The Economic Efficiency Case for Road User Charging

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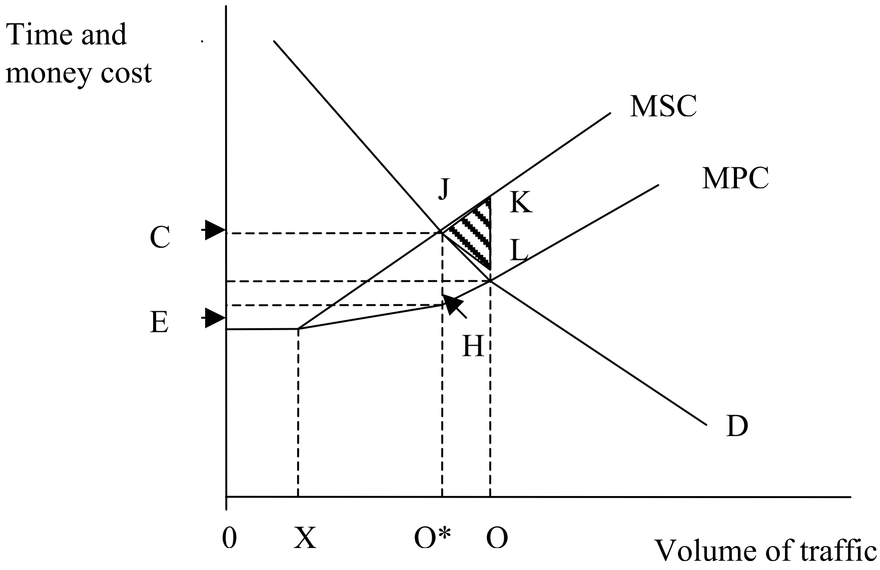
1) Introduction

The basic principle of efficient road user charging is that users should be charged for all the additional costs they impose by their use of the road system – road wear and tear, delays to other users, increased accident risk and environmental cost. The term used to refer to these additional costs is marginal external cost. When these are added to those costs borne directly by the user (e.g. fuel, their own time) the result is called marginal social cost. Only when they face all these costs will users have the right incentive to choose whether to make the journey at all, or to adapt destination, mode of transport, route and time of travel in such a way that the overall costs of transport are reduced.

The principle is that all these costs are valued at the compensation needed for those incurring them willingly to do so. Those users, who value their use above the costs they impose by adding to traffic flows, will travel. Those who value their use below that cost will not travel or will use some alternative means. Consequently, when modifying traffic volume and pattern to the level implied by marginal social cost pricing, it would be possible to make everyone better off; society could fully compensate all those bearing costs and still be left with a net gain.

Figure 1 – Efficient Pricing



Time and money cost
MSC
MPC
J
K
C
L
E
H
D
0
X
O*
O
Volume of traffic

The argument is illustrated in Figure 1. The demand curve (D) shows the valuation which each successive traveller places on using the road in terms of the maximum time and money cost he/she is willing to incur. The marginal private cost curve (MPC) shows the time and money costs which are incurred at each level of traffic. The curve rises because at higher volumes of traffic, congestion increases and speeds fall. The equilibrium outcome where users make well-informed rational choices in their own self-interest lies at point L on the diagram. Here, users decide to travel provided the value they place on making the journey exceeds the time and money costs to them of travelling. The resulting user equilibrium volume of traffic is Q.

But there is a market failure. When such an individual makes a decision to travel, he/she takes no account of the impact on travel time for the rest of the traffic flow. In free-flow conditions (OX on the diagram), there are no such effects. But in congested flow conditions (beyond X), my decision to travel slows down your journey. Very roughly speaking, if travel speeds fall to half their free flow level, then each additional user is imposing as much delay cost on the rest of the flow as his own journey time is taking. So, in an urban system with a free flow speed of 40kph, if traffic volume is such that actual speed is 20kph, then each user in the system is experiencing 3 mins/km of travel time and is imposing additionally 3 mins/km of delay in aggregate on the rest of the traffic (KL on the diagram). But, crucially, the self-interested user does not consider this external cost when deciding to travel.

The essence of the economic case for road user charging, first put forward by Pigou in the 1920s, is to introduce a price which is just sufficient to internalise the externality. In the diagram, this is a charge just sufficient to reduce the volume of traffic from Q to Q*. At this, the system optimum, all users are at least willing to pay their marginal social cost (MSC) of use including the delay costs they impose on other travellers. What price is needed in order to achieve this? The time and money cost incurred by travellers is read off from their marginal private costs at point H. To clear the market, the cost they need to pay is J. So the road price is JH (=CE). The net social gain from efficient pricing is represented by ΔJKL – the benefit from removing the social cost of inefficient pricing.

The above analysis contains many simplifications. All users are assumed to have the same valuation of travel time. All vehicles take up the same amount of road space. No allowance is made for pollution costs. The fuel tax users pay already is not specifically considered. The pricing system itself is assumed to be costless and super efficient. All these simplifications can be considered further within the framework of analysis outlined above.

There have been two main constraints in the development of road user charging – technical and economic. Only now, forty years after the Smeed report, are we beginning to see that widespread road user charging using sophisticated technology might be a real technical possibility. But the greater constraint has been in a broad sense, economic. Road user charging would involve significant change. The economics require it to be demonstrated that the costs of change – including the capital and running costs of the charging system itself – are significantly outweighed by the benefits.

Currently, we do have a form of charging – called fuel duty and Vehicle Excise Duty. These instruments are not bad at doing some things such as influencing the choice of fuel (leaded, unleaded, Liquid Petroleum Gas) and representing the relative average wear and tear costs of different vehicle classes and weights. But they do not reflect adequately the relative congestion costs of use of road space at different times and in different locations. They are just not sharp enough instruments for representing congestion and pollution in the price paid for users. The case for road user charging rests on there being a social advantage in moving to a system in which prices better reflect the relevant congestion and pollution costs, as well as the infrastructure costs, of using road. In the following section, we examine these arguments further, and provide some empirical evidence.

2) Efficient Prices

The Marginal Social Cost (MSC) Concept

A starting point is the fundamental economic rule explained above that prices should reflect the incremental, or marginal, social cost imposed on society from consumption of the good.

