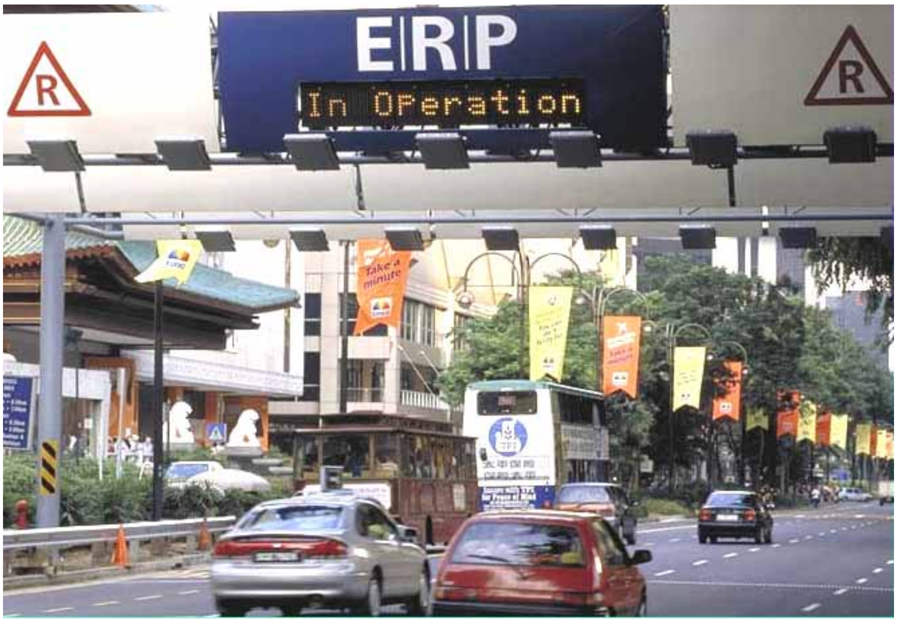
CONGESTION AND ROAD PRICING

Reference Material
for
COMPETENCE



COMPETENCE

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The aim of this material is to strengthen the knowledge of local / regional managing agencies in the transport field and to accelerate the take up of EU research results in the field of local and regional transport. The beneficiaries of the project are managing (energy) agencies who want to play a bigger role in the transport field.

Due to the size and (in some cases) the number of individual projects, it is not possible to explain each single result in detail and include it into these written materials. The following set of material should rather act as a portal and facilitate the access of single projects and detailed results. Therefore the material in hand doesn't lay claim to completeness.

The following compendium contains results of EU research-projects and complementary results of national research-projects. A complete list of the projects, consortia, and cited literature is given at the end of the material.

The material for the topic **"Congestion and Road Pricing"** was compiled by Tom RYE (Napier University, Edinburgh) for the STEER training project COMPETENCE in 2006.

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1. Introduction

The issue of charging more directly for the use of roads has become the subject of heated debate in recent years. But, as we shall see, the concept of charging directly for use of congested road space has been under consideration for many years. The early discussions were very much led by economic theory – applying market pricing to the allocation of a scarce resource. In recent years, in some countries, the issue has also been tied into the discussion on how the improvement of our transport networks can be funded outside the inadequate budgets allocated from general taxation.

This part of COMPETENCE uses experience from European research projects and actual schemes that have been implemented to consider the following issues:

- The core economic principles of road pricing/congestion charging.
- Basic definitions of different types of scheme.
- The technological aspects of congestion charging/pricing schemes.
- The policy context for pricing.
- Why schemes are implemented and what they are supposed to achieve.
- How to maximise the chances of a scheme being implemented, with particular reference to public acceptability.
- Some case studies of schemes that have been implemented, and some that have been planned but not implemented, together with an analysis of the reasons for their (non-) implementation.

Because the author is from the UK there is considerable detail provided on certain UK schemes. This is also because they are excellent and instructive examples of congestion charging in practice, and in the design stage. However, considerable experience from other parts of Europe and the rest of the world is reviewed as well. The material draws heavily on recent European Commission research projects in the area, including IMPRINT, CUPID, PROGRESS and EUROPRICE.

Learning outcomes

Once you have worked your way through this material, including the activities, you should be able to:

- explain the economic principles behind the theory of road pricing;
- summarise the various methods of road pricing and the technology associated with these;
- identify the advantages and disadvantages of each method;
- summarise the key elements of existing and proposed congestion charging schemes in Europe and elsewhere; and
- Understand the key barriers to the implementation of charging schemes, and steps that can be taken to reduce/eliminate these barriers.

1.1 Background

Paying for the use of roads is not a new concept. Indeed, it could be argued that the development of the first national road network in Britain (since Roman times) was achieved through the introduction of the turnpike system in the second half of the 18th century. It is worth noting, however, that the administration of the system had become so corrupt by the middle of the 19th century that in parts of the country the 'Daughters of Rebecca'[1] attacked and destroyed a number of the toll gates, in some cases killing or injuring the gate keepers – this illustrates some of the problems of the acceptability of pricing, which we will return to later (although the author is not aware of any 20th or 21st century examples of revenge killings of advocates and planners of pricing schemes, so you should not be overly afraid if you are planning one!) . More recently, in France and Italy, the motorway networks of those countries have been developed as toll-road systems. It has also been common practice to levy tolls on estuarial crossings (bridges and tunnels).

It is important here to note a first key definition. Congestion charging/road pricing normally refers to the application of a charge to use an *existing* road. If a road is built and, as soon as it opens, a charge is made for its use to recoup all or part of the construction costs, then this is tolling, but not really road pricing/congestion charging in the sense of applying a charge to *manage demand* for that road. Also, applying charges only to newly-built roads, but as soon as they open, is much more publicly acceptable than applying it to existing roads since, in the former case, people will not feel that they are having to pay a charge for something that they previously got for nothing.

A second key definition involves types of charging. There are basically three types of charge:

- A cordon or point-based charge – traffic entering a defined area or passing a point has to pay at the point of passing/entry.
- An area licence – traffic entering an area, but also driving within it, must pay a charge.
- Distance/speed based charging – vehicles pay according to how far they travel within a defined area and this may be refined by relating the charge also to the speed of travel, on the assumption that slower speeds indicate more congested areas, which would be more costly, because external costs of congestion (see below for a definition) are higher in congested areas.

Since the Second World War – with the exception of estuarial crossings – the assumption in most northern European countries (with the notable exception of France's *autoroutes*) has been that funding of the road network is the responsibility of central and local government through general taxation, and there has been little political discussion of charging for the use of existing roads (as opposed to charging a toll on a new road or bridge to repay its construction costs). However, the concept of charging road users more directly has been discussed by transport economists since the late 1950s. In the period between 1954 and 1963 academics such as Roth,[2] Walters,[3] Beesley[4] and Thompson[5] exchanged papers on the economic theory of charging for roads – to move the price charged closer to the full cost of road use, including externalities (see below for a fuller discussion of the economics of charging). In spite of this academic interest, which has not ceased since these

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[1] The 'Daughters of Rebecca' were a direct action group of farmers and others who dressed as women to avoid recognition! Nothing changes!

[2] See G J Roth (1959) 'Economic benefits to be obtained from road improvements with special reference to vehicle operating costs' RRL Report No. RN 3426, unpublished; G J Roth (1962) 'Pricing the use of roads: potential gains available in Cambridge' *Aspect* Vol.1, No.3

[3] A A Walters (April 1954) 'Track costs and motor taxation' *Journal of Industrial Economics*; A A Walters (1961) 'The theory and measurement of private and social cost of highway congestion' *Econometrica* Vol.29, No.4

[4] M E Beesley and G J Roth (1962) 'Restraint of traffic in congested areas' *Town Planning Review*

[5] J M Thomson (1963) 'Economic effects of road pricing upon the Central London bus fleet' RRL Paper PRP 33, unpublished

first exchanges, the number of schemes actually implemented has been very limited. Very briefly, these include (more details are provided in the final chapter of these notes):

- Supplementary licensing – Singapore introduced a system of supplementary licensing in 1975 for its Central Business District (CBD) and then, later, on a number of key traffic routes. Those who wished to drive on the priced roads at times when the prices applied had to buy and display a paper licence.

- Manual cordon charging – a point pricing system which can be applied to a single zone with charging via toll booths and reserved lanes. The City of Bergen in Norway introduced a toll ring in 1986 with the main objective of funding by-pass roads for this historic city.

- Cordon charging with automatic scanning and automatic vehicle identification – this system requires all vehicles to carry an electronic identity tag, which is "read" by roadside equipment. Stockholm has very recently implemented such a scheme – it began on an experimental basis on 3rd January 2006 (and its continuation is subject to a referendum). Details (in English) are available at http://www.stockholmsforsoket.se/templates/page.aspx?id=2453
- Cordon or point-based charging with automatic scanning and manual payment as well– Oslo and Trondheim have introduced mixed control systems to avoid the difficulty of catering for non-local traffic.
- Area licence enforced by Automatic Number Plate Recognition (APNR) technology – this scheme was introduced with a £5 (€7.50) weekday charge in central London in February 2003, and was due to be extended in late 2006. It has been more successful in reducing traffic than was predicted, and has consequently also raised less money than was predicted.
- Traffic limited zones in Italy. Several Italian cities, including Milan, Bologna and Rome have declared part of the centres of their cities as traffic limited zones. Originally, at certain times of day/days of the week, most traffic was barred from entering the zones. Residents and businesses received an entry permit. There is now an increasing trend to refine the operation of these zones by selling further permits. Hence schemes that were originally traffic management measures have evolved into something resembling a congestion charging scheme.

It can be seen from these examples that there are cases where cities charge for the use of existing roads. However, these examples are few and far between. In this Unit, as well as looking at the methods by which people can be charged for road use, we will also examine the barriers to implementing such schemes and how these can be overcome.

1.2 The economic theory

Congestion may be said to occur when one road user impedes the movement of another. On highly congested roads one driver may cause inconvenience and delay to many others. For example, cars slow each other down, pedestrians slow down cars and fast-moving vehicles delay pedestrians or impose diversions on them. Over the years, a variety of traffic-management measures and capital project schemes have been implemented to regulate these conflicts, such as traffic lights, pedestrian crossings, underpasses, cycle lanes, bus lanes, double yellow lines and red routes as well as major road-building schemes. However, experience has shown that improved traffic capacity is quickly filled up by increased demand. The classic state is one where traffic volumes adjust to an acceptable level of congestion (or inefficiency).

The economic concepts of road pricing were set out in the Smeed Report[6] and were explained in this way.

Marginal cost

Considering a particular road which permits vehicles to undertake a specific journey from a point X to another point Y. The service which the road supplies (including such lighting, traffic control, cleaning maintenance, and so on as are provided) is the facility for the vehicles, together with their passengers and other contents, to make the journey from X to Y.

We make the following simplifying assumptions:

- all vehicles make the same journey
- all vehicles using the road are identical and are driven in an identical manner so that in any given set of conditions the costs associated with their use are identical
- the influence upon traffic speed of all factors other than the number of vehicles, such as pedestrians or weather conditions, or spacing of vehicles, is constant and may be regarded as one of the permanent characteristics of the road determining its speed/flow relationships.

If there is no tax of any sort, and if n vehicles per hour make the journey in t minutes each, the costs incurred are:

$$nf(t) = r(n) = s(n)$$

where f(t) represents the operating costs of each vehicle, as a function of time, and r(n) represents the road maintenance costs and s(n) represents other social costs such as the effects of noise, dirt and fumes. It may be noted that these costs do not include the original costs of building the road or any other costs which are not affected by the volume of traffic which now uses the road.

If the flow of vehicles increases to n+1 per hour and the journey time for each vehicle consequently rises from t to t^1 the total costs increase to $(n+1)f(t^1) + r(n+1) + s(n+1)$. Thus the increase in total costs is:

$$(n+1)f(t^1) - nf(t) + r(n+1) - r(n) + s(n+1) - s(n)$$

This is the marginal cost at (n+1) vehicles per hour.

Private and public cost

Now for the sake of simplicity, let us assume that the differences $r(n+1) - r(n)$ and $s(n+1) - s(n)$ are both negligible when n is large, although this may not always be valid. Then marginal cost equals

$(n+1)f(t^1) – nf(t)$. This is the cost that could be avoided if any one vehicle refrained from making the journey. But the cost actually borne by each vehicle, if there is no tax, is only $f(t^1)$ which is less than the costs it causes by an amount $n[f(t^1) – f(t)]$. This is sometimes called the difference between private and public cost. According to the theory, unless some added constraint is exercised journeys will be made which are valued at more than the private cost but less than the public cost. A tax may provide the added restraint.

