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"Quality of Life", Road Pricing and the "Level of Service" of Urban Roads

by

William Young
Peter Daly

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ABSTRACT: This paper addresses the definition of the “level of service” of urban roads in the context of developments in road pricing. It investigates the measurement of the “level of service”, technological developments in road tolling, drivers acceptance of road pricing, and the impacts of road pricing on the “quality of life” of urban areas.

AUTHOR: William Young
Peter Daly

INTRODUCTION

The "quality of life" in urban areas depends on the ability of people to do what they desire. This often involves moving from one location to another to partake in activities. The automobile, and the supporting transport system, provides the flexibility needed to meet this desire for freedom, while the "level of service" provided to the traffic system is integral to economic performance and social satisfaction. In this context transport can be seen as a "derived demand".

Transport, however, has a cost which must be met. Accessibility to the road network has become a scarce resource. At the same time congestion, pollution, energy consumption, and noise intrusion are important issues in both developed and developing countries. These costs can be met indirectly through taxes and charges on vehicles, petrol or the community. It can also be met directly through charging for the use of the transport system. This direct charging approach must view the provision of transport as a "service" which can be charged for. Direct charging has gained acceptance amongst many transport professionals, however, the general community still perceives the provision of road services as a right with direct charging reducing the "level of service" of the road system. Government investment in transport infrastructure over the last few decades has reduced in many countries with society giving priority to expenditure in other areas of the economy. More recently, the investment potential of transport infrastructure has been identified by private enterprise. It has stepped in to alleviate the lack of investment by government organisations and has been involved in developing infrastructure to meet the growing demand for travel. The cost of this investment must be met by users, hence road tolls and pricing schemes are being introduced. In order to monitor the impact of the privatisation of the road system it is necessary to quantify the service provided by the road system, its "level of service".

The aims of this paper are to determine some of the parameters associated with the quantification of the "level of service" on roads, to investigate developments in road pricing and their impact on "level of service", and to discuss the relationship between "level of service" and broader urban issues.

Quantification of the "level of service" of roads can be viewed from a pure traffic engineering approach or via network modelling of trips. Both these approaches will be discussed below.

Traffic engineering approach

The Highway Capacity Manual (TRB 1985) defines "level of service" as:

a qualitative measure describing operational conditions within a traffic stream and their perception by motorists and/or passengers……in terms of such factors as speed and travel time, freedom to manoeuvre, traffic interruptions, comfort and convenience and safety". (TRB, 1985)

The "level of service" of roads in rural areas is dependent on the relationship between speed and traffic flow and is strongly influenced by road cross section, traffic composition and directional distribution. It has been investigated widely and is the basis of present rural road design.

Proxy measures for “level of service” on rural roads have been used for many years. Relationships developed in the 1950’s or earlier have undergone continual refinement. Examples include car following models (eg. the General Motors model), lane changing and overtaking models and bunching models (eg. Borel-Tanner and negative exponential models). This is a reflection of the perception of significant cost that drivers associate with time spent following other vehicles.

In an urban context the Highway Capacity Manual (TRB 1985) substantially changed the approach taken in the Highway Capacity Manual of 1965 (TRB 1965) by the exclusion of operating cost. The “level of service” measures suggested by the manual include density, average travel speed, flow rate and stop delay.

Network modelling

People make trips if the perceived benefits gained from the trip exceed the costs. The trip is made up of components which when taken together determine its cost. The components of the trip can be analysed in terms of their contribution to the cost. The cost of travel along a link can be related to the monetary cost and the time spent in travel. The time spent in travel is related to the impedance which in turn is related to the traffic flow, type of intersections, parking and the level of pedestrian intrusion. The relative safety of the road and probability of being involved in an accident or an incident is increasingly thought to be important in people’s perception of the cost of travel along a road. Network modelling attempts to replicate this choice process. It involves the investigation of trip generation, trip distribution, mode split and route choice. The “level of service” influences each of these model types.

