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Implementation of optimum toll pricing system in bridges

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ABSTRACT: A newly constructed bridge connects one region of the country to other. People use this new path rather than using the previous transportation paths. But an equilibrium condition should exist to make the efficient use of the newly built bridge. Growing traffic congestion in highways and bridges raise the travel duration and make the bridge inefficient. To subside the inferior consequences of traffic congestion implementation of congestion pricing is a matter of time demand nowadays. Congestion pricing will help to reduce the traffic impact so that there will exist a user equilibrium condition. This paper conducts a review of congestion charging systems in different countries and drilled it's advantages. The study considers congestion charging experiences in developed countries. An optimum toll pricing can be implemented for the best use of a bridge. It will also make sure of the use of other travelling routes and make all the routes are in user equilibrium condition. This pricing is helpful to increase public transportation ridership and travel speed. Optimum toll will reduce the travel time as well as the discharge of green house gases. The revenue earned from this system can be used for bridge maintenance purpose and for developing other transportation facilities. In Bangladesh there is a huge scope of using this system in bridges with the integration of bus lane.

1 INTRODUCTION

1.1 *Optimum Congestion Pricing and User Equilibrium (EQ)*

Urban road networks, highways and bridges in Bangladesh are highly congested during peak periods. Long vehicle queues at bottlenecks such as the opening of bridges or flyovers, have become a natural event. An efficient control scheme must, therefore, take into account the effects of traffic control and road pricing on network flow. Road pricing has long been recognized as an efficient way to improve the economic efficiency of the transportation system and implemented in many metropolises around the world to reduce traffic congestion and pollution.In the traffic assignment literature, it is well known that a marginal-cost toll is charged on each link to drive a user equilibrium (UQ) flow pattern toward a system optimum in a general network. Although this principle is theoretically reasonable, it is not practically appealing for many reasons such as the high operating cost and poor public acceptance.

The main source of efficiency gains from optimal toll pricing is the rescheduling of departure times from the trip origin. By using this scheme flow at maximum capacity of bridge is maintained.

1.2 *Congestion Pricing*

Congestion pricing is defined as a charging method used in urban city to reduce congestion during rush hours. Vehicles especially private cars, goods vehicles, taxis, motorcycles have to pay a fee for entering into a charging zone. Congestion pricing can also be implemented for the best use of a route.

Increased population will add new traffic on existing roads. Due to unplanned road network the free flow speed of the vehicles will be lower and the roads will be congested. New infrastructures have been built to tackle the situation. But due to insufficient funding it is not possible to fulfill the required demand. Developing infrastructure is also a time consuming issue and sometimes there will exist no other way to build new roads. A potential solution like congestion pricing system will help to reduce traffic congestion. Congestion pricing may be implemented without increasing supply. Congestion pricing has been recommended as a competent way to minimize the road congestion by the transport economists and traffic planners.

According to economists, no utility should be free of cost e.g., public goods. Market failure will occur when a utility is free. Here road surface and time is regarded as a utility, so its uses have to be charged. As congestion pricing is a very popular perception from economic point of view, few developed countries have implemented it practically. Developing countries have not adopted this concept yet.

This paper regards the charging experiences in London, Singapore, Stockholm and Hong Kong pilot program that (Hong Kong) did not conduct full-scale implementation. The advantages and objectives of pricing schemes are reviewed for the best use of congestion pricing in developing country like Bangladesh. It is seen that, congestion pricing can reduce congestion in city area as well as bridges and prevent to create bottleneck in entrance areas of bridges. Optimum toll pricing will ensure user equilibrium in newly built bridges. So it will raise the life time of bridges. Travel speed also increases with the reduction of vehicle trips in bridge area. Emission of green house gases also decreased which is one of the big environmental reliefs.