Diagrammatic demonstration

The theory may be demonstrated by means of a diagram, Figure 1, as in Beesley and Roth.[7] Three variables are represented. First, the average cost curve shows the sum of the avoidable vehicle operating and road costs, for a journey, at different volumes of traffic, ie vehicle flows. As the flow increases, after a certain point speed declines and costs rise. (At some extreme point there is a maximum possible flow and it is believed that, if the number of vehicles trying to use the road exceeds this maximum, it can lead to an actual flow less than the maximum. Hence the cost curve will turn back at this point. But this is irrelevant to the argument.)

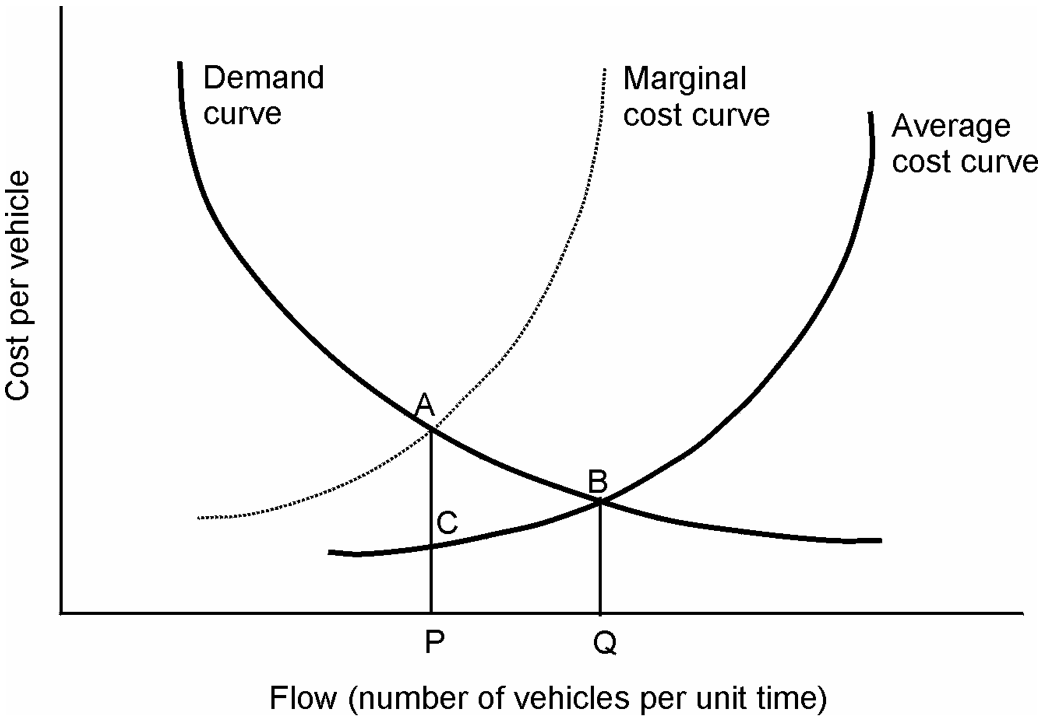

Figure 1 Cost/flow curves

Road users pay their own operating costs, which for the sake of simplicity are assumed to be equal for all vehicles, and we shall now also assume that they pay their part of road costs through fuel tax. Then, if no additional charge is made, the price of a journey which each vehicle has to pay is the sum of its own operating costs and its contribution to road costs, ie the average cost. As the price rises, the number of vehicles that will make the journey declines, and this is represented by

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[6] Ministry of Transport (1964) *Road Pricing: the economic and technical possibilities* (The Smeed Report) (HMSO)
[7] M E Beesley and G J Roth (October 1962) ‘Restraint of traffic in congested areas’ *Town Planning Review*

the demand curve. The position of equilibrium is indicated at the point of intersection B, between the demand curve and the average cost curve, where the flow is Q.

The third curve, the marginal cost curve, shows the marginal cost at different levels of flow, ie the increase in total costs caused by the addition of each extra vehicle. It is evident that, as the flow increases, each extra vehicle adds more to the total cost than it pays and, when the flow exceeds P, there are some vehicles which are not willing to pay the costs they cause. If a charge CA reduces the flow of traffic from Q to P, where the demand curve intersects the marginal cost curve, journeys will not be made unless they are valued at more than the cost they cause.

Variations between vehicles

In the above argument it was assumed that all vehicles were identical and that their costs in any given set of conditions were also identical. If that assumption is withdrawn it is clear that the cost per mile caused by one vehicle can vary considerably from that of other vehicles. If the same price per mile is charged to all vehicles, some will pay more than the costs they cause and others less. (It is sometimes useful to measure costs and prices in units of time rather than of distance since a price per minute will usually give a closer approximation to cost than will a price per mile.)

The inefficiency of charging all vehicles the same price clearly varies with the extent to which individual vehicle costs vary. One way of reducing this inefficiency is to classify the vehicle population (into, say, cars, motorcycles, taxis, lorries of various sizes, etc.) and to charge each vehicle according to its class. There may be other reasons too for wanting to charge one class of vehicles more than another.

Variability of other factors

The assumptions have excluded the effect on journey costs of fluctuations in external factors, such as pedestrians and weather, and also of fluctuations in the timing of journeys themselves. The occurrence of these factors can at any time cause journey costs to be higher or lower than normal. Many fluctuations are unpredictable and unavoidable. But many others are predictable and can, in theory, be allowed for in the setting of prices. For instance, hourly, daily and seasonal fluctuations are largely predictable both as regards the volume and composition of traffic demand and the degree of interruption to be expected from pedestrians and other factors. Nevertheless, insofar as such fluctuations occur and are not allowed for, further inefficiencies may occur.

Recovery of total costs

In some circumstances it may be perceived to be necessary to recover total costs, including original building costs, or to contribute towards general taxation. If prices are made equal to marginal cost, the total revenue obtained may fall short of the required amount. It may be necessary to avoid either a surplus or a deficit and this probably cannot be done without causing a divergence between price and marginal cost and hence some shift in the use of resources. There are, however, several different methods of increasing revenue, and some methods cause a smaller shift than others in the use of resources. A deficit may sometimes be recovered simply by raising prices, or by price discrimination, or by various kinds of indirect prices or taxes, the choice of the method depending upon the circumstances and, in particular, upon the complex of demand elasticities.

Economic theory: conclusions

The foregoing has tried to distinguish between road costs and vehicle-operating costs, although both groups of costs are equally essential to the production of journeys. The reason for the distinction is simply that the first group, road costs, are usually paid by agencies which manage the road infrastructure while the second group, the vehicle-operating costs, are usually paid direct by the consumer. This unusual division of responsibility for the costs causes much confusion about road pricing. It is helpful to think of a situation similar to that on the railways in which the management of the road also owns all the vehicles and pays all the drivers. They, the management, are then required to take account of the marginal cost of journeys, ie the effect of each additional journey on the costs of the whole enterprise, and will try to prevent journeys taking place which do not yield a return at least equal to their marginal cost, unless there are special circumstances.

The most efficient price system might appear to be one in which price varies with cost on every road at every moment of the day. But this presupposes that road users are able and willing to take account of such a highly complicated system. In practice, of course, they are not. If the price system is complicated road users will probably find simple 'rule of thumb' methods to tell them approximately what the average prices are and roughly what the prices of particular journeys are likely to be, and they will act accordingly. If this is the case the complicated system will be no more efficient than a simpler one.

Post script

That was how the economic argument was put in the 1960s. Since that time whilst the economic principles have not changed, many other things have. Back in the 1960s the concept was one of adjusting the taxation system to ensure that the public costs imposed by congestion were understood by individuals and behaviour modified accordingly. In this way, use of roads would be adjusted to an optimal (non-congested) level. In recent years however, some practical applications of road pricing have adopted a sub-optimal pricing level (ie one that does not eliminate congestion). In these applications the scheme objective has primarily been revenue generation to fund general transport expenditure.

2. Types of scheme and technologies used

2.1 Introduction

As you will see in the next chapter, there are often different objectives for a scheme and these will influence the type of scheme chosen, and the technology used to operate and enforce it. In addition, there is an interrelationship between how a scheme works, and its acceptability to the public. For example, a pilot scheme in Hong Kong encountered acceptability problems because it was perceived to be too much of an invasion of privacy (since it tracked individual road users) (Ison and Rye, 2005). In turn, it is also worth noting that technology acts as a constraint on the type of scheme that can be implemented. For example, an economically optimal pricing scheme that charges users a different rate per km depending on how congested are the roads on which they are driving at that time is, at present, not possible because the technology – although it exists - is not reliable enough.

In this section we review briefly types of scheme and the way they are operated and enforced, concentrating in the main on schemes that are actually in operation.

2.2 Basic definitions

Charging schemes fall into four main categories:

- An area licence – a charge is levied for driving within a defined area (e.g. London).
- A point charge – a charge is levied when a driver passes a point or crosses a cordon or screenline(s) (e.g. Trondheim, Singapore CBD).
- Distance based charge – the user pays according to how far they travel within a charged area, with a possible variation in charge depending on levels of congestion. (There are currently no such schemes available although one is planned for trucks in Germany; however, the rate paid there would not vary in real time with congestion levels. The UK transport minister has expressed a desire to see such a scheme in the UK in the next 10-15 years.)
- Traffic limited zone with the sale of licences for certain users.

Charges can be levied and collected in a number of ways – and different means of charging can be used with schemes in the different categories listed above. These methods (which are not mutually exclusive – they may in some cases be combined) include:

- Manual collection of the point charge at the entry point into (or out of) the area, or use of a coin-operated barrier (e.g. Durham, UK; Trondheim, Norway (in part)).
- Decrementing smart-card – this communicates with roadside equipment and a charge is deducted from the smart-card when the vehicle passes a charging point, enters a charged area, or when its speed falls below a certain level (e.g. Singapore (charging point); as proposed in Cambridge (speed-related)).
- Once payment has been received, registration of the vehicle details on a database. When enforcement equipment recognises the vehicle, it is registered on the system as having paid, and no further action is taken (e.g. London).

- Electronic tagging of the vehicle and the dispatch of a monthly bill to the owner depending on the number of times the vehicle has passed a charging point/entered a charged zone that month (e.g. Stavanger, Norway).
- Paper licences similar to a parking permit (formerly, in Singapore), sold at various outlets.

Enforcement is usually carried out by means of a camera with APNR technology to record violators. However, manual enforcement must be employed for paper licences; and it is also used in London, to detect parked vehicles (in particular), that must be paid for even when they are parked on the public road. Enforcement of moving vehicles through numberplate recognition requires access to the national numberplate database so that the owner of the car can be identified and any necessary enforcement action taken against him or her.

There are a number of "back-office" functions such as maintenance of communication links, processing of payments and so on that are also required but are less critical to the design of the scheme than the previous points.

Means of payment

Certain means of payment have been listed above. Some schemes employ more means than those listed, however. For example, in London, it is possible to pay by direct debit, on the internet, by mobile phone, and at paypoints around the capital (which accept cash and credit cards). In general, the more forms of payment that are available, the more acceptable the scheme. It is notable that in London 50% of transactions are made at paypoints, meaning that it is impossible to trace the person paying (with other methods, they must register their details before using the scheme). Many users obviously prefer the anonymity as well as the convenience of the paypoints.

2.3 Conclusion

This section has very briefly considered some of the techological options available for congestion charging and pricing schemes. It is a fundamental point that the technology and enforcement of a congestion charging scheme will absorb a proportion of the revenue generated by the scheme. The more complex the technology and enforcement, then the larger the proportion of the scheme revenue that will be absorbed by its operating costs. When the London scheme charged £5/€7.50 (the charge has now increased to £8/€12), around half this charge was absorbed by operating costs (scheme start-up costs were paid separately, but were estimated at £200/€300 million (Ison and Rye, 2005). Thus, while a scheme with a wide variety of payment methods may be more acceptable from that point of view, it may be more costly to set up, a factor that might make it *less* acceptable than a scheme with a lower set-up cost but a smaller range of payment methods.

The Unit now continues to look at the policy context for schemes.

Task

Look once again at the University of Westminster Road User Charging Option Generator available at www.wmin.ac.uk/ruc. Use it to familiarise yourself with the different technologies available for charging.