Trip generation

The “level of service” of the transport system influences the number of trips. Highly congested city streets tend to discourage travel while uncongested conditions encourage travel. The phenomena of increased trip making as a consequence of road improvements is typical of change. This can be quite detrimental to the system when viewed in a strategic level network context. Increased spending on narrowly focussed road infrastructure improvements may degrade overall “level of service” if it is not sympathetic to urban wide travel improvements. Strategic objectives to improve overall travel quality must consider transport system integration and sustainability issues given the potential that changes may have on trip generation patterns.

Mode choice

Mode choice is influenced by travel time and travel cost. Changes in the “level of service” influences the choice of mode. In the longer term this also impacts on the availability of modes. Economic rationalist approaches may associate poor patronage on public transport routes (due to a low “level of service”) with a reduced need for the service, placing further stress on alternative modes. Conversely, improvements to the road system resulting in a higher “level of service” for car travellers may have the potentially undesirable effect of increased car ownership and use levels.

Route Choice

The "level of service" of network links, expressed as a travel time or travel cost influences the route people will travel. Several theoretical studies have investigated the application of equilibrium assignment to replicate the impact of road pricing on route choice.

Trip distribution

The cost of travel to a destination and the travel time impedance combine to influence the decision of which route to take and which destination to move to. Ferrari (1995) outlines a deterministic static equilibrium model for urban transport networks with elastic demand and capacity constraints. The model is applied to a simple network and it was found that the capacity constraints can be satisfied by introducing additional costs on links of the network. These costs could be road pricing. The model was not calibrated for a large network although discussion was made of application to the Hong Kong road pricing system. These models have not been calibrated and there is little empirical research to provide an indication of the magnitude of the coefficients for the cost component.

Activity/behavioural models

Activity and behavioural approaches (Jones 1979) to modelling the transport network are relatively new but are increasing in acceptance. They have the advantage of implicitly treating travel as a derived demand and examining constructs of activity patterns, trip chaining and travel time utility in a more realistic manner. This has important implications for the assessment of perceived "level of service" in relation to changes in the transport system as this in turn may result in further changes to activity participation, location and travel behaviour.

Improving the "level of service"

Clearly there have been many attempts to improve the "level of service" offered and to obtain the maximum usage from the transport system. These approaches relate to the increasing of capacity through the construction of additional infrastructure and the development of new technology to minimise delay in the system.

In addition to measures designed to expand or maximise the efficiency of the road system, the use of technology can play an important role in the provision of information to the driver. This may be in the form of static or dynamic information regarding the current or predicted state of the road system, perhaps in a proxy form such as travel time. This can increase the perceived "level of service" for the driver in two ways:

- it enables the driver to select an alternative route if the current or planned route has an unacceptable "level of service", and
- it can reduce the higher subjective cost of 'waiting time' for drivers caught in congestion with little freedom to make route choice decisions, through predictions of delay.

However, improving "level of service" is not just about 'fixing' roads but in the wider sense, increasing the amenity of travel. Some people willingly accept higher travel time to use their private vehicles than travel on public transport, as the overall perceived "level of service" of the private vehicle trip is higher. A challenge that is facing a number of countries with well-developed infrastructure and increasing vehicle/kilometres of travel is the management of the transport asset.

This is more than a mode choice trade-off, it is a rethink of the structure and nature of the urban form. This will be addressed later in the paper.

ROAD PRICING AND IT'S IMPACT ON "LEVEL OF SERVICE"

Until recently the cost of travel has been related to the travel impedance as measured by travel time, running cost of vehicle or public transport fare, and measures of comfort, convenience and reliability. The need to pay for the construction of transport infrastructure and the excess demand (congestion) on particular parts of the network has introduced the need to take into account payment for the use of the transport system. Road tolling and congestion pricing enter the discussion. This section will introduce some pricing systems and technology, discuss the acceptance of these systems, and relate road pricing to the "level of service" provided by the road system.