1.3 *Worldwide Used Congestion Pricing Schemes*

Cordon pricing

Cordon pricing is a type pricing method that would be introduced in the city center or a geographic area to restrict traffic movement during peak travel hours. Desired outcomes consist of decreased traffic congestion and environmental issues, enlarged transit, bicycle and pedestrian service and improvement of a dedicated, locally controlled revenue flow.

Toll system

In order to recover the construction work and maintenance of road rod tolls are collected. To reduce congestion especially in highway roads.

Dynamic volume pricing

Dynamic volume charging system is mainly the replacement of existing high occupancy vehicle lane with a high occupancy toll lane.

Network pricing studies

Network pricing system is implemented hardly for the whole network based on either how much area of the system is used by a vehicle or considering for how long it uses the system.

HOT lanes

High occupancy toll (HOT) lanes are high occupancy vehicle (HOV) lanes that also permit use by a restricted number of low occupancy vehicles if they pay a toll. It is also called managed lane.

Vehicle use fees

Distance based charges such as mileage fees can be used to fund roadways or to reduce traffic impacts, such as congestion, environment pollution and accident chance. Pay-as-you-drive vehicle insurance, prorates premiums by mileage so traffic insurance becomes a variable cost, which gives motorists an inducement to reduce traffic impacts, but provides no additional revenue.

Road space rationing

A variation of road pricing is to ration peak period vehicle trips or vehicle miles using a revenue neutral credit based scheme. The result is a form of congestion charging in which the advantages are captured by residents rather than governments.

Vignette

Vignette is a form of road pricing imposed on vehicles, usually in addition to the compulsory road tax, based on a period of time instead of the usual road toll method based on distance traveled, and is currently used in several non-English speaking European countries.

2 APPLICATION OF CONGESTION PRICING

2.1 *Singapore*

RPS covers the initial entry to the 5.96 km^2 central area of the city from 7.30 – 10.15 hours. This scheme charged US$2 per business day on any given weekday for every vehicle which contained 3 or fewer people. Vehicles reduced about 45% after applying this scheme for each business day (Larson and Sasanuma, 2010). Entry of car reduced by 70% and average vehicle increased from 19 – 36 km/h (Santos, 2004). Bus ridership increased about 20 % for this scheme (Ed Pike, 2010).

The charging area of ERP is categorized into central business districts (CBD's), which is also included to the previously covered area by RPS. Charging applies from 7.30 – 19.00 hours in CBD's and 7.30 to 9.30 hours in expressways or outer ring road. A radio transponder named In-vehicle Unit (IU) is used in which a Cash Card is inserted. A fee is deducted from the Cash Card when the vehicle passes the restricted zone (RZ) and displays the remaining balance. Overall traffic had dropped to 15 % during whole day and 16 % during peak periods.

2.2 *London, England*

LCCS covers 22 km2 in Central London which is the 1.3% of Greater London. It performs from Monday – Friday, from 7.00 – 18.30 hours, except public holidays. The charge was £5 per day for all motor vehicles. Some vehicles are not charged, such as – certain military vehicle, local government service vehicles etc. During charging hours the total vehicles entering central London dropped about 25% the day congestion pricing were implemented (Larson and Sasanuma, 2010). Car trips reduced about 50-60%, as car users diverted to PT (TfL, 2004a). Traffic speeds increased between 10 and 15% (Ison and Rye, 2004). During the first year bus passengers entering the charging area elevated to 37% (Larson and Sasanuma, 2010). Buses increased in charging zone by 20% (Beevers and Carslaw, 2004). Carbon dioxide emissions have minimized more than 15% (Larson and Sasanuma, 2010).