3. Principles, policy context and objectives of road pricing schemes

3.1 Introduction

Vehicle users in many countries already pay significant sums for the use of their vehicles either directly or indirectly. The main direct charges are for fuel, parking and tolls for bridges. The indirect charges include vehicle excise duty, garaging and maintenance costs. Included within these are VAT and other government taxes on services. However, the current taxation system in many countries imposes charges on motorists in a way which bears little relation to the way in which they use their cars.

The Smeed Panel in the 1960s UK was specifically set up, by the government, to examine and report on alternative methods of levying taxation on road users so that any system employed could more accurately reflect the costs, to society at large, of individuals' trips. The existing taxes applied generally to the whole road network, and the Panel's work concentrated on the urban context. However, the principle of adjusting the taxation system so that it more accurately reflects the costs of providing infrastructure and the costs imposed by individual road users on the community at large, applies equally to inter-urban roads. The Smeed Report set out eight important requirements of a system of road pricing:

- Charges should be closely related to the amount of use made of roads.
- It should be possible to vary prices to some extent for different roads (or areas), at different times of day, week or year, and for different classes of vehicles.
- Prices should be stable and readily ascertainable by road users before they embark upon a journey.
- Payment in advance should be possible, although credit facilities may also be permissible under certain conditions.
- The incidence of the system upon individual road users should be accepted as fair.
- The method should be simple for road users to understand.
- Any equipment should have a high degree of reliability.
- It should be reasonably free from the possibility of fraud and evasion, both deliberate and unintentional.

Task

Read the document *PROGESS Project Deliverable D7.2 – Recommendations and Exploitation Practical Implementation Guide for Cities* from the EU Framework 5 Transport Research Programme.

Compare its recommendations with the principles of the Smeed report. Are there any that are different? Has the European research built significantly on the work of its predecessor 40 years before and, if so, in what ways?

3.2 Scheme objectives

As you will have seen from a number of the case studies in the final section of these notes, the objectives of road pricing schemes vary. Whilst the debate of the 1950s and 1960s may have been about the application of market pricing to achieve the optimum usage of city streets, much of the more recent discussion has centred on ways of funding transport facilities – in particular, alternatives to the car. The debate has also had an environmental dimension, in the belief that only serious curbs on the use of cars in cities will bring about the reduction in emissions sought by international treaties. Consequently, commentators such as Peter Jones[8] of the University of Westminster have argued that the motivation to introduce road pricing may lie in one or more of three broad objectives:

1. Congestion relief
2. Revenue raising
3. Environmental improvements.

The simplistic division between revenue raising and congestion management is unlikely to apply if the results from the schemes now operational in Europe can be generalized; some schemes (e.g. Durham, London) were intended to raise revenue but have affected demand more than expected with a consequently lower than anticipated revenue stream. Equally, although the third objective does not appear explicitly it is underlying the need to reduce congestion and demand for car travel.

Most cities which are considering road pricing, will require considerable investment to bring alternative forms of transport up to an acceptable standard. In these circumstances, local politicians are unlikely to be able to win support, in the short term, for a scheme which is sufficiently draconian to eliminate congestion altogether. In all probability, schemes will be hybrid and may well start life as revenue raising but move more towards congestion relief over time. The key elements of an urban road-pricing scheme which have to be considered when designing a scheme are:

1. Who should be charged?
2. When should they be charged?
3. Where should they be charged?
4. How should they be charged?

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[8] Peter Jones (January 1994) 'Achieving environmental goals through urban road pricing', Paper to IBG Conference, Nottingham. Searching for Peter Jones on Google, on www.sciencedirect.com, or on the Transport electronic database available on the http://nulis.ac.uk website (you will need an ATHENS login for both, available from the library support people) will reveal a multitude of papers by him and others on the important topic of the acceptability of congestion charging, as well as pretty much every other aspect of this topic, which has been "done to death" by transport academics. It is well worth reading one or two recent papers on acceptability aspects, however; and also something on the land-use impacts of congestion charging.

5. How much should they pay?
6. How does the combination of the above choices affect the acceptability of the scheme?
7. What should the charging authority do with the money?

The way in which the scheme design responds to the first five of these elements will determine the degree to which the scheme will lean towards revenue raising or congestion relief. In Table 1 the key characteristics of the two types of scheme are compared:

Congestion reduction	**Revenue raising**
1. Target parts of the network and time periods when heavily congested. 2. Limited spatially and temporally. 3. Boundaries of the charged area may be selected to encourage diversion. 4. Categories of vehicles may be exempt (buses and trucks). 5. Range of charging schemes proposed (point based, cordon, area length, congestion based). 6. Charges at high levels to achieve desired behavioural change.	7. Wide geographic and temporal coverage. 8. Fewer exemptions. 9. Geographical boundaries drawn to minimise the chance of traffic diverting. 10. Use of Area Licensing or cordon toll system. 11. Charges generally lower as there is political pressure not to change driver behaviour.
Equity issues	**Equity issues**
1. Necessary trips by poorer people priced off the network in favour of less essential trips by more affluent people. 2. Everyone is asked to pay the same regardless of income.	Not all drivers who will benefit from the road improvements are making a contribution towards the cost of construction. The charging mechanisms tend to be too crude to pick up all the trips made in the urban area (Oslo toll ring intercepts 40% of trips and the Trondheim toll ring a third. Consideration being given to a second ring).

Table 3.1 Congestion reduction and revenue-raising schemes compared

Very recent experience from the London scheme shows that it may have some perverse un-intended impacts. In the first 3 months of the scheme's operation, retail sales at major Oxford St department stores (within the charging zone) were down, compared with increases at other branches elsewhere in the Greater London area. If this effect continues, it may lead to relocation of retail activity to un-charged areas – which invariably are more difficult to serve with public transport. This effect has also been observed in Oslo to a limited extent.

If congestion charging has the effect of reducing the (perceived) accessibility of the charged area – which, invariably, is the city centre – then this can run directly counter to the land use policies of the city or region, and send development to peripheral un-charged areas that are accessible mainly by car. This potentially questions the wisdom of central area charging; perhaps it is congested peripheral areas (I am sure you can think of examples – shopping centres and/or business parks - in cities known to you) that should be charged (more?), and city centre traffic congestion dealt with using more conventional traffic restraint techniques such as parking charging. At present there is a danger that our land use policies could be undermined by charging policies, ultimately aiding urban dispersal and transport problems further out into urban regions.

Task

Try out the University of Westminster Road User Charging Option Generator available at www.wmin.ac.uk/ruc. Try to use it as if you were considering different options for a road user charging or congestion charging scheme for your town/city/area. Does it help you to select options in a rational way? Why or why not?

3.3 The policy and legal context – European and member states

The European Transport White Paper *Transport 2010 – Time to Decide*, issued in 2001, is clearly supportive of the concept of charging drivers for using roads, in line with the economic theory that is outlined in the following section of these notes. It identifies that Europe's roads suffer from the economic and environmental burden of congestion, that this is inefficient, and that the efficiency of the system can be raised by adopting the ”user pays” principle – that is, that the traveller should bear the full economic, social and environmental costs of their choice of mode. The implication of this approach is that some form of road user charging should be adopted so that those who choose to travel on the most congested roads at the most congested times will pay more than they do at present.

However, the European Transport White Paper is a policy statement issued by the European Commission, and does not necessarily reflect the views of the Parliament or the Council of Ministers. In the majority of member states at the present time there is no legislation in existence that permits local, regional or national authorities to introduce charging for existing roads. The European Commission has no plans at the present time to initiate a Directive that would require member states to pass legislation that would make congestion pricing legally possible (i.e. to give local or regional authorities that wanted to introduce it, the legal ability to do so – but not to *require* its implementation) in every member state. Some commentators have suggested that this is because the current Commissioner is not particularly keen on congestion charging, and also because many member state governments are not supportive (see for example van Elburg, 2002) and would thus oppose any such directive in the Council of Ministers. There is a new Directive which makes it impossible for member states to outlaw pricing of existing roads; but this is rather different from them having to pass legislation which would permit the pricing of urban roads.

Thus, at the current time, road pricing/congestion charging of existing roads (as opposed to the introduction of tolls to recoup the construction costs of new roads, which is normal in several member states) is a legal impossibility in the majority of member states. The UK, Norway, Italy and now Sweden *do* have legislation that would enable some form of congestion charging. The Swedish case is an interesting one: two years ago there was no enabling legislation in Sweden, but the County and city authorities in Stockholm wanted to introduce congestion charging in the Swedish capital. They were able to persuade the national parliament to pass enabling legislation, so they have now (2006) been able to implement their scheme. But there is no guarantee that regional and local authorities wanting to introduce congestion charging in other member states would be able to influence their national parliaments in this way – and, if they did not, then their plans for a congestion charge could fall at the first hurdle. Meanwhile, the Italian legislation theoretically permits congestion charging but the legal process required is extremely lengthy with much room for procrastination by politicians and civil servants who may disagree with a scheme.

European projects such as LEDA and COST342 have reviewed the transport policy objectives of national, regional and local governments across the EU. Generally, they find a remarkable similarity: such governments are attempting to improve road safety, enhance the accessibility of the transport system, and bring about mode shift in order to reduce car use and hence cut congestion and pollution from traffic. However, there are relatively few cities and regions that have incorporated road pricing/congestion charging into their strategies for achieving these objectives, although there are more that have *considered* the option of charging, either as participants in European projects, or in discussions with their national governments. However, the majority remain reluctant to include the idea in their policy documents. Later in these notes we will consider some of the reasons why this might be. But we might conclude, at this stage, that congestion charging/pricing exists more as an idea or possibility, than a fully-fledged policy, in most towns and cities in the EU25.

Task

Think about your home city or region. If it wanted to introduce a system for charging drivers for the use of existing roads, would it need legislation to do so? If so, does enabling legislation exist? If so, which level of government makes the decision under that legislation to allow a scheme to go ahead (e.g. in the UK outside London, a local authority has to apply for permission to central government to have a scheme – the local authority cannot give permission to itself). If there is no legislation, which level of government would have to make the law to make charging a legal possibility – and does that level of government have any plans for such a law?

3.4 Policy framework at the local/regional level

Any charging system should be a part of a charging authority's integrated policy framework of a series of measures for an area and be compatible with the planning, transport and environmental policies for the area. Each measure in the package should provide a net benefit to the community in the area (which is not to say that there might be some individuals who are worse off as a result of the scheme; but overall, society should be better off). Each measure in the package should be realisable within the plan's time horizon – so, for example, it is unlikely to be very useful to promise a new tram system as an improvement "in exchange for" road pricing, if that tram scheme is not likely to be built for the next 15 or 20 years.

Charging regime

The urban road pricing system may:

- relate to vehicle use of the road space (utilisation and location)
- include an associated parking charge system on the street
- be managed and controlled locally under the authority's supervision
- be fair and enforceable
- be based on differential charges for different vehicle categories at different times of day

- incorporate optimal pricing based on setting a congestion charge which equates to the difference between the marginal cost and average variable cost of each trip.

Operating system

The operating system should be robust and reliable, simple and flexible. It should respect privacy. Information on the charging rate being levied at any time should be clearly outlined to travellers prior to the start of a trip. The charging system could accept pre- or post-use methods of payment, although the latter must take cognisance of collection and enforcement problems.

Revenue expenditure

The economic benefits (net surplus revenue from user charges for the system) should be spent directly on:

- the transport sector within the area, and/or
- public-transport services, road improvements and traffic management schemes, and/or
- considered as additional local revenue available for expenditure in accordance with the authority's defined priorities.

4. The acceptability of charging schemes

4.1 Introduction

Through their primary economic objective to increase the perceived cost of road use in congested urban areas to cover the external costs of driving, urban RUC schemes have been proposed to help to meet a number of policy objectives, including: reduced traffic levels and/or congestion; improved environmental quality (pollution, noise etc); and/or extra revenue for transport investments. In practice, public acceptability is a necessary condition for RUC to be possible and successful (PATS, 2001). One can establish a trade-off between the effectiveness with which these objectives are achieved and public acceptability, as illustrated schematically by the curve (red line) in Figure 1.3 showing a 'basic acceptability' level.

Although there are limited RUC schemes in existence, there are a few feasibility (e.g. ROCOL, 2000) and academic studies (e.g. May and Milne, 2000) that have investigated the effectiveness of certain scheme combinations. The overall acceptability level of highly effective schemes varies from high to low (as reported in Higgins, 1994; Gomez-Ibanez, 1992; Vickery, 1993; Jaensirisak, 2002). There tends, nonetheless, to be an inverse relationship between the economic and technical efficiency of a scheme, and its acceptability. Acceptability can in general be increased by reducing charging levels, or broadening the range of groups being offered exemptions or discounts (PRIMA, 2000 and Jaensirisak, 2002), but this reduces their effectiveness – and moves us to the left of the curve. However, acceptability should, if possible, not be over-emphasised to the extent that schemes would no longer be efficient or effective in achieving their intended objective(s).