When car users or the operators of other vehicles decide to travel additional kilometres or to make additional trips they impose additional costs on themselves, on the infrastructure-provider, on other users and on the rest of society. Costs to other users and to the rest of society are referred to as 'external' costs. External costs or benefits arise when the social or economic activities of one agent have an impact on the welfare of another agent, without that impact having been taken into account by the first agent. For example, a motorist making a journey along a congested road will cause delays to the existing vehicles on that road and on the surrounding network of roads. These delays to existing vehicles are costs which are borne, not by the motorist, but by the existing vehicles in the form of longer journey times. Similarly, emissions from the same motorist's car engine will contribute to an increase in local air pollution, the costs of which will be borne by pedestrians and residents along the route he or she travels.

If monetary values can be placed upon externalities then they can be incorporated into the pricing mechanism by means of direct charges or subsidies; in this way they will then be taken into account by all economic agents. The basic principle used to compute such money values is to ask how much compensation the person suffering from the externality would theoretically need to be no worse off as a result of it. Techniques for establishing these values include examining the degree to which travellers are willing to undertake slower journeys to save money, the degree to which householders will **knowingly** put up with environmental nuisance to get cheaper housing, and the willingness to pay for greater comfort or reliability.

Prices which reflect the additional infrastructure and external costs will act as signals to travellers about the marginal social costs associated with their additional travel. They will then base their demand decisions – whether, how and how far to travel - upon these price signals, as measured by their willingness to pay for it. If an individual or firm's benefit from a trip is more than marginal social cost it will be possible to make everyone better off by the trip going ahead, as the person making the trip could fully compensate all those who lose by it and still be better off themselves. The converse is true: if their willingness to pay for the trip is less than marginal social cost, it will be possible to make everyone better off if the trip does not go ahead.

Short Run vs Long Run Marginal Social Cost

There are two concepts of MSC, short run MSC and long run MSC. The former is defined as the social cost of an additional vehicle kilometre at the current level of infrastructure provision. This changes over time as the level of infrastructure provision and the level of traffic changes. It is the answer to the question ‘Given the level of infrastructure provided, what is the additional social cost of handling more traffic?’ Under this approach the existing capital stock is a bygone; relevant costs are the future costs such as marginal maintenance of the road network, congestion and environment cost of handling more traffic.

Long run MSC is defined as the social cost of an additional vehicle kilometre when infrastructure provision is optimally adjusted to the level of demand. This involves balancing capacity costs against congestion costs. Long run MSC therefore includes the same cost categories as short run MSC (but allowing for adjustment to the optimal level of capacity) but also the cost of additional infrastructure provision per unit of traffic.

Both approaches have their advantages and disadvantages, but there are two situations where a choice between the two need not be made. Firstly, where infrastructure provision happens to be optimal the short run and long run marginal costs will be identical. Secondly, in circumstances where infrastructure can be assumed to be fixed for the foreseeable future, including urban roads (e.g. in built up areas) and non-primary rural roads, capacity changes are unlikely, so that only the short run marginal cost is of relevance.

It tends to be the inter-urban strategic road network where the competing claims of short and long run approaches require consideration. Adjustment to the optimal level of capacity can involve major time lags, indivisibilities requiring a minimum level of additional provision (moving from a three lane motorway to a four lane motorway) and may be subject to politically determined investment priorities. In such circumstances short run marginal cost pricing achieves optimal use of the existing infrastructure, irrespective of whether capacity provision is optimal or not, as explained above. In contrast, pricing based on long run marginal cost offers a different advantage. Many long-term decisions such as location choice and the choice of whether or not to own a car depend on signals about future prices. If infrastructure capacity does not follow an optimal expansion path there is a danger that current prices serve as a poor guide to future prices and consequently lead to individuals being locked into situations that are inefficient over the longer term. An alternative approach to overcoming this issue for the short run marginal cost approach would be to smooth charges over time to avoid excessive fluctuation once new infrastructure is provided.

An earlier study by ITS for the DETR (Sansom et al, 2002) concluded that short run marginal cost was the most important and relevant cost to estimate, although data on long run marginal cost would also be valuable in terms of examining the case for investment.[1]

Key Components of Short Run MSC

What the principle of short run MSC pricing translates into, in terms of road pricing, is a need to measure three components of cost. The first is the cost imposed by an additional unit of traffic on the infrastructure provider. This comprises additional maintenance and renewals costs plus any additional operating costs. The second component is the marginal cost imposed on other infrastructure users, in terms of delays, congestion, and accidents. The third element is the cost imposed outside the transport system; this is mainly environmental cost, but some elements of other costs such as accidents, for instance where these are borne in part by the police or health service and not recovered from users, may enter here. Table 1 helps to illustrate what cost components make up Short Run MSC.

Table 1 Key Components of Short Run Marginal Social Cost

Incidence of Cost	Cost Elements
1) Infrastructure Providers	Maintenance & renewal costs
2) Infrastructure Users	Delays, congestion, accidents
3) Non-infrastructure Users	Local air pollution, global warming, noise pollution

3) Current Pricing Structures in the UK

Currently, MSC pricing does not exist in the UK for transport services, although low cost airlines and some long distance rail operators charge fares which vary in part according to differences in the private costs of their operations. Instead, the motorist or freight haulier is faced with charging mechanisms that are blunt by comparison, consisting of:

- Vehicle Excise Duty for road vehicles. Differentiation exists by engine size, engine standard (pre-Euro I etc.) and vehicle category

- Fuel duty for road vehicles. Differentiation exists by fuel type and to a very limited extent by vehicle type (e.g. coloured diesel for agricultural vehicles).

