ROAD TOLLS AND ROAD PRICING: INNOVATIVE METHODS TO CHARGE FOR THE USE OF ROAD SYSTEMS

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Abstract - *Directly charging for the usage of roads to finance investment and operation of the infrastructure through tolling systems is now a widely accepted and implemented technique in developed countries.*

The relatively recent introduction of electronic toll collection techniques in a context of limited resources, growing congestion, and rising concerns on environmental impacts of road transport, allowed the sophistication of the road usage tariff structure with the objective to reduce traffic congestion and, as an end result, to internalize economic costs of accidents, pollution, or noise.

The new technologies introduced for toll collection such as electronic toll lanes on French motorways (Liber-T), Automatic Number Plate Recognition connected to personal invoicing systems in Israel, remain methods for fast and convenient collection of tolls. However, special discount on High Occupancy Toll lanes (HOT) in San Diego or Orange County in California, higher tolls during peak hours on whole motorways or on a reserved lane, congestion charge in Central London or Stockholm are going beyond this and aim at optimizing transport demand and utilisation of available infrastructure capacity.

The paper discusses and provides details about these technologies, the tariff structures and their impact on the traffic levels and on the utilization of infrastructures.

Introduction

The continuously high road transport travel demand growth rate over the last decades has reached a critical level that is beginning in certain parts of the world to threaten economic competitiveness and hamper sustainable development.

Indeed, in the 2001 White Paper, the European Commission estimated that about 7.500 km or 10% of the road network were affected daily by traffic jams and that the external costs of road traffic congested alone amounted to 0.5% of Community GDP. The Commission also estimated that if nothing is done, the costs attributable to congestion could increase by 142% in 2010 to reach €80 billion per year, e.g. 1% of Community GDP.

The major challenges facing the road transport sector nowadays are not only to collect revenues to cover the costs of constructing, operating and maintaining highway infrastructures in a context of sparse public budgets, but also to mitigate growing traffic congestion on major routes, improve road safety and reduce pollution and environmental disturbances caused by road transport.

Tackling these challenges comes at a price while the current context is characterized by limited public funding available for infrastructure development and projected weakness of revenues generated by the collection of motor fuel tax. Indeed, revenues from fuel taxes are expected to be affected in the years to come by both the improvement of automobile fuel efficiency and the development of alternative fuel sources. Raising motor fuel taxes could offset in the short run the fuel efficiency improvements impacts, but would not in the long run be sufficient to cope with highway growing capacity needs.

Hence, more and more countries are considering alternate options and public private partnerships for highway financing based on toll or direct user charging systems.

The following paper presents innovative tolling and charging systems based upon direct user charges that have been implemented or experimented throughout the world, from electronic toll collection systems to mileage based user charge systems, and analyses their tariff structures, their impact on traffic levels and on the utilization of infrastructures as well as the economic, equity, privacy or public policy issues they raise.

Part I – What do we consider as innovative methods to charge for the use of road infrastructure?

The main debate regarding the implementation of systems based upon direct user charges is to determine which costs should be reflected in the tariff structure.

At present, the most common approach to tolling is to set the tariffs so that they generate sufficient revenues to pay off bonds contracted to build the road and to pay for maintenance and operation costs. In the same vein, when the revenues generated by the toll road exceed the construction, maintenance and operation costs, the surplus can be used to finance other highway infrastructure investments.

However, in the current financial and political context, the new approach promoted *inter alia* by the European Commission or the US Federal Highway Administration (FHWA), is now to promote more efficient road pricing – charging as a method to also reduce congestion by a better utilisation of the available road capacity as well as allow road authorities to implement public policies that charge more equitably and efficiently the use of road infrastructures.

The paper focuses on three types of systems that follow three different approaches to road user charging:

- **Electronic toll collection systems** that introduced innovative technologies to suppress waiting time at toll booths. They aim at efficiently generating revenues to pay for construction, maintenance and operation costs.
- **Managed lanes and mileage based user charges** that use road pricing methods to combine cost recovery goals with traffic demand management objectives such as congestion relief, improvement of traffic safety or reduction of polluting emissions.
- **Urban tolls** resulting from a political will to reduce traffic, noise and pollution in severely congested metropolitan areas. In the current context of growing congestion and rising concerns on traffic safety and environmental impacts of road transport, their main goal is the implementation of proactive public policies to discourage motorists to use their cars and then, to use collected revenues to promote and develop public transportation and improve existing roadways.

