Final report of ITS Center project: Road pricing

For the Center for ITS Implementation Research

A U.S. DOT University Transportation Center

Road pricing

Principal investigator: Kenneth Button

Center for Transportation Policy, Operations and Logistics
School of Public Policy
George Mason University
Fairfax, VA 22030
703-993-4647,
kbutton@gmu.edu

March 2004

CONTENTS

Project abstract

Road pricing, sometimes called congestion pricing or value pricing, aims to apportion scarce road space by market pricing rather than queuing. As increasing population densities in growing metropolitan areas press on available resources, pricing has been used to deal with land, communications facilities, public transportation service, waste disposal, and building construction. But in the case of roads queuing, not pricing, apportions available capacity. Value pricing could correct this anomaly. Road pricing can also provide useful information to motorists about congestion, as, for example, SR 91 in Southern California, by continuously adjusting toll rates to reflect congestion levels, the system communicates to motorists approaching the route just how bad congestion ahead is. At the same time, there is at present widespread political resistance to road pricing. This study will examine issues of political feasibility of road pricing.

1. CONGESTION PRICING: STANDARD THEORY AND THE LATEST ADVANCES[1]

1.1 INTRODUCTION

Road traffic congestion is a major problem in all large cities and is becoming increasingly common on some inter-urban highways. The efforts to build a way out of the problem has not proved successful largely because once constructed there has been limited effort to ensure the new capacity is appropriately used. Efforts to attract people out of their automobiles have been equally ineffectual partly because of land-use patterns in the US are seldom conducive to the economic provision of transit and, in any case, many people do not see buses or local rail services as offering comparable services to the automobile at the current prices being charged for road use.

Road Pricing is a simple concept that extends the common practice that is virtually ubiquitous in every other sector of a market economy whereby prices are used to reflect scarcity, and to allocate resources to those that can best use them. In most places road space, even in such supposedly market orientated societies as the US, is in actuality allocated in a manner more akin to the general practices employed in pre-1989 communist Russia, namely by waiting in queues and lines.

While there are some that see merit in using waiting as an allocation device (Barzel, 1974), by and large society finds congestion inefficient and wasteful. After many

[1] This chapter draws upon Button (2004).

years of adding capacity in an attempt to reduce congestion, a number of transport and road authorities at national, regional and local level are seeking to move away from the centralist approach to roads policy to one that has at least a veneer of economic rationality underpinning it.

The introduction of Area Licensing to Singapore in 1975 is the classic case study of a pioneering application[2], but despite the success of the measure it is often seen as not

[2] Since May 1975 Singapore has operated an area licensing system for rush hour traffic. The Singapore scheme offers some practical evidence of the effects of congestion pricing. The initial policy of simply charging for vehicles entering the centre of the city between 7.30 a.m. and 9.30 a.m. was found to be inadequate as traffic spread to either side of the licensing period and in August 1979 the period of licensing was extended to between 7.30 a.m. and 10.15 a.m. Later, an evening period of pricing was also brought in. The impact of the scheme was, nevertheless, impressive from its inception. There was an immediate reduction of 24,700 cars traveling during the peak period. Traffic speeds during the peak rose by about 22%. The table indicates that there have been subsequent increases in traffic volume since 1975, these are considerably below the levels anticipated in the absence of road pricing. There was also some initial geographical spread of traffic to 'escape corridors' outside of the licensing area, but this was contained by adjusting traffic signals and other control measures on circumferential routes.

Time	Vehicle	May 1975	May 1976	May 1977	May 1978	May 1979
0700-0730	Cars	5384	5675 (+5.4)	6488 (+14.3)	6723 (+3.6)	5723 (-14.9)
	Car pools	176	509 (-17.5)	636 (+25.0)	606 (-4.7)	497 (-18.1)
	Total	9800	10332 (+5.4)	11489 (+11.2)	11692 (-1.8)	10596 (-11.9)
0730-1015	Cars	42790	10754 (-74.9)	10350 (-3.8)	11350 (+9.7)	13181 (+16.1)
(Control Period)	Car pools	2369	4641 (+95.9)	5337 (+15.0)	5684 (+6.5)	5756 (+1.3)
	Total	74014	37587 (-49.2)	44318 (+17.2)	47503 (+7.2)	49606 (+4.4)
1015-1045	Cars	n.a.	6459	6636 (+2.7)	6326 (-4.7)	5527 (-12.6)
	Car pools	n.a.	320	280 (-12.5)	281 (+3.2)	232 (-17.4)
	Total	n.a.	13441	13805 (+2.7)	14308 (+3.6)	15179 (+6.1)

(Parenthesis indicates percentage change over previous year.)
Source: Seah (1980).

The scheme was initially seen as part of a comprehensive package of measures embracing ring route designations and public transport, park-and-ride facilities. The latter proved singularly unsuccessful as commuters took to car-pooling – since full cars were initially exempt from the licensing fee – rather than public transport. The minibuses forming the park-and-ride fleet were eventually diverted to other uses and the parking sites transformed into housing estates, tennis courts, etc. It was anticipated that the reduced being particularly relevant for other cities, and especially those in Western Europe and North America. It has taken over a quarter of a century for another scheme to essentially replicate it. Certainly there have been toll rings introduced in a number of Norwegian cities. High occupancy/toll lanes have emerged with the opening of Californian's FASTRACK north of San Diego where there is capacity being priced on a real time basis in lanes that run parallel to free lanes. Although a number of other initiatives have also taken place, they have all generally been driven primarily by the need to find revenues for engineering works rather than as a policy to allocate traffic on extant networks.

1.2 CONGESTION COSTS

Travel demand is mainly a derived demand. Travel is usually demanded not for its own sake but as a means of consuming some other good or service. Because the activities with which transport is associated vary over time, the demand for transport is not constant over time. For example, many towns and cities experience traffic congestion during commuting times (morning and evening), and holiday routes experience seasonal congestion.

Transport infrastructure in the short run has a finite capacity. When users of a particular road begin to interfere with other users because the capacity of the road is limited, then congestion externalities arise. Although some degree of congestion is desirable, or

---

morning traffic flow would be mirrored in the evening but evening peak hour traffic flow only declined by 3% – 4%. This is because commuters diverting to escape corridors or traveling earlier in the morning had no incentive to do so at night while others engaging in car pooling were collected in the evening by other members of the family who, by adjusting their own daily routine, acted as chauffeurs after making trips into the city for shopping, recreation or other purposes. More recently the system has moved to an electronic cordon system.

capacity would be under-utilized most of the time, excessive congestion is not. The question then is, what is the optimal level of congestion?

The economic costs of traffic congestion can be calculated using the engineering concept of the speed-flow relationship.[3] If a straight one-way street is assumed, the relationship between speed and flow over time typically looks like the relationship depicted on Figure 1.1. Flow (defined as the number of vehicles or passenger car units[4], PCU, past a certain point) is dependent upon the number of vehicles entering a road and the speed of traffic. Hence, at low volumes of traffic, high speeds are possible, constrained only by the capability of the vehicle and the legal speed limits. As the number of vehicles trying to enter the road increases, vehicles affect each other's speeds and slow one another down. As more traffic enters the road, speeds fall but, up to a point, flow will continue to rise because the effect of additional vehicles outweighs the reduction in average speed. This is the congested branch of the speed-flow curve. At the point where increased traffic volume ceases to offset the reduced speed the road's capacity is reached at the maximum flow or capacity of the link, indicated *k* on Figure 1.1. At that point the flows turns unstable, with the characteristic stop-start conditions, typical of a traffic jam. If vehicles keep on entering the road further drops in speed and flow will result. This is known as forced flow or hyper-congestion. As flow keeps on decreasing, average speed will eventually increase and jump back to some point along the normal flow portion of the speed-flow relationship.

---

[3] Speed-flow relationships have been studied by engineers, physicists and mathematicians since the 1930s.

[4] Passenger car units (PCU) are ratings given to different vehicle categories according to the degree of disruption they cause to the road. Thus, a car has a PCU rating of 1, whereas a bus has a PCU rating of 2.5, and a motorcycle has a PCU rating of 0.5.

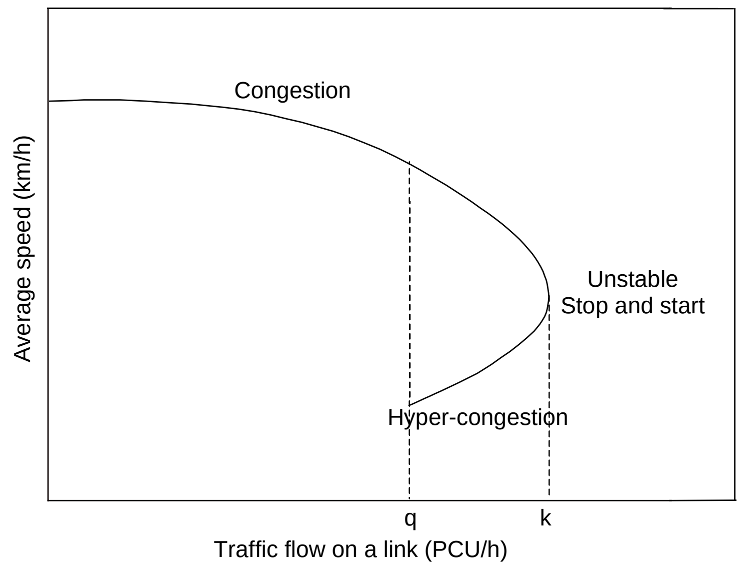

Figure 1.1 Speed-flow relationship for a link

The actual form of the speed-flow relationship depends on a number of factors including width of the lanes, grade, road curvature, speed limit, weather, mix of vehicle types, etc. (Button, 1993; Lindsay and Verhoef, 2002).

Walters (1961) was the first one to translate the backward bending speed-flow function into a cost function. Today's standard transport economic analysis still uses that framework to compute congestion costs and optimal pricing in static models. Thus, the speed-flow curve can be converted into a time-flow curve. Multiplying time per unit of distance (mile or kilometre) by the value of travel time and adding vehicle operating costs (monetary units per unit of distance) gives the average social cost-flow curve, ASC (Morrison, 1986). This is shown on Figure 1.2.

The ASC is a reverse of the speed-flow curve seen on Figure 1.1, with the positively sloped portion corresponding to the negatively sloped section of the speed-flow curve. As speeds tend to zero, time and therefore costs, tend to infinity (Verhoef, 1999). The MSC curve is also shown. It represents the extra cost the additional user places on the existing traffic flow. The MSC approaches infinity as flow approaches capacity (Morrison, 1986).

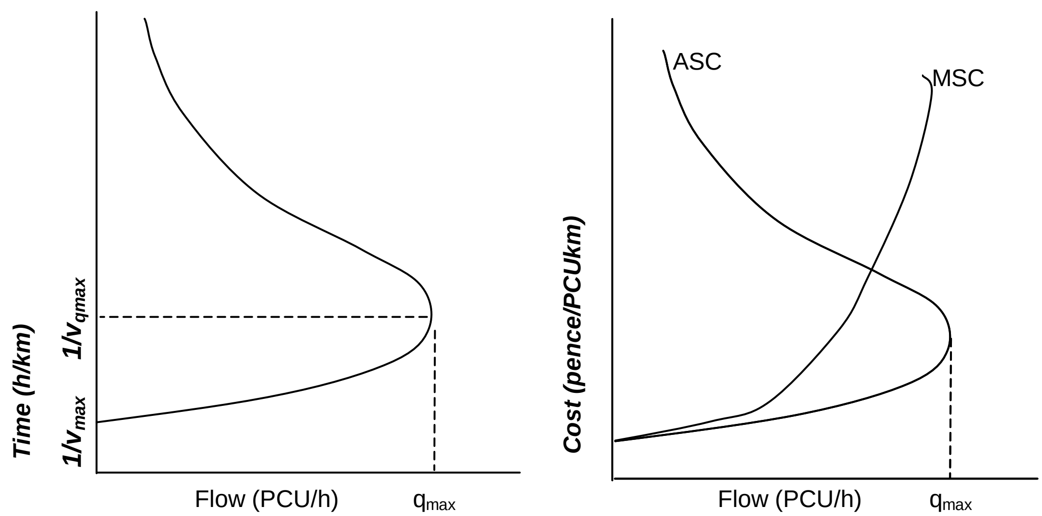

Figure 1.2 Derivation of the cost-flow relationship

Although the hyper-congested portion of the speed-flow function and its associated backward bending ASC curve with multiple equilibria has recently been the subject of much study (Small and Chu, 1997; Verhoef, 1999, 2003), for economic analysis it is common to ignore it (Button, 1993) and this is what shall be done here.[5]

When a demand curve is added on to the upward sloping portion of the ASC, Figure 1.3 is obtained. Road users are assumed to be identical except for their marginal willingness

---

5 In any case, it would be necessary to use dynamic models to study the hyper-congested branch of the speed-flow function (Lindsay and Verhoef, 2000).

to pay to traverse the link, represented by the demand curve, D, equal to the marginal private benefit (MPB) which, for simplicity shall be assumed to be equal to the marginal social benefit (MSB).

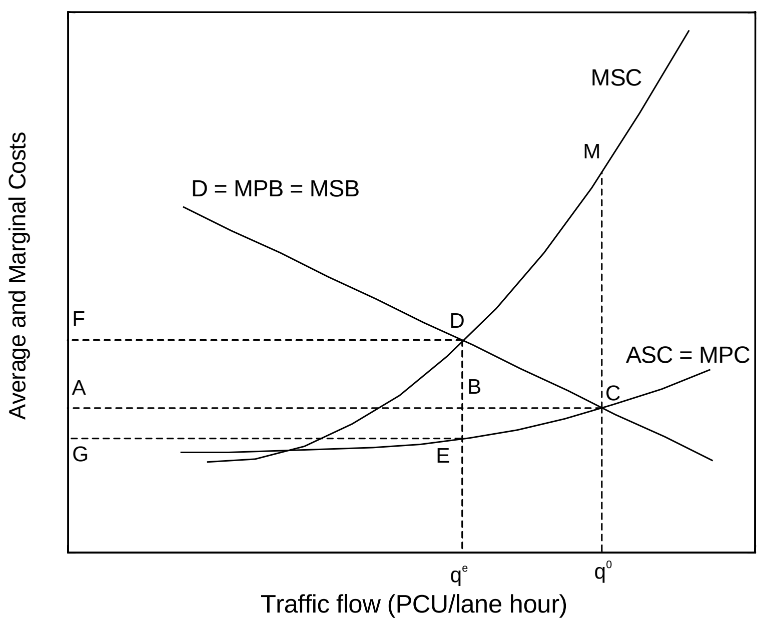

Figure 1.3 The simple diagram of congestion pricing

According to standard economic theory, the optimal flow is q^e, where marginal social cost equals marginal social benefit. The actual flow however will typically be q^0, because road users ignore the congestion they impose on others.

The ASC and MSC curves reflect the average and marginal generalized costs associated with different flows; they show time and vehicle operating costs borne by road users when making trips. They can be seen as representing social costs, in the limited sense that they are costs to the society of road users.

Any individual driver entering the road will only consider his time and vehicle operating costs, including the congestion costs he will have to bear, which with many users, will be equal to the average cost prevailing at that moment or ASC. Thus the ASC is often referred to as the marginal private cost (MPC), or cost the new user will bear. He will not however take into account the costs that he will impose on other vehicles already on the road. The difference between the ASC and MSC curves at any flow level reflects the marginal congestion cost.

From a social point of view the actual flow, q^0, is excessive because the q^0th motorist is only enjoying a benefit of q^0C but imposing costs of q^0M. The additional traffic beyond the optimal level q^e can be seen as generating costs q^0MDq^e but only enjoying a benefit of q^0CDq^e. This yields what in transport economics is called the social cost of congestion or deadweight welfare loss, given by triangle DMC.

It should be noted that at the optimal flow q^e there is still a congestion externality, given by segment DE. The difference is that at this point the congestion externality is internalized, and drivers are paying for the full social costs of their trips.

1.3 CONGESTION PRICING

One idea to optimize the level of congestion and ensure that q^e is achieved, is to use the price mechanism to make travelers more fully aware of the congestion externality they impose on others. The idea is that motorists should pay for the additional congestion they create when entering a congested road.[6]

The optimal congestion charge reflects the difference between the MSC and the ASC, as defined in Section 1.2. On Figure 1.3 this optimal congestion charge is equal to

6 There are in principle other ways of achieving the optimal level of congestion. These include subsidies, marketable permits, and command and control policies, as well as other transport policies, such as improvement and/or subsidy of public transport. None of these is the subject of this volume and so they shall be ignored.

DE. That is the charge that equates MSB and MSC at the efficient level of traffic. Congestion pricing generates a welfare gain of DMC. Traffic flow is reduced from q^0 to q^e, resulting in some motorists not using the road any longer and thus loosing consumers' surplus of BCD. At the same time however, the road authority collects revenues FDEG. From these revenues, FDBA are a transfer of consumers' surplus enjoyed by road users to the road authority in the form of revenue. These revenues can (and perhaps should) be returned to road users.[7]

In mathematical terms the following model can be used to compute the efficient congestion charge. If the average social cost per km of a representative vehicle is

$$c = a + b/v \tag{1.1}$$

where a is the cost per PCU.km (pence per PCU.km), and b is the value of time (pence per PCU.h) and the total social cost of a flow of q vehicles is $C = cq$, then when an additional vehicle is added to the flow, the total social cost will be increased by

$$MSC = \frac{dC}{dq} = c + q\frac{dc}{dq} \tag{1.2}$$

The congestion externality or marginal congestion cost is given by $q\frac{dc}{dq}$. This externality measured at the efficient level of traffic q^e gives the optimal congestion charge DE on Figure 1.3. It can be numerically estimated by specifying a speed-flow relationship, v,

[7] The use of revenues is central to a congestion pricing scheme as it typically determines the final distributional impacts and the acceptability by the public.

and making the relevant substitutions in Equations (1.1) and (1.2). There are innumerable case studies that have sought to place a value on the optimal road price indifferent circumstances. These vary in their degree of sophistication and Table 1.1 lists a few of the earliest North American efforts. Recent work have tended to make use of more sophisticated models are a less easy to tabulate.

Table 1.1 Some early North American findings relating to road pricing.

Study	Place	Fee at date of Study	Traffic effect	Comments
Cheslow (1978)	Berkely (1977)	$2.00 per vehicle per morning peak	Reduce Traffic by 30%	Part of a transport package including bus provision
Spielberg (1978)	Madison (1977)	$1.00 per vehicle per morning peak	Reduce Traffic by 30%	Part of a transport package including bus provision
Gomez-Ibanez and Fauth (1980)	Boston (1975)	$0.5.-1.00 per vehicle per peak period	Reduce Traffic by 30%	
Keeler and Small (1977)	San Francisco Bay Area (1972)	$0.02-0.09 per vehicle per mile (suburban) $0.06-0.35 per vehicle per mile (central areas)		Optimal tolls, differentiated by road type to allow for differing long run cost
Elliot (1975)	Los Angeles	$0.03-0.15 per vehicle per mile (central areas)	Reduced congestion by 20-30%	Also reduces smog significantly
Kraus, Mohring and Pinfold (1976)	Twin-Cities Area (1970)	$0.03-0.09 per vehicle mile (suburban) $0.05-0.15 per vehicle mile (central areas)		
Dewees (1978)	Toronto (1973)	$0.38 per vehicle mile per peak period		Specifically an estimate of the average marginal social cost of a trip over a range of streets
Mohring (1979)	Minneapolis and St. Paul	$0.66 per vehicle mile per peak period $0.33 per vehicle mile per off-peak period		Estimates of optima user charges

1.4 PIONEERING WORK

The standard analysis presented in Sections 1.2 and 1.3 has its roots in work that was carried out in the 19th and early 20th centuries. This section honors that work as without it, today's understanding of the problem of traffic congestion and congestion charging would probably be different.