This structure of charges fails to reflect the variation in marginal social cost across the network in terms of congestion and environmental costs – although it is true that fuel consumption and therefore tax paid is higher in congested circumstances than elsewhere, the difference in tax paid is nothing like as great as the difference in marginal social cost. Similarly it fails to reflect **at the margin** the difference in wear

[1]It should be noted that neither short run nor long run MSC approaches guarantee that infrastructure cost recovery will be achieved (although, were it deemed necessary, there are a number of ways that this could be achieved, such as a "two-part tariff" combining a fixed fee for the right to use infrastructure with a variable component based on marginal costs). Conversely, marginal social cost pricing might well recover considerably more than total infrastructure costs, particularly in a situation where major external costs are present.

and tear caused by heavy axle-load vehicles. Again, these may tend to pay more fuel tax because of higher fuel consumption but not in proportion to the wear and tear caused. They also pay more Vehicle Excise Duty, but this is an annual lump sum which does not vary with the distance driven and therefore with the damage caused. A further problem is that vehicles from abroad do not pay British Vehicle Excise Duty; they may have paid a substantially lower rate in their own country and indeed also come into the country with a tank of fuel on which they have paid tax at a lower rate.

It is often argued that the overall level of charges should be set to recover the total cost of road transport. This may be seen as fair and perhaps also there is a view that it will avoid on the one hand use of road transport simply as a convenient source of revenue for the Exchequer, and on the other hand pressure from the road transport sector for excessive expansion of infrastructure for which they do not have to pay. However, this argument has two problems. The first is that it does not lead to any unique view as to how these costs should be shared between different vehicle types. In practice, the British government did develop some formulae for doing this on the basis of various cost drivers such as vehicle kilometres and axle-weight. This led to estimates of what may be called fully allocated costs which were published in a document entitled road track costs. However, the rather arbitrary nature of many of these allocations led to the withdrawal of this approach in 1995. The second problem is that efficient pricing at marginal social cost may require very different relative and absolute levels of charge from the fully allocated costs approach, and may under or over recover total cost.

Impact of Current Charging Regime in Great Britain

The last 50 years has seen a substantial growth in car ownership and travel within Great Britain (RAC Foundation, 2002). The situation today is that 85% of all passenger kilometres (kms) travelled are made by car, either as a driver or as a passenger, this compares with around 30% in the 1950s. This reflects the change in car ownership which has grown from around 2 million cars for a population of just under 49 million in the 1950s, to today’s situation of 24.5 million cars for a population of around 58 million, e.g. 73% of households now have at least one car compared to 14% in the 1950s.

With car ownership and car travel forecast to grow over the next 30 years (a combination of growing real incomes, falling vehicle purchase and running costs, and demographic changes) there is good reason to believe that there will be a significant deterioration in travel conditions, even with additional road capacity. A recent study by the RAC Foundation (2002) predicted a possible rise in average journey times of around 7% by 2011 and 20% by 2031 compared with the average journey time in 2001. Congestion is likely to spread in both time and space, particularly in urban areas and most major motorways. Journey reliability is forecast in the study to fall with an associated impact upon both businesses and travellers for whom punctuality is an issue. In addition both accident and external costs are predicted to rise, although new engine and fuel technologies will help to moderate the increase in the latter.

The report by Sansom et al (2002) estimated the fully allocated costs per car unit (pcu) vehicle km and the MSC pcu vehicle km for a 1998 base case. These are presented in Table 2 below that also includes information on revenues collected by the government. The fully allocated costs include environmental and full accident costs.

For the fully allocated cost analysis, at both low and high values of cost estimates, costs are covered by taxes specific to the road sector - ranging from a multiple of 1.0 to 2.1. Infrastructure-related costs comprise up to half of overall costs, with environmental costs dominating the remainder for the low costs estimates and also exceeding external accident costs in the high cost scenario. It should be noted that congestion costs are excluded from this average cost calculation since people experience average congestion costs when they use the road system. It is only when we look at marginal costs that an additional road user may impose substantial costs on other users.

The marginal cost analysis provides contrasting results, with marginal costs exceeding revenues by a factor of 2.0 or more. Congestion costs dominate marginal external costs, making up 80% of the low cost estimate, and some two-thirds of the high estimate. The authors note that the marginal external congestion costs are calculated at the current level of demand and no modelling of demand responses to price changes has been carried out. From recent EC research projects[2] such responses would be expected to result in a dramatic reduction in external costs. Thus, the results may not be interpreted directly as the magnitude of change needed to achieve more economically efficient prices. From Table 2 it can be seen that marginal costs of congestion dominate all other marginal cost estimates, and almost invariably exceed revenues.

From the figures in Table 2 it would appear that the current charging regime in Great Britain is, *for the average motorist*, only covering at best 50% of their MSC. This has given rise to traffic growth that has stretched the capacity of certain sections of the network during certain times of the day. However, we note that there is substantial variation in MSC dependent upon time period, area type and road type and we present these in Tables 3 and 4. It can be seen that the level of undercharging for road users can vary quite considerably and that in some cases road users are being overcharged relative to short-run MSC.

Table 2 Comparison of 1988 Road Sector Costs and Revenues

[2] In the PETS project the Lisbon case study (Viegas et al., 1999) and the Cross Channel case study (Sansom et al., 2000); and the case studies in the TRENEN project Proost and Van Dender (1999).

Pence per vehicle km, Great Britain, 1998 prices and values

Cost or revenue category	Fully allocated cost		Marginal cost	
	low	high	low	high
Costs:				
Cost of capital for infrastructure	0.78	1.34	n/a	n/a
Infrastructure operating costs and depreciation	0.75	0.97	0.42	0.54
Vehicle operating costs (PSV)	0.87	0.87	0.87	0.87
Congestion	n/a	n/a	9.71	11.16
Mohring effect (PSV)	n/a	n/a	-0.16	-0.16
External accident costs	0.06	0.78	0.82	1.40
Air pollution	0.34	1.70	0.34	1.70
Noise	0.24	0.78	0.02	0.78
Climate change	0.15	0.62	0.15	0.62
VAT not paid	0.15	0.15	0.15	0.15
Sub-total of costs	**3.34**	**7.20**	**12.32**	**17.05**
Revenues:				
Fares (PSV)	0.84	0.84	0.84	0.84
Vehicle excise duty	1.10	1.10	0.14	0.14
Fuel duty	4.42	4.42	4.42	4.42
VAT on fuel duty	0.77	0.77	0.77	0.77
Sub-total of revenues	**7.14**	**7.14**	**6.17**	**6.17**
Comparison of costs, revenues:				
Difference (cost-revenue)	**-3.79**	**0.07**	**6.15**	**10.88**
Ratio: revenues/costs	**2.13**	**0.99**	**0.50**	**0.36**

Notes: Road sector costs exclude costs attributable to pedestrians, bicycles and motorcycles;
Accident costs are reported net of insurance payments;
Vehicle Excise Duty in the marginal analysis relates to HGVs and PSVs;
n/a – not applicable.