The following section presents worldwide examples of projects following these three approaches to road user charging and analyses their specificities, advantages and disadvantages. Part III discusses the main issues raised by the implementation of these projects. Part IV shows the lessons learned and the way forward.

Part II – From electronic toll collection to managing traffic demand

1- Electronic toll collection systems

The most common and widely implemented way of directly charging road users are tolls. They have the major advantage to only charge for the actual usage of the highway facility. Yet, they often raise criticism from road users not only because of their cost, but also because of time loss at toll booths

Electronic Toll Collection (ETC) systems aim at eliminating the waiting time at toll booths. They determine whether the cars passing are enrolled in the program, alerts enforcers for those that are not and debits electronically the accounts of registered cars without their stopping or even opening a window. Since the first introduction of an ETC in Alesund (Norway) in 1987, electronic toll collection systems have been implemented in many parts of the world from Asia, to Europe, North America, South America, and Australia.

There are mainly two methods for vehicles' identification and billing:

- the first method involves the automatic number plate recognition which consists in a system of cameras that captures images of vehicles passing, when entering or exiting through tolled road sections. The image of the number plate is then extracted and used to identify the vehicle.

The major disadvantage of this method is that fully automatic recognition has significant error rate that leads to billing errors on the one hand, and on the other hand, the cost of transaction processing, which includes locating and corresponding with the customer, is rather significant. Some systems even incorporate a manual review stage which lower the error rate, but raise the cost of the invoicing process (additional staffing, ect.).

- the second method requires a transponder that travellers install on the windscreen of their vehicle (usually delivered against a deposit) and which communicates with the electronic toll system mostly using a radio-frequency system (RFID) via Dedicated Short Range Communications (DRSC).

The major disadvantage of this method is the cost of equipping each vehicle with a transponder, which represents a major start-up investment if paid by the agency and a major customer deterrent if paid by the customer.

Its main advantage is the reduction and even sometimes the suppression of congestion at toll booths by allowing cars to go through electronic lanes without stopping and in some areas even at full speed such as at Garden State Parkway (New Jersey, USA) or SR91 in Orange County, California (USA) which uses *FasTrak* that can handle up to 2,500 vehicles per hour per lane and can communicate with transponders at speeds of 60 miles per hour and up. The Open Road Tolling program of Illinois covers more than 250 miles of barrier-free highways, for which E-ZPass holders can pass through at full speed while the others pull off the main roadway to pay at tollbooths. At present, more than 75% of daily users of Illinois drivers use the open road tolling program.

Image 1 FasTrak electronic transponder

Most often, this method is combined with the use of cameras which takes picture of the car to identify the vehicle and send a notice and fine to cars that pass through without having an active account or paying a toll. In Israel, the Yitzhak Rabin Highway (Highway 6), also known as the Cross-Israel Highway, stretches for 87 km. It is the first toll road in Israel (opened in January 2004 and operated by Derech Eretz Highway Ltd) and uses a combination of the two ETC methods to collect tolls at an highway speed limit of 100 km per hour. Different toll rates are applied for motorcycles, cars, buses and trucks and cheaper tariffs are consented to transponder's holders. In 2006, 80 000 vehicles travel daily along the highway, showing a 14% increase comparing to the 2005 figure, and 500 000 vehicles have an active account for driving on Highway 6. Out of the 2.2 million vehicles circulating on Israel roads, about 1.5 million vehicles have already used the electronic tolling facility. The same type of ETC system has been implemented on Highway 407 near Toronto, the first electronic toll road in Canada, which operator (Canadian Highways Infrastructure Corp.) is also involved in the Derech Eretz Highway Ltd consortium operating Highway 6.

Moreover, in some countries, toll-collection companies using similar ETC technology have set up roaming arrangements between each other allowing vehicles to drive from one operator's toll road to another using the same transponder and toll's payment account. This type of arrangement exists in France with Liber-T and allows cars to pass through toll barriers of almost every toll road of the country run by the Federation of French Motorway Companies (AFSA). Likewise, in the United States E-ZPass tag is accepted in toll roads in more than twelve states from Virginia to Maine as well as in Australia where the CityLink e-Tag is compatible with several Sydney's motorways.