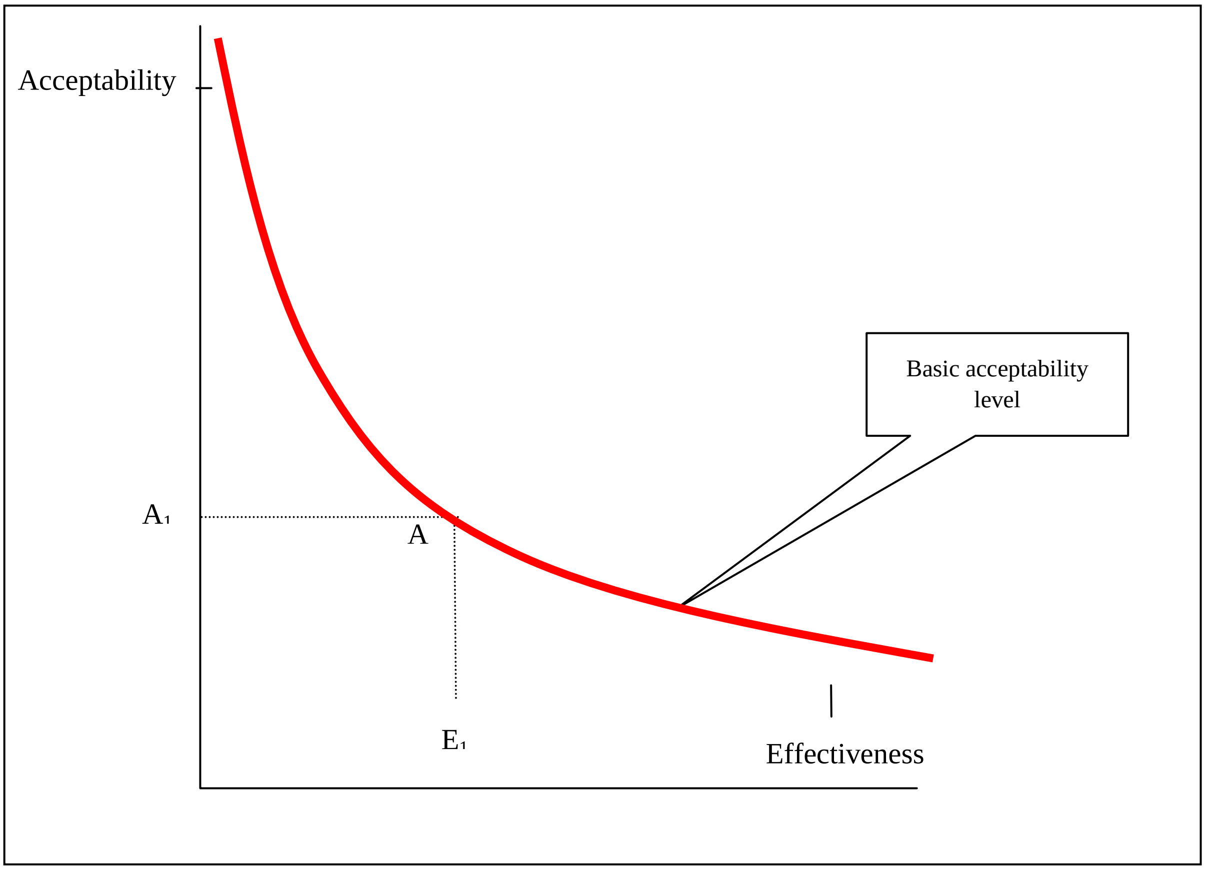


Figure 4.3 A Schematic Relationship between Acceptability and Effectiveness of RUC

The types of urban road user charge (RUC) schemes of which the public are currently aware (if any) tend to be based on a simple cordon scheme (e.g. as in Norway), and tend neither to be that effective (May and Milne, 2000) nor that acceptable (i.e. at around point A_1 in Figure 1.3). Recent MORI surveys in England (in 2000, 2001 and 2002), have found that public support for charging to drive into city centres at peak hours was only 27%, 37% and 30%, respectively, compared with opposition of 53%, 47% and 54% (CfIT,2000, 2001, 2002). The situation is similar at the European level, where PRIMA (2000) found that there is, on average, less than 30% support for the introduction of RUC across Europe.

There are various reasons why RUC has not achieved public and political acceptability. Some of the concerns expressed by stakeholder and other groups, based on Jones (1993; 1998), Viagas (2001) and Schade, J., & Schlag, B. (2000) , is summarised in Table 1.2. This also illustrates the type of arguments that need to be won, and the issues that need to be addressed, if levels of acceptability are to be significantly increased.

Concerns	Evidence needed
Need carrot, not stick:	There is a need to implement RUC as the alternatives to RUC are ineffective or insufficient in a given situation.
Ineffective and another form of tax	RUC is a practical and effective measure; RUC can be designed to reduce traffic volumes, improve environmental quality and if necessary to raise revenue for local transport investments. Therefore it is not another form of tax.
Undesirable impacts	A scheme can be devised that will minimise boundary problems and undesirable impacts on business either within or outside the area
Not fair-(equity)	Geographic and social equity concerns can be met by varying RUC design variables and introducing a package of measures and revenue distribution that can be provided from the net revenue.
Technology and privacy	The RUC technology is reliable, it allows privacy and the system is enforceable.

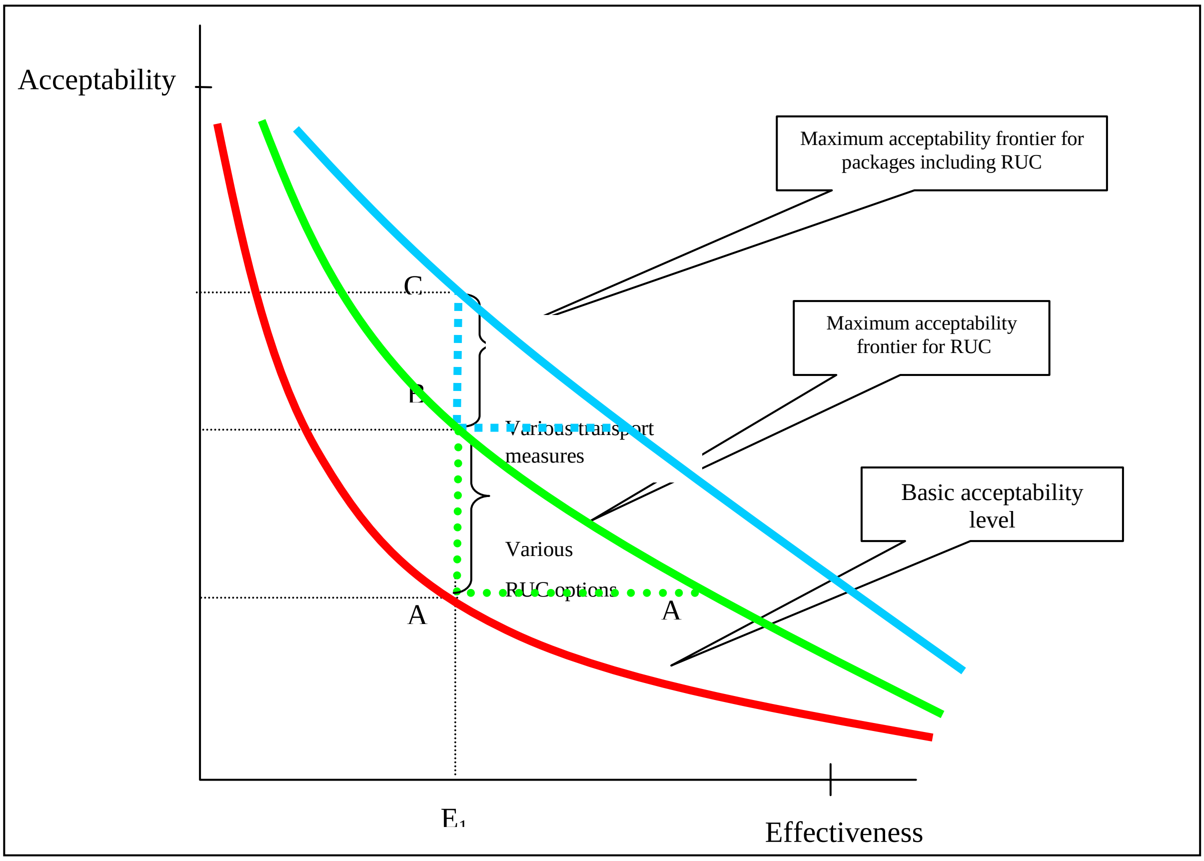
Table 4.1 Key Public Concerns About RUC (based on Jones, (1992; 1998), Viegas (2001), Schade, J., & Schlag, B. (2000))

There are many RUC design parameters that can be modified in an effort to shift the 'basic acceptability' to a higher level. These include: varying the area of coverage; the type, time and level of charge; the availability of discounts and exemptions; and/or the administration and the technology that is used for operation and enforcement. Combinations of various design parameters allow a very large number of possible scheme options, which can variously address the concerns and needs of key stakeholders. For example, the concerns of delivery companies could be addressed by providing them with a period pass, while charging car-based users on a per-trip basis.

Studies of public acceptability have further shown that support for RUC increases substantially when the net revenues are hypothecated for transport-related improvements. Jones (1995) found that support for RUC virtually doubled when it was presented as the cornerstone of a package of measures that improved alternative modes and provided a safer and more pleasant environment. The PATS (2001) study recommended the simultaneous use of different measures, in order to make pricing acceptable to policy makers, businesses and users, since single measures were found never to be fully effective if applied in an isolated way. In the case of the MORI studies cited above, support increases (to 39%, 54%, 58%) when the revenue raised is to be invested in public transport, with only 41%, 30%, 23% against (in 2000, 2001 and 2002, respectively). Similarly, in the EU TransPrice (2000) project, there was a considerable increase in support, to between 41% to 64%, for a transport pricing package which included specific revenue hypothecation. The study also suggests that RUC should be considered as part of a package of demand management measures, in order to increase its effectiveness as well as its acceptability.

Therefore, tools are required to enable Local Authorities to design options that draw on the full range of potential RUC design combinations, and (taking into account stakeholder concerns) the widest possible range of complementary measures. This could potentially shift the focus from basic acceptability to the top (blue) curve in Figure 1.4, whilst not compromising the desired outcomes and effectiveness of the scheme.

Figure 4.2 A Schematic Approach to Increase Acceptability and Effectiveness of RUC schemes



If provided with new techniques and some tools to examine RUC design options in a much more comprehensive and rigorous manner, Local Authorities can have opportunities to identify wider options that could achieve a greater level of public acceptability for a given level of effectiveness (i.e. moving from point A to point B), or achieve a higher level of effectiveness for a given level of acceptability (moving from A to A*) – or some combination of the two. This is shown schematically in Figure 1.4 by the upper (Blue) line, representing the "*maximum package acceptability*" curve. For example, by adding a package of suitable complementary measures to an 'optimised' RUC option at point B, it would be possible to further increase support to point C.

The relationship between the acceptability and effectiveness of RUC schemes is presented in this way because, it is argued, a graphical representation shows very clearly how any scheme will of necessity be a trade-off between the two attributes, and a more acceptable scheme will tend to be a less effective one (to the point where a scheme could in fact be almost completely ineffective, but almost completely acceptable, and vice versa). The graphical representation also illustrates one of the central arguments of this thesis: that the generation of a wide range of scheme options will tend to lead to the selection of an option that combines a high level of acceptability with a high level of effectiveness, compared with a scheme that is not the result of a wide ranging option generation exercise. It also shows that the packaging of RUC with other transport measures will enhance its acceptability for a scheme of a given level of effectiveness. Finally, it demonstrates that there is a theoretical maximum level of combined effectiveness and acceptability beyond which a scheme cannot go (the acceptability frontier).