Source: Sansom et al (2002)

Table 3 Marginal Cost/Revenue Analysis – by Area Type and Road Type (pence/vkm, low cost estimates)

Categories	**Costs**							**Revenues**			**Difference**
	Infrastructure operating cost & depreciation	**Congestion**	**External accident costs**	**Air pollution**	**Noise**	**Climate change**	**Total**	**Fuel duty**	**Value added tax on fuel duty**	**Total**	**Costs - Revenues**
Central London											
Motorway	0.01	53.75	0.01	0.57	0.04	0.11	54.4	3.86	0.68	4.5	49.9
Trunk & Principal	0.04	71.09	1.68	0.77	0.03	0.16	73.8	3.86	0.68	4.5	69.2
Other	0.08	187.79	1.68	0.87	0.04	0.19	190.6	3.86	0.68	4.5	186.1
Inner London											
Motorway	0.01	20.10	0.01	0.42	0.03	0.11	20.7	3.86	0.68	4.5	16.1
Trunk & Principal	0.04	54.13	1.68	0.61	0.04	0.16	56.6	3.86	0.68	4.5	52.1
Other	0.08	94.48	1.68	0.66	0.03	0.17	97.1	3.86	0.68	4.5	92.6
Outer London											
Motorway	0.01	31.09	0.01	0.47	0.02	0.11	31.5	3.86	0.68	4.5	27.0
Trunk & Principal	0.04	28.03	1.68	0.55	0.02	0.14	30.3	3.86	0.68	4.5	25.8
Other	0.08	39.66	1.68	0.66	0.02	0.17	42.0	3.86	0.68	4.5	37.5
Inner Conurbation											
Motorway	0.01	53.90	0.01	0.47	0.02	0.11	54.5	3.86	0.68	4.5	50.0
Trunk & Principal	0.04	33.97	1.68	0.55	0.02	0.14	36.4	3.86	0.68	4.5	31.9
Other	0.08	60.25	1.68	0.66	0.02	0.17	62.9	3.86	0.68	4.5	58.3
Outer Conurbation											
Motorway	0.01	35.23	0.01	0.25	0.02	0.10	35.6	3.86	0.68	4.5	31.1
Trunk & Principle	0.04	12.28	1.68	0.30	0.02	0.12	14.4	3.86	0.68	4.5	9.9
Other	0.08	0.00	1.68	0.32	0.02	0.13	2.2	3.86	0.68	4.5	-2.3
Urban>25 km2											
Motorway	0.04	10.13	1.68	0.25	0.02	0.12	12.2	3.86	0.68	4.5	7.7
Trunk & Principal	0.08	0.72	1.68	0.26	0.02	0.13	2.9	3.86	0.68	4.5	-1.6
Other											
Urban 15-25 km2											
Trunk & Principal	0.04	7.01	1.68	0.25	0.02	0.12	9.1	3.86	0.68	4.5	4.6
Other	0.08	0.00	1.68	0.24	0.02	0.12	2.1	3.86	0.68	4.5	-2.4
Urban 10-15 km2											
Trunk & Principal	0.04	0.00	1.68	0.17	0.02	0.11	2.0	3.86	0.68	4.5	-2.5
Other	0.08	0.00	1.68	0.19	0.02	0.12	2.1	3.86	0.68	4.5	-2.4
Urban 5-10 km2											
Trunk & Principal	0.04	2.94	1.68	0.15	0.02	0.11	4.9	3.86	0.68	4.5	0.4
Other	0.08	0.00	1.68	0.16	0.02	0.12	2.1	3.86	0.68	4.5	-2.5
Urban 0.01-5 km2											
Trunk & Principal	0.04	1.37	1.68	0.13	0.01	0.11	3.3	3.86	0.68	4.5	-1.2
Other	0.08	0.00	1.68	0.14	0.01	0.12	2.0	3.86	0.68	4.5	-2.5
Rural											
Motorway	0.01	4.01	0.01	0.11	0.00	0.13	4.3	3.86	0.68	4.5	-0.3
Trunk & Principal	0.04	8.48	0.30	0.10	0.00	0.11	9.0	3.86	0.68	4.5	4.5
Other	0.08	1.28	0.30	0.10	0.01	0.10	1.9	3.86	0.68	4.5	-2.7

Source: Sansom et al (2002)

Table 4 Marginal Cost/Revenue Analysis – by Vehicle Class and Time Period (pence/vkm, low cost estimates)

Categories	Costs										Revenues					Difference
	Infrastructure operating cost & depreciation	Vehicle operating cost (PSV)	Congestion	Mohring effect (PSV)	External accident costs	Air pollution	Noise	Climate change	VAT not paid (PSV)	Total	Fares (PSV)	Vehicle Excise Duty (part)	Fuel duty	Value added tax on fuel duty	Total	Cost Revenues
Car, peak	0.05	-	13.22	-	0.78	0.18	0.01	0.12	-	14.4	-	-	3.86	0.68	4.5	9.8
Car, off-peak	0.05		7.01	-	0.80	0.18	0.01	0.12	-	8.2	-	-	3.86	0.68	4.5	3.6
LDV, peak	0.06	-	13.99	-	0.52	0.76	0.02	0.19	-	15.5	-	-	3.86	0.68	4.5	11.0
LDV, off-peak	0.06	-	7.07	-	0.53	0.68	0.02	0.18	-	8.5	-	-	3.86	0.68	4.5	4.0
HGV – Rigid peak	3.82	-	26.00	-	1.40	1.84	0.06	0.44	-	33.6	-	2.25	13.11	2.29	17.6	15.9
HGV – Rigid, off-peak	3.77	-	12.75	-	1.39	1.57	0.06	0.43	-	20.0	-	2.25	13.11	2.29	17.6	2.3
HGV – Artic, peak	7.57	-	33.45	-	0.99	1.42	0.07	0.72	-	44.2	-	2.50	14.47	2.53	19.5	24.7
HGV – Artic, off peak	7.55	-	19.81	-	0.99	1.41	0.08	0.71	-	30.5	-	2.50	14.47	2.53	19.5	11.0
PSV – peak	5.74	78.73	20.31	-14.43	3.82	3.17	0.09	0.58	13.33	111.3	76.19	0.61	5.26	0.92	83.0	28.4
PSV – off peak	4.93	80.10	12.31	-14.86	3.69	3.15	0.09	0.55	13.49	103.5	77.10	0.61	5.26	0.92	83.9	19.6