Road pricing systems technology

Luk and Chung (1997) divide road pricing approaches into:

- road tolling, where tolls are charged to recover road construction, maintenance, and operation costs,
- peak period or variable tolling, where tolls are varied by time of day as a proxy for traffic congestion, and
- congestion pricing, where road users pay the marginal social cost of using the road system (Luk and Hepburn 1995).

Which ever pricing mechanism is used a tolling system must be set up which can, recognise the vehicle (roadside reader, vehicle detection), make decisions (vehicle classification, toll determination) and control activities (collection of toll, enforce lane discipline). This can have various levels of automation. Clearly the level of automation and technology used to collect the fees will influence its effectiveness. This section will discuss manual tolling, electronic tolling, and co-ordination of tolling systems or road pricing systems.

Manual Tolls

Manual tolls have been in place in many cities for many years. Some of these include Sydney motorways, Sydney Harbour Bridge, Brisbane Storey Bridge, Melbourne Westgate Bridge (removed in 1992). Such tolls are still used and being developed in many countries.

Electronic Tolls

Notwithstanding the introduction of many manual tolling systems, they are a constraint on vehicle movement. Electronic toll collection (ETC) provides a method of overcoming this problem. The toll lane is usually equipped with an antenna connected to a reader mounted above the road way. The reader communicates via a radio frequency (RF) identification (ID) tag mounted on the vehicle with an antenna (Luk and Chung, 1997). Systems using optical and infrared automatic vehicle identification (AVI) systems are not as common due to poorer durability and accuracy in adverse conditions.

The process of communication is initiated when the reader sends a signal to the tag. The tag provides the reader with a unique ID. Vehicles may be classified using detector loops, video, ultrasonic scanners or infra-red scanners. Video may also be used to record number plates for those vehicles with illegal or no tags. The information read from the tag is provided to a lane controller by the reader. Transaction data is communicated to the host computer (Luk and Chung 1997). The RF tags take many forms, they can be read only, receive and send signals, and interact with a smart card taking information on the vehicle or payment mechanisms.

Some tolling developments are outlined below. Most systems restrain vehicles to one lane. However, there is a growing development of electronic multi-lane open road tolling systems (EMuLORT)

The Storebaelt Strait crossing between Sealand and Fuhnen in Denmark presented another opportunity to control traffic flow for collection of road tolls (Vincentsen and Skadsheim 1997). The system will use smart cards for anonymous payment by bridge users:

- in roadside card readers. These will be set at three levels to obtain cards for different vehicle types.
- insertion in transponders fixed to the inside of the windowscreen.

The cards will be initialised with card identity, user identity, vehicle class, type of ticket, validation date and expiry date. The cards will be updated during passage with transaction data for the last 20 trips. Empty anonymous cards are confiscated by the roadside reader and recycled. A major problem with smartcards is the time needed for safe communication between smartcard, its transponder and the roadside at high speed. To overcome this problem barriers are used in all lanes to limit the speed of vehicles. Electronic pre-classification of vehicles will be used to determine the toll to be used. The price structure will be similar to that used for the existing ferry system. Two video cameras will be used to provide images which can be analysed stereoscopically. Enforcement cameras will be placed in each lane to check vehicles that may behave inappropriately. These cameras can also be used if the driver disputes the toll charged. The system opens in mid 1998.

