MEASURING SYSTEM PERFORMANCE OF ROAD USER CHARGING SCHEMES

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ABSTRACT

Road user charging (RUC) is a relatively new term that embraces all policies that charge for road space. In popular literature the term 'tolling' is often used as a generalisation to cover demand management as well as funding the development and operation of new infrastructure. This confusion extends to the measures by which the performance of charging schemes is assessed. Applying the same measures to schemes that have different policy objectives for the purposes of comparison or to develop a business case for the scheme risks introducing large errors and consequently suboptimal decisions on scheme design and operation.

This paper describes the different policy options, their respective strategic objectives and introduces performance measures for each. Common misconceptions are explored and alternative suggestions are made to improve the accuracy by which some performance measures can be compared even if the underlying objectives are different.

The techniques are applicable to RUC scheme designers and organisations that wish to assess scheme efficiency and value for money.

Keywords: *Road User Charging, Public Acceptance, Policy*

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Road User Charging

Road user charging is now on the political and public agenda of governments and regional authorities worldwide although charging for road use is by no means a new concept. Toll roads can be traced back to at least Roman times, where travellers paid a fee for using a road/track maintained (and in many cases protected) by the authorities of the day. Across the world today toll-roads make up a significant proportion of the arterial road networks, and in many countries the tolling of estuarial crossings and tunnels is commonplace.

Tolling is essentially the recovery of a fee from users of a facility to cover the capital building, operation and maintenance costs of the road. In many cases toll roads have been given to private operators to Design, Build, Finance and Operate (DBFO) or to operate as a concession for a particular period of time. Other schemes may have a more demand management-led set of objectives, of managing travel demand by car and the consequential congestion when demand (for travel by car) out-strips the supply (of road space). So it is clear that the policies of road user charging could differ by location and by road type. Over time the policies of road user charging may change, for example from no charging (free at the point of use) to area-wide charging or perhaps the addition of a single charged-for High Occupancy & Toll (HOT) lane alongside general travel lanes.

The policy objectives of each scheme will be different so it is reasonable to assume that the measures of success for each policy will be different. This paper identifies the various feasible policy options and progressively links them to metrics and performance measures by which a charging scheme can be rated for its efficiency and attainment of scheme objectives. An understanding of these measures and when they should and should not apply can help scheme designers make investment decisions, enable the value of third party services to be assessed alongside internally-developed services (e.g. the 'make / buy decision), enable schemes to be compared and measure the incremental cost of adding a charged road or area into an existing network of charged roads or areas.

Policy Options

Tolls are becoming increasingly recognised as an acceptable method of funding infrastructure developments. Innovative debt/equity funding mechanisms have put the private sector closer to the heart of many road building programmes in North America, Australasia, SE Asia, India, China, South America and Europe.

Replacing the dwindling contribution that fuel taxation makes to the development and

maintenance of the road network is prompting governments to consider alternative funding mechanisms. The imposition of fuel duty ('gas tax') was innovative in the early parts of the 20th Century but changing travel behaviour, increased fuel efficiency coupled with increasing average journey lengths is slowly loosening the relevance of a consumption tax on fuel. Fuel duty replacement mechanisms could conceivably be based on a charging strategy that introduces a closer dependency between distance travelled and the charge for all vehicles.

Congestion charging, whether this is applied to a single link or a road network, aims to manage traffic demand and maintain an expected quality of service for road users of all modes, whether travelling by public transport, private car or commercial vehicle. The relationship between traffic demand and flow rate is traditionally described by the 'c-curve'. Here, as in many examples, road performance is measured in terms of 'vehicles / hour' and the demand management objective may be described by maximising this, typically used by Value Pricing schemes in the US for interurban highways where road users are offered the use of a road segment that (usually) guarantees a specific service level such as the time to travel on the road segment.

However the objectives of a congestion charging scheme may alternatively be described as reduction of congestion or alternatively, reduction of the mean segment delay time. Transport for London measures congestion within the London Congestion Charging Zone by comparing link time at periods of no congestion (i.e. 04.00 in the morning) and link times under daytime congestion conditions. Daily demand is measured by the quantity of vehicles that cross the boundary of the zone. This measure would be more appropriate to a road network where there are many possible travel paths.

There are frequent examples of schemes being compared by their relative operating cost. Again this is fraught with difficulty, prone to large errors, can lead to unfair comparisons and in the worst case could lead to the wrong charging policy being chosen. The usual comparison is the ratio (operating costs / revenues) so let us consider the contributors to each of these factors:

(a) Operating costs

Operating cost drivers include the following:

- Volume (economies of scale: lots of similar activities),
- Volume (economies of scope: diversity such as payment channel options, account types, complexity of discount structure, etc.),
- Whether or not the cost of enforcement is included,
- The proportion of services provided internally,
- Investment decisions to achieve high or moderate levels of compliance,
- Accounting treatment (amortisation) of scheme development, and;
- Cost of enforcement (related to choice of civil or criminal regime).