However, though electronic toll collection systems are very efficient at increasing toll gates' throughput by significantly reducing delay, critics have raised concerns about issues such as high error rates and privacy intrusion. Moreover, though the systems are improving and becoming more accurate and reliable, one of the main issue remain violation enforcement against toll evasion.

Finally, although electronic toll collection systems have suppressed waiting time at toll booths, they do not specifically address the major issue currently affecting many road infrastructures across the world which is the growing traffic congestion. In this context, transport planners and road authorities have more and more considered ways of using road tolls to smooth traffic demand and mitigate congestion during peak periods. Thus, on French motorways, tariffs are higher during predefined “peak periods” to encourage motorists to travel off-peak and therefore smooth traffic demand. In the same vein, more and more road authorities implement road toll projects using road pricing varying with the time of day, the day of the week or with the prevailing traffic conditions combined with vehicle occupancy requirements to optimize available infrastructure capacity and manage traffic demand while still achieving cost recovery objectives. The following paragraph thus describes such type of road toll projects.

2- Managed lanes

As presented by J. Obenberger [4], “*the concept of managed lanes involves proactively applying proven operational strategies in response to changing traffic and roadway conditions. By actively managing and controlling traffic though a combination of access control, , vehicle eligibility, and pricing strategies, agencies can keep vehicular demand and roadway capacity in balance by taking the appropriate actions before congestion forms*”.

Different types of “managed lanes” have been implemented over the last decade which includes High Occupancy Vehicle lanes (HOV), High Occupancy Vehicle Tolls (HOT) and congestion pricing lanes. They aim at reducing significantly congestion by encouraging higher vehicle occupancies and carpooling, shifting traffic from peak periods and keep traffic flowing freely even at the height of rush hours while generating revenue to pay off construction, maintenance and operation costs.

One efficient and cost-effective method to optimize existing highway capacities and mitigate congestion is to combine tolls with vehicle occupancy requirement in the form of High Occupancy Toll (HOT) lanes. HOT lane pricing allows vehicles with a number of occupants higher than a specified minimum to drive free or pay a lower tariff on the designated lanes. HOT lanes are also available to vehicles that do no meet occupancy requirements against the payment of a toll that can vary with the time-of-day and the traffic congestion level. Such toll lanes have been experimented on several highways such as the I-15 in San Diego, California (where tariffs can vary as often as every 6 minutes), the SR 91 in Orange County, California, or the Madrid’s N-VI median reversible HOV lane operated since 1995 in Spain.

One the most successful example of HOT lane combined with congestion pricing is the SR 91 in Orange County, California whose franchise rights were purchased in January 2003 by the Orange County Transport Authority (OCTA) which implemented a congestion management pricing policy since July 2003. The 16 km long four lane HOT facility is located in median of the existing freeway. The toll rates vary from $1 to $6.25 per trip depending on the time of the day and the day of the week. Vehicles meeting the occupancy requirements (three

Image 2 SR 91 Toll facilities, Orange County, California

or more persons) drive free (except between 6 and 8 pm eastbound) and user of the facility must be equipped with electronic transponder. During the average weekly peak hour and in the peak direction (eastbound), the express lanes carry 49% of the total number of vehicles travelling on SR 91 and their average speed was surveyed between 96 and 104 km per hour while at the same time the average speed on the general purpose lanes was surveyed between 24 and 32 km per hour due to congestion, e.g. 3 to 4 times lower than on the HOT lanes [4].

The OCTA objectives are: "provide customers with a safe, reliable, predictable commute; optimize the number of vehicles that can travel through the SR91 express lanes at free-flow speeds; balance capacity and demand, thereby serving both full-pay customers and carpools with three or more people; generate sufficient revenue to sustain the financial viability of the SR 91 express lanes". In 2006, the facility totalized 14.2 million trips and $39.6 million revenues in the 2005 fiscal year (75% of which were toll revenues). Using toll revenues, OCTA has for instance funded a $2.5 million pavement maintenance project scheduled to be completed in 2007.