1.4.1 The French engineers

The French engineers of the 1840s-1850s were as concerned with how their structures should be financed and used as with their physical construction. Dupuit's (1844) work on the provision of public goods, their pricing and investment assessment is seminal[8]. Dupuit's well-known analysis of bridge pricing (actually he has six examples scattered throughout his work and they are not entirely consistent), argues for a pricing structure that maximises utility whilst at the same time covering up-keep and capital costs. With an economically optimal capacity this is essentially what a congestion charge does.

Minard (1850) also recognised this and, although he thought primarily in terms of physical wear-and-tear, his work also had an implicit congestion component in it. He pioneered the fact that travel time-savings have economic value and suggested simple, revealed preference based, ways of measuring it. He did not, however, possibly because of the context of his work that mainly concerned uncongested facilities, explicitly link time savings into his infrastructure pricing concepts.

[8] A comprehensive account of the work of the French engineers can be found in Ekelund and Hébert (1999).

At the turn of the 20th century, the French engineering concepts were not widely known yet. In part, the originators were outside of mainstream economics and the fact that their material was not widely available in English did not help. Perhaps more importantly, the railway age removed much of the interest in charging for road infrastructure. The track costs issue debate switched to considering the appropriate way for railways to recover their fixed costs without a regulated environment designed to limit their quasi-monopoly powers. Matters akin to the later work on Ramsey pricing and the like came to the fore.

1.4.2 The Pigou debate

Perhaps the most frequently cited name in the development of Road Pricing is that of Arthur Pigou's. His book *The Economics of Welfare* (Pigou, 1920) laid the foundation for much of the subsequent academic literature in the field.[9]

Pigou's overriding objective in *The Economics of Welfare* was to systematically try to bring positive analysis to an area of study that had previously been dominated by normative arguments. Indeed, economics was still often treated as moral philosophy at the time. He made the case that roads were not being utilized efficiently because users were not being charged for the congestion costs they imposed on others. Many would not use the facility if they had to bear this cost and their resources and time would be more gainfully employed doing something else.

His analysis looks at two competing roads, one wide but with a poor track and hence slow, and the other narrow but with a good track. Traffic will disperse itself

[9] One should always be wary of any literature that juxtapositions road pricing and the 1924, 1929, 1932 or 1952 editions of *The Economics of Welfare*. Road pricing is not in them.

between these alternatives up to the point where travel time to the destination is the same irrespective of the road used. He argues that imposing a differential charge on the narrower road will redistribute traffic that does not value travel time savings very highly to the wider, slower road. The result is that aggregate travel time is reduced and society as a whole gains.[10]

Pigou's style of analysis however relies upon the argument that roads are public goods in the sense that they are publicly owned and allocated, if not in the more technical sense of them being non-rival and non-excludable. Knight (1924) pointed this out, and illustrated that a privately owned road in a competitive situation would give the provider the incentive to limit the road's use to the optimal level by fixing tolls to reflect congestion costs. Pigou clearly accepted this argument and that is why he cut Road Pricing from later editions of *The Economics of Welfare*. Basically, the argument is only relevant when for institutional reasons roads fall outside of the private market.

Knight's argument has stood the test of time within its context of a competitive road system. But others (Buchanan, 1956; Mills, 1981) have correctly pointed out that an assumption of competing private road suppliers is a strong one. Private road owners would in practice enjoy a degree of monopoly power and may have an incentive to over-price roads. However, while in a simple model with a uniform road price would see a rent seeking monopolist limit traffic excessively (Edelson, 1971), a monopolist, with the capacity to perfectly price discriminate between users, basically adopting non-anonymous charges, would have the incentive to ensure that the road is used optimally. The consumer

[10] This does assume a perfectly inelastic demand curve for total trips generated which deviates from much of the work by the French engineers. In other words for simplicity he took no account of what has more recently been rediscovered by traffic engineers, although well known to economists, as 'latent demand'.

surplus in this case would be transferred as economic rent to the road owner, and although this may not be liked, it would be efficient.

In a sense, one could see the analysis of Knight and Dupuit as providing benchmarks for road charging, the former taking a competitive market where there are numerous alternative routes and congestion, and the latter looking more at an optimal monopoly facility without congestion.

1.5 THE RESURECTION OF THE 1960s

The 1960s saw a sudden interest in congestion pricing. Two seminal papers were published by leading academics of the day (Walters, 1961; Vickery, 1963), and in the UK a government study provided the first major policy analysis of road pricing (Ministry of Transport, 1964). The interest grew largely from practical considerations. Automobile ownership was expanding and cities were getting congested. Land-use planning, urban design and infrastructure expansion were in vogue as mechanisms for combating this but were seen as long term and costly. Subsidizing public transport as an alternative to the automobile was under review but had not been widely adopted. In this context, road pricing was seen as a potential means for containing commuter traffic whilst leaving road users options about when, how and where they could travel.

The Vickrey/Walters approach very much followed the lines of Pigou's analysis. There would be some decision on what the optimal traffic flow should be, essentially determined by estimating the traffic speed-flow relationship underlying the cost curves on Figure 1.3 together with the demand function. The congestion charge would then be an efficient way of attaining the target flow of traffic. It was seen as a fiscal instrument allowing those who gained the most utility from road use to use the facility. The model presented on Figure 1.3 was developed in the 1960s and is still in use today. The basis for that model are of course much older and as stated above, they go all the way back to the work by Pigou (1920) and the engineers and physicists that had been studying the relationship between speed and flow since the 1930s.

Vickrey (1968) combined his analysis with a comparable one for urban public transport. While the analysis was technically more rigorous than that of Pigou's in that congestion was carefully defined, the argument was essentially the same – roads are being publicly provided and in the absence of a market they should be used to maximise social welfare.

A slightly different conceptual approach within this vein that emerged at the same time as the Vickrey/Walters analysis is to treat roads as club goods (Buchanan, 1965). This approach has the intellectual attraction of isolating the allocation of road space debate from debates centered on more conventional Pigouvian externalities (that are retained in all of the editions of *The Economics of Welfare*) involving the impacts of traffic on non-road users. This latter group embodies such things as environmental effects that are outside of the market.

A club good approach strictly assumes that a group of people derive sufficient benefit from a facility to provide it, exclude non-members whilst allocating out its use amongst members according to incremental costs (which would include a scarcity cost).[11] Since road users are often willing to pay above their incremental costs to use a road, debates arose about ways in which commercial road builders would operate such a

[11] Academic articles on club goods often revolve around the 'ski-lift' problem where there are day passes giving access but then allocation issues arise.

system. It may also be tied into a road charging regime that would involve a ‘membership fee’ such as an annual license, and then user fees that capture wear-and-tear costs plus an element to reflect scarcity and congestion at various times.

1.6 RECENT REFINEMENTS IN SHORT-RUN PRICING

The upsurge of interest amongst academics, as well as practitioners since the 1960s has led to refinements in assessing how the congestion charge should be calculated. As Vickrey (1963) pointed out, there is in ideal circumstances a need to vary the price according to traffic demand and costs. The type of day, the traffic mix, the physical features of the network and local road conditions (such as the weather and accidents) may influence these.

The simple static model presented in Sections 1.2 and 1.3 has been extended in different directions. Introducing more realism into this framework adds to its complexity and ipso facto to the ultimate difficulty in calculation of the congestion charge.

Research on the demand function, the time dependency and scheduling of trips, second-best pricing, heterogeneity of trip makers, transaction costs, technologies, and the shape of the speed-flow relationship and cost curves for links and areas, are only some of the issues on which attention has focused in the last four decades.

Alan Evans (1992) and Hills (1993) for example raised issues about the validity of using a demand curve defined over flow, that has a per-unit-of-time dimension, because road users demand trips and not passages per unit of time. They advocate stock-based models using density or number of trips.

Vickrey (1969) developed a bottleneck model, where congestion is assumed to arise when vehicles queue behind a bottleneck. All commuters wish to arrive at work at a certain time but there is a bottleneck with finite capacity that will not allow all of them to arrive at their preferred time. There are costs associated with early and late arrival, which together with the toll, are added to the cost of the trip, which commuters try to minimise by choosing their departure time. Queuing time evolves during the rush hour and this imposes a time pattern of departures. The evolution of congestion over the rush hour is thus endogenously determined. This bottleneck model was further extended, mainly by Arnott, De Palma and Lindsay (1988, 1990a, 1990b, 1992, 1993, 1994, 1998) to include heterogeneous commuters, route choice, stochasticity in capacity, elastic demand, and time-varying tolls.

A second generic form of the dynamic congestion model, initially developed by Henderson (1974), does not completely eliminate travel delays at the social optimum (Chu, 1975). Both approaches involve the distribution of travel delays and scheduling of costs of the peak, and the duration of the peak in the untolled equilibrium and the social optimum, being determined exogenously.

Road pricing is designed to produce a Pareto optimal use of a facility but this is dependent upon the standard assumptions that surround first-best partial equilibrium analysis and especially that all other prices are equal to marginal costs. Moving into the realm of 'second-best', where the assumptions of the Pareto world are relaxed, is less tidy and inevitably the efficient price becomes situation specific.

One particular issue that is often addressed in this context is the pricing of substitutes to road transport, and especially public transport. In many cases subsidies have been given to public transport to attract trip-makers away from congested streets. Irrespective of whether this has effected any significant transfer, this is an instrument that could be used to optimize the modal split of traffic. A road user in the absence of road pricing will only consider the marginal private cost of a trip that is lower than the full marginal social cost of the road space taken up. A subsidy to public transport, accurately reflecting the cross-elasticity of demand between the modes, could theoretically be used to attract sufficient motorists from the roads to limit road use to q^e in Figure 1.3.

Other topics within second-best pricing have been the pricing of only part of a road network, or pricing subject to constraints (Verhoef *et al*, 1996; Liu and McDonald, 1999; Verhoef, 2000, 2002a, 2002b; Small and Yan, 2001). When some routes are priced and some are not road users are left with a choice between a facility where access is unpriced but the service quality poor and one where there is an access price but congestion is optimized.[12] The road price introduced on such routes requires to reflect the opportunity cost of not using the unpriced roads as well as the first best toll on the priced road. Ignoring the cross-effects will lead to sub-optimally high use of the unpriced facility. Marchand (1968) was one of the first to look at this type of situation in terms of setting a charge that weighs the welfare benefits of reducing traffic on the unpriced facilities against the losses from deviating from first-best pricing on the priced route.

Second-best considerations may also become important in the context of complements to, as well as substitutes for, a priced facility. Parking is, not unexpectedly, the most explored complimentary good (Glazer and Niskanen, 1992; Verhoef, 1996,

[12] This is the *de facto* situation found with some of the high occupancy/toll lanes found in California, although these are slightly more complex because high-occupancy allows the toll to be avoided (Li, 2001). The idea there is marketed under the notion of 'value pricing' on the basis that the toll for using the high occupancy/toll lanes reflects the value they confer.

Calthrop *et al* 2000) although even here the literature is remarkably thin. Indeed because of the complementary nature of road use and parking, parking charges have in some cases been are treated as an alternative to a road price (Verhoef *et al*, 1995). Although parking charges often involve low transactions costs the circumstances where they can act as complete substitutes for road pricing are very stylized.

In a first-best world there would be optimal parking fees reflecting the opportunity cost of taking up land to 'rest' a vehicle as well as the congestion costs associated with cruising around seeking a parking spot.[13] In practice, parking is often provided free or perverse charging regimes are employed. Such regimes are frequently structured to limit certain categories of users such as long stay users irrespective of willingness to pay. Parking fees should ideally be structured to reflect the traffic congestion caused by drivers cruising around looking for a parking place. Parking costs can also affect traffic demand by influencing the lengths of trips made over a network. Low parking fees, being a fixed cost of a trip, are spread more over a longer trip than a shorter one. This may affect congestion in sub-urban areas.

A further input into urban car trips that has received a lot of attention is that of environmental costs. There are few that argue that motor traffic does not make considerable demands on the environment and that the costs involved are external to the market. These effects are both wide-ranging going through the emission of a variety of local, regional and global atmospheric pollutants, to noise, ground water contamination, through to visual intrusion, and in some cases very large. A road price that reflected the total marginal social cost would internalize both the congestion and the environmental

[13] Much of the work on parking charges has tended to ignore this second element, and treat it as cost at the end of a trip (Calthrop *et al* 2000; Glazer and Niskanen, 1992) and neglect the effect this price has on the demand for cruising.

externality, and would include a congestion charge and an environmental charge. This is a large subject area, the issues complex, and the literature substantial and is not dealt with here. Fuel taxes however can approximate optimal environmental charges because most environmental externalities are closely dependent on fuel consumption.[14]

There is another side to the second-best debate that should perhaps just be touched upon. There has been a mounting interest in how other road taxes, public transport fares and road investment decisions can be made in the absence of optimal road pricing. In this context Sherman (1971), Bertrand (1977), and Arnott and Yan (2000) have looked at pricing across multi-modal systems; Wheaton (1978) developed ideas of second-best road investment strategies; and Chia *et al* (1996) examined the appropriate fuel taxation policy to pursue if appropriate congestion charges are absent.

Much of the early work on congestion pricing treated all road users as being identical, Strotz (1965) being an exception. Variations in their income and, linked to this the valuations that they place on travel time saving and the size of vehicles driven, which affects road take, are now appreciated as being important considerations for both efficiency and equity reasons. At the very least, they raise questions about whether the congestion charge should reflect these features. If the concern is purely with efficiency and standard first-best conditions hold then there is no need to consider these variations with time varying congestion pricing. This is because all that matters are the congestion costs imposed. Arnott and Kraus (1992) provide a rigorous proof of this.

Where there are alternative routes in the network (including different lanes on a road) then where users have different utility functions, optimality is attained by offering

---

[14] The high fuel duties in the UK for example have been defended by different governments on environmental grounds.

various congestion charge/congestion level combinations. This, as Pigou indicated, maximizes welfare by allowing those with a high travel time value to buy their way onto the faster routes, leaving those with a lower value on the cheaper, more congested ones.[15] The situation can also be compared with having users with different trip-time preferences using a single route. Arnott *et al* (1992) show that where there are temporally inflexible congestion charges, a different charge on each of two roads is more efficient than a single uniform charge for both.

Other situations that have attracted attention include those when drivers have different preferences for speed that are unrelated to income. Here the models have often tended to exclude the possibility of overtaking making them particularly relevant to bridge and tunnel cases. The results suggest that the congestion charge needs to be higher for slow vehicles to reflect their impact on slowing to higher speed vehicles. But that the differential, because slow vehicles affect fewer fast vehicles on average and also because the speed of fast vehicles declines asymptotically to that of the slower vehicle, should decrease with the proportion of slow vehicles in the traffic stream. This approach would require differential approaches to congestion pricing depending on drivers' speed preferences – in practical terms this may be done by having different pricing regimes for cars and trucks. (Dafermos, 1973).

Added to these challenges, even if public transport is not an issue, the network is simple and road users are homogeneous, the standard model of congestion pricing excludes any consideration of implementation and operation costs like for example, the costs of collecting the fees and policing the system.[16] These may be significant and may

[15] The high occupancy/toll lanes in California may be seen as a practical reflection of this.
[16] The operating costs for the London Congestion Charging scheme are certainly substantial.

become entwined with other issues such as how much information the road user has on the 'product' that is being purchased (De Palma and Lindsey, 1998).

The idea of using electronic technology to collect a real time, variable congestion charge was initially advanced by William Vickrey (1959) in evidence to a US congressional committee as early as the late 1950s. Despite the largely successful testing of electronic road pricing equipment in Hong Kong (Hau, 1990)[17], operating costs, issues of privacy and concern over technical reliability have favored area based systems. This means that a road price does not vary directly with traffic conditions but rather location or time of day is used as proxy for congestion levels. The Singapore and the recent London schemes use a combination of these surrogates largely for pragmatic reasons.

The efficiency of these discrete charges is inevitably less than a continuous congestion charge, the loss of efficiency being a function of just how closely the proxies reflect changing congestion levels. This in turns often depends on the number of 'steps' involved and the prices charged at each step. Empirical estimates of the extent to which these systems lose efficiency are found in Chu (1999) and Arnott *et al* (1993, 1998) and they seem to be significant.

[17] There is very little practical experience of full electronic road pricing to-date and a lot of reliance has to be placed on desk-top studies and the testing of equipment for other purposes (e.g., toll collection). There has been experimentation with equipment and operational practices in Hong Kong (Dawson and Catling, 1986). On the operational side, the two-year experiment during the mid-1980s involved fitting over 2500 vehicles with AVIs together with the setting of electronic loops in the road surface at the edge of charge zones. When a vehicle crossed a boundary, a power loop energized its AVI that in turn sent a message, via inductive receiver loops, to a road-side recorder. What it did was to give some credence to the view expressed. The technical and economic feasibility of the electronic road pricing system used was found to have achieved 99% effectiveness and reliability against the criteria set it.

There are, however, practical difficulties with the Hong Kong style of road pricing, especially in terms of devising a mechanism enabling its phased introduction on a large scale and of road users having a poor idea of the road price they must pay in advance of making a trip.

1.7 CAPACITY EXPANSION

A market price serves not only to allocate current facilities optimally but it also provides signals to where capacity should be expanded, and the revenues from the price provide resources for that expansion. In a perfect market situation, effectively Knight's position, there is no requirement for separate consideration of capacity expansion – the net revenue flows give the necessary guidance. Given the reality of public ownership of most road track and the possibility of internalizing the congestion externality with a corrective congestion charge, there have been a number of studies looking at the link between the optimal congestion charge and road investment strategies (Mohring, 1970).

An important result that provides an additional incentive for the road agency to internalize the congestion externality is that the optimal congestion charge, as defined in Section 1.3, equal to the difference between the MSC and the ASC at the efficient level of traffic, covers the fixed operating cost, equal to the sum of interest, depreciation and policing, provided there are constant returns to scale in road construction and maintenance and capacity can be increased in continuous increments (Mohring and Harwitz, 1962). This result was later expanded to include damage. In this sense, a road charge equal to the sum of the optimal congestion charge and the road damage charge, covers the fixed operating cost as defined above, and the variable maintenance cost, provided there are constant returns to scale in construction, maintenance and use of road capacity (Newbery, 1989).

Under constant returns and optimal pricing, whenever there is economic profit, the capacity of the road should be expanded, and when there is economic loss, the road has been overbuilt and should be abandoned or closed. The optimal pricing and investment decision for roads can thus be dealt with in a single model (Mohring and Harwitz, 1962; Keeler and Small, 1977). When there are diseconomies of scale then at the optimal capacity and with an optimal congestion charge, economic rent will be earned. This reflects a scarcity rent on a fixed factor of production, in this case, the land. Equally, if there are economies of scale, and in some instances when there are large indivisibilities in investments, the optimal congestion charge will not generate sufficient revenue to cover the fixed operating cost. Subsidies will be required and techniques such as cost-benefit analysis come into play in determining their level.