2.3 *Stockholm, Sweden*

Approximately 1.4 – 8.5 US$ was charged to motor vehicles entering the inner city of Stockholm which covers 34 km^2. Charging conducted from 6.30 – 18.30 hours on weekdays. Volume of traffic reduce by 25% after implementing the pricing scheme (Larson and Sasanuma, 2010). Car trips were minimized by 20% to/from inner city and for this PT travel was increased by less than 9% (Kottenhoff, 2009). It is seen from travel survey (Smidfelt et al., 2006b) that PT travel increased by 3%. Work trips by car reduced by 24% across the cordon area (Franklin et al., 2008). Vehicle emission reduced between 10 to 15% due to reduction of vehicles. From the inner city it found that carbon-dioxide emission decreased to 14% (Eliasson et al., 2009).

2.4 *Hong Kong*

To evaluate the technical, economic and utility of ERP Hong Kong adopted road pricing and it is seen that private cars and taxis are the most dominated vehicle in the Central Area, i.e. 76% (Hau, 1990; Harrison, 1986). It is found that approximately 40% car trips reduced because of diversion to public transport (Opiola, 2010). The gross environmental betterments in the pricing zone were estimated to 12-16% (Opiola, 2010). Average vehicle speed improved about 40% in urban areas (Hau, 1990). Car trips will reduce approximately 20-24% in the charging zone and overall vehicle speed increased to 10% (Hau, 1990).

2.5 *Milan, Italy*

Milan ecopass scheme (MES) was founded in January 2008 which covers a small area of 8 km^2 to ameliorate climate condition. This area was charged from 7.30 to 19.30 hours and charges up to 5 Euro according to different toll classes (Rotaris et al., 2010). Improving air quality is an implied goal for all of these congestion pricing systems, by discouraging private cars. Milan has cut out the middle man and made improving air quality the state mission of its system the Eco pass. The scheme is designed to squeeze access to the CBD in Milan and in an eminently obvious but never before applied way, drivers are charged based on *how dirty their cars are*. Hummers and Piaggios aren't going to be charged the same rate to enter downtown Milan because they are not doing the same damage to the environment—in fact the Piaggio Porter Electric wouldn't be charged anything to enter the CBD.

Air emission (PM_{10}, NO_x and CO_2) reduced upto 19% (Rotaris et al., 2010).Though it was a pollution reduction scheme, this scheme had some other benefits in congestion reduction. There was a sharp decrease

(23%) of traffic entries in implemented time and overall traffic speed increased by 4% (Rotaris et al., 2010). It is measured that PT uses increased by 9.2% (Rotaris et al., 2010).

3 IMPLEMENTATION BENEFITS

In our study we have studied on five countries and from our study we invented that developed countries are more concern about congestion pricing. From our review it is seen that private cars are the main source of congestion and public transportation system is the most effective alternate of private cars to reduce the congestion.

Environmental pollution is also caused by private cars if we do not take preventive measures. From our study positive environmental impact is found from the study from different charging schemes which is summarized below in Table 1.

Table 1. Summary table of pollution abatement of different charging schemes

	LCCS	ERP Singapore	ERP Hong Kong	Stockholm Charging Scheme	MES
Area covered	22 km^2	CBD's	Central, Wan Chai, Causeway Bay	34 km^2	8 km^2
Reduction(%) of CO_2 emission	>15 (CO_2)	not available	not available	14	15
Reduction(%) of vehicle emission	10-20	not available	12-16	10-15	14-19

From the objectives of the charging schemes it is clear that congestion reduction is the primary objective which is related to how many traffic is dropped. Figure 1 has showed the comparison of Singapore, London, Stockholm, Hong Kong and Milan considering various factors. An effective reduction of car trips in the charging zone is possible only when the PT system will be well established. Traffic drop rate in Singapore is not so high but increase of traffic speed and diversion rate to PT is the highest. Traffic drop rate of Central London and Stockholm is same because the gross implemented area is quite similar to each other. As MES is pollution reduction scheme that is why traffic speed and diversion rate to PT is very poor. A certain traffic drop rate will ensure the user equilibrium (EQ) of a bridge. From this context optimum use of bridge or roadway can be maintained. User equilibrium (EQ) also ensure minimization of green house gases.