(b) Revenue

The drivers of revenue include the following:

- Charging policy (high charges versus low charges); to collect tolls to pay for infrastructure build/operations or to elicit change in road user behaviour,
- Demand and willingness to pay charges for services received (elasticity of demand), and;
- Whether or not enforcement revenues are included (accounting policy)

Furthermore, comparing an area pricing scheme such as the London Congestion Charging scheme with the German LKW truck tolling scheme with simple cost/revenue measures is therefore inappropriate; Transport for London aggregates all revenues and costs whereas the public reports for the German LKW heavy goods vehicle tolling scheme and Stockholm Congestion Charging Scheme do not include any figures relating to the operating cost and fees collected from enforcement.

There are many examples of historically useful measures derived from the era of toll collection being applied to new charging policies aimed at widely different objectives. However, the absence of disclosure from many public agencies worldwide, prevents an accurate assessment and often leads to these overly-simplified comparative measures being used. A new approach is needed.

There are several categories of measures, each corresponding to an entity within the RUC domain: the organisations:

- internal: process and inter-process interfaces,
- external: road network,
- external: user
- external: vehicle

Each is outlined below. The external: user and external: vehicle costs will be elaborated further in the final version of the paper.

Internal: Process and Inter-process Costs

From the perspective of an authority that provides charging and enforcement services, Fig 1 below highlights the internal and external interfaces to payment channels, customers and the generation and collection of charging and enforcement records. The performance of each of the internal and external interfaces can be measured. For example, at the design stage of a central system serving a single charged road network it may be feasible to procure services externally. So, knowing the cost to handle a low volume of complex enquiries by telephone may suggest internalising this service when the costs of training are considered. Handling routine payments for the most common class of vehicle using a call centre (not the lowest cost option) may suggest subcontracting this to capture the benefits of economies of scale

that a specialist service provider could offer. The ability to buy services rather than develop them internally could enable smaller charging schemes to increase their economic viability. A charge required to modify travel behaviour was small (i.e. responsive to price) may be too low to justify an internal development of many of the back office services. Increasing the charge to cover development costs is likely to be unjustified and could reduce public acceptability. This is typically referred to as the 'make / buy' decision – here applied to back office services – and may be critical to scheme viability. So, an understanding of process costs and ongoing monitoring of them is also important.

Other internal process costs include:

- Operating cost / account / period
- Average revenue recovered for each penalty / fine levied
- Quantity of incorrectly targeted account holders / road users
- Routine enquiry through call centre / minute or per call