Much, therefore, depends on the view taken about the nature of returns to scale and indivisibilities in road investment. Kraus (1981) argues that the existence of lanes implicitly means that there are indivisibilities in supply. In contrast, Starkie (1982), following the legacy of Keeler and Small (1977) looks at a road network as a whole and argues that within that context, actions such as resurfacing, changes in lane width, etc, can be varied incrementally. Hau (1998) argues that increasing, decreasing and constant returns to scale all exist in road transport and each case should be assessed individually.

1.8 THE VALUE OF TIME

Whilst road pricing results in an overall welfare loss to road users, some of those who continue to use the roads do benefit from faster trips. Others, while paying a higher monetary price for their road trips have this at least partly off-set by enjoying time savings. Time is a significant cost component of any trip and its value is therefore of fundamental importance. Indeed different values of travel time and travel time savings can lead to different answers on the viability of a transport project.

The extensive literature on the subject (Small, 1982; Hensher, 1997; Calfee and Winston, 1998; Wardman, 1998; Hague Consulting Group *et al*, 1999; Jara-Díaz, 2000; Lam and Small, 2001; Whelan and Bates, 2001; Mackie *et al*, 2001, 2003; Brownstone and Small, 2003) suggests there is ample evidence that the value of time varies amongst population subgroups (Small, 1999) according to income, gender and age, and also with trip purpose, mode used, length of the trip, prevailing conditions of congestion and sometimes weather, and the value given to the travel time variation depends on the sign (loss or saving) and the magnitude, and its ratio to total travel time.

As a consequence of this, each congestion pricing proposal will need to be evaluated on an individual basis, paying particular attention to the socio-economic characteristics and trip patterns of the road users to be affected. The value of the travel time savings will play a substantial role in the net benefits to be derived from any transport project, including congestion pricing schemes.

1.9 THE POLITICAL ECONOMY OF ROAD PRICING

As Small and Gómez-Ibáñez (1998) observed, ‘Winning political approval for any form of congestion pricing project is difficult in a democracy, even with careful planning.’ There may be a number of reasons for this but the political economy of road pricing has largely centered around the distribution implications of the policy. Indeed Andrew Evans (1992) sees it as the critical practical issue to large-scale application. This is hardly surprising since it is the road user that immediately loses as a result of charging for congestion. While economists tend to focus mainly on the efficiency implications of transport policies, politicians and administrators put more emphasis on the various effects on different groups in society.

Overall the road user would be worse off with congestion pricing, although within that some users who value travel time savings and reliability of service highly would gain. Those concerned with distributional effects essentially accept that congestion pricing may result in a potential Pareto improvement in as much as theoretically those who gain could be 'taxed' to yield compensation to those who lose out, and still enjoy a net benefit. The problem however is that congestion pricing projects tend to lack any actual compensation mechanism.

As a first step in introducing incidence into the analysis it is necessary to know exactly who gains and who loses, and in what ways. The distributional impacts will typically depend on the nature of the congestion pricing regime. While there are important theoretical contributions in this field, the studies have been mainly empirical in their approach (Vickrey, 1968; Small, 1983; Richardson, 1974; Segal and Steinmeir, 1980; Foster, 1975; Layard, 1977; Santos and Rojey, 2003). Chapter 12 in this book assesses the welfare and distributional effects of high occupancy/toll lanes and other road pricing policies in Metropolitan Washington DC.

What emerges from the mainly empirical literature on the distributional impacts of congestion pricing is a lack of consensus. Layard (1977) for example, argues that the policy is regressive. Foster (1975) argues that it is progressive. Giuliano (1992) takes a somewhat different position, namely that even if congestion pricing is regressive, the fact is used to disguise other objections to the policy rather than necessarily being important in itself. Santos and Rojey (2003) conclude that the distributional impacts depend on the design of the scheme and the geo-economic characteristics of the town in question (where do people live, where do they work and how do they get to work).

A related topic to the distributional effects is the implications of various ways of using the revenues from a congestion charge. Some, such as Small (1983) and Andrew Evans (1992) see this as the core of the political economy debate.

Newbery (1990, 1994) suggests that revenues from congestion pricing in the UK could to be returned to motorists in the form of lower fuel duties. Motorists as a group would then be made better off as they would pay the same total road user charges but would experience less congestion.

Goodwin (1989, 1990) and Small (1992) both propose that revenues should be allocated in thirds, one third to the reduction of taxes in general, or fuel taxes, or vehicle license fees or to the increase in social expenditure, one third to investment in public transit, and one third to investment in new roads or reimbursement to trip makers. Although arbitrary, this allocation in thirds would aim at compensating losers and promoting improvements in the transport sector.

The Lex Report on Motoring (Lex Services, 1998) based on two surveys carried out in England in 1997 suggests that the few motorists that would favor congestion pricing would do so as long as it were implemented in the form of charges rather than taxes, and the revenues stayed in the transport sector.

Ison (2000) conducted a survey in which, amongst other things, he compared public support for urban road pricing before and after the question relating to the use of revenues had been asked. He found that the acceptability increased from 11.3% to 54.6% after it was explained that revenues would be allocated to specific, clearly established objectives. Harrington *et al* (2001) found between 7% and 17% increase in support to congestion pricing when use of revenues was specified in a survey they conducted between residents in Southern California.

The 2003 RAC Report on Motoring *Making the Most of Britain's Roads* (RAC Foundation for Motoring, 2003) finds that 69% of motorists would be more supportive of road charging if revenues were spent on transport over other public services. 49% would support the idea if revenues were spent on improving existing roads.

In a purely competitive private market, large amounts of revenue would signal that road use was highly valued by users of the roads and the net revenues would go towards enhancement of the road network that would bring down the future cost to motorists of using it. In a second-best situation characterized by a variety of market and government failures across the economy this is not automatically the best way to meet concerns about compensation.

In any case, returning revenues to the transport sector and attempting some form of compensation to lower-income groups can only increase public and political acceptability.

1.10 SOME BRIEF THOUGHTS ON APPLICATIONS TO DATE

Despite all the energies of academics that have been expended, together with the time of a number of policy makers, the textbook application of congestion pricing has not yet emerged and it probably never will. The few applications of the idea are simplifications of the concept of the Pigouvian charge. This is perhaps inevitable, and the theoretical work should, at best, be viewed as providing important benchmarks against which success is measured.

The introduction and impact of the Area Licensing system in Singapore offered a perspective on the power of the price mechanism to control traffic flows – until then elasticities of demand for road space had been little more than conjectures on academics note pads. As seen below, estimation techniques seem to have improved but there would appear to still be a tendency to under-estimate response levels.

The subsequent experiments with electronic technologies in Hong Kong to make charges more reflective of real-time congestion illustrated that more sophisticated methods could be deployed if desired (Dawson and Catling, 1986). This has been supported in many places where conventional tolling has reverted to rapid pass collecting techniques.

Subsequent years have in many ways seen the initial impacts of the Singapore scheme and the Hong Kong experiment, limited as they were, be diluted. Indeed, this piece actually reflects some of the factors affecting this. Other miracle cures for traffic congestion problems, ranging from intelligent transportation systems that manage traffic more efficiently through the network to the aim of encouraging more teleworking to reduce the number of daily commuters, have come along, and largely gone away again after making a limited, albeit sometimes useful, contribution. None, however, have confronted the basic problem that road users do not take full account of their actions on others.

The London Congestion Charging Scheme initiated in February 2003 (see Chapter 2) however has attracted considerable attention from around the world and may be the landmark for the beginning of a new era on the application of congestion pricing[18].

The introduction of high occupancy/toll lanes in California provides useful insights into both viable technologies and has generated considerable amounts of new information about the sensitivity of road users behavior when confronted by variable road charges. The Norwegian toll rings (see Chapter 2 for details), initially conceived to generate revenues to fund transport infrastructure, may now be changed into time-varying tolls to manage demand and reduce congestion. There is a new breeze in transport policy that might be announcing that the times are about to change and congestion pricing may finally become an instrument used widely around the world.

1.11 CONCLUSIONS

It seems almost inevitable that motor traffic will grow well beyond the immediate future. This will impose additional strains on the road infrastructures of most countries. The associated impacts of longer commutes, and higher freight distribution costs have to be borne somewhere in the system. On top of that there are now additional costs that have recently come to the fore, most notably in the US, linked to security. While congestion has traditional economic costs, an excessively congested network also has costs in terms of impeding response to incidents. Reacting to single events by the emergency services often poses problems at present, but in context of a major catastrophic occurrence, large

18 The scheme introduced in Durham in October 2002 involving a £2.00 access fee for entering the central area during the day also offers some interesting insights

scale evacuation for example from many city centers would be chaotic. This realization may accelerate the adoption of more efficient traffic pricing.

Those responsible for road provision are moving to make use of fiscal tools to manage the normal economic concerns over traffic growth. One can debate why there has recently been an up-surge of interest in congestion pricing. It may reflect a sudden appreciation that roads are really no different to other goods and can be treated in similar ways. Markets may not be possible but at least some effort can be made to make more rational use of road space. It may also reflect a crisis. Other measures have either been designed to increase the available capacity with no form of allocation mechanism other than queuing, or have involved providing alternatives that road users could have used before but declined. Both of these broad approaches have been found wanting and have become ever more expensive to pursue. The shift in emphasis is thus towards treating the root course of the problem rather than the symptoms.

2. USING THE REVENUES FROM CONGESTION PRICING

2.1 INTRODUCTION

Urban traffic congestion is a major and growing problem not only in cities but also on many major inter-urban arteries. Using the price mechanism to control the problem has now moved on from textbook discussions and to become a central theme of political agendas in many countries. The evidence shows that road pricing can be an efficient mechanism for controlling congestion. Road pricing would also provide the road authorities with a significant fiscal dividend. The issue examined here is how the dividend should be spent.

Advocates of road pricing have long argued that pricing can in practice, as well as theory, improve the use of existing urban road networks and inter-urban systems. Mathematical models of bottleneck pricing, system wide pricing, second best principles and so on, as was seen in Chapter 1, now abound (Button and Verhoef, 1998; Lindsey and Verhoef, 2001; Verhoef, 1998). Technological advances have also made road pricing more relevant as tolls can now be collected electronically with no reduction in traffic flow. Electronic tolls also allow real-time price adjustments to reflect variations in traffic flow.

Simpler systems, such as ring tolls, whereby road users pay every time they cross a cordon, or area licenses still have some advantages, however, such as letting users know in advance of travel what the exact road price will be. Ring systems may also be cheaper although that advantage is fast diminishing as electronic toll technology improves. Simpler regimes may provide important measures along the way to electronic pricing as they illustrate the power of prices to influence travel behavior and create political support for more efficient methods of pricing (Behbehani *et al*, 1984).

The fact that there is no ideal method of charging for road congestion does not mean that there are no significant social benefits from deploying imperfect systems. Indeed, the power of road pricing as a mechanism for limiting traffic in urban areas has been amply illustrated by the few instances where it has been initiated (Table 2.1). Indeed, judging by the reactions of many of those questioned over the years, efficiency would not seem to be an issue, or at least not an over-riding one. There are wider concerns.[19]

Much less attention has been given to the issue of how to spend road pricing revenues than to calculating optimal toll prices.[20] The expenditure issue is not one that has been entirely ignored although the relevant material is rather fragmented.[21]

---

[19] The types of objection raised in the 1970s to the efforts to initiate road pricing trials in the US under the auspices of the Urban Mass Transportation Administration and to ideas for introducing road pricing for London at about the same time (see the table below) the nature of many concerns extend beyond national boundaries.

Major Objections	Minor objections
Interferes with right to travel	Hard to enforce (38)
(RAC campaign issue)	Overloads transit facilities (88)
Harms business or business image	Relocates traffic problem (22)
Discriminates against the poor (30)	Requires legislative clearance

(List relates to UMTA initiative; information in parenthesis to London initiative)
Source Button (1984)

[20] Indeed, the *Smeed Report* (UK Department of Transport, 1964), which is often cited as one of the key pioneering of road pricing twice explicitly states that that consideration of the use of the congestion tax was outside of its terms of reference.

[21] Income expenditure effects, or the public perception of them, can be complex as illustrated by a Dutch example. Road pricing has been considered seriously in the Netherlands over the last 15 years. The 'Randstad area'suffers severe traffic congestion and associated environment damage. Four types of road

Table 2.1. Effectiveness of road pricing and quasi-road pricing, international experience

Instrument	Reduction in road usage
London (UK) cordon	–30% per day
Durham (UK) cordon	–90% per day
Bergen (Norway) cordon	–6% to 7% per day
Oslo (Norway) cordon	–5% to 11% per day
Rome (Italy) cordon	–20% per day
Trondheim (Norway) cordon	–5% to 10% per day
Seoul (South Korea) peak tunnel toll differential	– 24% peak reduction
New York/New Jersey (US) small peak beridges/tunnel toll differential	–7% (am) and –4% (pm)
Paris (France) A1 peak toll	– 13% peak reduction
Singapore (1992) evening peak	– 53% in peak-hours

pricing have recently been considered: peak-hour permits ('spitsvignet'), toll plaza's ('tolpleinen'), electronic peak-hour cordon charging ('rekeningrijden'), and kilometre charges.

In 1991, tolls were proposed using toll plazas (*tollpleinen*) with the objective of fund raising: tolls would apply 24 hours during working days. A major objection was that this would lead to congestion around toll plazas, which themselves would take up scarce space, and would also lead to significant traffic diversion onto the secondary road system. In 1993, a system of permits (*spitsvignet*) was reviewed involving a fixed annual payment for those traveling during peak hours. A disadvantage was that after payment there would be no incentive not to travel during the rush hour. Although the system failed through lack of popular support, the government developed more ambitious plans. In 1994, the Dutch parliament agreed in principle to the introduction of *Rekeningrijden*: a system of electronic toll-cordons around the four biggest cities in the Randstad area and in 1998, the measure came close to implementation.

Most recently the discussion has focused on a charge per kilometer driven based on the idea that car driver should pay according to the use made of infrastructure. The idea of the *Rekeningrijden* was introduced in 1998 with revenues not hypothecated to the transport sector and in 2000 the measure became part of a large package of measures that included measures to invest large sums of money in public transport and pay-lanes partly financed with the toll revenues. Anyone requiring access to the Amsterdam, Rotterdam, Utrecht or The Hague between 7am and 9 a.m. on weekdays, would pay for this access either immediately (electronically), or later via a bill sent to the vehicle owner. The basic rate would be €3.2 per trip, with users paying electronically receiving a discount of around €1.

Tests of the system showed that automatic in-vehicle payment unit worked with 99.99% reliability, although less efficiently in bad weather in combination with high speeds on non-porous asphalt – splashing water clouds the license plate being photographed. It was assumed that the scheme would lead to 30% less traffic in the peak hours. The major barrier to implementation of *rekeningrijden* has been the institutional feasibility (Boot et al., 1999). A number of organizations, for example, voiced strong opposition to the plan, including employers' organizations, one of the major daily news-paper, and the Dutch Automobile Association ANWB.

Much less attention has been given to the issue of how to spend road pricing revenues than to calculating optimal toll prices.[22] The expenditure issue is not one that has been entirely ignored although the relevant material is rather fragmented.[23]

If roads were provided privately and competitively then the inefficient congestion problem would not exist. Road owners would price to maximize profits and in so doing would take into account the costs of congestion each driver imposes on other drivers.[24] In

---

22 Indeed, the *Smeed Report* (UK Department of Transport, 1964), which is often cited as one of the key pioneering of road pricing twice explicitly states that that consideration of the use of the congestion tax was outside of its terms of reference.

23 Income expenditure effects, or the public perception of them, can be complex as illustrated by a Dutch example. Road pricing has been considered seriously in the Netherlands over the last 15 years. The 'Randstad area'suffers severe traffic congestion and associated environment damage. Four types of road pricing have recently been considered: peak-hour permits ('spitsvignet'), toll plaza's ('tolpleinen'), electronic peak-hour cordon charging ('rekeningrijden'), and kilometre charges.

In 1991, tolls were proposed using toll plazas (*tollpleinen*) with the objective of fund raising: tolls would apply 24 hours during working days. A major objection was that this would lead to congestion around toll plazas, which themselves would take up scarce space, and would also lead to significant traffic diversion onto the secondary road system.

In 1993, a system of permits (*spitsvignet*) was reviewed involving a fixed annual payment for those traveling during peak hours. A disadvantage was that after payment there would be no incentive not to travel during the rush hour. Although the system failed through lack of popular support, the government developed more ambitious plans. In 1994, the Dutch parliament agreed in principle to the introduction of *Rekeningrijden*: a system of electronic toll-cordons around the four biggest cities in the Randstad area and in 1998, the measure came close to implementation.

Most recently the discussion has focused on a charge per kilometer driven based on the idea that car driver should pay according to the use made of infrastructure. The idea of the *Rekeningrijden* was introduced in 1998 with revenues not hypothecated to the transport sector and in 2000 the measure became part of a large package of measures that included measures to invest large sums of money in public transport and pay-lanes partly financed with the toll revenues. Anyone requiring access to the Amsterdam, Rotterdam, Utrecht or The Hague between 7am and 9 a.m. on weekdays, would pay for this access either immediately (electronically), or later via a bill sent to the vehicle owner. The basic rate would be €3.2 per trip, with users paying electronically receiving a discount of around €1.

Tests of the system showed that automatic in-vehicle payment unit worked with 99.99% reliability, although less efficiently in bad weather in combination with high speeds on non-porous asphalt – splashing water clouds the license plate being photographed. It was assumed that the scheme would lead to 30% less traffic in the peak hours. The major barrier to implementation of *rekeningrijden* has been the institutional feasibility (Boot et al., 1999). A number of organizations, for example, voiced strong opposition to the plan, including employers' organizations, one of the major daily news-paper, and the Dutch Automobile Association ANWB.

24 As noted in Chapter 1, Knight (1924) stated this point clearly in his critique of certain sections of Pigou's *Economics of Welfare.*

addition the issue of net investment would also be taken care of as prices would accurately convey information about where and when to build new roads.[25]

Prices administratively set by the authorities, however, will rarely mimic those that would be set by the forces of supply and demand. The authorities, for example, must rely on estimates of the underlying market parameters in setting charges and these are inevitably not totally accurate and in any case bureaucratic incentives are unlikely to be coincident with the profit and loss incentives of entrepreneurs. Administrative charges, however, are generically a more efficient mechanism than devices such as queuing and congestion to allocate scarce publicly owned resources (Baumol and Oates, 1975).

The problem of the surpluses can be seen from another, welfare economics based, perspective. What congestion charges do in theoretical terms is to produce a Hicks-Kaldor-Scitovsky improvement in welfare. This means that there would be an aggregate social gain from such charges. What they do not do is produce a Pareto improvement that would require that no one is made worse off by the charges. This is, to reiterate the situation, because the main immediate direct beneficiaries of road pricing are the pricing authorities that take the windfall net revenues of pricing. It is a Hicks-Kaldor-Scitovsky improvement because these authorities could compensate those road users who lose out, pay for the administration of the system and still have surplus revenue. Whether this compensation is actually given is a crucial matter when looking at the implications of the distribution gains from road pricing. It also determines the degree of opposition to it.

---

[25] Strictly this assumes that there are no economies or diseconomies of scale in road provision and that the provider optimizes investment decisions (Mohring and Harwitz, 1962). If there are increasing returns to scale for road provision then there is in theory an efficiency case for subsidizing roads beyond the revenue collected from the optimal road price (unless some optimal form of price discrimination is possible) even if capacity is optimal. Only if roads suffer from decreasing returns to scale at the optimal charge is there a reason for revenue from an optimal road price to exceed the costs of road provision and maintenance.