However, though this example shows how efficient and cost effective can be HOT combined with congestion pricing, there are also practical implementation issues that need to be addressed to ensure a successful project such as the connectivity and competition with an existing mature freeway system for instance. Indeed, when a toll facility that aims to keep free flowing traffic is set up, the risk is that users will be willing to pay only when the free roads are congested, which could generate insufficient revenues to offset construction, maintenance or operation costs.

One example of this situation is the Dulles Greenway (near Washington DC in Northern Virginia), a privately owned toll road equipped with both the SmartTag (Virginia) and E-ZPass (Maryland to Maine) electronic toll collection systems. In the first six months of its opening in August 2005, the traffic on the toll road averaged 10,500 daily vehicles, far below the expectations of 39,000 daily vehicles at the end of the first year of operation. Consequently, the facility earned only $7 million at the end of the first year (far below the target of $27 million), which was not even enough to pay for the toll operation expenses. There are two main explanations for this situation: on the one hand, the traffic projections were made during the late 1980s commercial real estate boom and overestimated the development of the region as well as the resulting demand; on the other hand, the Greenway intended to offer a faster westward link to Dulles Airport, but the time savings offered by the toll road were not perceived as attractive enough since the alternate free bypass to Leesburg is relatively uncongested most of the time. Therefore, the owner was led to restructure its debt and then, thanks to a new economic boom in the region, was able to generate enough revenue to invest in extension and improvement of the road.

3- Towards Mileage-based User Charges

Pushing the idea of more fair and equitable road user charging system , the University of Iowa has developed, on behalf of the FHWA-sponsored Transportation Pooled Fund Program; a prototype mileage-based user charge relying on GPS technology, via satellite, to measure the actual number of miles travelled by the vehicle [2]. The technology requires vehicles to be equipped with GPS devices but is independent of the roadway on which they travel.

Once implemented, the road authorities would be able to fix tariffs depending on the actual number of travelled miles by type of vehicle and type of roads and then also charge user depending on the relative cost associated with their specific use of the considered roadway. For instance, as trucks impose more damage to the pavement, produce more polluting emissions and contribute more to congestion than passenger cars, the respective fees would be calculated accordingly. "*Once implemented, the system would entail a low cost of collection for both agency and users. […]This system could facilitate pursuing other initiatives such as congestion pricing, privately operated tollways, lane specific user charges to encourage carpooling, pricing to encourage use of environment-friendly vehicles and to reflect road damage imposed by different classes of vehicles, improved travel demand analyses, and a shift of the financial burden for roads from property owners to road users"*[2].

Yet, though this system does not require investment on roads, it does require all the vehicles to be equipped with GPS receiver; which constrains significantly the possibility of its implementation at full scale.

Thus, managed lanes or mileage-based user charges have a dual core objective which consists in achieving cost recovery while managing traffic demand and optimizing utilisation of existing infrastructure capacities.

4- Urban Tolls

Over the last ten years, more and more city officials across the world have been envisaging toll systems to reduce traffic, noise and pollution in severely congested and polluted metropolitan areas such as in Singapore, London, Oslo or more recently Stockholm. These tolls were installed with the goal of discouraging the utilisation of private cars in congested urban streets and then, using the generated revenues to invest in the development of public transportation and the improvement of existing road infrastructures. The underlying approach in these cases is to force user to change their behaviour regarding road transport to pave the way towards sustainable development.

Singapore was the first city to set an Electronic Toll Collection system that charges motorists that wants to enter the city center. This system replaced the "Singapore area licensing scheme" which was first introduced in 1975 and charged drivers entering downtown Singapore to relieve downtown congestion. The new system consists in Electronic Road Pricing (ERP) gantries located at all entrances to Singapore's central business district areas and along roads with heavy traffic to discourage their usage during peak hours. All Singaporean vehicles must be equipped with a transponder named "in-vehicle unit" (IU) in which a stored-value card (CashCard) is inserted. Non Singaporean cars can either rent an IU or pay a daily flat fee. The deducted amount varies with time of day and location (from S$0.25 to S$3 for passenger cars) while free entrance is allowed during off-peak hours.