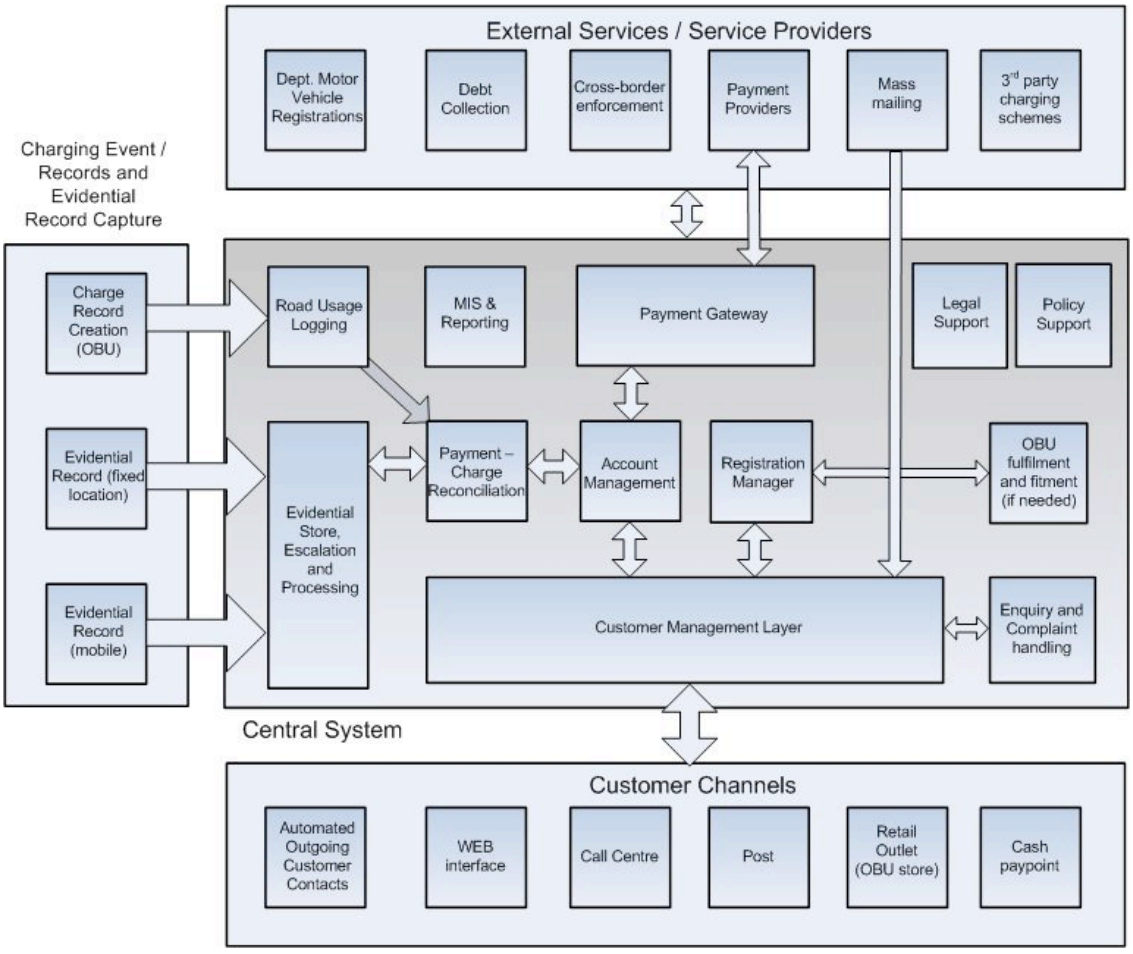

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Fig 1. Functional Organisation of a Charging Authority

External: Costs

External costs are the most widely reported, typically vehicle volumes. Other measures are included in annual reports. In any case the external costs also reflect the type of charging policy. So it makes sense to make some comparisons within the same category of charging policy and others between schemes that operate different policies.

The performance measures that relate to the user, road network and vehicle are described below

External: User

Costs that relate to the user interaction with a scheme include:

- The cost to the user to pay the charge (excluding opportunity cost)
- The full cost to the user to pay the charge including opportunity cost)
- Cost / enquiry / enquiry channel
- Cost / payment event / type of payment channel

One of the objectives of any charging scheme is to make it easy for account holders to interface with a scheme. Typically the costs to an operator for each payment transaction are used to make investment decisions on sizing the payment channels – the true cost of the payment transaction to an account holder is either forgotten, ignored or assumed to be equal to the payment itself. Table 1 below highlights this point.

Traditional View	New View
Cost to a user = the value of the payment i.e. the user pays $20 into an account using a retail outlet. The cost to the user is assumed to be $20. The cost to the operator is the credit card company fee (i.e. 1.5% / credit card transaction)	Cost to an account holder = the opportunity cost of the time taken to make the payment, accessibility to the account holder and need for specialised equipment (mobile phone or computer terminal). The cost to the operator is the credit card company fee (i.e. 1.5% / credit card transaction).

Table 1: Cost to the user and operator for a payment transaction

A web-based payment front end that takes 4 minutes for each journey has a higher opportunity cost than a method that takes 3 minutes and/or allows payments to be made for multiple journeys. Currently the German and Swiss heavy good vehicle charging schemes have alternative manual payment methods based on retail and roadside terminals. These terminals have a higher cost per transaction than an equivalent web-based or vehicle equipment -based method but do have the advantage that no specialised interface or in-vehicle equipment is needed.

In general, encouraging a migration to means of payment that has lower transaction costs increases the economic viability of a scheme whether this is for demand management or toll collection. Logically, if payment by cash is required then, as the demand for cash payment declines, it may make economic sense to consolidate cash payment through fewer channels and different charging policy. For example, migrating cash-payment at every toll plaza to a daily fee, enforced through Automatic Number Plate Recognition (ANPR) at each toll plaza.

Typically, the transaction cost of a payment made to cover road usage (regardless of the underlying policy) ignores the opportunity cost to the user. This may include waiting time at a toll plaza to pay cash at an Automatic Coin Machine (ACM) or toll booth attendant. A detailed assessment would also consider the relative opportunity costs for different categories of road users, handling cost of cash and increased emissions and generation of particulates due to braking and accelerating into and out of a toll lane. Knowing how to measure the performance of a scheme may help explain the benefits of moving to a new means of revenue collection or revised charging policy. [1]

External: Vehicle

There are costs that relate to vehicles that participate frequently or occasionally in the scheme.