Pricing in a market context serves as an indicator of when more of a commodity should be provided and as a mechanism for generating the revenues necessary to expand supply. Hence in the longer term even those initially priced out of the market may have greater opportunities to consume if they are willing to wait and then pay the price that emerges after long-run output is optimized. But with the adoption of the Hicks-Kaldor-Scitovsky criteria in the road pricing context, there is no mechanism that automatically offers a stimulus for such an expansion of road capacity. The way net revenues could be spent is divorced from where they are collected and from the demands of previous and remaining road users.

2.2 THE PROBLEMS OF SPENDING

2.2.1 Efficiency considerations

It's often suggested that road revenues be used to offset license, car or fuel taxes.[26] Sharp (1966), however, pointed out this complicates the issue of pricing since it would cause road users to 'buy-back' some of the road space. Reducing fuel taxes, for example, would increase the incentive to drive. If the money is instead dispensed to non-related areas, say to the elderly, then this buy-back would likely be negligible. Given modern information systems and charging technologies it is still not a trivial matter to determine feedback effects but total perfection in setting any price is a utopian notion.

---

[26] Indeed, in the US there is now debate about the need for some form of direct highway charging to reflect declining mileage revenues from gasoline tax as vehicles become more fuel efficicient.

2.2.2 Distribution considerations

When looking at distribution issues there is sometimes confusion between the positive aspects of describing changes from the status quo with normative consideration of whether the effects of road pricing are in someway ‘inequitable’. Robbins’ (1932) view, that economics should be purged of value judgments, has merit in this respect. Whilst analysis of the implications of road pricing for different groups in society is unquestionably important in understanding why it is not widely used, whether the distribution of these impacts is fair or not is a matter for others.

Sharp touches upon distribution issues. He argues that those potential motorist’s ‘excluded’ from the road would only be as well off after the initiation of road pricing if public transport “was so improved by the decreased congestion that it provided an alternative service which the ‘excluded’ motorists regarded as being as (and no more costly than) the road space which they formerly consumed.” The matter of distribution effects is not, however, dealt with in any detail.

The problem of spending road pricing revenue was resurrected in a little more detail by Richardson (1974). He argued that road pricing has important distribution implications in terms of who is affected. It benefits the wealthy who would gain from the combination of them having a high value of time and the ability to make faster trips. It benefits existing, largely low income, urban bus users because their services would be faster and more reliable. It has adverse effects for middle income groups priced off the road and having to transfer to what they consider inferior public transport. Use of revenue from road pricing is seen by Richardson as a mechanism for, at least partly, compensating this group if it is expended on public transport improvements, especially if they improve service quality.

Gomez-Ibañez (1992) goes to a further level of disaggeregation and looks at eight groups who either directly gain or lose from road pricing. While his findings are not seen as reflecting any judgment about whether the distribution outcome meets any criteria of equity, the wide-ranging impacts are seen as reflecting the difficulties of obtaining political acceptance for road pricing. The degree of disaggregation can be taken further. For example Giuliano (1994) considers implications according to gender, opportunities to work flexi-time, availability of transit, etc. rather than income classes. But whichever way it is looked at, there are inevitable winners and losers and who they are is influenced by the way road pricing revenues are spent.

What these studies tend to neglect is that a full network based system of road pricing would not only increase the price of using congested facilities but would logically reduce the costs of using many uncongested sections (notably inter-urban roads). This was an implicit point made by Newbery (1988) in the context of the UK road network. The overall implications for distribution of impact across the motoring public would then depend on the relative use of different elements of the network as would the total net revenues collected. There is an argument, that in some countries the outcome could be revenue neutral and the distributional issue be reduced to the impacts on various groups of road user (Roy, 1998).

2.2.3 Political acceptability considerations

Since road pricing does not meet a strict Pareto criteria and, because it is unlikely that revenues will be used to fully compensate those adversely affected, there is a pragmatic need to ensure that net revenue is spent in ways that make road pricing attractive to a winning coalition of people. Winning coalitions are not simply coalitions of road users but may include a variety of other interests with ‘voting rights’. Since comprehensive road pricing would involve charging for both existing infrastructure and for new infrastructure the issue is not even a static one amongst road users. Successful efforts at initiating quasi-road pricing measures have often involved concessions for certain road user groups (car pools in Singapore), improvements to alternative modes (subsidies to transit in Oslo), increased choice for car users (HOT lanes in California), or additional road capacity (toll rings in Norway).

Arguing for the need to form dominant coalitions of advocacy to gain acceptance for road pricing a number of academic studies have sought to look at ways of in which distributing the proceeds of road pricing may assist in this process. Goodwin (1989) came up with the idea of a ‘Rule of Three’. This, rather arbitrary, rule would involve distributing the proceeds, although not in equal part, to improve the road system, to improve public transport, and to reduce taxation or to be spent as part of general expenditure. The improved road network would appease those forced to pay the road price and in the longer term reduce the number priced from the system. Improved public transport would partly placate those forced from the road as well as gaining the support of existing users. Lower taxes or increased general public expenditure would appeal more generally.

This theme of triple dispensation has been taken up by Small (1992) who looks at ways of using the net revenues from road pricing to improve transportation and make the package more attractive. He argues that regional wide pricing in the Los Angeles region would generate about $3 million annually that could be used to off-set regressive taxes and especially those such as fuel and sales taxes that are used to finance public transportation. And in particular, to gain the support of those in a small number of relatively concentrated geographical areas the revenue could be used subsidize local transportation.

The economic difficulty with putting large sums into public transportation, however, is that it may be wasteful and result in much of the benefits of the system being lost. In the past subsidies have been captured by the suppliers of public transportation services and by the labor operating those services. Studies of the UK bus industry prior to regulatory reform in the 1985 Transport Act indicated that a large proportion of subsidies, up to 50%, was absorbed in lower productivity and higher wages (Bly *et al*, 1980). There are ways of containing but not eliminating this problem. The regulatory changes that introduced network tendering in London in 1985, whilst not eliminating the problem, would seem to have reduced the seepage. Kennedy (1995) estimates the cost saving emanating from the London regime was about 20% over the previous regime of subsidies.

2.2.4 Broader issues of earmarking or 'ring-fencing'

Many economists dislike the earmarking of revenues,[27] their tying to particular expenditure items, in the ways that Goodwin, Small and others have discussed. Beside the fact that they are arbitrary, the argument is that any rational company in the private sector does not limit itself in the ways in which it spends its revenue flow. It seeks out those activities that generate the highest potential profits. Indeed, if this were not the case then there would be little innovation in the economy as investments would exclusively be channeled back into existing activities. The parallel argument for a public sector undertaking is that government should use any revenue that it gets to finance activities that produce the highest social rate of return.

The analogy of a government budget to the revenues of private firm, however, is flawed. A private firm faces a direct market test, if consumers do not regard its products as good value at the prices that it charges the firm will go bankrupt. Revenues are thus tied to consumer benefits. Taxes, however, are not prices and we have no direct way of assessing whether taxes paid are more than matched by benefits received. Voting is an indirect method of testing whether government is performing at par but voting is at best only a coarse test. Votes are typically registered only every four or more years and they are made over large bundles of goods that the voter cannot untie (a voter, for example, cannot vote for one party's position on the military and another party's position on the environment).

[27] The term 'ring-fencing' has often been used in a variety of contexts by UK authorities to denote limitations on ways particular revenue sources may be used. It circumvents the use of the term 'earmarking' which, for historic reasons, is an anathema to the Treasury. For example, in the specific case of congestion charges, the 1998 UK legislation discussed later in the paper explicitly 'ring-fences' road pricing revenue for local authority improvements in roads and public transport in the area where road pricing is introduced.

To begin the analysis of earmarking with the argument that it would be inefficient to constrain a private firm to spend its revenues in prescribed fields is to miss the point. The problem that earmarking attempts to address is one that private firms do not face. Earmarking tries to ensure that citizens can see how taxes paid are matched by benefits received.

For these sorts of reasons, Buchanan (1963) and others have advocated the use of earmarking.[28] Earmarking is seen by advocates as more transparent than general taxation and provides the populace with a clearer picture of the options confronting them and allows subsequent monitoring of actions. Accountability is stronger. Earmarking does not necessarily imply putting the revenues from the revenue back into the same activity from which it is raised but rather into some pre-specified expenditure package. From a public policy perspective, it provides 'voters' with choices of policy packages.

Earmarking, however, need not work in this way. Lottery funds "earmarked for education," for example, rarely result in more being spent on education just a reshuffling of fungible revenues (Borg and Mason 1990). In these cases earmarking is a form of fiscal illusion (Lee 1997).

Earmarking may also be necessary to create a dominant political coalition.[29] In some cases such coalitions may have some economic logic as when road revenues are earmarked for road building – thus ensuring that road users are not inefficiently subsidizing non-users and non-users not subsidizing users. In other cases, however,

---

[28] Earmarking or hypothecation can take a variety of forms. It may stipulate that the revenue from a tax on a particular activity be used to finance that activity – this is effectively a form of user fee. Alternative, and more generally, there is a stipulation that revenues from a specific tax be used for a particular purpose that may be unrelated, or only loosely to the source of the tax.

[29] See Keeler (1984) for analysis of the coalitions involved in US domestic aviation policy and Button (1989) for UK bus deregulation.

especially when the revenue and expenditures sides are not closely related, the coalition may be purely political.

The FASTRACK HOT lanes on an eight-mile section of I-15 north of San Diego are priced on a real time basis and run parallel to free lanes. Stretches of private road in Orange County California are priced in accordance with a pre-established time-table. Opposition from road users to the charge was placated in part by the fact that the revenue from the charges is put into maintaining and improving the road. This benefits not only the user of the FASTRACK facility but also users of the free parallel road that is now also less congested.

The evidence from numerous surveys also generally indicates road users favor the earmarking of net revenues from road pricing. For example, a National Economic Development Office (1991) study in London found that 43% of adults questioned supported road pricing as a stand-alone measure but this figure rose to 63% when hypothecation of revenues for purposes favored by respondents was of part of the package. In particular, 38% wanted it spent on public transportation, 25% on road improvements and 14% on non-transportation services such as the National Health Service.

Jones (1991) surveyed a large number of studies that have looked at attitudes towards road pricing in the UK and found that a high level of public acceptance required that revenues be dedicated to local transport and environmental projects. More recent generic findings are contained in the UK Department of Environment, Transport and the Regions (2000) consultation document, *Breaking the Logjam*. Forty-four percent of respondents said that road pricing revenues should be earmarked for better public transportation.[30]

The experience of FASTRACK, small as the sample is, indicates that private sector road suppliers find putting surplus revenue back into road infrastructure a commercial proposition, at least with current capacity and demand parameters. It also reflects the fact that prices do not simply ration out scarce resources but also act to stimulate an expansion in those resources. The difficulty with the public sector is that while earmarking to a portfolio of outlays may obtain a political coalition in favor of road pricing, this portfolio may well reduce the efficiency of the regime and be highly wasteful of resources. Earmark systems, even when seen as efficient in curbing government failures to spend wisely in the short-term are notoriously rigid in the face of changing circumstances.

2.3 BERGEN AND OTHER NORWEGIAN SCHEMES

Despite all the difficulties with introducing road pricing, a number of systems with some of the characteristics of road pricing are in place. The Norwegians have introduced from the late 1980s a series of cordon-pricing regimes, ‘toll rings’, around a number of their cities (Trondheim, Bergen and Oslo). These essentially involve payment for entry to the city. The geography of Norway, with its mountainous terrain and small cities with limited access points makes this a relatively straightforward way of charging road users. The monies are collected through both electronic and manual systems. Over time, as practical

---

[30] Care should be taken with interpreting survey findings in this context. How the question is posed can seriously bias the responses forthcoming. Car users, for example, may favor funding public transportation on the basis that it will attract others from using their cars. Equally, studies such as that reported in *Breaking the Logjam* do not represent systematic sampling but rather responses to an open invitation to comment.

experience has been gained and as technology has developed, so the systems have become more technically sophisticated. In all cases, the initial technology was not state-of-the-art but well tested to ensure that minimal operational problems would arise. Details of the various to toll ring schemes, together with some data on the cities themselves, are provided in Table 2.1.

The schemes are not strictly road pricing in the Pigouvian sense. They are more in the tradition of tolls. They do not directly relate to levels of congestion and, indeed, in some cases there are discounts offered to frequent users of the systems. As can be seen from Table 1 the charges are also relatively low. The positioning of the toll rings was also not designed to optimize traffic flows. They were located largely to capture revenue in what was seen as a politically equitable fashion. Nevertheless, since a charge is levied in the cordon schemes, it is almost inevitable that there will be some impact on travel behavior and, *ipso facto* they have implications for congestion.

In all cases there is a large element of earmarking in the ways revenues are used and this has also been seen as having longer-term implications for traffic congestion.
In the case of Oslo where a ring system was initiated in 1990, for example, an argument has been advanced that since the revenue collected is used largely to construct ring road facilities this will ultimately contribute to reducing congestion in the central area of the city. A further 10% of revenue is earmarked for public transportation that, it is argued, has an additional positive substitution effect (Solheim, 1990).

Table 2.1. The Norwegian Toll Rings (data for 1992)

	Bergen	Oslo	Trondheim[a]
Population of urban area (thousands)	300	700	136
Percent inside toll ring	10	28	40
Starting date of toll ring	January 1986	February 1990	October 1991
Number of stations	7	19	11
Entry fee for cars (NOK)[b]			
Single trip (manual or coin)[c]	5	11	10
Per trip (subscription)[d]			
With prepayment[e]	4.50	7.43	7
Off-peak discount (after 10.00pm)	NA	NA	2
Monthly pass[f]	100	250	NA
Time charges are in effect			
Days	Monday-Friday	All days	Monday-Friday
Hours	6.00am-10.00pm	All hours	6.00am-5.00pm
Average daily crossing during toll hours (thousands)	68	204.4	40.5
Percent by subscribers	59	63	85
1992 gross revenue (million NOK)	63	628	70.7

Notes:

a Figures exclude the pre-existing Ranheim toll station which has higher rates applicable in both directions and at all times.

b For 1992 the exchange rate was NOK1 = $0.16.

c Bergen: all stations manned. Oslo: all stations manned, 8 have coin lanes. Trondheim: 1 station manned, others coin or magnetic card only.

d In Trondheim subscribers are charged for no more than one trip per hour and no mkore than 75 per month. Trondheim subscription rates rose in 1994 for people making 10 or fewer crossing per month.

e charges shown are for the following prepayment quantities. Bergen: booklets of 20. Oslo: 350 trips. Trondheim: NOK 1500 prepayment. A post payment option is also available in Trondheim.

f Six and twelve month passes are available at lower rates.

Source: Small and Gomez-Ibañez (1998)

The Bergen system of cordon tolling was initiated in 1986 (Larsen, 1988) and is perhaps the most studied of the Norwegian rings. The city is small and the initial toll ring had six stations with another added after the completion of a new road link. The evidence from the outset was that, whilst the tolls were nor specifically designed to impact on congestion, they did lead to some limited spreading of peaks. The initial system covered the period 6.00am to 10.00pm each weekday and hence did not differentiate peak flows. The result was a very rapid reduction of traffic in the urban area by some 6% to 7%. Small reductions were initially recorded in Oslo, but within nine months traffic had built up again in the urban core. The Trondheim system has the least impact on congestion because about a third of the region's drivers live within the toll ring (Ramjerdi, 1994).[31]

Whilst there are technical issues of toll collection technologies and the like that are of interest in the Norwegian case, of more importance is perhaps the political mechanisms by which the authorities gained acceptance for their policies. In all cases there was earmarking of revenues. In the case of Oslo, the introduction of a toll ring was coincidental with the opening of an express bypass that would be financed from toll revenues. Despite this, surveys indicate that only 29% of those questioned in Oslo before the toll rings were introduced had a positive view of the scheme, with 7% in Trondheim. The figures rose to 39% and 20% respectively after a short period of operation. While clearly still not a majority, this does indicate a rapid change of opinion for a large number of people. Similar feelings were expressed in Bergen.

The crucial point about the Norwegian toll rings is rather less the impact they have had on traffic congestion in the short terms, and the support that some of the

[31] In 1997 three new 'inner' screenlines were proposed to capture revenue from those inside the original ring.

schemes have given to the technology possibilities, than how one can gain increased political acceptance for what were at the outset unpopular measures. The ideas outline earlier for earmarking road pricing revenues for road improvements, public transportation subsidies and for reduction in other (possibly partly car related) taxes largely fall into this coalition forming framework

3.4 ROAD PRICING IN LONDON

Over the years a number of proposals have come forward for the introduction of road pricing in London. Much of the debate in the *Smeed Report* of the early 1960s was about London. While attracting public and political attention, the idea was abandoned in favor of institutional and urban planning reforms with a focus on improving public transport.

Road pricing was reconsidered in detail in the 1970s and major studies of the implications of a system of 'supplementary licensing' were undertaken. A number of variants were considered but an option involving a daily fee of £2.00 (1973 prices) per vehicle driving on inner London roads between 8.00am and 6.00pm on weekdays was subjected to considerable scrutiny. The simulations indicated that this would reduce peak traffic in the 3.4 square miles of Central London and raise speeds by up to 40% (May, 1975).

The 1980s saw a restructuring of the local government in London and another resurgence of interest in road pricing (May *et al,* 1990). This also coincided with a shift in national transportation priorities with more emphasis on traffic management and making better use of existing networks. Cordon pricing was examined in detail with London divided into six zones with all-day charges for crossing screenlines between the inner zones and peak charges only for crossing the boundaries of outer zones. Estimates of the most favored toll structure found that traffic peak traffic in London would decline by 15% with a 25% fall in Central London.

Another set of studies were completed in the early 1990s looking mainly at cordon pricing around Central London deploying somewhat higher fees than previous work had assumed (ranging up to £14.00 for a peak inward crossing). The cordon charges were explored in combinations with changes in parking and public transportation policies. The models indicated that traffic speeds would rise in Central London by up to 32% with traffic volume falling by up to 22%. Additional traffic reductions could be attained adopting more cordons but only at the cost of more complex and expensive structures (Bates *et al*, 1896).

A further restructuring of London's government has brought about a much less academic approach to road pricing. UK transportation policy shifted in 1998 to explicitly facilitate local government to initiate road pricing within their jurisdictions allowing them, at least at the outset of any scheme, to retain all revenue generated. More germane here, the Greater London Authority Act 1999 conferred road user charging powers in Greater London on the Authority. Since that time the mayor of London has been developing plans to introduce a simple form of road pricing within the capital largely based on the report of the Government Office for London (2000). The report concluded that a daily charge between 7.00 am and 7.00 pm for cars of £5.00 per day (£15.00 for trucks) enforced by digital cameras would reduce traffic by about 12%. The study also found that a daily charge of this magnitude would generate about £200 million annually (later revised down to £120 million, dependent on exemptions).

The outcome was the Central London Charging Scheme that came into effect in February 2003. This introduced the £5.00 for driving in the central zone of London between 7.00am and 6.30pm on weekdays. The charge for commercial vehicles is £5.50 to reflect higher collection costs. The scheme operates with a paper based system using automatic number plate recognition technology via cameras located at cordon entry points or in mobile locations throughout the charging area. Some vehicles categories (e.g., taxis, motorcycles and buses) are exempt. Those who live within the zone enjoy a 90% discount on the charge.