Source: Sansom et al (2002)

4) Evidence on the effects of Marginal Social Cost Pricing

After making the case for the introduction of MSC, or some form of MSC based pricing, in the previous section we now look in more detail at evidence on the effects of its introduction. Evidence is available on the implications of marginal cost pricing from a small number of actual implementations or demonstration projects, and from a much larger number of modelling exercises. Both will be reviewed in this section, which draws heavily on a report for the European Commission (CAPRI, 2001) updated from the stated sources.

The key factor to remember when considering the evidence is that the impact of MSC pricing will differ between user groups and by relative charges because each individual or group of individuals will respond differently to a change in prices. In general, all other things being equal, an increase in the costs facing a traveller will reduce travel, whilst a decrease in costs will increase travel. The size and direction of the change in demand following a change in costs can be expressed in terms of an *elasticity* and is defined as,

$$Elasticity = \frac{Percentage \quad Change \ in \ \ Demand}{Percentage \ Change \ in \ the \ Factor \ \ Affecting \ Demand}$$

For example, if the elasticity of car demand with respect to car operating costs is –0.2, and costs were to increase by 10% we would expect patronage to decrease by 2%. The elasticity is therefore a measure of the sensitivity of car travellers to the factor in question.

The absolute size of the elasticity conveys information on the sensitivity of demand to changes in the factor affecting demand and its sign conveys information on the direction of the change. A wide range of factors influence the size of elasticities, such as current cost levels, the availability of alternatives, and the size of the change in costs and income levels. Whilst these factors can be discussed in isolation it is likely that more than one of them will exert an influence at the same time. There is also a need to consider the dynamics of the impact of costs upon demand. An increase in costs would result in a reduction of traffic thus reducing the congestion costs experienced by the remaining travellers and so reducing their journey times. At the margin this journey time reduction may well allow some drivers to re-enter the road system for whom the total journey costs is now less than the benefit they gain from travelling. The whole process is iterative until an equilibrium situation is reached whereby the total costs of travel equals the total benefits gained from travel.

Direct Evidence

Regarding inter urban transport a number of countries either have tolls on motorways (and of course Britain has its first tolled motorway now open and a number of bridges or tunnels have tolls), or a supplementary vignette which much be purchased to authorise use of motorways. Neither of these is generally a good solution to the problem of accurately reflecting the marginal social cost of road use since the above evidence shows that marginal social cost is often higher off the motorways than on it; moreover the vignette is valid for a given period of time regardless of the distance travelled. What is needed therefore is a charging system relating to distance driven applying to all roads in the area in question. The first country in Europe to implement such a system in recent years was Switzerland, which in 2001 implemented a kilometre charge for use of its road systems by goods vehicles of more than 3.5 tonnes gross weight. This varies with the characteristics, such as pollution levels, of the vehicle in question and is based on explicit valuations of infrastructure and environmental costs. It is charged by means of an on-board unit linked to the tachograph. It does not currently vary by location and time of day, so it does not reflect differing levels of congestion. The kilometre charge is considered to be a success, resulting in a fall in motorway traffic and leading to the renovation of HGV fleet to lower and cheaper emission class vehicles. (Balmer, 2003) Germany proposes to introduce a distance-based HGV toll for the use of German motorways although this has been delayed by technical problems. The charge will apply to vehicles weighing over 12 tonnes: again it is differentiated by emissions levels and based on explicit calculations of infrastructure and environmental costs, but will not – initially at least – reflect differing levels of congestion costs. Britain also proposes for HGVs to implement a distance-based charge for the use of the entire UK road network in 2007-2008. The charge will apply to vehicles weighing over 3.5 tonnes; it will be offset by partially rebated fuel duty on these vehicles.

The charges all aim to take into account the costs imposed to infrastructure by HGVs. The Swiss toll also considers external costs such as air pollution, noise and accidents, but costs caused by congestion or the greenhouse effect were not considered. Revenue from the HGV tolls was proposed to be spent on the transport sector, particularly on infrastructure projects. Switzerland aimed to expand the capacity of the rail network in order to facilitate a modal shift from road freight to the railways, in order to reduce the costs on the roads and contribute to relieving road congestion. In order to ease the implementation of HGV charging, other policies were put forward. Switzerland increased the permitted gross vehicle weight of lorries simultaneously with the introduction of the HGV toll, which was hoped to raise the productivity of road transport. Britain proposes to introduce off-setting tax cuts in the form of a reduction in fuel duty, whilst Germany proposes to introduce a toll rebate scheme if proof of mineral oil tax paid was produced, lowering motor-vehicle tax for HGVs to the minimum level admissible under EU law and a HGV innovation programme where an investment subsidy is given for purchasing HGVs with lower emission classes. These policies were thought to enable a much fairer and smoother implementation of the HGV tolls.

For the use of urban roads, the Norwegian experience goes back more than ten years. In Norway, special area entry permits are being used in Oslo, Bergen, and Trondheim. Although they are primarily used to raise revenues, there is evidence that there has been some impact on the overall traffic levels in the controlled area. In Oslo, the car traffic reduction is estimated as 5%; but the toll was introduced at a low level with the main aim of raising revenue for the building of transport infrastructure. At Bergen the effect is slightly higher at 6-7%.

A form of area pricing system has been in use in Singapore since 1975 with considerable success. From 1998, this was adapted into a more sophisticated electronic charging system, the early results of which show a 15% reduction in overall traffic levels (Menon, 2000). However, it should be noted that these examples of pricing reform could only be described as having been 'loosely' based on principles of marginal cost.