Image 3 Electronic Road Pricing Gantry at North Bridge Road, Singapore

After visiting Singapore, the London City Mayor introduced in February 2003 the London Congestion Charge managed by Transport for London (TfL), making London the biggest city to adopt a congestion charge model. The system uses Automatic Number Plate Recognition cameras located at the edge of the zone and additional mobile cameras deployed within the zone. In February 2003, the Area subject to the congestion charge corresponded to the "London Inner

Ring Road Area" but since February 2007, it has been enlarged to include a western extension. The charge amounts at a daily fee of £8 (or €12) to registered motorists that enter, leave or circulated within the Congestion charge area between 7 a.m. and 6 p.m, from Monday to Friday. The captured images of number plates are transmitted to a data center where the identity of the vehicle is compared to the list of registered owners that have paid the congestion charge and those who have not paid are fined. Fines for travelling within the zone without paying the charge are at least of £50 (or €75) if paid within 14 days.

Though these systems are often unpopular amongst road users, their impacts on road traffic are quite significant. Indeed, in October 2003, Transport for London published a report analyzing the first 6 months of the Congestion Charge implementation [14] which shows that on average the number of cars entering the central zone dropped by 60 000 vehicles compared to the previous year figures , representing a drop in non-exempt vehicles of 30%. 50 to 60% of the traffic drop was attributed to modal shifts towards public transport, 20 to 30% to journeys avoiding the charge zone and the remainder to carpooling, reduced number of journeys, increased number of journeys during uncharged hours and increased number of journeys using motorbikes and cycles. Journey times were reduced by 15%, below the government target for London. This was considered mainly due to the configuration of the city with sprawling suburbs where it is difficult to provide a comprehensive public transport service and where cars could maintain a high travel share.

The London Congestion Charge implementation and its new western extension have raised much criticism. Opponents argue that the high level of the fee hit more severely low and middle income commuters than the wealthier and that several shops and businesses have been heavily impacted by the costs of the charge, both because of lost sales and of increased delivery costs. In addition, the system has also generated controversy in Outer London, where commuters park at suburban railway or underground stations at the expense of local residents. Moreover, Capita, the firm contracted to manage the charge for TfL, has failed to generate sufficient revenues in order, as intended initially, to finance improvements in public transport and road infrastructure and therefore has been fined in 2005 £4.5 million for "missing vital targets" and has paid the equivalent of £7,400 in charges and fines for every day the toll has been in operation. Capita has been fined for reasons such as late management reports, carts incorrectly clamped for non-payment, valid complaints from users, problems at its call center and for errors on its "persistent evader" list.

Part III – Main issues raised by the implementation of road toll systems

Whatever goals they pursue, either more efficient and equitable toll collection, traffic demand management or traffic reduction, road toll systems raise major economic, equity, privacy or public policy issues. The following section discusses the three following main issues that need to be analyzed and settled by decision-makers when considering such types of projects:

- Is the project equitable in a socio-economic perspective?
- How can the project be accepted by potential users?
- How much time and money does the full implementation of the project require?

1. Socio-economic equity

Whereas the underlying approach of direct user charging system is to charge in a more efficient and equitable way the use of infrastructure from an economic perspective, one of the first concerns in implementing direct user charging systems is that it could be inequitable in a socioeconomic point of view by affecting more the low and middle income level socio-economic groups while it would benefit more the higher income level groups.

Likewise, where variable tolls are charged to maintain free flowing traffic such as SR91 in Orange County, California, the tolled lanes have been often regarded as “Lexus Lanes” out of concern that they would benefit more the wealthy than other socioeconomic group since they would be not only willing but able to pay more for a better service. In 2000, the *Continuous Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes* at California Polytechnic State University by Edward Sullivan [10] however shows that “*while a clear correlation exists between frequency of toll lane use and income level, users from all income groups regularly make use of the facility*”. Indeed, in many cases, travellers with lower incomes have benefited from HOT lanes using carpooling to drive free.

When urban tolls were implemented in London, Stockholm, Oslo or Singapore, critics have argued that they would hit low and middle income workers commuting from the suburbs to the city center as well as shops and businesses that would suffer from high delivery costs and lost sales. This is all the more true in the case of London where the congestion charge that motorists pay to enter the city center is very high at £8 (or €12) and announced to be raised at £10 (or €15) by 2008. However, in these cases, the underlying approach is more to reduce drastically traffic in city centers and therefore use tolls as a way of deterring motorists from using their cars to travel and of encourage them to shift towards public transportation.