The results for the first year indicate congestion has fallen by 30% within the central zone, that traffic levels are down by 18% with a 30% reduction in the number of cars and that bus patronage has gone up by nearly 30,000 passengers during the morning peak. The latter is partly due to bus reliability increasing – additional wait time at bus stops is down 20% across London and by 20% within the charging zone. There is little impact on traffic levels immediately around the central zone. The greater than expected traffic impact combined with legal issues of enforcement has meant revenues were only £68 million in the initial year[32], although the figure is anticipated to rise to £80 million to £100 million in future years (Mayor of London, 2003).

Here we are not concerned with whether £5.00 is a reasonable figure, whether the exemptions are justified, whether the enforcement technology is appropriate, or whether the temporal and spatial boundaries. Rather attention is with the implications of £100 million or suddenly becoming available to London's public authorities and with the distribution of impacts and the ways it is spent. These latter considerations are important because the desk-top studies supporting the daily charge indicated that reduced traffic

[32] Comprising £165 million in revenue and £68 million in costs.

congestion would, despite any financial payments, generate benefits for bus users and freight transportation and for medium and lower income car users. This, however, runs counter to the general arguments of Richardson cited above and seems somewhat counterintuitive.

The UK legislation only guarantees that a local authority may maintain the rights to this for 10 years. This is clear, if limited, earmarking in the sense that the ring fencing implicitly means the revenues must be spent locally. The Government Office for London study indicated that the traffic benefits from road pricing would be greater if the scheme were complemented by improved public transportation. Its modeling efforts, however, involved only a limited number of scenarios that directly looked at taking monies from road users to fund public transportation.[33] But, equally, the models, largely because of the complexity of London's transportation system, did not consider potential traffic gains from investing revenues into improved road infrastructure (either in terms of civil engineering schemes or improved telematics and control systems). Nevertheless, and accepting that the proposals are still in their formative stages, the general impression is that the vast majority of monies raised will go to public transportation.

The issue ultimately comes down to whether a fairly crude form of road pricing that reduces congestion in Central London is justified if its political acceptance depends upon revenues collected being earmarked for public transportation. The successful adoption of the Norwegian schemes was largely predicated on the basis that the majority of revenues would go to clearly defined road projects. In some cases public transportation would receive some limited resources. While it may be true that public transportation in

[33] The included the provision of 10 high-quality bus routes between Inner and Central London costing £100 million and reduced bus fares involving a £100 million per annum subsidy.

London is in need of additional investment, it is also true that the road network is in need of improvements.

Perhaps more important is the potential resource loss that could stem from road pricing revenues crowding out other sources of funding for London's public transportation. If road pricing does reduce traffic flows by 15% or more over the long term[34], then the inevitable outward shift in the demand for public transportation would make private investment more attractive. The subsidization of additional investment or the provision of operating subsidies effectively competes with this commercially driven finance. Unless it is clearly demonstrable that the subsidized activities generate more social welfare than those favored by the market then resources that could be utilized with benefit elsewhere are wasted.[35]

Finally, the focus on public transportation as an alternative to car use may neglect other consumer choices. There is the potential substitution of resources to other activities that may be socially preferable to offering publicly financed transportation. Indeed, the record of Singapore which introduced area licensing a quarter of a century or so ago is that it is extremely difficult to foresee what happens after charges are initiated. In this case the expectation that there would be a substantial mode switch to local buses proved wrong, people car pooled or switched travel times, and many of the new bus depots were very rapidly abandoned. The London case may be different and the situation is certainly more complex. Nevertheless, public transportation expansion may not be the optimal approach. As an example, the ability of many of those in the service sector to telework at

[34] There are plans to modify the scheme, and in particular to enlarge the zone where charging applies.

[35] There are theoretical arguments concerning asymmetry of risk bearing that could justify transfers to public investment but need to be empirically demonstrated on a case-by-case basis.

least part of the week now allows then to avoid many higher priced car trips. Offering public transportation at artificially low costs would not encourage this natural form of substitution.

3.5 CONCLUSIONS

The idea that urban traffic flows would be considerably more efficient if road users were made to make more rational payments for their use of the system has been around for a long time. Road pricing does not meet the theoretical ideal of eliminating excessive congestion costs of trips but it an efficient way of achieving many public policy objectives.

Efforts to introduce it, however, have seldom met with success despite numerous studies of various forms of charging showing how society would benefit. For technical reasons there is certainly no ideal way of charging road users but there are many road pricing options that are tractable and would certainly generate significant societal gains if initiated. One of the obstacles to action is that the main immediate beneficiaries of road pricing are the revenue-gathering authorities. There are thus important redistribution implications involved. To gain wider acceptance there would appear from both desk top studies and the experiences of where quasi-road pricing has been implemented in Norway, the need to develop a coalition of interests favoring congestion charges.

The difficulty is that while, by definition, there should be sufficient revenues to 'buy-off' all adversely affected parties after introducing road pricing how this is done can affect overall societal welfare. This is aside from any normative questions concerning the extent that it is desirable to do so.[36] To use it most effectively would not involve earmarking but this seems to be a necessity in most cases for gaining the minimum public acceptance. Its use as a source of funds for road improvements would seem a logical initial application given that the need for congestion pricing *per se* indicates a high social return from capacity expansion.

The crucial policy question for London is whether a sub-optimal, at least from an efficient perspective, road pricing system with earmarking of significant revenues to public transportation is justified. In a sense, the political constraint that revenues will revert to general taxation after 10 years may reduce any longer term distortion effects.

Certainly, from what has occurred in Norway, where pure revenue-collecting approaches are gradually evolving into congestion charges, it does seem that reforms can take place once a regime is in place. There would seem from the experiences of Norway and from some of the admittedly limited survey analysis conducted of road users in the UK, that if ring-fencing of revenues is done then there is at least a better case for ensuring that monies are devoted to road improvements where there is demonstrable demand, than to public transportation. Indeed, since public transportation often uses a common track there are potential synergies.

[36] If only a limited number of individuals and groups are needed to create a dominant coalition in favor of road pricing then use of revenue to compensate others effectively becomes a redistribution rather than an efficient concern.

3. THE POLITICAL ECONOMY CONSTRAINTS ON DEPLOYMENT OF A LARGE SCALE ELECTRONIC 'HOT ROADWAY'[37]

3.1 INTRODUCTION

As argued above, urban and metropolitan transportation networks are experiencing increased traffic congestion and delays for both passenger and freight movement. This trend is driven by a variety of factors including population growth, migration to urban areas stemming from increased benefits of economic agglomeration, technology breakthroughs in telecommunications, and defective traffic management strategies.

A variety of measures including building infrastructure, adding or segregating high occupancy vehicle (HOV) lanes, and more general travel demand management measures such as lane control, truck embargoes, vehicle restrictions and time of day requirements have not proved to be a remedy for urban congestion problems. In short, due to the failure of these measures urban areas are allocating scarce transport infrastructure by congestion. An alternative in the form of appropriate pricing or charging for use of infrastructure exists and is the focus here.

While growing congestion is a problem in most major metropolitan areas in the US and many other countries, there are some cases where these problems are manifest in urban corridors that stretch across multiple metropolitan areas. Examples in the US include most parts of the Northeast Corridor, San Diego to Los Angles, Milwaukee to Chicago to South Bend Indiana, and Miami to West Palm Beach. Overseas much of the

[37] This chapter draws on Button *et al* (2004)

Island of Taiwan, the North Rhine-Westfalia region in Germany and large parts of the UK motorway network are heavily congested. These corridors exhibit the same sort of traffic problems that characterize metropolitan areas but can be more complex because of their long and continuous nature. Managing traffic flow is more problematic in this context.

In this paper mixed road charging in the form of a long 140 miles, four-lane 'HOT Roadway' is considered as an important but untried alternative for allocating scarce roadway resources. More specifically, a case study of the corridor that stretches from Fredericksburg, Virginia about 140 miles to the Delaware-Maryland border is defined for examining the plausibility of the concept of such a HOT Roadway.

3.2 ALLOCATING SCARCE INFRASTRUCTURE

Pigou (1920) introduced the concept of congestion pricing (terming it 'Road Pricing'[38]), i.e., developing a pricing structure to reflect time costs due to sub-optimal levels of congestion. Congestion today is, however, still the usual method for allocating scarce roadway and other transportation infrastructure in the US and elsewhere. There are several problems with this.[39] Time is not a good allocative mechanism because it does not accurately reflect opportunity costs. Second, people do not know in advance the time costs of undertaking travel behavior, or at least there is often a high degree of uncertainty associated with it. Third, time does not have all the attributes of money. In particular, it is

[38] The term (with upper case) has a specific meaning. It involves prices that seek to make road users aware of the congestion costs they impose on other road users. It is not a full price of using a road in the sense that environmental costs are not included. For a technical discussion of the economics of congestion see Lindsey and Verhoef (2000).

[39] Although there are some who point to the equity benefits of congestion as an allocative device (Barzel, 1974)

not a good medium of exchange, by definition it is not a good store of value and is not easily used in transactions. In short, from the perspective of economic efficiency, time, (i.e., congestion) is not a good allocative mechanism.

Consequently, as congestion has grown, the time lost due to congestion has increased, and as information technology breakthroughs (such as intelligent transportation systems – ITS) have made possible the cheap electronic collection of charges for road usage[40], interest in pricing as an alternative allocative mechanism has increased. Some of the early work on this by Vickery (1969) and Walters (1961) extols the virtue of pricing approaches that of course are the counter points to the critique of using time as an allocative mechanism. More recently work by Arnott et al, 1993; Lindsey and Vehroef, 2001; Small, and Gomez-Ibanez, 1999 and others have expanded and deepened the intellectual arguments in support of pricing approaches.

Conceptual and theoretical interest in pricing as an allocative mechanism for roads grew in the latter part of the 20th Century. This was partly driven by local circumstances and conditions, but also stimulated by a more general up-surge of interest in using fiscal allocative devices in transportation. The privatization and deregulation of large parts of the transportation system is an element of this. A number of attempts have been made to adopt more rational pricing of roads on a more or less experimental basis. Many of these involve urban schemes, however inter-urban congested routes have been subjected to less analysis. Large scale toll roads were built in Europe, where within the European Union about 40% of the core network is tolled, and Asia and to a lesser extent

---

[40] Elsewhere earlier considerations to introduced electronic, congestion based charges on inter-urban roads were often abandoned because of concerns about the costs of the technology required (Chartered Institute of Transport, 1993.). Experiences with conventional toll collection in places such as Melbourne have seen this concern removed (Lay and Daley, 2002).

in the US. However, most of these simply have a fixed toll schedule and thus use pricing as a cost recovery method, not as an allocative mechanism.

Congestion pricing imposes a monetary value on the use of transportation systems when there is congestion. This encourages consumers to seek alternatives (e.g., switching to off-peak periods, changing routes, taking forms of transportation, or relocating) or to reduce travel. At its simplest level it may involve paying a toll to cross a cordon into a congested network (as in a number of Norwegian cities) but it can also involve real time electronic charging at the point and time the congestion occurs.

Since there is often opposition to road pricing, because of misunderstandings over what it seeks to do, concerns over how the revenues will be spent, and worries about the welfare distribution consequences, road pricing is now being packaged by politicians in a variety of sugar coated ways. With 'value pricing' consumers are given a choice between a conventional toll free road and a road with a toll on.[41] A more sophisticated extension of this is variable pricing where the cost to users on the tolled facility varies with the level of congestion. In contrast to value pricing, with cordon pricing consumers pay for the access to facilities. Area licensing (as used in Singapore and to be introduced into

---

[41] This is not a new idea and there are arguments that this approach, by widening consumer choice, is technically superior to charging all parts of a network (Starkie, 1986). It offers road users a choice between low fees/high time and high fees/low time rather than spreading congestion equally across a system as some forms of congestion pricing do. The evidence from a range of opinion based studies is that thei form of pricing for enhanced service meets with more popular approval the strict economic notion of road pricing as seen in the table below.

General congestion pricing	acceptable	HOT lanes	acceptable
Los Angeles (1990)	28%	Los Angeles (1996)	54%
Minneapolis (1995)	26%	San Diego (1996)	62%-72%
Sacramento (1995)	24%	Orange County (1997)	50%-74%
Oregon (1996)	23%-29%	Phoenix (1997)	58%
Los Angeles (1996)	37%-40%	Minneapolis (2002)	57%

London in 2003) whereby purchase of a license is required to drive in designated zones, is a particular form of this.

3.3 EXPERIENCE WITH HIGH-OCCUPANCY TOLL LANES

In the US, the three most prominent operational projects involving HOT lanes are I–15 in San Diego, SR-91 in Los Angeles, and I-10 Katy in Houston.[42] Depending on the primary objective, Single-occupancy vehicles (SOV) were either allowed to buy-in to HOV lanes (I-15), or HOV may use toll lanes at a reduced rate (SR-91). Mass transit is generally exempt from toll payments. The HOT lanes were established by converting existing HOV lanes into HOT lanes (I-10, I-15), and by building new lanes and access points (SR-91).

A study by the Washington State Department of Transportation (2002) provides a synopsis of the features of 13 different toll facilities in North America. Outside the US, there are no true HOT lanes, but a number of municipalities have already introduced very basic forms of congestion pricing.[43] Examples are the Singapore Area License Scheme, the Bergen, Oslo and Trondheim Toll Rings in Norway, and the A1 motorway in Paris. In all of these cases, the conditions for using the lanes can differ in terms of: the types of vehicles permitted (cars, trucks), the parameters defining the toll (time of day, traffic volume, travel distance, frequency of travel, type of vehicle), and the payment options available (electronic deduction, cash)

The most common approach is to have rates that vary with time of day. The Singapore Area License Scheme from its beginning 1975 limited access to the central business district during the morning peak hours to cars with a valid permit. Only vehicles

---

42 Internationally, there are a number of variations on the theme of HOT lanes and also truck-only lanes, see Pitfield and Watson (2001)

43 A survey of giving details of many of these is found in Small and Gomez-Ibanez (1998)

with 4 persons or more were exempt. In 1994 the system was extended to all vehicles and covered the working day. The system has proved effective with initial traffic volumes falling by 45% and average speed increasing from 18 to 35 km/h. In 1998, electronic road pricing was introduced with a staggered pricing system depending on zones entered and time of day (Willoughby, 2000). Prices are adjusted quarterly to maintain speeds of 45-65 kph on expressways and 20-30 kph on arterial roads. The system requires a transponder and a smart card with a positive balance.

The Trondheim Ring was established in 1991 and converted in 1998 to a zone-based system. All vehicles passing the zones between 6 a.m. and 6 p.m. have to pay a toll mainly collected using AVI tags. The toll ring resulted in a 10% reduction in the central area traffic during toll hours and an 8% increase outside toll hours, and an overall decrease of 4%.

Around Paris, variable pricing was introduced on the A1 in 1992 to reduce the weekend rush back into the city (Francois-Poncet and Larcher, 1998).[44] The normal toll is calculated by distance travelled and vehicle class. However on Sunday evenings during 'green' hours (2.30 pm to 4.30 pm and 8.30 pm to 11.30 pm) the normal toll is reduced by 25%, while it is increased by 25% in the 'red' intervening hours. As a result, about10% of the peak traffic is diverted to off-peak hours. In addition, the private operating companies, SANEF and SAPRR, reduced the toll on the alternate A26 route.

The 407 Express Toll Road in Toronto used to have a variable fee structure distinguishing between weekday peaks/off peaks, and weekends. The volume reached a peak-hour average of 12,000 and 300,000 average workday trips per month. The speeds

---

[44] In fact the entire French tolled road network is akin to a crude Road Pricing system in that tolled facilities are built to compete with free roads and hence users have a choice of high speed and high tolls or low speed and no tolls.

were about double that of parallel free highways. From 2002, flat charges were introduced.

Demand-sensitive rates that depend on traffic volume are less common.[45] The I-15 HOT lane project in San Diego consists of an 8-mile stretch of two reversible HOV-2 lanes in the median of I-15. It opened in 1996 for a limited number of single-occupancy vehicles (no trucks) for which a monthly *ExpressPass* had been purchased. In March 1998, it switched to the transponder-based, dynamic pricing system, *FasTrack*. The fees vary depending on the real-time congestion levels to maintain free-flow conditions.[46] The buy-in opportunity led to a significant increase in HOVs using the Express Lanes, and significant decrease in SOV violation rates (Supernak 2001). However, whether traffic congestion was reduced on the free I-15 lanes is inconclusive. Users were satisfied with the reduction in their travel time, the reliability of on-time arrival at their destinations, and the perception of improved safety. The majority also strongly agreed or somewhat agreed with the pricing concept.

The SR 91 facility in Orange County, California, consists of a 10-mile stretch of four express lanes in the median of State Route 91, an 8-lane freeway. It opened in December 1995. Transponders are used to control traffic and to maintain a 65 mph speed. Vehicles with 3 or more occupants pay half the rate of other cars. The average peak-period speed in free lanes has increased from 15 to 32 mph (Sullivan 2000). Most of the new trips induced by improved travel conditions were for non-work related purposes and majority of them used the free lanes. Most commuters do not use the toll lanes on a daily

---

[45] The HOT lanes in the US have tended to be analyzed form a traffic engineering rather than from an economic perspective. Hence, there is limited evidence on many of the trade-offs involved. Kim (2000) is an exception to this.

[46] The free-flow state is seen as 65mph. There is some discussion of whether a target of 35-50mph would be preferable because this would maximize flow.

basis. The proportion of travelers using the express lanes ranges from 7% in the mid-day off-peak to 35% during the peak. In addition to time saving, comfort and the perception of greater safety were cited as the principal supplemental benefits.

The I-10 HOT lane in Houston varies tolls with occupancy (Stockton et al, 2000). It uses an existing 13-mile HOV lane of the Katy Freeway. Starting in 1998, a congestion pricing experiment, *QuickRide* was introduced allowing a limited number of 2 occupant HOV carpools to buy into 3 occupant HOV lane. Initially, a limited number of transponders were issued, but it is expected that the number of permits will increased to 1,000. Overall, HOV use has increased.[47]

3.4 CASE STUDY: VIRGINIA AND MARYLAND HOT LANE

The study area is defined by the linear region that begins in Fredericksburg Virginia, located on the southern extremity of the Washington D.C. Metropolitan Region and the Delaware border, located on the northern extremity of the Baltimore Maryland Metropolitan Region. This is part of the I-95 corridor, the major interstate highway running through the study area and connects to points south and north. The I-95 corridor has a variety of road infrastructure that supports movement up and down the corridor including US Route 1, US Route 301, various turnpikes (e.g., the Pennsylvania Turnpike and the New Jersey Turnpike), the Baltimore-Washington Parkway and the Garden State Parkway. Despite these multiple route-ways through the study corridor congestion at

[47] There are also a number bridges and tunnels with differential charges that *de facto* serve as pricing points on a network. These include two tunnels in Seoul, two bridges in Lee County, Florida, the Tappan Zee Bridge in Bew York, and bridges and tunnels controlled by the New York Part Authority. In all cases there has been a temporal spread in traffic.

peak, shoulder and bridging periods is one of the three highest in the US. In short, the costs of allocating road use in this corridor are very high.

The purpose of this part of the chapter is to construct scenarios of a hypothetical HOT Roadway from Fredericksburg to the Delaware boarder north of Baltimore. Such a road has elements of occupancy and pricing as control features. A HOV component is being considered because there will be a demand for intra-city commuter use as well as inter city flow through use. At the same time there are many alternative ways that such a road could be designed ranging from cars only, trucks only[48], to mixed use, and these may be combined with pricing schemes ranging from flat tolls, to tolls varying by type of vehicle and congestion levels.