In February 2003 London became the first city in Britain (excluding a very small scheme in Durham) to introduce congestion charging (Transport for London, 2003). All vehicles have to pay a charge of £5 to drive in Central London between 7.00 a.m. and 6.30 p.m. Mondays to Fridays, with certain exceptions. Buses and taxis are exempt and residents within the area can obtain a 90% discount. Payment can be by web, mobile phone text message or over the counter at Paypoint outlets. Enforcement is by cameras linked to number plate recognition technology.

The aims of the scheme were to reduce traffic within the charging zone by 10-15%, improve bus services and raise net revenue of £130m for investment in improved transport. To date the scheme has been judged a success with approximately 110,000 motorists per day paying the charge. Survey figures from December 2003 show a reduction in congestion of around 30% with typical traffic delays in the charging zone showing a reduction from 2.3 minutes per kilometre to 1.7 minutes per kilometre (TfL, 2004). The survey results also reveal that compared with 2002 equivalents the number of vehicle kilometres for vehicles with 4 or more wheels has seen a 15% reduction and for car specifically, a 34% reduction. The scheme would appear to have been successful in achieving its aims of reducing congestion and, indeed, almost too successful, resulting in a predicted £38 million shortfall in the revenues it was expected to raise (Litman, 2004) to help fund improvements in public transport. It is noteworthy that traffic has turned out to be more responsive than conventional wisdom might suggest.

Evidence from Modelling Studies

Modelling studies for urban and inter-urban road pricing indicate that proposed price changes can induce small but significant changes in behaviour – small changes in behaviour can make a major contribution to the reduction of congestion and other externalities. In some studies a small reduction in demand has been shown to result in the marginal external cost of congestion falling to 20% of the pre-charge level, e.g. the reduction in demand has occurred on the most congested sections of the highway. Two particularly important studies of road pricing in Britain at the national level.

a) Paying For Road Use: Technical Report (CfIT, 2002)

This study developed a UK model of road congestion to assess the marginal external costs per vehicle-km at existing traffic flows, and then, allowing for the impact of congestion charges on demand, to estimate the optimal congestion charges that should be levied on different types of road and in different areas of the country. These charges have then been used to calculate the overall benefit of road congestion charges if it were introduced throughout the UK. The overall benefits are comprised of:

1) changes in traffic speeds;
2) changes in congestion;
3) changes in traffic flows;
4) changes in time savings;

5) road price revenues, and;
6) reduction in fuel tax revenue.

The study is designed to test the appropriateness of the Ten Year Plan, which emphasises the implementation of urban cordon charging and workplace parking levies as contributing towards its policy of reducing urban congestion. The Ten Year Plan assumes that congestion charging schemes will have been introduced in the central parts of eight of the largest cities and towns in England (as well as London) by 2010. In addition the same eight cities and towns, plus four others, will have introduced workplace parking levies.

The model developed by the study is able to forecast results for a variety of charging regimes but has chosen to concentrate on charging systems that would operate between 7 am and 7 pm. The findings of the study are outlined in Tables 5 and 6.

b) Transport Pricing and Investment in England (Glaister & Graham, 2003)

The aim of the model in this study was to move demand from the point where it equals marginal private cost to the point where it equals marginal social cost. The data used in the model was supplied by the DfT for the year 2000 and was used in the FORGE Road Capacity and Costs Model. The traffic flow data relates to 8,960 observations that cover 9 regions, 10 area types, 20 times of day, 15 road types, 5 vehicle types and by 'busy' or 'non-busy' direction

In total nine scenarios were examined which are outlined below.

1) Do-Nothing
- No change in real taxes or charges
- A 22% increase in the underlying demand for all modes
- Implementation of 10 year plan.

2) Environmental Charges (EC)
- Travel as today.
- Fuel and other charges as today.
- Additional charge to reflect environmental costs.

3) Environmental Charges and Congestion Charges (EC & CC)
- As EC.
- Congestion cost charges to reflect the congestion costs inflicted by each vehicle on others.

4) EC & CC & Compensating Rebate
- As EC & CC but with a rebate for users so that total tax + CC are equal to today's, e.g. revenue neutral.

5) Zero Fuel Tax
- All fuel taxes removed (VAT remain on fuel).
- In principle subsidies would be eliminated for public transport but not feasible. Instead bus fares raised by 20% & 33% in London and rail fares by 80%.

6) Zero Fuel Tax with EC and CC

7) Zero Fuel Tax with EC and CC with a Revenue Neutral Mark-Up

- As in the previous case but with the imposition of an proportionate mark-up on all EC and CC, returning over Exchequer income to today's levels.

8) Tax Revenue Maximisation

- Fuel tax and public transport fares raised to the point of maximum revenue to the Exchequer.

9) Tax Revenue Maximisation and Free Public Transport

The results are presented in a series of tables (7 to 9) presented below for a series of low and high environmental values.

Both of these studies show potential benefits of the order of £2-4b, excluding administration costs, with the biggest benefits in London and the other conurbations.

Table 5 Results of Marginal Congestion Charges for Some Selected Roads

	Outer London PM Peak (5pm-6pm)	Inner Provincial Conurbations AM Peak (8am-10am)	National Motorways Inter-Peak (10am-4pm)
Speed before charging	21.1 mph	22.6 mph	64.2 mph
Speed after charging	24.6 mph	24.8 mph	65.1 mph
Annual traffic flow before	549m PCU miles	639m PCU miles	15,311m PCU miles
Annual traffic flow after	483m PCU miles	557m PCU miles	15,122m PCU miles
Annual revenue	£159.1m	£71.5m	£204.8m
Annual time savings	9.7 m PCU hours	2.3mPCU hours	5.9m PCU hours
Annual VoT savings	£92.6m	£25.2m	£59.9m
Annual reliability benefits	£23.1m	£6.3m	£15.0m
Annual loss to those not travelling	£9.0m	£5.8m	£8.3m
Change in congestion	-68%	-40%	-24%

Source: CfIT (2002)