- Cost to equip each vehicle (excluding opportunity cost), may be zero if provided by another authority offering contractual interoperability.
- Cost to equip each vehicle (including the opportunity cost), may be zero if provided by another authority offering contractual interoperability.
- Quantity of vehicle classifications (and proportion of measurable and non-measurable), the greater the number of vehicle classification the greater the complexity of the vehicle detection system and potentially the higher probability of errors.
- Transaction cost (vehicle detection event)/ vehicle entry into charged area (or passage through an ETC-equipped toll plaza)
- Reporting cost / event (e.g. distance-based charging) via a cellular connection (eg German LKW scheme) or Integrated Chip Card (e.g. Swiss LSVA scheme)

The charging policy itself will define the options for measuring and capturing charging records. From a DSRC-led beginning, currently the two preferred charging technologies are DSRC (microwave in-vehicle tags communicating with roadside antennas) and satellite-based location system that locates the position of the vehicle on an on-board digital map and charges the vehicle appropriately, in charged areas, based upon cordon, point or distance based charging. However, harnessing the intelligence and communications options offered by mobile wireless networks, RFID, mobile phone technology or camera-based ANPR solutions may also be appropriate to support future nationwide road pricing solutions. Each of these technologies has a 'cost' – not only the acquisition and operations cost but its lifetime cost.

A concession operator with a planning horizon of 30 years will increase the value of its technology investments if the long run cost is reduced with consequent enhancements in quality of service provided. These investments may be prohibitive if the planning horizon was shorter. Similarly an operator may not need to invest as much in vehicle equipment if there is a critical mass of equipped vehicles / account holders already available. In the future a mandatory national road user charging scheme that replaces fuel tax with a distance-based charge will enable local charging schemes to be provided at lower cost per vehicle or account than a pioneer scheme setting up in isolation. Effectively the economics of an individual scheme can be impacted favourably by a national approach to road user charging.

External: Road Network

The most common measure of road network performance is the flow rate. The performance of an ETC lane can be measured in vehicles / hour, ranging upto 800 vehicles / hour / lane. There are generally two measures of road network performance relevant to charging – the choice depends on the charging policy:

- Number of vehicles / hour passing a defined point, applicable to urban charging schemes (toll ring, cordon or area pricing) for a complex road network
- Link time under congested conditions / link time under non-congested conditions applicable to easily identifiable interurban road segments

One of the objectives of a demand management scheme is to change travel behaviour for the reasons stated above. The objective is not to reduce net accessibility for people or goods. So, a simple measure of the flow rate at one or more locations is not adequate. Vehicle occupancy, captured through roadside surveys and automatic counters on transit and metro schemes, will help present a complete picture of accessibility to the charged area by all modes. Counting vehicles will show a reduction in demand but, by definition, this cannot represent a useful measure of accessibility of people (as a measure of economic and social well-being). However, a reduction in commercial vehicles entering the zone (net of those that only transit through the zone) is undesirable since this reflects a reduction in economic generating capacity for the charged area. Note that if charging period is limited to a few hours per day the measuring period needs to be longer than this since demand management using pricing will also induce some demand to be shifted outside of the charging hours (e.g. it is recommended that measurements are made 24/7, including weekends if charging is limited to weekdays only).

The measurement of flow rate past a point does have other uses, however. A GNSS-based charging scheme also requires enforcement, typically a mix of mobile enforcement and fixed enforcement. A fixed enforcement point that is located on a strategic interurban highway is likely to have lower lifetime and operating costs than a mobile enforcement system at the same location. Mobile enforcement is flexible and can be deployed at most locations but, depending on enforcement technology used may have reduced road coverage than a fixed multi-lane solution particularly if roadside cameras are used as part of an evidential

enforcement strategy. In this case, an understanding of the cost drivers and appropriate performance metrics is critical to help decide whether fixed or mobile enforcement is needed and its cost of use

Additionally, the concentration of harmful emissions (NOx, PM10, etc.) and noise (frequency band, amplitude and randomness) is also a useful measure, particularly if the reduction in concentration of harmful emissions or perceived noise levels are scheme operating objectives [2].

The Future

It is expected that the intelligence available in the future will enable innovative forms of road pricing that could have a significant demand restraining effect to provide an additional tool to deal with traffic congestion. As the charging policies become more complex and the underlying processes that generate charging transactions become more complex then policy and scale-specific metrics will be needed.

Summary and Conclusions

The charging policy and scale of operations are the two most important measures of a charging scheme. As the complexity of charging policies increases and as schemes become more interconnected through interoperability agreement then the traditional measures of performance become increasingly irrelevant and comparisons become increasingly tenuous. A Value Pricing Scheme aimed at delivering a predictable level of road network performance to a road user (for which the user pays a free) is not directly comparable to an area pricing scheme that has, as its primary objective to reduce demand and reduce travel times across the road network. Several performance measures were identified and classified into one of four categories; internal interfaces, external user-related, external road network-related and external vehicle-related.

It is only when these measures are recognised and identified can they be used to make investment decisions and, to the extent to which they are disclosed, can be used to compare scheme along relevant dimensions.

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