The costs and revenues from three different scenarios designed are estimated to provide different perspectives from which to surface and consider institutional and technical barriers that would need to be addressed in the actual development of a HOT Roadway. The three scenarios are, autos only with all subject to the same congestion variable rate structure; auto only but autos with 2 or more passengers would not pay for usage; and trucks only with variable rate structure based on number of axles. Many other construction and operational models could have been examined such as mixed auto and truck models but it is well understood that mixing trucks into the traffic flow (especially on 4 lane highways) seriously reduces the average speed of all. A flat rate pricing model could have been adopted however this would have missed the point of using cost rather than time as an allocation mechanism.

To gain insights into the economics of constructing HOT roadways some basic calculations were done on the possibility of developing facilities on the I-95 Corridor.

48 Samuel, et al (2002) offers a fuller discussion of truck only toll ways.

The assumptions of the cost estimation and revenue generating models are presented in detail in Table 3.1. Tables 3.2 to 3.4 provide details of the specific details regarding each of three scenarios employed regarding the type of road being considered.

Table 3.1 The basic assumptions of the HOT lane analysis

- Calculations are for through-traffic. That is, long distance traffic, traveling the extent of the toll roadway (140 miles)
- Truck toll rates are based upon per mile estimates from Samuel et al (2002)
- Amortization of construction costs are based upon 40 years with 12 monthly payments
- Traffic volume calculated from estimates from US Department of Transportation's *Highway Capacity Manual*, and several reports on traffic volumes in DC region
- There is no growth in the amount of traffic. This will underestimate the revenue generated and operating costs
- Classification of trucks based on toll schedule for the New Jersey Turnpike. The proportion of trucks comes from NJ Turnpike figures and verbal accounts of the truck volume in DC region. Since this is long-haul traffic, the proportion of semi-tractor trailer units is higher.
- An extra two-inch depth of asphalt was incorporated into the construction costs for the Truck-only roadway. According to Virginia Department of Transportation, the maintenance costs would remain the same.
- The SOV/HOV split is 85/15
- For car toll rates, the fixed cost was \$6.00 (\$0.043 per mile) fixed rate. When varied for congestion, the rate was doubled to \$12.00.
- When HOVs paid tolls, they are half rate of SOVs

Table 3.2 All cars pay

SOV/HOV Proportion			Capacity Time and Rates						
SOV	85%	Variable Toll		Hours/day	SOV Toll Rate	HOV Toll Rate	Total Cars	Number SOV	Number HOV
HOV	15%		100% Capacity	8	6.00	3.00	5,600	4,760	840
	100%		80% Capacity	8	4.80	2.40	4,480	3,808	672
			50% Capacity	4	3.00	1.50	2,800	2,380	420
			20% Capacity	4	1.20	0.60	1,120	952	168
			Daily Revenue	443,822					
			Annual Revenue	161,995,176					
		Fixed Toll	100% Capacity	8	6.00	6.00	5,600	4,760	840
			80% Capacity	8	6.00	6.00	4,480	3,808	672
			50% Capacity	4	6.00	6.00	2,800	2,380	420
			20% Capacity	4	6.00	6.00	1,120	952	168
			Daily Revenue	577,920					
			Annual Revenue	210,940,800					

Table 3.3. Single occupant vehicles pay and high occupant vehicles do not pay

SOV/HOV Proportion			Capacity Time and Rates						
SOV	85%	Variable Toll		Hours/day	SOV Toll Rate	HOV Toll Rate	Total Cars	Number SOV	Number HOV
HOV	15%		100% Capacity	8	12.00	0.00	5,600	4,760	840
	100%		80% Capacity	8	9.60	0.00	4,480	3,808	672
			50% Capacity	4	6.00	0.00	2,800	2,380	420
			20% Capacity	4	4.80	0.00	1,120	952	168
			Daily Revenue	845,674					
			Annual Revenue	297,720,864					
		Fixed Toll	100% Capacity	8	6.00	0.00	5,600	4,760	840
			80% Capacity	8	6.00	0.00	4,480	3,808	672
			50% Capacity	4	6.00	0.00	2,800	2,380	420
			20% Capacity	4	6.00	0.00	1,120	952	168
			Daily Revenue	71,400					
			Annual Revenue	26,061,000					

Table 3.4 Truck only roadway

Truck Toll Rate			Capacity Time and Rates					
Class 6	112.00	Fixed Toll		Truck Volume	Class 6	Class 5	Class 4	Class 3
Class 5	84.00		100% Capacity	2400	1200	600	400	200
Class 4	56.00		80% Capacity	1920	960	480	320	160
Class 3	28.00		50% Capacity	1200	600	300	200	100
			20% Capacity	480	240	120	80	40
			Daily Revenue	531,720				
			Annual Revenue	194,077,800				

The cost estimates for the HOT Roadway uses normal engineering design parameters and combine them with cost estimates provided by the Virginia Department of Transportation. It is assumed that 10% of the capital costs are paid for from cash reserves and the remainder financed with a 40 years 5% bond issue. It is assumed that in the truck only lane scenario the track will be built to a higher engineering standard that will keep maintenance costs at the level of a standard track. Higher capital costs are allowed for. On the demand side no allowance is made for traffic growth over the period. This will inevitably take place and as result revenues will be higher than in the estimates in Table 4.5. The cost of electronic collection of tolls is assumed to be small when spread over the 40 year period and is treated as negligible in the calculations.

The results, which look at a truck only tolled lane as well and two variations of an electronic tolling system for cars. The second of the car only options being the HOT Roadway. The tolls are based on what seem acceptable from experiences of such facilities as the New Jersey Turnpike and, in the case of trucking, on the opportunity cost of using the existing congested I-95 facility.

The outcomes are clearly sensitive to the assumptions summarised in Table 3.5 seem to provide relatively sensible outcomes with small losses or 'profits' being made according to the nature of the lanes.

Table 3.5 Net revenue scenarios (annual figures)

		Cars Only		Trucks Only
		All Cars Pay[a]	SOV Pay, HOV No Pay[b]	Rate Varies based on Axle Size[c]
Total Revenue	Fixed Toll[d]	$210,940,800	$176,474,680	$194,077,800
	Variable Toll[e]	$161,995,176	$297,720,864	
Total Financial Cost	Construction Costs	$152,989,632	$152,989,632	$154,170,459
	Operating Costs	$16,848,380	$16,848,380	$16,848,380
Net Revenue (Fixed Tolls – Costs)		$41,102,788	$6,637,000	$23,058961
Net Revenue (Variable Tolls – Costs)		-$7,842,836	$127,882,852	

Notes

[a] All cars will pay a toll regardless of number of occupants.

[b] At any time, multiple occupant vehicles do not pay tolls

[c] Truck rates are based on the four highest classifications of trucks from the New Jersey Turnpike Commission. The toll rates are based on a per mile rate discussed in Samuel et al (2002).

[d] Rates do not vary based on time of day (congestion)

[e] Rates vary based on time of day

3.5 INSTITUTIONAL AND TECHNICAL BARRIERS TO DEPLOYMENT OF A HOT ROAD

The construction of any large piece of infrastructure raises a plethora of institutional challenges. Indeed, the problems of finance, coordination and obligations that go with such schemes provide the main *raison d'être* for Adam Smith (1776), in one of his few deviations from supporting the free market, arguing for government provision. The general barriers to the construction of large-scale HOT Roads are large and differ according to context. Here some of the generic issues are highlighted in the specifics of the case study.[49]

Long-distance HOT Roadways will require multiple jurisdiction political and bureaucratic coordination. This is particularly important in areas such as the one for the proposed HOT Roadway that will traverse two states, a federal district (Washington, DC) and dozens of local counties and municipalities not to mention any special transportation authorities that these government units may have created.

In the US political system there is a complicated relationship between states that are constitutionally responsible for providing domestic transportation services and the federal government that has assumed responsibility for significant funding rationalized on the basis of support for interstate commerce and defense. This all becomes even more complex at the sub-state levels. For example, in Maryland, a home rule state, each of the State's jurisdictions hold title to the road infrastructure within their boundaries other than state and federal routes. Thus, it is possible that each would have some role in the

[49] Unlike the case of urban Road Pricing where there is likely to be a massive surplus of revenue generated because the opportunities for expenditure on road expansion are limited, the nature of Hot Roadways are such that only very modest net revenues are likely. The literature on how to make the best use of urban Road Pricing funds is extensive and may be of some relevance for special cases of Hot Roadways (see Small, 1992).

planning, development, construction and operation of the HOT Roadway. In contrast, The State of Virginia, a Dillon Rule state, holds title to and 'owns' nearly all of the road infrastructure in the state (exceptions are independent cities and two exempt counties). Presumably coordination in the Virginia part of the corridor would therefore be less of an issue. However, land acquisition could be a major issue in all jurisdictions and this would be a local issue. The federal district of Washington, DC holds title to and is responsible for all of its road infrastructure. Additionally, each of the major metropolitan regions (the Greater Washington Metropolitan Region and the Greater Baltimore Metropolitan Region) by federal law have a metropolitan transportation planning unit called transportation planning boards (TPBs) that must approve all major transportation investments in their regions before construction may go forward. TPBs have difficulty reaching agreement on how scarce road resources should be allocated so coordination across two TPBs and two states and one federal district and dozens of local governments will be very challenging.

Coordination will be required in areas such as financing, land acquisition, operations responsibility and revenue collection and allocation. These issues are examined briefly below.

Financing will in principle be less of a problem than some other issues. First, a bond issue could finance the proposed HOT Roadway, that is, by borrowing the funds to construct the project. This is possible because there is a revenue source from the tolls collected. Determining what entity or entities will assume responsibility for floating the bond issue could be a difficulty. The states will be concerned that a large project like the one proposed may limit their ability to go into the bond market for funds to support other projects. One solution would be to form an interstate authority whereby the States and localities release their responsibility over road policy and programs to a HOT Road authority. There are many precedents for this but most are not interstate in nature such as the Pennsylvania Turnpike Authority, The Garden State Parkway Authority, etc. Similarly, the project could be privatized, i.e., turned over to a private company, or formalized into a public-private partnership where the responsibility for financing rested upon the private contractor or the Partnership. In short, the main coordination issue in the area of financing the project would be achieving agreement on going forward with the project and a financing plan and a governance model.

Land acquisition could be the most difficult issue to address in a coordinated fashion. Land will be required to construct the proposed HOT Road. While some of this may already be in public ownership much that is in private ownership will need to be acquired. Laws covering the ownership and acquisition of land are largely a state and local matter in the US governance model. Thus acquiring the land for the project will require coordination across all levels of government despite the possibility of "taking" under "right of eminent domain" statutes, i.e., for the greater good. It would seem that this would be far more easily accomplished via a multi-state authority or a joint authority arrangement (each state having its own authority) across Virginia, Maryland and the District of Columbia.

Operations, maintenance, revenue collection and management would be most easily achieved through an interstate authority as described above. Without such an authority the cross-jurisdiction coordination of these fundamental components of delivering transportation services will be nearly impossible.

The coordination issue seems to hinge on the feasibility of forming an interstate authority to construct and operate the proposed HOT Road. Forming such authorities is not difficult if the major state level entities want to, i.e., they agree upon the need for the authority. Many such authorities exist but most have to do with managing resources that spillover state boundaries such as river systems. Maggio and Stough (2002) provide a description of a large number of these and also assess their strengths and weaknesses. The basic issues are first whether there is general agreement among the state partners to form an authority. If there is they together have the ability under the US Constitution to do so. Usually when interstate authorities are formed the partnered states approach the US Congress and ask that a bill be passed formally establishing such authorities (but it is not required for them to be officially sanctioned and operating entities). But in final analysis such an authority can only be established if there is agreement to do so.

There are additional issues that will impact the ability to get agreement on a multi-state road project like the proposed HOT Roadway project. Some of these are related to local preferences and preferences of political leaders and some are more general in scope. Some of these are described below to round out the understanding of the types of barriers that may exist.

The State of Maryland may pose a major barrier to successfully implementing the proposed project. The current state administration openly opposed the notion of express toll lanes within the state.[50] However, a recent election of a new administration and governor may lead to a more favorable disposition to the HOT lane concept.

[50] In 2001, the governor instructed the state transportation secretary to "remove HOT lane proposals from his departments plans" for transportation improvements (Sunnucks, 2001).

The Commonwealth of Virginia, while seemingly more amenable to the idea of HOT lanes is facing circumstances that could make it difficult to support a HOT Road proposal. As noted above, Virginia is a 'Dillon Rule' state and as such restricts powers to local jurisdictions. Unlike Maryland, where local jurisdictions have considerable autonomy in transportation decisions, Virginia's transportation planning is completed by the State with the exception of the jurisdictions located in metropolitan areas where Transportation Planning Boards must also be in agreement with plans and planning elements. Local jurisdictional needs may be superceded by state policies and as such, the benefits of the HOT lanes project will need to be seen as accruing to the state as a whole to receive maximum support from the state (Lewis Berger Group, 2001).

The Commonwealth of Virginia, like most states in the US, is currently under severe financial pressure and will find it difficult to support a HOT Road even in concept if there are costs or threats to its AAA bond rating status. Early in 2002, Virginia announced budgetary shortfalls, and instituted cost cutting measures in all state departments. Further, in a recent election (November 2002), residents of the northern Virginia region turned down a half-cent on the dollar increase in the sales tax, which was designed to provide funds for northern Virginia transportation projects. So neither at the state or the local jurisdiction level in the part of Virginia where the proposed HOT Road would be located is there open support for increased transportation expenditures.

3.6 SOCIAL AND ENVIRONMENTAL BARRIERS

Opposition to HOT lanes is often expressed with regard to the social and environmental consequences of this development. It has been argued that creation of toll roads in general create potential fairness issues. For example, a proposed variable rate toll road in Minneapolis-St. Paul Minnesota was stopped before plans were even finished. This was because one of the candidates for the upcoming governor's race labeled the project as creating 'Lexus Lanes' despite the fact that there were more than a few alternative non-tolled options (Schoenberger, 2002). Thus, the view that those who can pay benefit and those who cannot suffer disbenefits often is taken at face value without recognizing that there are alternative options whereby lower income individuals end up paying in time rather than money. At the same time the issue may be more complicated as illustrated by the following discussion of household transportation costs vs. housing and food.

Transportation and congestion are rising costs for American households. In 2000, the average US household spent $0.18 per dollar earned on transportation, the second largest expense after housing ($0.19 per dollar earned). This does not include the cost of the inconvenience time of congestion. Food is the third largest expense at $0.13. For the lower income, (less than $12,000 annual family income) the cost of transportation per dollar earned doubles to $0.36 cents (Surface Transportation Policy Project, 2000; Katz, 2002).

Congestion places another heavy burden on households and employers. In 1999, the Texas Transportation Institute (2001) estimated that on average for 68 metropolitan areas in the US, one work-week is lost annually per employee, due to traffic delays. In addition to lost revenue to employers, this also reflects lost income to employees. The total congestion bill for 1999 was $78 billion, 4.5 billion hours of delay, and 6.8 billion gallons of excess fuel consumed.

The region through which the HOT Roadway would pass has a number of environmental groups and civic organizations that tend to act against the development of new highway projects. Advocacy groups for public transit alternatives to roadway projects, smart growth initiatives, and stricter environmental measures (air, water and noise) have increased their visibility and lobbying power within the greater Washington DC region (Lewis Berger Group, 2001). There are several important issues here. There is an argument that increased road capacity in a region will stimulate additional demand because in effect new capacity lowers the relative cost of transportation when time is the only measure used to allocate the resource. With an appropriate pricing model increased capacity should not have a demand increasing effect because that demand is dampened by the payment made for use of the new capacity.

3.7 SAFETY AND ENVIRONMENTAL ISSUES

Road transportation has been described as 'Industry on wheels' (Thomson, 1974) because of the pollution it causes and the dangers associated with its use. There is some evidence albeit not undisputed, that much of the danger of road travel is associated with variability in the speed of vehicles using a road as with the average level of speed.[51] Variable speeds, for example, cause more movement across lanes for over taking and inability to maneuver can lead to frustration and reckless actions. In terms of the severity of accidents, larger vehicles such as trucks impacting on lighter vehicles, such as cars, increases the changes of fatalities and of serious injuries. Separating vehicles types and vehicles moving at different speeds, therefore, is likely to reduce accident costs. The difficulty is that the general public and policy makers are often moved by Bayesian

[51] For a discussion see Greenstone (2002)

estimations of risk rather than Gausssian estimates. There is often an irrational fear of faster traffic (as opposed to its more even flow) and to concentrations of trucks (even when separated from cares).

HOT Roadways may lead to higher pollution costs in the sense that they will attract more traffic. But if the flow moves at a relatively constant speed then individual vehicles could well generate less pollution. There is also the issue of the opportunity environmental cost. If traffic does not use the HOT Roadway then it is more likely to transit urban areas with the adverse local environmental costs that this can create.[52]

3.8 CONCLUSIONS

Inter city roads are now becoming more congested. This is due to a variety of factors but the concern here is with providing at least some relief from the worst of the congestion. It looks at the possibility of building a HOT Roadway, for either exclusive car or truck use, down the I-95 corridor in the US. A series of basic calculations provide indicators of the financial implications of such a policy. These are seen as a starting point for further analysis that focuses on the institutional problems of initiating this and similar types of project. There is powerful theoretical arguments, and ample, albeit small-scale illustrations that congestion problems can be limited by using fiscal incentives to make road users more aware of the costs of their actions. Most of this analysis and policy 'experimentation' has been at the urban level. This was appropriate when congestion was concentrated in metropolitan areas, but the problem has now become much more widespread.

---

[52] There is also the possibility that the manufacturing plant may be located in more environmentally sensitive areas without good transportation. The environmental issue should be seen to extend well beyond the simple matter of emissions on a road (see Van den Bergh et al, 1997)

4. CONGESTION RESPONSE BEHAVIOR – THE NEW RESEARCH AGENDA[53]

4.1. SCOPE AND PURPOSE

The premise of this section is that one is ultimately interested in congestion for public policy, commercial and practical reasons. Whilst there may be an intrinsic academic interest in individual and societal perceptions of, and reactions to congestion, these will constitute only part of the following.

The policy and practical interest has evolved because the level of traffic congestion of all types, together with the social dissatisfaction that accompanies it, continues to grow and to impose inefficiencies in the transportation system. This is not just reflected in technical, engineering parameters but also seen in terms of the findings of numerous public opinion polls. Further, the traditional focus on urban, peak hour traffic flows has extended to embrace congestion that is now occurring with regard to all modes of transportation and at different places and at various times. That excessive congestion is inefficient from a purely transportation perspective is generally accepted, and in many cases there are wider adverse social and environmental implications.

The amount of theoretical and empirical work that has been conducted looking at traffic congestion over the years is very extensive and has embodied efforts, albeit in varying degrees, of those from a plethora of disciplines. In some areas we actually know quite a lot about congestion (e.g., on queuing theory) but in others, most notably that

[53] This chapter draws upon Button *et al*, 2002

regarding human attitudes, perceptions, response behavior and decision making, and priorities we are still finding our way through a fog. Regarding virtually every other aspect of human endeavor or activity, western society throws up clear indicators of social and individual priorities, at least in an ordinal form, through choices and purchases in markets. These are certainly not ideal and need careful interpretation, but they offer various benchmarks or guidelines. Congestion is not traded in markets, by definition being a club good it is external to market mechanisms, and hence social and individual attitudes are more difficult to elicit.