Table 6 Impact of Congestion

	All England	Central England	Inner London	Outer London	All London	Inner Conurb.	Outer Conurb.	All Conurb.	Largest Other Cities	Other Major Towns	Urban Medium	Urban Small	Rural	Motorways
Charge per car mile (pence)	4.2	54.6	35.5	21.1	26.6	11.0	4.3	5.6	12.6	4.2	3.0	1.9	1.0	3.5
Change in traffic levels (%)	-4.2	-18.5	-15.9	-11.5	-13	-12.3	-5.6	-7.0	-8.4	-6.1	-4.8	-3.2	-2.4	-2.6
Change in speeds (%)	+2.9	+13.7	+11.6	+13.4	+13.5	+8.0	+2.0	+3.3	+6.2	+2.3	+1.5	+0.5	+0.4	+3.2
Change in congestion (%)	-44	-34	-59	-63	-56	-30	-35	-34	-65	-31	-25	-12	-11	-36
Total time savings (million vehicle hrs)	182.1	11.7	28.1	50.8	90.6	10.1	11.3	21.4	24.4	3.1	8.9	0.6	4.4	28.8
Annual revenue from congestion charges (£m)	5666	243	574	1021	1838	357	525	882	469	175	585	81	494	1140
Benefit of reduced travel time (£m)	1875	103	288	524	915	112	116	228	228	28	96	8	40	332
Benefit of increased reliability (£m)	469	26	72	131	229	28	29	57	57	7	24	2	10	83
Loss to those 'tolled off' (£m)	313	22	36	69	127	25	25	50	26	6	30	4	18	52
Net benefit before collection costs (£m)	2031	107	324	586	1017	115	120	235	259	29	90	6	32	363

Source: CfIT (2002)

Note: Conurbations: Birmingham, Leeds, Liverpool, Manchester, Newcastle, Sheffield.
Largest other cities: Blackpool, Bournemouth, Brighton, Bristol, Hull, Leicester, Middlesborough, Nottingham, Plymouth, Portsmouth, Southampton, Stoke.
Other major cities: Basildon, Blackburn, Cheltenham, Colchester, Derby, Gloucester, Ipswich, Luton, Milton Keynes, Northampton, Norwich, Oxford, Peterborough, Preston, Reading, Slough, Southend, Swindon, Telford, Torbay, Warrington.

Table 7 Summary Results of Low Environmental Costs

	Scenario	Traffic	All pax. km	Car km	Commercial Vehicle km	Bus Pax. km	Rail Pax. km	Car cost £ per km	Bus Subsidy	Bus Fare (ex-London)	Rail Subsidy	Rail Fare
		Ratio of flow to the current value[1]							£m pa	% change	£m pa	% change
1	Current (2003)	1	1	1	1	1	1	0.104	1,408	-	1,597	-
2	Do nothing, 22% demand growth	1.20	1.20	1.19	1.20	1.20	1.24	0.104	1,425	0	828	0
3	EC	0.94	0.95	0.95	0.94	1.014	1.015	0.116	1,403	0	1,547	0
4	EC & CC	0.91	0.92	0.91	0.90	1.07	1.02	0.132	1,358	0	1,520	0
5	EC & CC, rev neutral	1.01	1.04	1.01	1.01	1.05	0.99	0.103	1,371	0	1,633	0
6	Zero tax	1.26	1.19	1.22	1.31	1.04	0.85	0.061	917	+20	994	+80
7	Zero tax, EC & CC	1.12	1.06	1.09	1.16	1.12	0.67	0.093	793	+20	914	+80
8	Zero tax, EC & CC & revenue neutral mark-up	1.04	1.00	1.02	1.06	1.13	0.69	0.108	777	+20	822	80
9	Rev. max	0.37	0.45	0.35	0.31	1.20	1.45	0.32	1,369	0	73	0
10	Rev. max & free PT	0.39	0.49	0.37	0.317	2.07	1.82	0.32	6,377	n/a	4,844	n/a

[1] For example, a ratio of 1.2 would normally be interpreted as a 20% increase and a ratio of 0.94 as a 6% reduction.

[2] Row 2 represents 22% demand growth relative to the base year, whereas other rows represent the consequences of policy changes in the base year relative to the base year.

Source: Glaister & Graham (2003)

Table 8 Economic Evaluation, Low Environmental Costs. Change relative to current situation (£bn pa, 2003 prices)

	Scenario	Saving in environ. cost	Passenger & freight benefit	Reduction in bus subsidy	Reduction in rail subsidy	Env. tax, congestion charge rev. & rebates	Net benefits	Tax revenue correction	Net gain to exchequer	Benefits net of all costs to exchequer	Ave. weighted ave. marg. cong. costs
1	(Column Reference)	(1)	(2)	(3)	(4)	(5)	(6) =(1+2+3+4+5)	(7)	(8) =(3+4+5+7)	(9) =(1+2+3) =(1+2+3+4+5+7)	
3	EC	0.54	-4.66	0.01	0.05	5.8	1.7	-1.3	4.56	0.4	0.080
4	EC & CC	0.91	-7.99	0.05	0.08	11.9	4.9	-2.2	9.83	2.8	0.075
5	EC & CC, rev neutral	0.28	0.88	0.04	-0.04	0	1.2	0.6	0.6	1.8	0.068
6	Zero tax	-1.63	18.03	0.49	0.60	-27.5	-10.0	+6.0	-20.41	-4.0	0.010
7	Zero tax, EC & CC	-0.40	6.81	0.62	0.68	-7.9	-0.2	+2.8	-3.80	2.6	0.062
8	Zero tax, EC & CC & rev neutral mark-up	0.32	0.15	0.63	0.77	0	1.9	+1.0	2.40	2.9	0.064
9	Rev. max	3.95	-57.97	0.04	1.47	+35.8	-16.8	-13.8	23.51	-30.5	0.174
10	Rev. max Free pt	3.97	-53.33	-4.9	-3.25	+35.6	-22.0	-13.8	13.65	-35.7	0.174

Source: Glaister and Graham (2003)

Table 9 Summary Results of High Environmental Costs

	Scenario	Traffic	All pax. km	Car km	Commercial Vehicle km	Bus Pax. km	Rail Pax. km	Car cost £ per km	Bus Subsidy	Bus Fare (ex-London)	Rail Subsidy	Rail Fare
1		Ratio of flow to the current value[1]							£m pa	% change	£m pa	% change
2	EC & CC	0.81	0.87	0.82	0.77	1.09	1.06	0.152	1,390	0	1,447	0
3	Zero tax, EC & CC	1.01	0.98	1.0	1.0	1.14	0.69	0.111	783	+20	807	+80
4	Zero tax, EC & CC & Revenue neutral mark-down	1.04	1.01	1.03	1.04	1.13	0.68	0.106	787	+20	844	80

Source: Glaister & Graham (2003)

Evidence from Demonstrations of Urban Road Pricing

Demonstrations such as the Leicester demonstration in EUROTOLL as well as modelling exercises confirm the main impact of more variable road charging is likely to be travel at different times or by different routes by the same mode – the user's first preference will often be to continue to use their vehicle, but in a different way (different departure time, route, linking trip purposes together etc.). Provision of park and ride appears to be important in the use of road pricing for promotion of public transport, and car occupancies may also rise (they have risen by some 10% in Central London following the introduction of congestion charging).