All that said, there are a number of caveats that need to be applied when interpreting these figures. They are schematic only and do not illustrate an actual measurable relationship – it is recognised that the actual relationship between effectiveness and acceptability can be more complex and "messy" than the figures imply, so the slope and the location of the lines on the figures would be different for different contexts (e.g. in different cities, for local versus national RUC schemes etc.). In addition, the relationship between acceptability and effectiveness is not static but dynamic in time and location, as evidenced by the recent experience of trying to implement RUC in Edinburgh (Rye, Ison and Enoch 2005). Finally, it is likely to be very difficult if not impossible to predict the acceptability/effectiveness frontier – this could only be derived empirically.

4.2 How to make schemes more likely to succeed in practice

Ison and Rye (2004, 2005) have considered congestion charging schemes that have been implemented (e.g. London, Oslo) and also schemes that were planned, but have for a variety of reasons failed to become a reality (Cambridge, Hong Kong, Edinburgh). Using this analysis they have highlighted a number of key factors which, they argue, should be in place if a planned scheme is to maximise its acceptability, and therefore its chances of implementation. These key factors include:

- Agreement (as much as possible) on scheme objectives. If people are not agreed that there is a congestion problem that needs to be solved, for example, then they are even less likely to agree that there is a need for a congestion charging scheme.
- Having the resources available to implement the scheme. This may seem like an obvious point, but it is crucially important. Included in these resources should be the people and the money to be able to *market* the proposals to citizens.
- The ability, and resources, to noticeably improve the alternatives to driving your car, before the congestion charging scheme is implemented. This means improvements to bus, rail, tram and park and ride services across the city, not just in one or two areas.
- A political champion – a politician who is willing to take the risk of promoting and being associated with the scheme. Ken Livingstone, the Mayor of London, is an example of such a "champion". They are however relatively rare figures in politics! If this politician has the direct power to be able to implement the scheme on their own, so much the better.
- Lack of interface required by different political bodies – ideally, the scheme should be the responsibility of one political entity only. If several different levels of government and/or neighbouring authorities have to get involved, then reaching consensus is likely to be impossible, and different levels of government have different electoral cycles, meaning that their work is slowed or stopped at certain times.
- A single agency to implement the scheme and any supporting measures. If there are many different agencies responsible for implementing different parts of the scheme, it may not all be ready at the same time and some people may completely fail to implement the part that they are responsible for, especially if they do not really agree with the scheme.

Bear these points in mind when you turn to the task at the end of the next chapter!

5. Developing charging systems: some experience to date from Asia and Europe

5.1 Introduction

As promised, this chapter considers the experience of implementing congestion charging in a number of cities and regions around the world.

5.2 The Singapore Charging Schemes

Singapore is a densely populated island-city state (population of over 4.2 million in 2004) in Southern part of Asia (SSA). Roads take more than 10% of its surface area leaving little scope for massive road infrastructure without major disruptions to the quality of life and to the environment. By 1975, car ownership levels were rising (while 60 in 1000 people owned a car in 1970s, it has risen to 111 in 1000) and the city was suffering from major congestion (Foo, 1997).

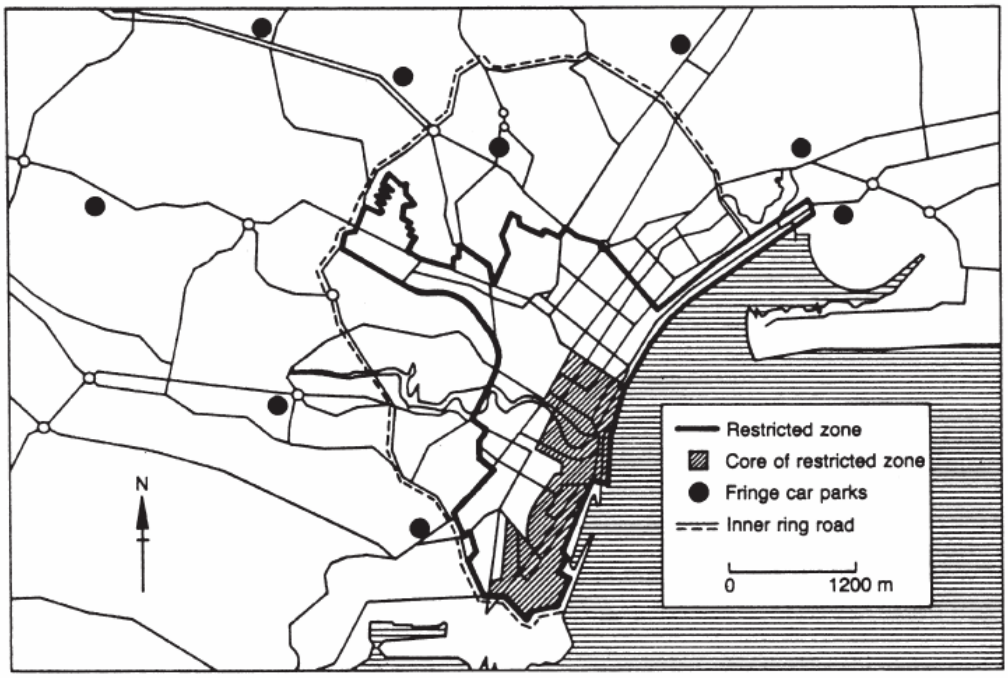
(a). The Area Licence Scheme

Form and features

Singapore implemented the first RUC scheme in the world in order to reduce car use and increase public transport patronage. The scheme cordoned an area called the Restricted Zone (RZ), about 5 km^2 of the most congested part of the Central Business District (see Figure 5.1) (Lewis, 1993). Although it is known as The Area Licensing Scheme (ALS), operationally it was an entry permit scheme since the licence (daily or monthly-peak or off peak) had to be displayed at the entry points only (22 in 1975-extended to 33 in 1989), on the vehicle windscreen.

The ALS was first implemented on weekdays between 0730 to 1015 hrs (initially to 0930). After a noticeable increase in congestion during free hours, the ALS was subsequently modified to include the evening peak (from 1630 to 1830 hrs) in 1989. In January 1994, the scheme was extended to cover the whole working day (weekdays only) from 0730 to 1830 hrs and 0730 to 1500 hrs on Saturdays (to 1400 in 1995).

Figure 5.1 Singapore ALS and EPR



(source: Lewis, 1993)

The operation of the scheme was kept simple. Drivers had to register their vehicle in the scheme in advance, as they bought the colour coded licences bearing their vehicle licence number for the period of use (daily or monthly- peak or off peak licences) from post offices, petrol stations, area licence sale booths (located on the approach roads) or convenience stores prior to entry. Licences were visually inspected on the moving vehicles by the wardens at the entry points. With the same area licence for a day, vehicles could make multiple trips into the area. Vehicles already in the area during the charging hours were allowed to travel free of charge (without a licence). The detailed scheme features and how they formed the ALS scheme is summarised in Appendix B.

Effectiveness

There is considerable data available on the effectiveness of the Singapore schemes. Soon after the implementation of the Area Licence Scheme (ALS), peak hour traffic into the Restricted Zone (RZ) was reduced by as much as 45% (Phang and Toh, 1997), traffic speeds increased by 20%, while accidents fell by 25% over the same period (Foo, 2000). Most of this was due to a significant reduction in through traffic and the earlier or later departure of traffic terminating in the RZ (Chin, 2002). Some 14% of car drivers entering the RZ shifted their morning departure time (for work trips) and the total shift to earlier hours accounted for around 5% of the reduction in car traffic during the restricted hours (Gomez-Ibanez and Small, 1994).

Foo (1997) reported that there was also a substantial modal shift after the implementation of the ALS. Immediately after implementation, 46% of all trips to work were by bus compared with 33% before implementation, representing a 13% increase in public transport use while there was a 10% reduction in car use. Modal shift continued so that by 1983, 69% of the total trips to work in the RZ were made by bus while only 23% were made by car. As expected, most of those who switched to bus were lower income groups.

An OECD study (as reported in Foo, 1997) reported that the ALS also improved environmental conditions and reduced the number of accidents in the area. Between the years of 1978 and 1982, average decreases in total acidity, smoke and levels of nitrogen oxides in the air in the restricted area were 10.7%, 32.2% and 8.4% respectively. During the same period, there was a 23% reduction in accidents within the Central Area region.

As there was still a congestion problem caused by the uncharged outbound trips from the Zone (due to work-to-home trips) which the ALS could not divert, in June 1989 charging was also applied to evening peak hours (from 1630 to 1830). This resulted in substantial reductions in the volume of inbound and outbound traffic. Between May 1989 and August 1989, inbound and outbound traffic during the evening peak hours reduced by between 26% and 47%, and average travel speeds increased from 23km/h to 30km/h (Foo, 1997).

Despite rising vehicle ownership, the ALS managed to retain the same level of traffic reduction until the early 1990s. However, increased traffic volume in the period between the morning and evening restrictions led to the introduction of the whole-day ALS in January 1994. This reduced the total volume of inbound traffic by 9.3% during the entire working-day (0730-1830) (Foo,1997). However, the degree of traffic jams occurring just outside the controlled zones worsened as drivers started to seek more non-ALS routes (Li. 2002).

Customer numbers and land values within the charged area were largely unaffected; and there was no large scale relocation of businesses to areas outside the zone. It has been argued that this may be related to Singapore’s existing strict land use planning controls (Foo, 1997).

It should be noted that ALS was not the only measure that was implemented to reduce congestion and its related problems in Singapore. The success of its implementation was supported by other more draconian measures to curb vehicle growth, such as increased road and petrol taxes, doubling the cost of parking at public housing estates and a Vehicle Quota System. There were also public transport improvements coupled with the ALS that led to increases in public transport usage in general (Willoughby, 2001).

(b) The Electronic Road Pricing Scheme

Following the success of the ALS, another scheme known as Road Pricing Scheme (RPS) was introduced on the congested sections of three major expressways in morning peak hours in 1995. Both ALS and RPS were operationally labour-intensive and subject to human error.

After cordon crossing based Electronic Road Pricing (ERP) technology proved to be technically feasible in trials in Hong Kong and the Netherlands, and in view of technological advances (in particular with smart-card technology), Singapore no longer needed to worry about privacy issues. The Singapore government had conducted a study on two major expressways between early 1997 and April 1998 to evaluate the possibility of introducing an electronic charging scheme. The success of this trial led to the application of ERP, first on the expressways in April 1998, and then in the CBD area in September 1998 (Li, 2002).

Form and features

Both ALS and RPS had under-penalised contributions to traffic congestion as, having paid for the daily licence fee, drivers could make multiple trips to the zone. In the ERP scheme, which is an inbound cordon scheme, drivers have to pay anytime they cross the cordon inbound. Therefore it is more closely related to actual use of the road so that those who contribute more to congestion, pay more and those who use the roads less frequently pay less.

The ERP scheme currently operates during working hours (0730 to 1900) but only during the morning peak period (0730 to 0930) on the expressways. All vehicles have been fitted with unique in-vehicle units (IU) with a smartcard (called CashCard) slot and have to pay anytime they enter the RZ and/or cross the charging points on the expressways.

Currently, the ERP scheme has differentiated charges for cars, taxis, LGVs, HGVs, buses, motorcycles. The IUs for different vehicles are programmed differently (varying rates based on vehicle size) so that the charge for the vehicle can be determined and deducted automatically from a CashCard. Charging rates are set based on the Passenger Car Unit (PCU) for different types of vehicles. 1.0 for cars private/company, and taxis and light goods vehicles, 0.5 for motorcycles, 1.5 for heavy goods vehicles and small buses (30 seats or less), and 2.0 for very heavy goods vehicles and big buses (more than 30 seats). The normal charge for 1 PCU is set to 1 Singaporean dollar (33 pence). To begin with, discounted rates applied to phase the full charges in over 2 to 3 years for users (Foo, 2000). Charges also varied according to time of day. For the first year, the morning peak hour rates for goods vehicles and buses were set at 25% of their full ERP rate, while that for taxis was one-third of their full ERP rates. Exempted vehicles include fire engines, ambulances and police cars.

All entry points and certain crossing points of expressways have gantries with antennas to communicate with the IUs to deduct the correct charge automatically from the inserted CashCard. There are two gantries at each cordon point. A control box co-ordinates the whole process. The first antenna detects the presence of the vehicle, communicates with the IU and checks the presence and the balance of the CashCard to execute debiting instructions to the IU if everything is in order. An optical line sensor mounted on the second gantry identifies the type of vehicle, and the second antenna, which is also mounted on the second gantry, communicates with the IU and acts as a confirmation device.