The aim here is to look at some of the less-well understood aspects of the topic, and in particular at the more sociologically and psychologically driven issues. While there is inevitably more technology that can be thrown at the congestion problem (e.g., associated with intelligent transportation systems and design of hardware), there are also other approaches. Indeed, even in the case of the technology fix there is a need, among others, to understand how policy-makers will treat technical innovations and how transport users will react to them.

4.2 SETTING THE SCENE

Initially, it would seem important to set the scene in terms of describing, and to a lesser extent, understanding what is actually taking place regarding research on either side of the Atlantic. This provides an inventory of the skill base that is available as well as the trends in what is actually being produced. This is not easy given the various individuals and institutions involved. Also, ideally, one would like some indication of the resources that are put into the work but this poses a major practical problem. In consequence, the analysis simply looks at outputs.

To do this for both sides of the Atlantic, and for purely pragmatic reasons of managing the data, a number of borders were defined. The focus is on surface transport congestion. This immediately rules out the considerable concern and the work that is undertaken on the societal and behavioral aspects of congestion in air transport and maritime networks. Further, the analysis is limited to congestion of motorized transportation (be it the public or private mode) and to the congestion that occurs on roads. This again rules out two very significant bodies of analysis. The first relates to the work that has been done on congestion at terminal sites of motorized trips (largely parking facilities). The second relates to the even larger body of work that has been undertaken on the social and behavior aspects of pedestrian transportation. This involves analysis of congestion in such locations as shopping centers and sports/entertainment locations. The omission of the work done in these areas is not entirely one of the management of the scale of the exercise. It also reflects the fact that those conducting a large part of it not normally embraced in the academic/policy work in transport arenas – namely private commercial developers and the policing and enforcement agencies. From a slightly more pragmatic perspective, the findings from this work are often in the 'gray literature' making analysis difficult.

The analysis was also concerned with trying to develop an inventory of some of the US younger workers in the field. There has been, for a variety of reasons, an aging of the research population and simply to look at the work of those who have been in the field for many years inevitably misses the fresher insights and the up and coming interest of the research community.

The data basis used to examine the US situation were developed by using search engines to pull up references of US work in the area conducted over the past five years. This covers published material, or at least material readily available in the public domain. To glean some insights into the interests of younger researchers, as well as being a compilation of who they are, the annual data base of *Transportation Research A* was tapped. This lists Ph.D.s by subject. An indication of the amount of work being done in the US on transport congestion issues amongst the younger community is seen in Table 4.1. The relevant Ph.D. dissertations are seen in bold when presented in Table 4.2.

Table 4.1 Doctoral dissertations focusing on transportation congestion in the USA

Year	Total	Congestion
1994	74	3
1995	91	2
1996	86	5
1997	133	15
1998	134	6
1999	105	5
2000	109	4
2001	85	8
2002	136	2
All Years	**953**	**50**

Source: Various issues of *Transportation Research Part A*

To provide a framework for categorizing the overall research output in the US, Table 4.2 offers a series of rather subjective assessments. These assessments divide the work into their main themes. This was done by reading the relevant abstracts or full papers. It inevitably has the weakness of being subjective in terms of the categorizations used and the allotment of individual pieces of work to them. There is the further limitation that each piece of work is only allocated to one category. In fact, there may be good reasons to allocate it to several but this would involve a somewhat more detailed assessment.

The data basis used to examine the European situation was developed through several key-word searches in the Web citation index, looking only for European authors within the last six years. Key words included traffic and road congestion, connected with behaviour, response and decision making. For comparison, the same framework of categorization as used for the US data was also used for the European search results (Table 4.3). The European file also bears the same limitations as characterize the US one.

Table 4.2 Studies of the social and behavioral aspects of transport congestion in the USA

	Quality	Theory	Practice	Trans Atlantic
Road Users				
Enforcement[1]	√√	√√	√√	√√√
Overtaking[2]	√	√	√	√
Diverting to Other Modes[3]	√√√√	√√√	√√√	√√√
Attitude toward Restraint Measures[4]	√√√√	√√	√√√	√√√√
Teleworking[5]	√√√	√√	√√	√√√
Attitudes of Truck Drivers[6]	√	√	√	√
Reaction to Incidents[7]	√	√	√√	√
Public Agents				
Attitudes toward Congestion Control[8]	√√	√√	√√	√√√
Attitudes toward Public Transport[9]	√√√	√√	√√√	√√
Planning and Investment[10]	√√√	√√	√√√	√√
Modeling[11]	√√√√	√√√√	√√	√√√√
Land Use[12]	√√√	√√√	√	√√
Researchers				
Congestion Theory[13]	√√√√	√√√	NA	√√√√
Economic Theory[14]	√√√√	√√√	NA	√√√√
Land Use[15]	√√√	√√√	√√	√√√
Junction Design[16]	√√	√√	√	√
Project Assessement[17]	√√√	√√√	√√√	√√
Environment[18]	√√	√√	√√√	√√√

*Notes***:** The gradings in the columns are subjective and on an ascending scale from √ to √√√√

Sources

1. Lave, C. and Elias, P. (1997) Resource allocation in public policy: the effects of the 65-mph speed limit, *Economic Inquiry,* 35: 614-621.
2. Hohn, R.L. and J. Harrison (1998) Aggressive driving: traffic safety scourge, *Police Chief*, 65:16-20.
3. Cain, A., M.W. Burris, and R.M. Pendyala. (2001) Impacts of variables pricing on temporal distribution of travel demand, *Transportation Research Board*, 1747: 36-43; Collura, J., D. L. Fisher, and A. E. Hester. (2002) Drivers' parking decisions: advanced parking management systems, *Journal of Transportation Engineering*, 128: pp 49-57; Verhoef, E.T. Emmerick, R.H.M. Nijkamp, P. and Rietvelt, P. (1996) Information provision, flat and fine congestion tolling, and the efficiency of road usage, *Regional Science and Urban Economics*, 26: 505-529; Poulenez, D., and Jesus, C. (1996)

Public policy impacts on organizational behavior: A case study program evaluation. Transportation demand management in Washington State., *Transportation Research Part A: Policy and Practice*, 30: 86-87; Dueker, K.J., J.G. Strathman, and M.J. Bianco. (1998) *Strategies to Attract Auto Users to Public Transportation*. TCRP Report 40. Transportation Research Board, Washington, DC; Koskenoja, P.M. (1996) *The Effect of Unreliable Commuting Time on Commuter Preferences*, University of California, Irvine; Fox, J. and Harris. E. (1998) *The Effects of Age and ATIS Congestion Information Accuracy on User Truck and Compliance,* George Mason University, Fairfax; Garcia, R.C. (1999) *A Pareto Improving Strategy for the Time-Dependent Morning Commute Problem*, University of California, Berkeley; Parkany, A.E. (1999) *Traveler Responses to New Choices: Toll vs. Free Alternatives in a Congested Corridor,* University of California, Irvine.

4. Harrington, W., Krupnick, A.J. and Alberini, A. (2001) Overcoming public aversion to congestion pricing, *Transportation Research Part A*, 35: 93-111; Golob, T.F. (2001) Joint models of attitudes and behavior in evaluation of the San Diego I-15 Congestion Pricing Project, *Transportation Research Part A*, 6: 495-514; Levine, J., Park, S., Wallace, R.R. and Underwood, S.E. (1999) Public choice in transit organization and finance: the structure of support, *Transportation Research Record*, 1669: 87-95; Baldassare, M., Ryan, S. and Katz, C. (1998) Suburban attitudes toward policies aimed at reducing solo driving, *Transportation,* 25: 99-117; Ulberg, C. and MacFarland, G. (1995) *An Evaluation Of Public Opinion About Congestion Pricing And Tolls,* Washington State Transportation Center, Washington University, Washington State Department of Transportation;

5. Wells, K., Douma, F., Loimer, H., Olson, L. and Pansing, C. (2001) Telecommuting implications for travel behavior: Case studies from Minnesota, *Transportation Research Record*, 1752:148-156; *Innovative Briefs* (2001) Travel habits and demographic trends at the turn of the century, *Innovative Briefs,* 12: 5-7; World Congress On Intelligent Transport Systems (1999) *The Impact Of Information and Communications. Technology On Surface Passenger Transportation in Canada*, Toronto; Joice, W. (2000) *The Evolution of Telework in the Federal Government*, General Services Administration, Washington, DC. ; Mokhtaraian, P.L. (1997) Now that travel can be virtual, will congestion virtually disappear? *Scientific American, Special Issue - The Future Of Transportation* :93; Kim, S.-W. (1997) *Impacts of Telecommuting Policies on Urban Spatial Structure and the Environment: Home-Based and Center Based Telecommuting*, University of Pennsylvania, Philadelphia.

6. Kawamura, K. (1999) *Commercial Vehicle Value of Time and Perceived Benefits of Congestion Pricing*, University of California, Berkeley.

7. Ran, B., Sonntag, R. and Corbin, J. (1999) Evaluation of the traffic incident management enhancement (TIME) program for Southeastern Wisconsin, *Proceedings Of 6th World Congress On Intelligent Transport Systems*, Toronto; Cunard, B. (2000) Incident management programs in the United States, *Proceedings of the C Road Safety On Three Continents,* Pretoria; Androutsopoulos, K.N., Vasilakis, G.M. and Zografos, K.G. (2002) A real-time decision support system for roadway network incident response logistics, *Transportation Research. Part C: Emerging Technologies,* 10: 1-18.; Narupiti,. (1996) *Testing Traffic Control Strategies for Incident Congestion Management of a Surface Street System,* Michigan State University.

8. Rodier, C.J. and Johnston, R.J. (1997) Incentives for local governments to implement travel demand management measures, *Transportation Research Part A: Policy and Practice*, 31: 295-308*;* Kulash, D.J. (2000) Transportation User fees in the United States, *Transportation Quarterly*, 55: 33-49.

9. Ferguson, E. (2001) Three faces of Eve: how engineers, economists, planners variously view congestion control, demand management, and mobility enhancement strategies, *Journal of Transportation Statistics*, 4: 51-73; Philips, J.K. (1999) *The Performance of Public Transit: A Study of the Variant Definitions of Stakeholder Groups*, Pennsylvania State University.

10. Zimmerman, C.A., Campbell, J.L. and Cluett, C. (2001) *Impact Of New Information And Communication Technologies On Transportation Agencies*, NDHRP Synthesis of Highway Practice; Salomon, I. and Mokhtarian, P.L. (1997) Coping with congestion: understanding the gap between policy assumptions and behavior, *Transportation Research Part D: Transport and Environment,* 2: 107-123*;* Lindsey G. and Knapp, G. (1999) Willingness to pay for urban greenway projects, *APA Journal*, 65: 297-313; Dowling, R.G. and Colman, S.B. (1995) Effects of increased highway capacity: results of households travel behavior, *Transportation Research Record*, 1493: 143-149. Logi, F. (1999) *CARTESIUS: A Cooperative Approach to Real-Time Decision Support for Multijurisdictional Traffic Congestion Management*, University of California, Irvine.

11. Lo, H.K.and W.Y. Szeto. (2002) A methodology for sustainable traveler information services, *Transportation Research. Part B: Methodological*, 36: 113-130; Dhingra, S.L. and Shrivastava, P. (2002) Development of coordinated schedules using genetic algorithms, *Journal of Transportation Engineering*, 128: 89-96; Raney, E.A., Mokhtarian, P.L. and Salomon, I. (2000) Modeling individuals' consideration of strategies to cope with congestion, *Transportation Research. Part F: Traffic Psychology and Behavior*, 3: 141-165; Mokhtarian, P.L., Raney, E.A., and Salomon, I. (1997) Behavioral responses to congestion: identifying patterns and socio-economic differences in adoption, *Transport Policy*, 4: 147–160.
12. *ITE Journal*. (1998) US 301 South Corridor Study: Applying Land Use Planning To Manage Congestion, 68; de la Loza, J and Murthy, A.S. (2000) Socioeconomic characteristics, land use and travel patterns In Los Angeles County, *Urban Public Transportation Systems. Proceedings of the First International Conference.*
13. Daganzo, C.F. (2002) Behavioral theory of multi-lane traffic flow. Part I: Long homogeneous freeway sections, *Transportation Research. Part B: Methodological,* 36: 131-158; Doohee, M. (1997) *Econometric Analysis of Highway Incident Duration, Public Perceptions and Information for Advanced Traveler Information Systems,* University of Washington.
14. Willoughby C. (2000) *Managing Motorization, World Bank*, Washington, DC; Verhoef, E.T. (1999) The implementation of marginal external cost pricing in road transport, *Papers in Regional Science*, 79: 307-322; Lam, T.C. and Small, K.A. (2001) The value of time and reliability: measurement from a value of pricing experiment, *Transportation Research Part E*, 37: 231-251; Anderson, D.R. (1996) *Congestion Pricing on a Transportation Network: Efficiency Gains and Distributional Consequences*, University of Minnesota; Zhee, W. (1996) *A Study on the Impact of Congestion Pricing: Benefits and Revenue Redistribution for the Case of Seoul and Los Angeles*, University of Southern California.
15. Gawronski, C., Gibson, K., Habig, W.C. and Marchbanks, J. (2001) Land use: the key to unlocking congestion, *Conference on Managing Our Mobility as We Grow - Congestion Summit*; Timothy, D.P. (1996) *Urban Labor Markets and Commuting*, MIT, Cambridge; Rodriquez, D.A. (2000). *Unwanted Excess Commuting: Proximate Commuting, Transportation Demand Management, and the Transportation-Land Use Connection*, University of Michigan.
16. Milazzo, J.S., Goode, L.R. and Foyle, R.S (2000) ValuExpress lanes: an Alternative to Hov/Hot, *ITE 2000 Annual Meeting*; Simmons, T. (2000) The Interstate 25 and Interstate 40 interchange traffic management applications, *Institute of Transportation Engineers District Annual Meeting*.
17. Small, K.A. (2001) The value of value pricing, *Access*, 18: 23-27; Donnell, E.R., Patten, M.L. and Mason Jr., J.M. (1999) Evaluating a roadside assistance program: Penn-Lincoln Parkway Service Patrol, *Transportation Research Record,* 1683: 143-149; Savonis, M.J. (2000) Toward a strategic plan for transportation-air quality research, 2000-2010, *Transportation Research Record*, 1738: 68-73; Lomax, T. (1998) Decade of delay offers congestion Suggestions, *Texas Transportation Researcher*, 34: 3; Hall, R. W. (2002) Incident dispatching, clearance and delay, *Transportation Research. Part A: Policy and Practice*, 36: 1-16; Kim, E.J. (2000) *HOT Lanes: A Comparative Evaluation of Costs, Benefits and Performance,* University of California, Los Angeles
18. Joumard, R., Lamure, C., Lambert, J. and Tripiana, F. (1996) Air quality and urban space management, *The Science of the Total Environment,* 189-190: 57-67; Howitt, A.M. and Altshuler, A. (1999) The politics of controlling auto air pollution, *Essays in Transportation Economics and Policy*, Brookings, Washington, DC; Margiotta, R. (1996) *Improved Vehicle Speed Estimation Procedures for Air Quality and Planning Applications,* University of Tennessee; Ramanujam, P. (1999) *Transportation Network Policy Modeling for Congestion and Pollution Control: a Variational Inequality* Approach, University of Massachusetts

Table 4.3 Studies of the Social and Behavior Aspects of Transport Congestion in Europe (1997-2002).

	Quality	Theory	Practice	Trans Atlantic
Road Users				
Diverting to Other Modes[1]	√√	√	√√√	√√√
Attitude toward Restraint Measures[2]		√√	√√√	√√√√
Teleworking/Telecommuting[3]	√√√	√√√	√√√	√√√√
Reactions to Incidents and Situations[4]	√√√	√√√	√√√	√√√√
Public Agents				
Planning and Investment[5]	√√√	√√	√√√	√√√
Modeling[6]	√√√√	√√√	√√√	√√√√
Researchers				
Congestion Theory[7]	√√√	√√√√	NA	√√√√
Economic Theory[8]	√√√√	√√	NA	√√
Land Use[9]	√√√	√	√√√	√√√√
Project Assessement[10]	√√√	√√	√√√√	√√√√
Environment[11]	√√	√√	√√√	√√√

NOTES: The gradings in the columns are subjective and on an ascending scale from √ to √√√√

Sources:

1. Priemus, H. (1999), On Modes, nodes, and networks: Technological and spatial conditions for a breakthrough towards multimodal terminals and networks of freight transport in Europe, *Transportation Planning and Technology*, 23: 83-103; Spentzas, C.N. (1998), Towards an electric vehicle policy, *International Journal of Vehicle Design*, 14: 118-123.
2. Khattak, A.J., and DePalma, A. (1997), The impact of adverse weather conditions on the propensity to change travel decisions: A survey of Brussels commuters, *Transportation Research A*, 31:181-203; Stern, E. (1996), Congestion response behaviour in Tel Aviv metropolitan area, in Gradus, Y. and Liphshitz, G. (eds.), *The Mosaic of Israeli Geography*, Ben-Gurion University Press, Beer Sheva.
3. Zumkeller, D. (2001), The impact of telecommunication and transport on spatial behaviour, in Hensher, A.D (ed.), *Travel Behaviour Research: The Leading Edge*, Pergamon, Oxford.
4. Bonsal, P. (2001), Predicting travellers' response to uncertainty, in Hensher, A.D (ed.), *Travel Behaviour Research: The Leading Edge*, Pergamon, Oxford; Salomon, I., and Mokhtarian, P. (1997), Coping with congestion: reconciling behavioural responses and policy analysis, *Transportation Research D*, 2: 107-123; Stern, E., Bovy, E.L.P., and Tacken, M. (1998), Traffic congestion and behavioural reactions: policy implications exemplified for the Dutch case, in Button, K., Nijkamp, P., and Priemus, H. (eds.) (1998) *Transport Networks in Europe*, Edward Elgar, Cheltenham;

5. Bovy, P.H.L. (1998), *Traffic flooding in the low countries*, Delft University of Technology, Faculty of Civil Engineering, Delft; Bovy. P.H.L., and Van Wee, B. (2002), Infrastructure and congestion: can rail save the road? can public transport replace the car?, in Stern, E., Salomon. I., and Bovy, P.H.L. (eds.), *Travel Behaviour: Spatial Patterns, Congestion and Modelling*, Edward Elgar: Cheltenham, 123-142; Marshall, S., and Banister, D. (2000), Travel reduction strategies: intentions and outcomes, *Transportation Research* A, 34:321-338; Orfeuil, J.P. (2002), Geographical classification of trips as a tool for policy assessment, in Stern, E., Salomon. I., and Bovy, P.H.L. (eds.), *Travel Behaviour: Spatial Patterns, Congestion and Modelling*, Edward Elgar: Cheltenham; McDowell, W. (1995), Operational of citric – midlife reflections, *Proceedings of the Institue of Civil Engineers*, 111: 70-79; Callafel, J., and Pyne, M. (2001), In-vehicle traffic information systems in Europe: never mind the (band) width, fiil the quality, *Journal of Navigation*, 54: 329-335; Logi, F., Ritchie, S.G. (2001), Development and evaluation of a knowledge-based system for traffic congestion management and control, *Transportation Research C*, 9:433-459; Lewis, N.C. (1996), Traffic congestion and road pricing, *Proceedings of the Institution of Civil Engineers – Transport*, 117: 122-135.
6. Axhausen, K., Koll, H., and Bader, M. (2002), Stated preference and conjoint analysis: a comparison using mode-choice behaviour, in Stern, E., Salomon. I., and Bovy, P.H.L. (eds.), *Travel Behaviour: Spatial Patterns, Congestion and Modelling*, Edward Elgar: Cheltenham; Roberg, P., and Abbes, C.R. (1998), Diagnosis and treatment of congestion in urban areas, *European Journal of Operational Research*, 104:218-230; Dial, R.B. (1997), Bicriterion traffic assignment: efficient algorithms plus examples, *Transportation Research B*, 31: 357-379; Stern, E. (1999), Reactions to congestion under time pressure, *Transportation research C*, 7:75-90; Stern, E. (2002), Behavioural thresholds of commuters under congestion, in Stern, E., Salomon. I., and Bovy, P.H.L. (eds.), *Travel Behaviour: Spatial Patterns, Congestion and Modelling*, Edward Elgar: Cheltenham.
7. Wright, C., and Lupton, K. (2001), Traffic congestion and the fundamental relationships of traffic flow, *Proceedings of the Institution of Civil Engineers – Transport*, 147: 231-238.
8. Verhoef, E., Nijkamp, P., and Rietveld, P. (1995), The economics of regulatory parking policies – the (IM) possibilities of parking policies in traffic regulation, *Transportation Research A*, 29: 141-156.
9. Moinzadeh, K., Klastorin, T., and Berk, E. (1997), The impact of small lot ordering on traffic congestion in a physical distribution system, *IIE Transactions*, 29: 671-679; Bovy, P.H/L, and Salomon, I. (1997), *The spread of congestion in Europe*, Report to the Round Table 109, ECMT, Paris; Bukold, S. (1997), *Bottlenecks in European Infrastructure*, ECIS, Rotterdam.
10. Baiocchi, A., Cuomo, F., and Martello, C. (2002), Optimizing the radio resource utilization of multi-access systems with a traffic-transmission quality adaptive packet scheduling, *Computer Networks* 38: 225-246; Wren, A., and Gualda, N.D.F. (1999), Integrated scheduling of buses and drivers, *Computer-Aided Transit scheduling*, 471: 155-176.
11. Campisi, D., and Gasaldi, M. (1996), Environmental protection, economic and intermodal competition in freight transport, *Transportation Research C*, 4: 391-406; Polkowska, Z., Grynkiewicz, M., Gorecki, T., and Namiesnik, J. (2001), Levels of lead in atmospheric deposition in a large urban agglomeration in Poland, *Journal of Environmental Monitoring*, 3: 146-149.