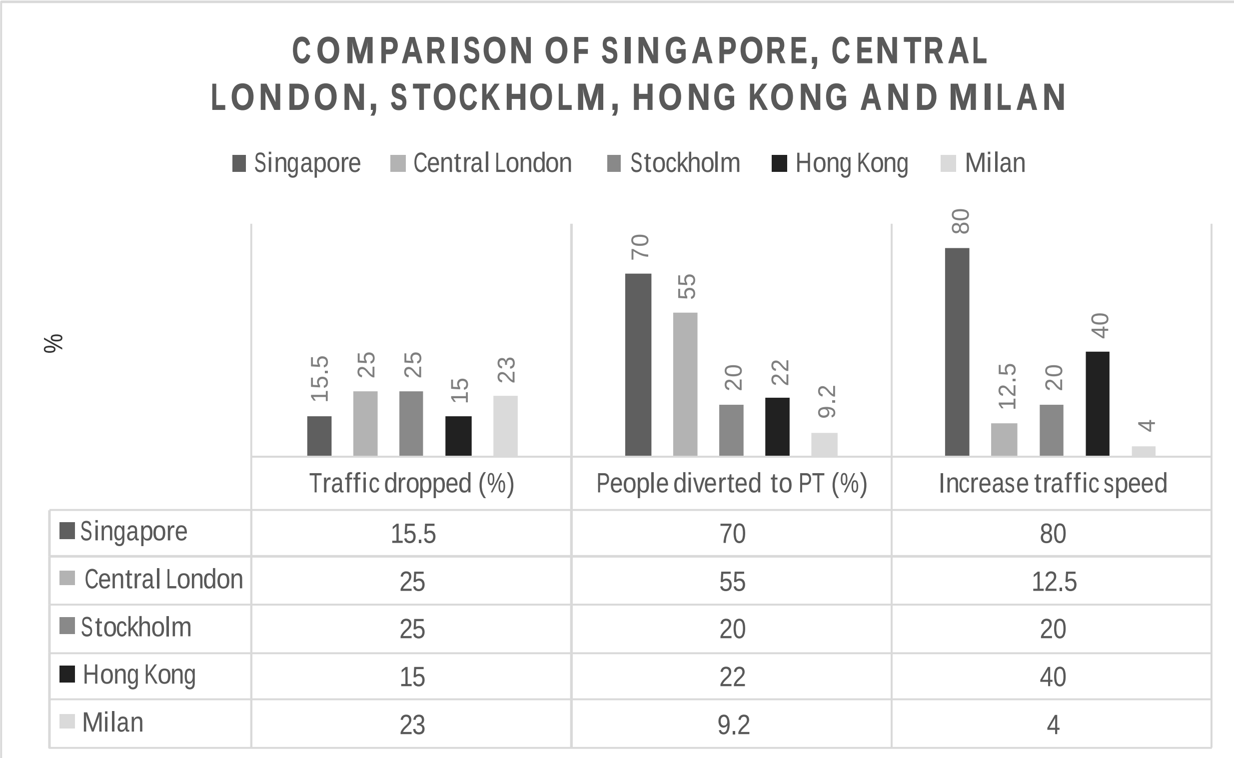

Figure 1. Comparison of Congestion Reduction in Singapore, Central London, Stockholm and Hong Kong

4 CONCLUSIONS

This paper explores worldwide achievements of different congestion pricing schemes. It is seen that congestion charging will help to reduce congestion during hasten hours. Congestion pricing also shows some constructive impact on environment. Traffic jam cause vulnerable effect in bridges and it will reduce the life time of bridges. Optimum congestion pricing would play a monumental role in reducing traffic jam in bridges. Due to this pricing system traffic will try to use other routes of transportation. User equilibrium (UQ) will be achieved by obtaining optimum toll levels on predetermined toll links and toll locations. In further studies we have to determine this two things for the best use of optimum toll pricing.

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