If any system error or violation is detected, cameras mounted on the gantries take a picture of the vehicle and its number plate. Violation information is sent to the police to be matched against vehicle registration records. The central computer prepares reports of offences and system errors and sends them to the vehicle owners. Currently, those without an IU have to pay a fine of $70 (approx. £23) while those without a CashCard or insufficient balance will have to pay $10 (approx. £3.3) on top of the un-deducted charge.

Effectiveness

Under the operation of ERP, traffic was more evenly spread out during the day. It increased the efficiency of the main road network by reducing traffic levels closer to its design capacity. During the peak hours, travel speeds in the CBD were more consistent and, on the expressways, improved from 45 to 65 km/h (Goh, 2002). On the first day of its implementation (April 1, 1998), in the morning peak period (0730- 0930) traffic along one of the heavily congested expressways decreased by as much as 17% (Kaur, 1998 as in Goh, 2002).

The EPR was even more effective than the previous scheme (ALS). It both increased the average traffic speeds and decreased the traffic volumes in both the Restricted Zone and on the expressways. Table 5.1 shows the traffic volume and speed changes prior to and after its implementation. Detailed outcomes of the ERP are reported in detail in Menon (2000), Goh (2002) and Foo(2000).

During the operation of the scheme, average speeds on expressways and main roads within the restricted zone are monitored every half an hour. When the speeds fall below 45 km/h on the expressways and 20 km/h on main roads, the level of charges is increased. Correspondingly, when the speeds improve to 65 km/h and 30 km/h, charges are decreased to obtain optimal speeds on the network. This was perceived as a fair system by the users and was widely supported (Menon, 2000).

Table 5.1 Impact of ERP on daily traffic volumes and speeds in September 1998

	Traffic volume (no. of vehicles)			Traffic speed (km/h^{-1})	
	Pre-ERP	Post-ERP	Change	Pre-ERP	Post-ERP
Areas covered under ERP					
Restricted Zone	271 051	206 000 to 216 000	−20% to −24%	30–35	40–45
East Coast Parkway	16 203	14 400 to 14 900	−8% to −11%	36–67	55–65
Central Expressway	12 398	15 200 to 15 800	23% to 27%	45–63	35–50
Pan-Island Expressway	8020	9400 to 9900	17% to 23%	55–59	55–60

source: Foo, 2000

Surveys after the implementation of ERP stated that 95% of those who drove into the Restricted Zone during the operation of the ALS have continued to drive, while only 2% have abandoned their trips. There was not a great number of drivers switching to public transport. It was found that the ERP achieved traffic reduction by cutting down the number of multiple trips drivers used to make under the flat fee system and by diverting some of these trips to alternative free routes.

In contrast to the ALS, the residents of the Restricted zone enjoyed free travel if they only travelled within the zone. There was a fall in the number of taxis entering the area without passengers and this increased the taxi waiting times within the area. This was because, unlike the previous flat fee system under the ALS, drivers of such taxis have to bear the charges themselves each time they enter the area. Revenues obtained from the ERP were lower than the previous system (ALS), but also the operating costs of the new system were much lower then the manual system (Foo,2000).

Singapore's ERP system shows the following advantages compared with manual systems:

- Prices can be directly and easily adjusted to charge more during peak hours and high traffic volume periods according to vehicle class and location.
- It is a fully automated operation and highly enforceable and does not rely on manpower to manage and maintain the scheme.
- It can be used to reduce air pollution arising from excessive traffic flow on the major arterial roads.
- Prices at under-utilised entry points can be reduced to obtain more balanced traffic levels. However, there is a risk of increasing total vehicles km travelled if this is done.
- Smart card use can overcome the drivers' privacy concerns.
- It is considered to be the most promising instrument to achieve equity in road usage as those who drive more, pay more.

5.3 Norwegian RUC schemes

(a) Bergen Toll ring

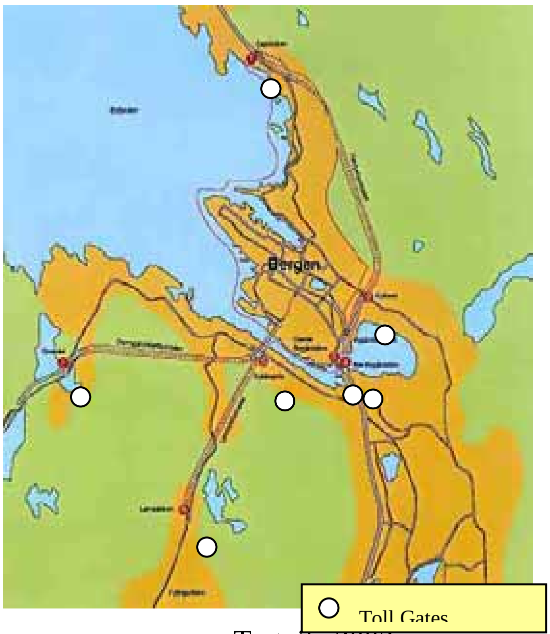
Bergen is a small coastal city with approximately 237 thousand inhabitants (Statistics Norway, 2004). Due to its topography, access to the central historic area was effectively determined by the limited number of roads and bridges. The city needed a new bypass tunnel to improve its access and traffic flows (Lewis, 1993).

Form and features

Bergen's RUC scheme was the first Norwegian toll ring to be introduced in 1986 to match fund a comprehensive road widening and tunnelling programme designed to improve access to and around the city's business district area and to reduce congestion and accidents. It was a simple inbound cordon crossing scheme that covered an area slightly larger than Bergen's CBD with seven (initially six) toll gates (See Figure 5.2). Because the major objective was to raise revenue, not to deter traffic, there were no effective by-pass routes. The charging cordon therefore covered a wider area than that which was needed solely for traffic reduction. It operated between 0600 and 2200 hours, Monday to Friday. Although a 24 hour, 7 day option was considered, it was rejected due to much lower traffic levels at night and the fear of deterring shoppers from visiting Bergen at the weekends (Lewis, 1993).

Each toll station had two types of lanes: drive through lanes for period pass users and manual lanes with manned booths (see Figure 5.3). A single payment of 10 NOK (approx. 80 pence) was made to attendants in cash. Drivers could buy a book of pre-paid tokens and hand in one

Figure 5.2 Bergen Toll Ring



source: Tretvik, 2003

at manned lanes. They can also subscribe to period passes at sales offices, or through the internet, to use drive-through lanes. Random digital video control was used to enforce the drive through lanes. The cameras read the licence plates (60% accuracy), simultaneously checking against a data file of all valid numbers (registered prepaid pass owners). This was a

Figure 5.3 Bergen manual and drive through lanes

fairly cost effective filter, leaving about 30 - 40 % for back-office manual handling. However the system is currently being revised to improve accuracy. Non-paying motorists, if they are found to be violators, are liable to a fine of NOK 200 (£16). Currently 1.5 % of the traffic is unauthorised - approximately 1000 entries a day. This represented a loss of 1 mill NOK per year. However this loss is offset by the penalty fee income of more than 5 million NOK (Lewis, 1993).

Effectiveness

Although the Bergen scheme permitted no alternative routes due to the city's unique topology and the scheme's design, it has had little impact on traffic. There was some evidence of travel time shift (Lewis, 1993), and carpooling increased a little, but there was no evidence of impacts on public transport use. Although an increase in city centre-bound traffic was predicted in studies before implementation, in the first year (1986-87) it was actually reduced by 6-7% (LEDA, 2004)

The scheme was effective in raising revenue. The initial investment to establish the ring was 15 mill NOK (approx £1.27 m). The yearly income has proved to be far higher than expected, and now amounts to 70 million NOK (£6 m) per annum, of this 50 million NOK (£4.23 m) is allocated to road construction, 14 million NOK (£1.2 m) for operating costs and 6 million (£0.5 m) is put aside in a fund for improvements. (Bro & Tunnelselskapet AS**,** 2003**)**

(b) The Oslo Toll Ring

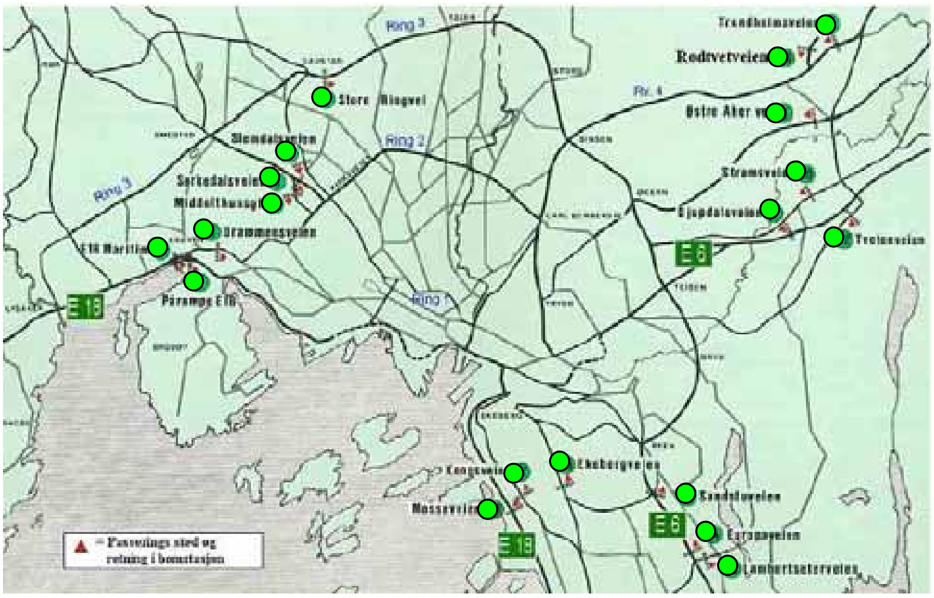
Oslo is the capital city of Norway with 700,000 inhabitants. The topography of the city restricted road widening to improve its deteriorating traffic condition. As a solution, a new tunnel was planned under the central part of Oslo (Lewis, 1993).

Form and features

Following the success of Bergen, the toll ring system in Oslo was set up in 1990 primarily to finance future urban road construction schemes and, secondly, to reduce car/vehicle traffic in the city centre. A simple inbound cordon crossing system forms a boundary of three to eight kilometres from Oslo City centre. It was designed with 19 toll stations to price all traffic entering the area

(See Figure 5.4). It is difficult to find an overall principle that governs the location of tolled gates in Oslo other than revenue maximisation. The toll ring is in continuous operation (24 hours a day everyday) and the toll is the same all day and all week (Lewis, 1993).

Figure 5.4 Oslo Toll Ring



source: Tretvik, 2003

The Oslo toll ring started with lanes for season passes, but also lanes with coin operated machines. In November 1990 Oslo switched to electronic season passes (an electronic tag inside the front window is used), which greatly improved the control of the lanes reserved for regular users. An electronic season pass is valid for only one car. In December 1991 the system was extended to include pre-paid trips. The windscreen-mounted unit holds details of the identification of the driver, and sends these by two-way radio communication to a roadside beacon. These are checked against a central database and, if the account is not valid, the vehicle is photographed automatically and the driver fined (Fjellinjen, 2003).

Effectiveness

Similar to the Bergen scheme, the administration of the Oslo scheme is very successful from a revenue creation perspective. The capital cost of the scheme was about 250 m NOK (£21.5 m) and the annual operating cost is 66 m NOK (£5.7 m). Annual gross revenues are about 600 m NOK (£51.6 m) (LEDA, 2004). However the reduction of traffic has been less significant. The EU AFFORD project website reported the following outcomes resulting from the scheme:

"Comparison of the trip rates before and after the implementation of the toll ring shows that the total number of inbound trips through the cordon decreased by between 2% and 8%. There was an overall decrease in the number of trips of 10%. The decrease affected all modes, travel purposes and combinations of origin and destinations. There was no shift to other modes of transport. It thus seems that the relative reduction in car trips crossing the cordon was caused mainly by changes in the destinations of car trips and to some extent also a reduction in the total number of car trips. Car occupancy for cars crossing the cordon did not show any significant changes" (AFFORD, 2004).