2. Public acceptance

Though toll facilities represent for many road sector managers the opportunity to generate revenues for highway investment and therefore better address transportation growing needs in an efficient and cost effective way, authorities are also very cautious about the public willingness to pay for the use of highway infrastructures. Public resistance is all the more high when tolls are implemented on existing infrastructures.

However, when innovative approaches, such as electronic toll collection, are used to suppress waiting lines at toll booths or congestion pricing combined with vehicle occupancy requirements to relieve congestion, various studies show that users are willing, to a certain extent, to pay for improved travel time, traffic safety and highway infrastructure.

As Mr Nasseredine, vice president for traffic operations and planning at Highway 407 in Canada says [6] : “*Research [shows] that customers mainly value three factors in their decision to use the toll highway. These include the time savings achieved, the reliability and convenience of the trip, and safety of the highway*”.

Likewise, urban tolls are frequently cited as very unpopular projects. Yet, in September 2006, Stockholm voters approved the traffic toll with 51.7% of voters in favour of the projects and 45.6% against it. Public opinion indeed swung in favour of the charges after studies showed that during weekdays on average during the trial period, traffic passing over the city’s cordon dropped by 22%, traffic accidents causing injuries fell by 5 to 10% and CO_2 levels fell by 14% in the inner city.

3. Costs and time necessary to full implementation

Fully implementing direct user charge systems based upon electronic collection requires higher administration, collection and violation enforcement costs and takes time to get the vehicles properly equipped with required devices, such as electronic transponders.

Thus, though the Stockholm toll experiment shows very positive results as mentioned above, an economic evaluation [7] shows that the projects ends up costing tax payers more than 400 million kronor a year (€43 million or US$55 million) whereas it was supposed to generate revenues to be spent on improving public transportation and better roads. The costs include toll operating costs (240 million kronor), bus operating costs (341 million kronor), time loss for ring road users (4 million kronor) or surplus loss for excluded users (66 million kronor).

HOT and managed lane experiences have proven to be more successful in terms of revenue generation though. Indeed, the I-15 HOT FasTrak lanes in San Diego California generate about *"$2.2 million annual collections revenue – enough to run the program and pay for two Rapid Transit buses for the I-15 route, but not enough to float bonds to build new lanes*" [4] (Ray Trainor, senior project manager for the San Diego Association of Governments – SANDAG).

Part IV – Conclusion: Lessons learned and way forward

Severe congestion asphyxiating growing metropolitan areas and limited public funding available for road infrastructure investments have led public decision-makers to consider road toll projects as efficient and cost –effective ways of generating revenues to finance highways while implementing public policies encouraging better utilisation of road infrastructures.

However, although they can indeed generate revenue and reduce traffic congestion for the benefit of the whole community, the types of projects considered above pursue two different objectives:

- the first objective is to generate alternate sources of revenues to make up for the weakness of available public funding to finance highway infrastructures in a context of rising road transport demand
- the second objective is to mitigate congestion and reduce its negative impacts on the community by managing road transport demand and even in some cases reduce traffic.

Although projects pursuing the second objective may not lead automatically to the generation of sufficient revenues to break even quickly, decision-makers must bear in mind that the crucial issue is that they may generate sufficient benefits to the community in terms of congestion relief, traffic safety and pollution decrease to still implement them.

Yet, non-technical issues such as socio-economic equity and public acceptance must also be taken into account very carefully in the decision process towards the implementation of a toll project. This is all the more true when road toll systems are implemented in developing countries with important income discrepancies and social inequalities, and where the implementation of projects that would impose a greater financial burden on lower income users and benefit the wealthier socio-economic groups would not be considered as acceptable.

Indeed, road and urban toll projects should be considered as miracle stand-alone solutions. The decision to implement them must be integrated in the framework of regional and national transportation plans and requires to carry out informed debates amongst transport planners, public transport operators, elected officials and motorist groups to settle on what are their reasonable and realistic objectives and modalities taking into account the local context.

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