A recent development in the ETC area is the opportunity to let vehicle change lanes at tolling sites and drive at high speeds. The Melbourne City Link (MCL) will be the largest subscriber based electronic toll collection system in the world when it opens in 1999 (Waby 1997). The Central Toll Collection System (CTCS), will be a free-flow, multi-lane system that will collect toll fees from an estimated 600,000 vehicles per day, with up to 2,500 cars per lane per hour. Motorists will be billed through transponders linked to pre-paid accounts. The total charge is to be capped at $3.00 in 1996 prices irrespective of the number of toll points. The motorists will not be required to slow down. Tags will be provided to road users who open a tag account. Tags will be identified when a tagged vehicle passes a tolling point. The resulting toll information will be centrally processed and the appropriate toll charge debited from the account. Temporary users can buy a day pass. An imaging system will capture images of vehicles that pass tolling points without valid tags. The main business objectives of the MCL consortium (TransLink) are to minimise the loss of revenue, minimise the number of enforcement procedures undertaken in error, ensure data integrity and security, provide customer friendly services, automate processing and operation as much as possible, be operated and maintained independently of the CTCS supplier, and be flexible and capable of handling expected future financial flows and customer payments through the internet. CTCS employ an object oriented techniques and backup systems to ensure all will run smoothly when the first section opens in early 1999. The design enables growth through an adaptable system architecture. A risk management plan has been instigated to cover the areas of scope, schedule, cost and quality as well as high impact risks such as system security, disaster recovery procedures and fraudulent practices. The Melbourne system will have active read/write tags, a transmission frequency to be around 5.8 GHz, tags powered from their own battery, and a video imaging system for enforcement.

Co-ordination of toll collection

The next step after the automation of tolls on road links is the integration of these systems into road pricing systems. Some moves in that direction are outlined below.

The New Jersey Regional Consortium for Electronic Toll Collection (ETC) has joined the toll collection facilities for over 700 toll booths through the use of fibre optics. The toll facilities for three toll road agencies - The New Jersey Turnpike Authority, the New Jersey Highway Authority, and the South Jersey Transportation Authority joined with the Port Authority of New York and New Jersey to form a regional consortium for ETC. Payment for the co-ordination process will be derived from revenue form

The Singapore electronic road pricing (ERP) system is being introduced to replace the existing area licensing system. All 670,000 vehicles in Singapore are to be fitted with in-vehicle transponders units so that they can be charged for entering the central city area. Foreign motorists will have their vehicles fitted with temporary units. The central city area is to be bounded by 60 gantries which support the 2.45 GHz frequency electronic tolling system. The tags are to be powered from the vehicle battery and video imaging technology will be used for enforcement. This system has been dubbed the first electronic urban road pricing system in the world. Trials of two gantries have indicated that motorcycles, vibrations and radio frequency interference are causing problems and further refinement is required (Tolltrans 1997). On the introduction of the road pricing system the tax on vehicle ownership will be substantially reduced and replaced with a road toll.

Although the development of the technology associated with road pricing is rapid there are a number of technical issues that still require clarification. These include the adoption of common standards on communication frequencies, the use of different tagging mechanisms, and the improvement of video enforcement systems which are still in an early development stage.

Magnitude of road tolls

Decorla-Souza and Kane (1992) point to a toll of 16.6 cents per mile based on a value of time of $5.00 per vehicle hour using the short run marginal social cost approach. The long run cost approach points to a value between 22.3 cents per vehicle mile for peak period travel. Other research studies have pointed to an optimal congestion prices of between $0.15 and $0.25 per vehicle mile for freeway while twice that value is quoted for arterial roads.

The sensitivity to the magnitude of tolls may also be measured through the demand elasticity to tolls. Hirschman et al (1995) measured to toll elasticity in tunnels in New York. They found that it was negative and much less than one. The medium toll elasticity for automobiles was found to be -0.10, for light trucks it was -0.23 and heavy trucks it was -0.18. Automobile elasticity was therefore found to be highly inelastic with respect to toll rates. Light and heavy trucks had a higher elasticity than automobiles. Decorla-Souza and Kane (1992) in their study of the price elasticity of automobile commuter trips and parking conclude that a price elasticity of -0.16 is appropriate. These studies are however, short term in nature and did not look at the long term urban changes associated with road pricing.

Level of acceptance of tolls and road pricing

The previous discussion has indicated that the technology associated with road pricing schemes is developing rapidly and that a logical theory can be developed for setting tolls. The level of acceptance of tolls and road pricing varies from location to location. Luk and Chung (1997) reviewed studies of tolls and road pricing in 11 locations and found that:

- support for road pricing was greater in cities with congestion problems,
- a high proportion of motorists support traffic restrictions rather than road pricing,
- support for road pricing increased when motorists are offered a transport package which includes public transport, pedestrian and cyclist facilities, road improvements and tax reductions,
- road pricing can change drivers' behaviour such as trip start times and route choice,
- the ETC experience from OSLO is that the public would gradually accept the automatic payment method once introduced.