(c) The Trondheim Toll Ring

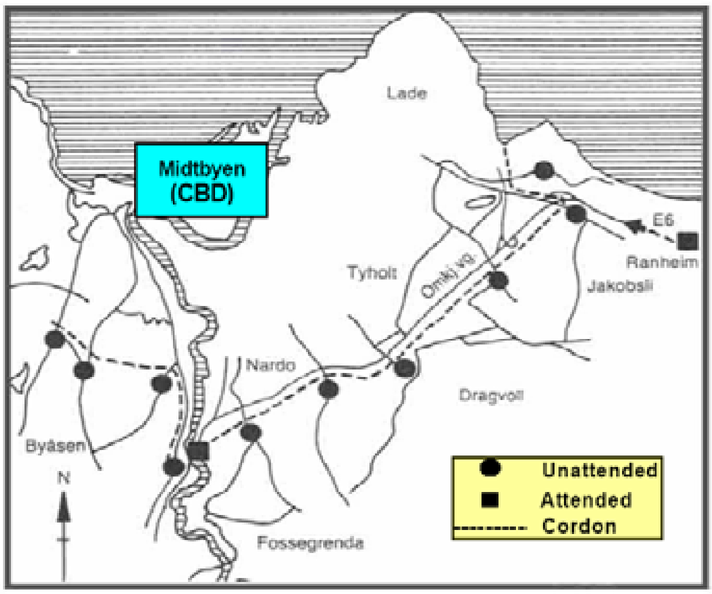
Trondheim is a coastal city with about 140 thousand inhabitants. Access to the city is determined by the topology of the city. The city needed to improve the quality of its transport system and environment with a comprehensive investments package.

Form and features

In 1991, Trondheim became the third city in Norway to implement RUC. As in the other cities, the aim was primarily to raise revenue to fund an urban transport investment package, featuring a range of improvements to the local transport system, including new road construction, improvements to facilities for pedestrians and enhanced priority and segregation for public transport (Meland, 1994). The scheme was unique in two aspects: it was fully electronic with non-stop toll lanes from the start; and the fully electronic application of the scheme provided an opportunity to apply differentiated charges to encourage a shift in traffic from morning peak to off-peak periods and so to alleviate traffic congestion (Tretvik, 1999).

When the scheme was first introduced in 1991, it was a simple inbound cordon with twelve toll gates covering the city centre and most of the surrounding residential areas as well as the airport road (see Figure 5.5). In 1998 the simple cordon scheme was revised and a zonal-like charging scheme came into operation, with five more toll stations added. This scheme uses several screen lines throughout the city to capture as many trips as possible, fulfilling its objective to raise revenue equitably. Since this revision, two way charges apply at some crossing points.

Figure 5.5 Trondheim Toll Ring Area



source: Tredvik, 2003

Charging hours were initially from 0600 to 1700 hrs on weekdays (Monday to Friday), but under the revised scheme they were extended to 1800hrs for the toll ring. No charge has been applied in the evenings or at the weekends, allowing shoppers to travel free of charge. However, a 24-hour charge applies to the airport road throughout the whole week.

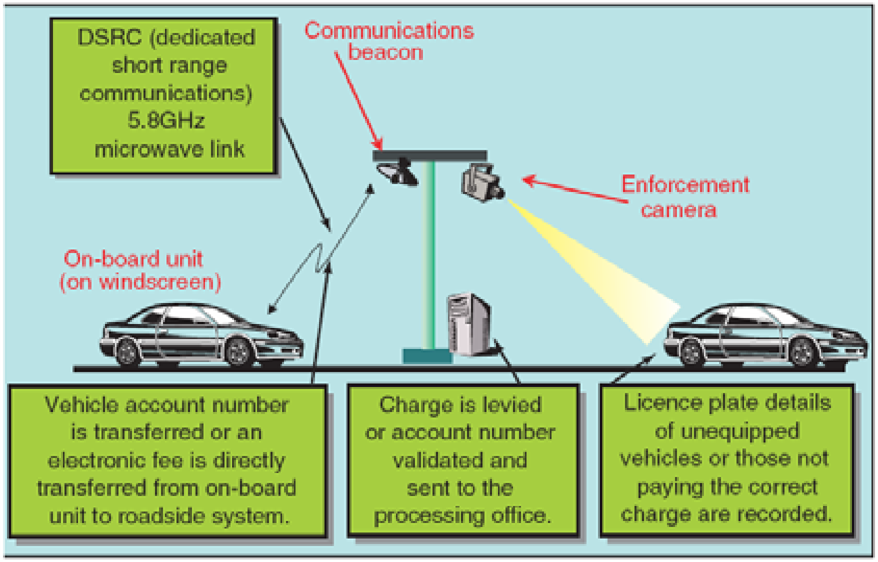
The basic toll level amounts to 15 NOK (*£1.20*). This is roughly equal to 10% of the average hourly earnings for Norwegian industrial workers. The system includes time differentiated charges to influence morning peak travel. Heavy cars (above 3500 kg) are levied double. After 2200 hrs (on the Airport Road) charges are slightly cheaper for those drivers who subscribe to the scheme as regular users. The electronic tags that are used for free-flow are free of charge to these subscribers. There are two methods of subscription: pre or post payment. The subscriber can pay an advance sum of NOK 500 (£43), 2500 (£215) or 5000 (£430). Charges for each crossing are then deducted from this sum. The subscriber can also have an agreement for direct debit from his/her bank account; the bank statement shows the amount debited for the use of the network at the end of each month. They have to pay only once per hour, even when passing the charging points several times; and a maximum of 60 passes per month is charged from the subscribers' account (Lewis, 1993). At some entry points there are plazas with attendants and cash/coin machines for visitors and occasional users, where vehicles can stop and pay the charge (see Figure 5.6) . At the coin machines a "pay later" button is also provided; the user enters the vehicle registration number and takes a receipt to pay the charge within three days.

Figure 5.6 A toll plaza with two Q-FREE lanes and a manual lane in Trondheim

Source: Tretvik, 1999

The Trondheim scheme operates with a Dedicated Short Range Communication (DSRC) technology (see Figure 5.7). At the toll plazas, a 5.8 GHz frequency antenna reads the tag, then identifies the subscriber and the details of subscription/payment. This is passed on to the lane controller: a computer with a charging algorithm which consists of the registration/subscription data, the payment data, and information on the settings for the charging structure. Coloured lights at the side of the road are used to inform the user about their current status. For each vehicle that passes, an automatic vehicle identification (AVI) system activates a camera that provides a number plate image. If passage is not validated for some reason, (such as no tag, invalid tag or insufficient credit, etc.) then the captured image is kept in the system on which the reason, time and location are recorded. If the passing is later validated then the image is deleted. The pictures are manually checked in the toll centre/office and if necessary a fine is issued to the user.

Figure 5.7 Schematic operation of the DSRC technology



source: Hills and Blythe (2002)

Effectiveness

There have been significant impacts on peak-hour traffic levels, with reductions of 10% immediately following the introduction of the differentiated charges, increasing over time to 17% (KONSULT, 2003). However, this was almost offset by an 8-9% increase in inbound car traffic during uncharged periods at evenings and at weekends. Thus, the toll ring seemed to encourage a time shift for home-work and shopping car trips (Table 5.2).

Table 5.2 Time Profile of Inbound Car Driver Trips through the Toll Ring (Weekdays)

Time Period	Home – Work		Work – Home		Home - Shopping	
	1990	1992	1990	1992	1990	1992
00-06 (No charges)	3%	4%	0%	2%	0%	0%
06-10 (High charges)	80%	76%	2%	1%	19%	5%
10-17 (Low charges)	10%	9%	81%	68%	54%	39%
17-24 (No charges)	7%	10%	17%	30%	27%	46%

Source:Tretvik,1999

As far as the effects on retailing are concerned, there is not much evidence that the scheme has caused a negative economic impact inside or outside of the charged area. The Trondheim Chamber of Commerce carried out a series of annual surveys before and after the implementation of the charging scheme. Their conclusion was that there was hardly any effect from the toll ring on retail trade (Tretvik, 1999).

5.4 RUC schemes Implemented in the UK

(a) The London Congestion Charging Scheme

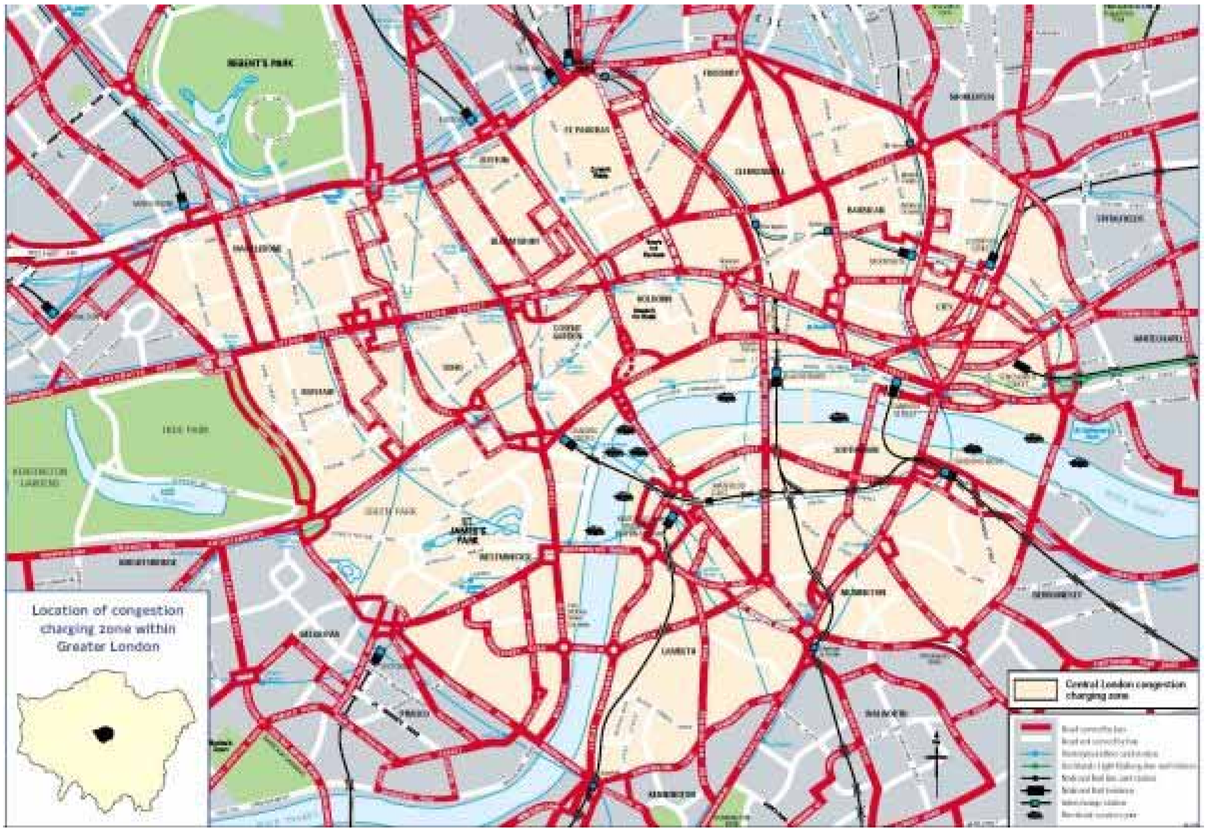
London is the capital city of the UK with over 7 million inhabitants. Vehicle ownership is about 263 cars per 1000 people (National Statistic Office, 2001). Although high proportion of the trips was made by public transport, congestion has been adversely affecting public transport and commercial activities in London.

Form and features

The ROCOL **(**Road User Charging Option for London) (2000) study prepared by an independent group of transport professionals was a report for the new Mayor of London on how the new road user charging and workplace parking levy powers could be put into practice. The objectives were to reduce congestion and through-traffic; to encourage use of public transport in central London; to benefit business efficiency by speeding up the movement of goods and people; and to create a better environment for walking and cycling. The ROCOL study considered several road user charging options. These included options covering various geographical areas and time periods for different types of charging and with a range of technologies. The Mayor of London decided on an Area Licence scheme with automatic number plate recognition technology as it was feasible to introduce in his first term. After an intensive public consultation and publicity campaign, the UK’s first comprehensive urban charging scheme came into operation in February 2003.

The Area Licence Scheme (called Congestion Charging) applies to the central business area of London (see Figure 5.8), since traffic movement in central and inner London is severely hampered by congestion. The inside edge of the inner ring road defines the charging boundary and also serves as a diversion route for those who decide not to the charging zone. Road signs and symbols on the roadway indicate to drivers approaching and in the area that they are liable for the charge. As three quarters of daily vehicle trips enter Central London between 0700 and 1900 hrs, the charging period was initially set to cover these hours. However, charging hours were revised to end at 1830 after complaints from the entertainment sector. Motorists who want to enter and/or travel within the area during these hours are subject to a £8 charge. The scheme applies very complicated exemptions and discounts to a wide range of vehicle and user groups. Exemptions include motorcycles, licensed taxis, vehicles used by disabled people, some alternative fuel vehicles, buses and emergency vehicles. Area residents also receive a 90% discount for their vehicles.

