Automated Highway in San Diego received considerable media attention last August. Despite this the US Department of Transport has decided to withdraw funding. The initial push came from the California Department of Transportation, which saw the Automated Highway as a solution to the problems of Los Angeles. However, it has now been decided that automated highways would not provide an answer to motorway problems in an urban area such as LA because of the large number of transitions between "manual" and "automated" highways the system would have to cope with.

It is suggested that the concept may make more sense on inter-urban routes with longer travel times and greater safety problems. The concept is, however, being investigated for application to a bus and carpool facility in Houston, Texas.

HOT Lanes in San Diego

In the I-15 corridor in San Diego, the HOV express lanes were being under-utilised. It was thought that the entire system would perform better if use of HOV lanes were maximised.

To accomplish this without eliminating incentives for ridesharing, the HOV lanes were converted to high-occupancy toll (HOT) lanes. These allow single-occupant vehicles to buy access to the express lanes for a price that is set dynamically to balance real-time demand against the requirement that free traffic flow be maintained.

A number of value pricing projects have been launched in the United States over the past 3 years. The private sector led the way in 1995 by constructing new tolled express lanes in the median of State Route 91 in Orange County, California. Tolls vary by time of day and level of congestion to maintain an uncongested alternative along one of the most heavily travelled commuter routes in the United States. Value pricing projects have been launched in San Diego, California; Houston, Texas; and Lee County, Florida. The California and Texas projects involve tolling on High Occupancy Vehicle (HOV), lanes to make better use of available capacity.

In Houston, Texas, drivers of vehicles with two occupants can pay a fixed toll during rush hour to use an HOV lane on Interstate 10, that is otherwise restricted to vehicles with three or more occupants. The project in Lee County, Florida involves the use of peak and off-peak toll variations to provide an incentive to shift travel out of the most heavily travelled time. A number of additional cities across the United States are evaluating the feasibility of value pricing to improve traffic flows and to enhance mobility. Several of these are expected to move toward implementation in the near future. Internationally, pricing projects have been implemented recently on a new beltway in Toronto, Canada, in three cities in Norway, on inter-city toll roads in France and in the central area of Singapore. Numerous cities in the European Community (the Netherlands, United Kingdom, Sweden and Greece) as well as Hong Kong are currently conducting feasibility and implementation studies and field tests of pricing concepts.

There are some questions that cannot be modeled given our current state of knowledge; willingness to pay for HOT lanes is one of them. In this case, the project itself is a real-world experiment that will help to advance the state of the art. Hopefully, lessons drawn from this experience will be useful in helping to make decisions about future projects.

Keith Bartholomew talked about a process box. From the box's perspective, there were three issues to think about:

- The trend toward emphasising better system management over new capital improvements.
- The need to be more specific about solutions; otherwise, what is the purpose of planning?
- The potential for ITS to have large benefits if existing models serve as a platform for real-time models.

During the morning peak, there is severe traffic congestion southbound on I-15. The primary lanes run at level-of-service F, while the express HOV lanes run at level-of-service C or better. It was becoming politically difficult to keep the HOV lanes open because they were seen as underutilized. Initially, elected officials did not understand the concept of pricing, and did not think there was anything to sell.

But ultimately, they came to see selling extra space on HOV as a means for improving their utilization, while preserving their benefits. The key to the success of the HOT lane proposal was that it preserved choice for travelers not willing to pay a toll. Goals of the I-15 project included maximizing use of the existing express lanes; relieving congestion on the primary lanes; and funding new transit and carpool services in the corridor. All revenues were to be used to further these goals.

In the initial phase, $70 monthly passes were sold to 900-1000 vehicles. During this phase, carpooling rose unexpectedly. Rising carpooling was expected in the final phase because its pay-per-use structure would facilitate occasional carpoolers. But it was unclear why it grew during the initial phase.

Under full implementation, users will buy into the express lane by paying per trip via electronic toll collection. The number of participants will be unlimited, but variable tolls will be set to ensure free-flow traffic while maximizing carpools and transit use. Signs will show real-time toll prices, so that drivers can make informed choices about which lane to use. Fee levels will be based on real-time traffic to maintain level-of-service C. The minimum toll will be set at 50 cents, and the average rush-hour toll is expected to be $3-$4 (during major traffic incidents, the toll will be capped at $8). Initially, prices will change at 30-minute segments.

The computer that sets prices uses a model, but the entire endeavor is a real-world model that can be used in the development of future modeling and/or management tools. Because fees will be determined real-time by a computer, we do not know yet what they will be. This experiment will show what people are really willing to pay.

Conclusion

Unlike most economists as George Bernard Shaw quipped, we have managed to reach a conclusion. The focus in road construction and maintenance should always be efficiency and incentives should reflect this. Managing congestion is an issue which is becoming increasingly important as the global economy is witnessing rapid growth in both vehicles and the population. Congestion is extremely costly, both in pecuniary terms and in quality of life terms. Introducing new mechanisms such as electronic tolling and the tendering of road design, maintenance, operation and financing can serve to minimise problems associated with congestion, and by focusing on efficiency we can use economic analysis to understand.

We began by examining the disincentive mechanisms aimed at curbing traffic and congestion. The prospective Toronto scheme was detailed where congestion pricing linked to other initiatives would be introduced. Road pricing mechanisms should meet the criteria outlined in the 'Smeed' Report. Then licensing schemes as a form of payment for road use were discussed and the Singapore case study was outlined, followed by the electronic cordon-pricing scheme in Norway. A final case study in this chapter regarded London where we discussed the proposed congestion charging scheme.

It is crucial to highlight the political issues in the adoption of congestion pricing mechanisms. There will always be a group of losers and this group may be loud, but it is important not to be swayed by political lobby groups and remain focused on economic efficiency. Conducting Cost Benefit Analysis sustains an element of objectivity.

The case study highlighted a payment mechanism linked to traffic flows and speeds. We discussed the intricacies of the payment structure, but the basic idea is that as flow and speeds rise, so too does payment and bonuses. This incentive encourages efficiency. Exogenous factors such as population and traffic growth, accidents and maintenance have been included in the risk profile of the project. Higher congestion in the future has also been modeled in. This novel approach seems to make more economic sense than alternative options, which tend to be more narrowly focused on volumes as opposed to speeds and flows combined. The future of congestion management also lies with electronic tolling. By availing of advanced technologies such as smart cards, flows and speeds on busy motorways can be sustained.

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