May (1992) reviews the success of the introduction of congestion pricing from a policy viewpoint (eg Singapore, Randstad and Stockholm), technology led approach (Hong Kong), analysis led approach (London), demonstration approach (USA) and a revenue generation for infrastructure construction approach (Norway). He concludes the last approach appears to gain the most support, warning that the implementation of congestion pricing schemes must pay as much regard to public acceptability as to technical performance. This view is shared by Decorla-Souza and Kane (1992).

Road pricing and "level of service"

The acceptance of road pricing is related to the "level of service" provided by the road system. Clearly the developments in electronic road pricing have reduced the time impedance associated with collecting tolls. The remaining decrease in the "level of service" of the road system is the toll itself. This toll may be used to internalise external costs or pay for infrastructure development. It will be compensated for by decreases in travel time and fuel consumption. Drivers will be asked to weigh up the increased "level of service" related to improved traffic conditions with the cost of the toll. The improved travel conditions will result from the increased capacity of the infrastructure. Taken from another point of view, Jones (1992) points to road pricing's potential as a traffic restraint measure.

It is important to assess the potential implications of fixed rate tolls on roads with varying "level of service" at different times of the day. Whilst motorists may willingly pay for increased "level of service" during peak times (when the difference in "level of service" is likely to be greatest), they may question the value during non-peak times. This may lead to the congestion of alternative routes, reducing the "level of service" of people who cannot pay the tolls.

IMPACT OF URBAN FORM

The previous discussion has looked at the definition of the "level of service" of road systems and the role of road pricing in this measure. However, the "level of service" of the road system is one part of the "quality of life" in urban and rural areas. Residents in urban areas have varying acceptance thresholds of the "level of service" of the transport system depending on the perceived quality of other dimensions of the "quality of life". Residents can react
cities in a number of ways:

- They can accept it and go about their activities. This adaptation may mean a reduction in the ability to undertake all activities or a rescheduling of particular tasks.
- They can choose not to travel or rationalise their travel activities by undertaking particular activities at the same time or location. This may incur increased cost.
- They can relocate their home, work or recreational activities. If employment is allowed to relocate to residential areas, this can occur.

Improved road systems have resulted in more goods being moved by road and increased flexibility in the choice of where people live and work. Telecommuting can influence the choice of location. These changes must be part of a larger urban framework.

A number of studies have examined the trip making characteristics of travellers (eg. Daly and Young 1996, Kumar and Levinson, 1995). Brotchie (1984) found that Melbourne had three different city structures within its boundaries. There was the city centre structure where people were drawn from all over Melbourne to work and shop in the centre. There was the suburban precincts where a large proportion of people work and shop in close proximity to home. The last group was the urban fringe where people drove to work and shop in suburbs closer to the city centre. This pattern of behaviour is supported and guided by the road system.

Acceptance of road pricing as a mechanism for allocating the scarce resource of transport infrastructure is a policy decision. It has, however, been shown in the previous paragraphs that the urban system is a complex interaction of many factors. The “level of service” of the road system is but one aspect of the “quality of life” of urban areas. It is therefore essential that urban and rural policy be co-ordinated to attain the required results. If they do not support one another then little will be achieved.

CONCLUSION

This paper has looked at the “level of service” provided by the transport system in the context of new technological developments to collect urban tolls. The paper addresses the definition of the “level of service” and its quantification concluding that more effort needs to be put on the quantification of the weighting given to the cost of travel. The technological developments in tolling and congestion pricing are then reviewed with the intention of determining the feasibility of collecting tolls without impedance to vehicles. The paper concludes with consideration of the broader urban impacts of tolling.

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