Figure 5.8. The London Congestion Charging Area of Coverage

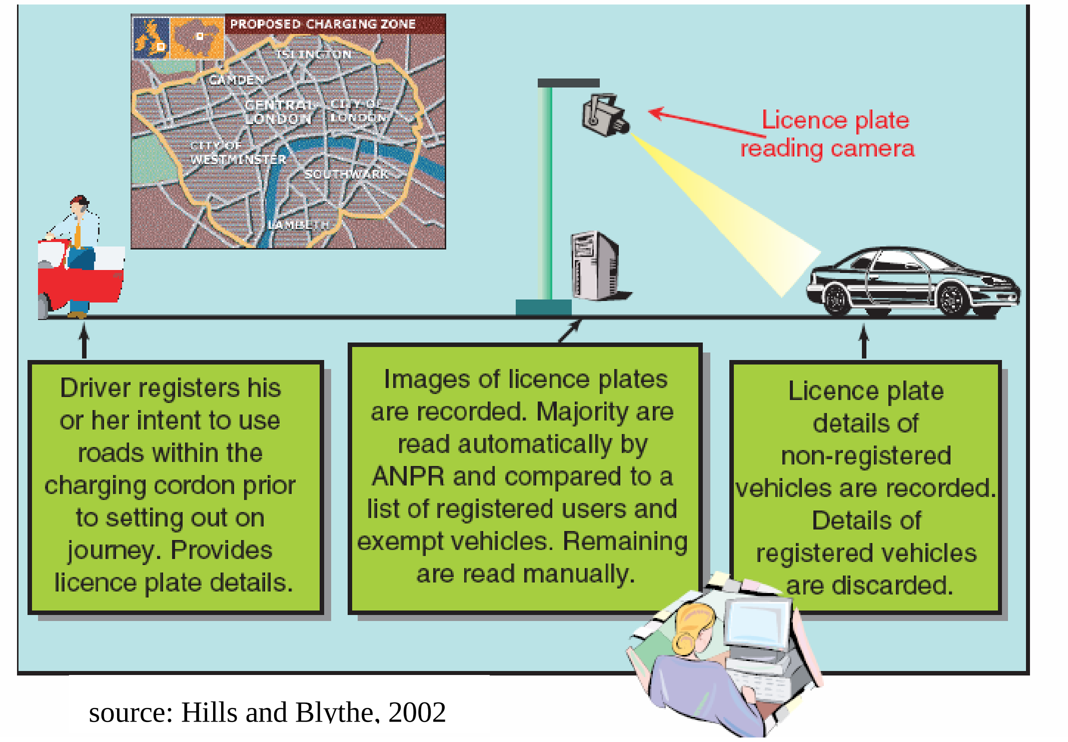


source; TfL, 2004

There is no discount for weekly (£25), monthly (£110) and annual (£1,250) licences that are purchased in advance. Motorists can register their vehicles and make payments for daily, weekly, monthly and annual passes at selected retail outlets; at payment machines located in the area; by Internet; mobile telephone messaging; or by phoning a call centre. For daily licences, registration and payment can be made until 2200 hrs. Although later registration is possible (after 2200 hrs but before 2400 hrs), it is subject to the payment of a double fee.

A network of video cameras located at the entry/exit points and within the area reads the licence plate numbers of passing vehicles and matches it with the list of registered and paid users (see Figure 5.9). In the case of images that are not clear enough for automatic number plate registration, a manual image checking process is used before sending penalty fines for each day (after midnight). As it is an area licence scheme, mobile cameras and wardens using handsets are also used to check moving and parked vehicles within the charging area. The owners of vehicles that have not paid are sent an £80 fine. This fine is reduced to £40 if paid within two weeks, and increases to £120 if not paid after a month. If individuals persistently evade the scheme and have 3 or more unpaid penalties outstanding, their vehicles will be clamped and removed from the public highways anywhere within Greater London (not just inside the central zone). Details of the scheme can be obtained from the official website at http://www.cclondon.com/.

Figure 5.9. Technology of the London Congestion Scheme: Automatic Number Plate Recognition



source: Hills and Blythe, 2002

Effectiveness

In London, a report on the effectiveness of the scheme after three months of charging (TfL, 2003) shows an overall reduction in all vehicles coming into the area of around 20% compared to one year previously. The number of incoming cars reduced by around 30% compared with the last few weeks before charging and by 38% compared with the equivalent period in 2002. There have been small increases in incoming buses, taxis, motorcycles and pedal cycles. Inside the zone, modeling studies predicted a reduction of 10-15% on traffic levels but the actual reduction, is around 16% compared to one year ago. The average speed of traffic across the charging day (including time spent queuing at junctions) is 17 km/hour (11 miles/hour) compared to 13km/hour for the same time of year in 2002. Year by year comparison of these bi-monthly results indicate that the reduction in congestion during charging hours is 40%.

The report on London's Congestion Charging scheme after one year (published in *Impacts monitoring – Second Annual Report: April 2004* by Transport for London, TfL, 2004), reported the impacts of the scheme on a number of indicators including, congestion; traffic patterns; public transport; social and behavioural impacts; business and economic impacts; and accidents, amenity and environment. Some of the key findings are discussed below.

There was a 18% reduction in traffic entering the zone, and a 15% reduction in traffic circulating within the zone (vehicles with four or more wheels). There was only a slight increase in traffic on the Inner Ring Road, but not enough to lead to any operational problems. There was no evidence of increases in traffic outside of the charging hours (on weekdays or weekends) or on local roads in response to charging. Both the general public and business acknowledged the congestion reductions in and around the charging zone. There were reductions of 30 % on average of congestion in the charging zone. On radial routes approaching the charging zone congestion appears to have reduced by up to 20% compared with the pre-charging levels.

There was a decrease in cars and increase in taxis and two-wheeled vehicles operating inside the zone. Around 65,000 to 70,000 car driver trips no longer cross into the charging zone per day, 50% to 60% of which have transferred to public transport. Some 20% to 30% diverted around the charging zone and the remaining 15% to 25% made a variety of other adaptations.

There were no disproportionate changes to the numbers of accidents involving two-wheeled vehicles but some evidence of an accelerated decline in overall accidents within the charging zone.

There has been reductions of approximately 12% in emissions of NOx and PM10 from road traffic within the zone and very small changes of less than plus/minus 2% on the Inner Ring Road (24-hour annual average day); also reductions of 19% in traffic-related emissions of CO2 and 20% in fuel consumed by road transport within the charging zone (24-hour annual average day).

Overall bus speeds within the charging zone improved by 6%. Additional waiting time due to bus service irregularity fell by 30%; disruption due to traffic delays fell by 60%. Prior to implementation, bus services had been improved to accommodate the additional trips switching from cars. A year after implementation, there are 23 % more buses and 38% more bus passengers entering the charging zone in the morning three hour peak period compared with the situation prior to charging, with some increase in the average number of passengers observed on each bus, although these have generally been accommodated acceptably.

These findings have shown the success (effectiveness) of the London scheme more than was predicted in the initial modelling studies prior to its implementation.

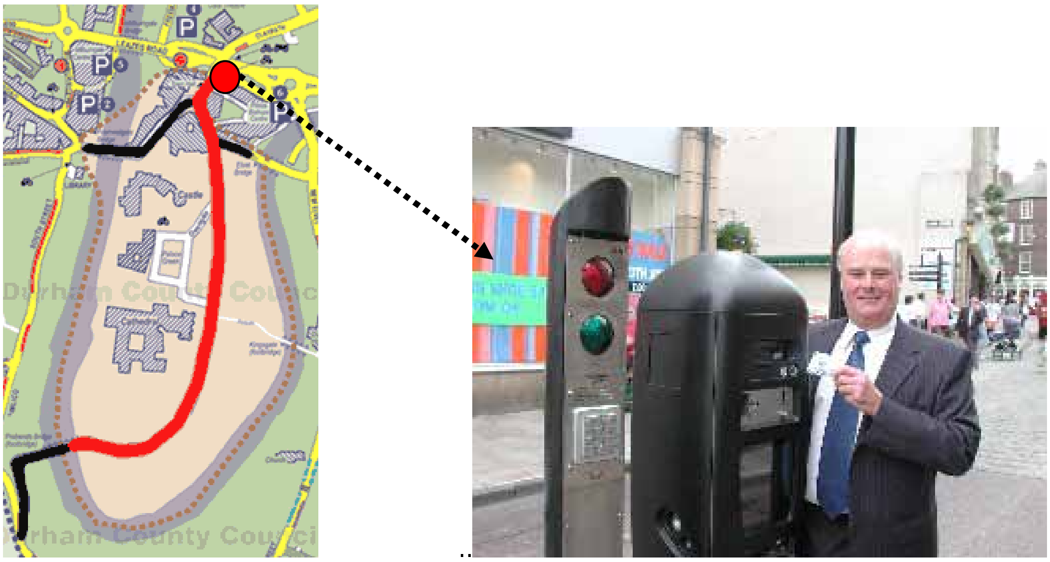
(b) Durham Scheme

Durham is an historic town with some 450 000 visitors a year. Its historic town centre is located in a peninsula accessed with a single carriageway. In 2002, some 4000 vehicles a day were entering the area and around half of them were dropping off and waiting for the passengers visiting the amenities and shops located in the area. This was creating a conflict between pedestrians and vehicles, and also raising environmental concerns (Ieromonachou et al, 2004).

Form and features

In October 2002, Durham County Council introduced a point based entry charge on one section of road to resolve the conflict of vehicles and pedestrians and to produce a better environment for pedestrians in the historic city centre where Durham's cathedral and castle are located (see Figure 5.10). Every day, up to 17,000 pedestrians (daily) use a stretch of road in the charging area that is only wide enough for just one vehicle to pass at a time. A £2 charge applies to all vehicles using Saddler Street and Market Place between 1000 and 1600 hrs on Monday to Saturday.

Figure 5.10. The Durham Point Charging and Pay Machine



source: Durham County Council

There is only one vehicle access point to the area as other access roads have already been closed to vehicles. Drivers are charged on exiting the controlled area at a pay machine mounted on an island in the centre of the carriageway that is linked to an automatic bollard which lowers on payment. The pay machine operates only with the correct cash amount. Alternatively, payment is accepted before 1800 hrs at a dedicated shop located in the area. The system is monitored by CCTV and linked to the operation unit via an intercom system. Exemption permits have been issued to a limited number of users who have access to a parking space on the Peninsula in one of two forms (CfIT, 2004):

- Permanent users' vehicles have transponder permits - plastic tags 200mm in length displayed in the windscreen of the vehicle.
- Daily exemption permits are credit card type permits and are presented and retained at the pay station.

Disabled persons can be issued with exemption permits by the establishments they choose to visit or can reserve a permit in advance by contacting the charging company. Exemption permits and the administration of normal permits are dealt with by the operating company who manage and administer the scheme on behalf of the local authority.

Task

At this stage it is worth you considering for yourself the issues involved in introducing road pricing in cities. Think of a city near you (probably with a minimum population of 250,000); what would be the issues facing politicians who wanted to introduce road pricing? Consider:

- how serious is congestion
- how effective are alternative forms of transport

- what would your objectives be
- if you lean towards full congestion charging or revenue raising
- how would you design the scheme to minimise unwanted effects?
- how would you design the scheme to maximise its acceptability to your electorate?
- What technology might you seek to use?

Again, there is no right answer to this – that is one of the problems of being a politician. In many senses, from their perspective, there are only wrong answers!

6. Literature and Websites

The following literature and websites have been used to set up this written materials. Here you can find further information, project results and good / best practice case studies. Please note that websites may be closed after a certain period.

PROGRESS (http://www.progress-project.org)

http://www.stockholmsforsoket.se/templates/page.aspx?id=2453 – English road pricing material on Stockholm scheme

http://trafiken.nu/

http://www.sll.se/w_trafik/41870.cs?dirid=18

http://www.tfl.gov.uk/tfl/cc_intro.shtml - lots of detail on the London scheme. www.london.gov.uk also includes details. A search on Google with the topic “London Congestion Charge” will throw up many voices of opposition to the scheme. www.abd.org.uk also represent the views of some opponents of congestion charging everywhere.

http://www.imprint-eu.org/ - papers on road pricing from around the world.

http://www.imprint-eu.org/links.htm - links to the myriad of EU research projects devoted to the topic.

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