Other studies

The under-charging of road-based modes in urban areas implies that efficient pricing will have the greatest impact in reducing externalities in urban areas. Modelling and demonstration work as part of the TRANSPRICE project (1999) confirmed that road use pricing is an effective way of changing modal split from private car to public transport and park & ride. Modelling tests for five cities taking part in the TRANSPRICE project produced city centre traffic reduction of 5-20%, with associated environmental benefits. In the case of Athens where both demonstration and modelling were carried out, a reasonably close result between the two sources was found. Parking pricing provides an effective way for restraining car trips (assuming that enforcement can be maximised), but less so than road use pricing options for which enforcement levels are expected to be higher than past experience with parking pricing.

For inter-urban passenger travel in uncongested conditions, it is likely that, internationally, road-based modes are over-priced – due to the combination of existing charging and taxation systems. For example, the PETS case studies (Nash et al, 2000) suggest that existing prices for inter- urban car broadly reflect and perhaps exceed MSC including all externalities. However, Sansom et al (2001) found that in Britain due to congestion inter urban road was typically underpriced, as was rail but to a lesser extent. In other words efficient pricing would probably induce some transfer to rail (although rail also suffers from capacity constraints in the peak) as well as resulting in fewer trips overall.

For inter-urban freight transport, Sansom et al (2001) suggests under-charging for much road haulage even in uncongested conditions, because of the failure to charge adequately for infrastructure costs, whilst rail freight in Britain was typically covering its marginal costs at the time of the study.

5) Further issues in Marginal Social Cost Pricing

In Section 1 of this annex, the concept of social marginal cost pricing was introduced. The basic case rests on consideration of economic efficiency, namely, that users are incentivised to travel only where the benefits to them of doing so exceed the MSC they impose. However, efficiency is not the only consideration and it is worth placing the efficiency argument in a broader policy context.

Equity

The efficiency approach takes no account of equity considerations. Yet in practice, many people think that for public utility type goods equity is as important as efficiency in determining how the tariff should be set. The difficulty is that equity is a multi-dimensional concept. We can think of,

- equity between road users of different classes;
- equity between heavy and light users of the system;
- equity between car and public transport users;
- equity between people on different locations (for example rural interests);
- equity between 'essential' and 'inessential' users;
- equity between road users and taxpayers; and
- equity between income groups.

Many of these concepts of equity seem to be based on some version of the 'benefit' principle whereby users pay for the benefit they receive. This principle might be applied at the margin, i.e. at the individual consumer level, or at a more aggregate level, e.g. requiring that all users of a particular mode of transport should collectively bear the total costs this mode of transport imposes.

Our view however, is the relevant consideration is the distributive impact of a policy measure (such as road user charging) on income and/or social groups. Again this will require empirical work starting from the current pattern of transport use by income and social group and modelling the impact of road user charging on that pattern. We will not speculate here, but it is essential that such work should consider impacts on public transport users as well as car users, and should consider possible uses of the revenues as well as the incidence of the costs.

Pricing Elsewhere in the Economy

The case for pure marginal social cost pricing on roads assumes the existence of MSC pricing elsewhere in the economy. For instance, if one good is charged a price below MSC, there is a case for charging substitute goods below MSC as well to reduce distortion of choices between them. The practical implication is that, where there are divergences between price and MSC in related markets, these lead to cases for divergences in the market in question. The most common application of this argument is in terms of competition between modes. For example, congestion and pollution costs of road transport in cities are one reason (not the only one) for subsidising urban rail services.

But there are other concerns, for instance, transport interaction with land use, where there is an implicit assumption that land is either correctly priced in social terms, or that it is managed by the planners as if it is. One of the concerns with road user charging is that might reinforce tendencies to more dispersed forms of land use. This would need to be recognised in the pricing structure. If the external costs of urban sprawl are not adequately reflected in property prices and local taxation, then it may be desirable to use transport prices to help offset this distortion and discourage sprawl. The implication is that, on those grounds, charges for entering town and city centres should not be raised as far as full marginal social costs. Similarly, if labour taxes discourage labour supply, that may lead to a case for subsidising the cost of commuting. These are examples of 'second best' pricing on which a wide literature exists (Verhoef, 2001). This literature gives techniques for appropriate adjustments to the prices to be charged although in general these may be quite complex and demanding in terms of information.

The best advice on second best pricing is to consider the most obvious distortions in other sectors, to correct them at source if at all possible, and then to adjust the prices being determined to allow for remaining distortions. Such adjustments will only be significant when there is a strong demand relationship of substitutability or complementarity between the goods in questions and when the distortions in the related markets are serious. It is thus unlikely that second best considerations seriously affect the case for marginal social cost pricing of road use, although land use and broader economic impacts remain the biggest cause for concern.

7) Conclusions

This paper has aimed to provide a guide to the basic arguments for the introduction of marginal social cost pricing of roads in Great Britain. The key rationale for this is to improve the economic efficiency of the travel currently undertaken by road users. That is to say, i*f an individual or firm's benefit from a trip is less than MSC, society as a whole will be better off if the trip is not made. Conversely, if the benefit exceeds MSC, there is a net gain to society from the trip being made.*

But efficiency is not everything – administrative costs, enforceability, equity, planning and land use consequences are also very important. This paper has focussed simply on the argument from economic efficiency. Other research done for the Road Pricing Feasibility Study has looked at these issues.

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