As an additional way of categorizing the work in both US and European files, the categories were subdivided according to the particular parties that would seem to have the greatest interest in them. Beesley (1989) pointed out that research in transport economics (but the argument can be extended beyond economics) is done basically for policy reasons and to allow academics to meet career aspirations. Sometimes the outcome may meet both criteria but this is actually seldom the case. What we deem as public policy related work is further sub-divided according to whether it is primarily concerned with the road users perspective of policy effects or the position of policy makers.

The various contributions to the literature are then assessed in several ways. There is a crude effort to get at their 'quality'. This is not in the sense of individual papers but rather in terms of where the broad subsection of the literature that they are part of is appearing with regard to other work in transportation. Put more simply is the subject matter or general quality of the work in each category being picked up in quality outlets or in secondary outlets. To do this a very crude and subjective assessment was made but with the backup of reference to the extensive survey of journal reviews conducted by Harzing (2001). This looks at a large number of studies that have sought to assign a 'quality' indicator to various journals. The results of these various studies themselves are often quite variable but they offer some sort of crude indicator. One should be added is that the studies included in these analyses only cover recent years. The fact that this period has perhaps focused on lesser issues under some heading, and hence appear in less academically prestigious and more professionally oriented publications, may be a reflection of major breakthroughs in the past. There are also trends in research interests partly related to the availability not funding but also pragmatically to researchers looking forward to job placements and career paths.

The work in each of the categories is also divided along lines of whether the work that is emerging is theoretical or applied in its emphasis. This can be useful for several reasons in terms of fostering transatlantic research initiatives. By its nature, theoretical analysis provides an understanding of issues in a general context and hence is not location specific. The main gains from transatlantic work would stem from individuals being able to bounce ideas and arguments off each other and to enjoy intellectual fruits of combined efforts. Applied analysis involves in some cases seeking out common features of actual behaviour and diversity of behaviour on either side of the Atlantic to see what lessons can be learned. It can also be focused on behaviour in congested circumstances on transatlantic transportation itself.

4.3 THE TRENDS

The subjective information regarding collaborative research simply reflects personal views stemming from looking at the work that has been done recently in the US and Europe. The subjective assessment also takes into account the type of work being done by the younger US workers. As a result, there seems to be some agreement that new energies need to be injected into the transport research community and to ignore what they feel important and worth exploring would seem to run counter to this.

As seen in Table 4.1, the proportion of new Ph.D. thesis concerning congestion is perhaps surprisingly small considering the widespread public interest and concern about congestion. Equally the number of published contributions in Europe and North America may not be considered very large. One reason for this is that much work has been done on congestion over the years and that the fundamental issues are pretty well understood. Those doing Ph.D.s, for example, may be finding it more interesting to look at newer areas of academic and public policy concern. Fine tuning in an area with a large existing literature is much less fun than exploring near virgin areas.

The picture painted in Tables 4.2 and 4.3 may also be slightly distorted because in many cases where various policies to reduce congestion have been actively considered much of the analysis is to be found in official reports and other forms of ‘gray’ literature that has not been picked up in out tables. (Indeed, a useful cross-national study would be to try to bring together this less readily accessible material so that a more complete picture of where we stand may be drawn.)

Nevertheless, some general comments can be made on the recent work in the field of congestion. The subjective information presented in Tables 4.2 and 4.3 reveal a wider range of topics related to social and behavioral aspects of congestion in the US than in Europe. The smaller topical spread in Europe reflects, however, a larger emphasis on practicality and less on theory. Table 4.4 shows that 60% of the European social and behavior studies on transport congestion concentrated on means of congestion relief, mainly through traffic management.

Perhaps the most obvious is the sparsity of work that has been done understanding the attitudes and reactions of those in the freight transport side to congestion issues. This is clear from both Tables 4.2 and 4.3. There may be reasons for this – most transport modeling and other forms of analysis has traditionally been focused upon person movements because they are numerically important. But from a congestion (and environmental) perspective, for example, truck movements on roads are major causes of congestion. Little is really know about how this part of the transport structure reactions to congested situations.

Table 4.4. General thematic division of the social and behavior studies on transport congestion in Europe (1996-2001).

Main Theme	%
Means to relieve congestion	60.0
Road pricing	5.4
Traffic management	27.3
Modal shift	5.4
Information & telecommunication	8.2
Infrastructure improvements	2.7
Mix of strategies	11.0
Behaviour/choice theory	2.0
Attitude, perception, and behavioural patterns	11.0
Response behaviour modeling	20.0
Environment and congestion	2.0
Spatial patterns	5.0

Source: Table 4.3.

In contrast to this, where one does see a lot of analysis is in the area of modeling. (This is perhaps not surprising since, following Beesley's reasoning, this is a clear way of gaining academic kudos and the promotions and salaries that go with it.) Indeed, the listing are probably an understatement of the work in this area because a lot of more generic transportation modeling embodies various forms of congestion sub-models and these do not show up in the survey. Undoubtedly many pure researchers would like to see even more work in this area although the use of more analysis in a situation where reality dictates the application of rather simple technologies has not gone unquestioned (Button, 2002). The trade-off between what is really policy relevant and what is research for the same of it is perhaps strongest here.

Given, however, the relatively smaller focus of the surveyed models on practicality, unsuccessful application of models stems perhaps from their inability to forecast accurately the dynamic reality of congested situations. One possible reason for that is the fact that all the models known so far still lack a cognitive explanatory mechanism of the choice process (Stern, 1998). It has already been recognized by psychologists, but less by transportation analysts, that "understanding the complexity of road-user behavior remains at the forefront of the problems which must be solved before useful models can be created" (Huguenin, 1997).

One area where there has also been relatively little work, and perhaps because of the way resources are allocated for research, is that regarding public attitudes towards congestion and congestion control measures. There is tentative evidence that, at least for some types of trips covering a short duration, that the traditional notion of travel having a disuitility may be wrong, or at least that the disutility may be much less than sometimes supposed. If this is so then the social costs of traffic congestion may be over estimated. We have insufficient work to date from either side of the Atlantic to reach any firm conclusion. Equally, we have many studies showing public concern about initiating measures that would reduce congestion (e.g. Table 4.4) – these are very much in line with work in very many fields where public policies to restrain social excesses have been suggested. What we know less about is the attitudes of those who have actually experienced some form of traffic restraint policy. Ex post studies are, as with many areas of research in short supply. They are seldom supported by policy makers and almost never result in the furtherment of an academic career and thus fail the Beesley test.

REFERENCES

Arnott, R, de Palma, A. and Lindsey, R. (1993) A structural model of peak-period congestion: a traffic bottleneck with elastic demand, *American Economic Review*, 83: 161-179.

Arnott, R. and Kraus, M. (1998). When are anonymous congestion charges consistent with marginal cost pricing? *Journal of Public Economics,* 67: 45-64.

Arnott, R. and Yan, A. (2000). The two-mode problem: second-best pricing and capacity. *Review of Urban and Regional Development Studies,* 12*:* 170-199.

Arnott, R., de Palma, A. and Lindsey, R. (1988). Schedule delay and departure time decisions with heterogeneous commuters. *Transportation Research Record*, 1197: 56-67.

Arnott, R., de Palma, A. and Lindsey, R. (1990a). Economics of a bottleneck. *Journal of Urban Economics,* 27: 111-130.

Arnott, R., de Palma, A. and Lindsey, R. (1990b). Departure time and route choice for routes in parallel. *Transportation Research B,* 24: 209-228.

Arnott, R., de Palma, A. and Lindsey, R. (1992). Route choice with heterogeneous drivers and group-specific congestion costs. *Regional Science and Urban Economics,* 22: 71-102.

Arnott, R., de Palma, A. and Lindsey, R. (1994). The welfare effects of congestion tolls with Heterogeneous Commuters. *Journal of Transport Economics and Policy,* 28, 139-161.

Arnott, R., de Palma, A. and Lindsey, R. (1998). Recent developments in the bottleneck model. In K.J. Button and E.T. Verhoef (Eds) *Road Pricing, Traffic Congestion and the Environment: Issues of Efficiency and Social Feasibility*. Edward Elgar, Cheltenham.

Barzel, Y. (1974) A theory of rationing by waiting, *Journal of Law and Economics*; 17: 73-95.

Bates, J., Williams, I., Coombe, D. and Leather, J. (1996) The London congestion charging programme: 4. The transport models, *Traffic Engineering and Control*; 37: 334-339.

Baumol, W.J. and Oates, W.E. (1975) *The Theory of Environmental Policy: Externalities, Public Outlays and the Quality of Life,* Prentice-Hall, New York.

Beesley, M.E. (1989) Transport research and economics, *Journal of Transport Economics and Policy*, 23: 17-28.

Behbehani, R., Pendakur, V.S. and Armstrong Wright, A.T. (1984) *Singapore Area Licensing Scheme: A Review of the Impact*, World Bank Water Supply and Urban Development Department, Washington.

Bertrand, T. (1977). Second-best congestion taxes in transportation systems. *Econometrica,* 45, 1703-1715.

Bly, P.H., Webster, F.V. and Pounds, S. (1980) Effects of subsidies on urban transport, *Transportation*, 9: 311-331.

Borg, M.O. and P.M. Mason (1990) Earmarked lottery revenue: Positive windfall or concealed redistribution mechanism? *Journal of Education Finance*, 15:289-301.

Brownstone, D. and Small, K. (2003). Valuing time and reliability: assessing the evidence from road pricing demonstrations. Paper presented at the American Economic Association, Washingtion DC

Buchanan, J.M. (1956). Private ownership and common usage: the road case re-examined. *Southern Economic Journal,* 22: 305-316.

Buchanan, J.M. (1963) The economics of earmarking, *Journal of Political Economy*, 71: 457-469.

Buchanan, J.M. (1965). An economic theory of clubs. *Economica*, 32, 1-14.

Button, K.J. (1984) Road pricing – an outsider's view of American experiences, *Transport Reviews*, 4: 73-98.

Button, K. J. (1993). *Transport Economics.* Aldershot: Edward Elgar.

Button, K.J. (1989) Economic theories of regulation and the regulation of the UK bus industry, *Antitrust Bulletin*, 33: 489-515.

Button, K.J. (2002) *Myths and Taboos in Transport Policy,* to the STELLA/STAR Conference on Institutions, Regulations, Markets, Brussels.

Button, K.J. (2004) The rationale for road pricing: standard theory and the latest advances, in G. Santos (ed) *Road Pricing: Theory and Practice*, Elsevier, Oxford.

Button, K.J. and Rothengatter, W. (1997) Motor transport, greenhouse gases and economic instruments, *International Journal of Environment and Pollution,* 7: 327-342.

Button, K.J. and Verhoef, E. (eds) (1998) *Road Pricing, Traffic Congestion and the Environment*, Edward Elgar, Cheltenham.

Button, K.J., Stern, E. and Vachel, K.Y. (2002) Congestion response behavior – the new research agenda, STELLA/STAR Network meeting, Bonn.

Button, K.J., Stough, R.R., Clarke, A., Pommerang, C., Jefferson, K. and Tiebout, M. (2004) The political economy constraints on deployment of a large scale electronic 'Hot Roadway': a US example, *International Journal of Transport Economics*, 29:.

Calfee, J. E. and Winston, C. (1998). The value of automobile travel time: implications for congestion policy. *Journal of Public Economics,* 69: 83-102.

Calthrop, E., Proost, S. and van Dender, K. (2000) Parking policies and road pricing. *Urban Studies,* 37*:* 63-76.

Charetered Institute of Transport (1993) P*aying for Better Motorway, Report of Committee under the Chairmanship of K. J. Button,* CIT, London.

Chia, N. C., Tsui, A. and Whalley, J. (2001). *Ownership and Use Taxes as Congestion Correcting Instruments*. Cambridge Mass.: NBER Working Paper 8278.

Chu, X. (1995). Endogenous trip scheduling: the Henderson approach reformulated and compared to the Vickrey approach. *Journal of Urban Economics:* 37: 324-343.

Chu, X. (1999). Alternative congestion pricing schedules. *Regional Science and Urban Economics*, 29: 697-722.

Dafermos, S. (1973) Toll patterns for multiclass-user transportation networks, *Transportation Science,* 7: 139-154

Dawson, J. and I. Catling (1986). Electronic road pricing in Hong Kong. *Transportation Research A.* 20: 129-134.

De Palma, A. and Lindsey, R. (1998). Information and usage of congestable facilities under different pricing Rregimes, *Canadian Journal of Economics,* 31: 666-692.

Dupuit, J. (1844). On the measurement of the utility of public works. *Annales des Ponts et Chaussées M´moires et Documents, 2nd Series* 8, 332-375 (Translated by R.H. Barback (1952) *International Economic Papers 2*, 83-110).

Edelson, N. E. (1971). Congestion tolls under monopoly, *American Economic Review,* 61: 872-882.

Ekelund, R. B. and Hébert, R. F. (1999). *Secret Origins of Modern Microeconomics: Dupuit and the Engineers*, Chicago University Press, Chicago.

Evans, Alan W. (1992). Road congestion; the diagrammatic analysis, *Journal of Political Economy,* 100: 211-217.

Evans, Andrew W. (1992). Road congestion pricing: ehen is it a good policy? *Journal of Transport Economics and Policy,* 26: 213-243.

Foster, C. D. (1975). A note on the distributional effects of road pricing: a comment. *Journal of Transport Economics and Policy,* 9: 186-187.

Francois-Poncet, J. and Larcher, G. (1998) *Remise en cause certains choix stratégiques concernant les infrastructures de communication*, Sénat de France, Paris.

Giuliano, G. (1992). An assessment of the political acceptability of congestion pricing. *Transportation,* 19, 335-358.

Giuliano, G. (1994) Equity and fairness considerations of congestion pricing, in Transportation Research Board, *Curbing Gridlock: Peak-Period Fees to Relieve Traffic Congestion*, TRB Special Report 242, Washington.

Glazer, A. and Niskanen, E. (1992). Parking fees and congestion. *Regional Science and Urban Economics,* 22: 123-132.

Gomez-Ibañez, J.A. (1992) The political economy of highway tolls and congestion charges, in Federal Highway Administration, *Exploring the Role of Pricing as a Congestion Management Tool*, FHA, Washington.

Goodwin P.B. (1989). The rule of three: a possible solution to the political problem of competing objectives for road pricing. *Traffic Engineering and Control,* 30: 495-497.

Goodwin P.B. (1990). How to make road pricing popular, *Economic Affairs*, 10: 6-7.

Government Office for London (2000) *Road Charging Options for London*, HMSO, London.

Greenstone, M. (2002) A reexamination of resource allocation responses to the 65-mph speed limit, *Economic Enquiry*, 40: 272-278.

Hague Consulting Group, Accent Marketing and Research, Department of the Environment, Transport and Regions (1999). *The Value of Travel Time on UK Roads*, The Hague.

Harrington, W., Krupnick, A. and Alberini, A. (2001). Overcoming public aversion to congestion pricing, *Transportation Research A* 35: 87-105.

Hau, T. D. (1990). Electronic road pricing: developments in Hong Kong. *Journal of Transport Economics and Policy,* 24: 203-214.

Hau, T. D. (1998). Congestion pricing and road investment. In K. J. Button and E. T. Verhoef (Eds) *Road Pricing, Traffic Congestion and the Environment: Issues of Efficiency and Social Feasibility*, Edward Elgar, Cheltenham

Harzing, A-W. (2001) *Bradford University School of Management Journal Quality List*, Bradford School of Management, Bradford.

Henderson, J. V. (1974). Road congestion: a reconsideration of price theory, *Journal of Urban Economics,* 1: 346-365.

Hensher, D.A. (1997). Value of travel time savings in personal and commercial automobile travel. In D. L. Greene, D.W. Jones, M. A. Delucchi (Eds.) *The Full Costs and Benefits of Transportation,* Springer-Verlag, New York.

Hills, P. (1993). Road congestion pricing: when is it a good policy? A comment. *Journal of Transport Economics and Policy,* 27: 91-99.

Huguenin, R.D. (1997) Do we need traffic psychology models?, in Rothengatter, T., and Vaya, E.C. (eds.), *Traffic and Transport Psychology*, Pergamon, Oxford.

Ison, S. (2000). Local authority and academic attitudes to urban road pricing: a UK perspective, *Transport Policy*, 7: 269-277.

Jara-Díaz, S. R. (2000). Allocation and valuation of travel-time savings. In D. A. Hensher and K. J. Button (Eds) *Handbook of Transport Modelling*, Pergamon, Oxford.

Jones, P.M. (1991) Gaining public support for road pricing through a package approach, *Traffic Engineering and Control*, 32: 194-196.

Katz, B. (2002) *Smart Growth: The Future of the American Metropolis?*, Centre for Analysis of Social Exclusion, London School of Economics, London.

Keeler, T.E. (1984), Theories of regulation and the deregulation movement, *Public Choice*, 44: 103–45.

Keeler, T.E. and Small, K.A. (1977). Optimal peak-load pricing, investment and service levels on urban expressways, *Journal of Political Economy*, 85: 1-25.

Kennedy, D. (1995) London bus tendering: the impact on costs, *International Review of Applied Economics*, 9: 305-317.

Kim, E. (2000) *HOT Lanes: A Comparative Evaluation of Costs, Benefits, and Performance*, PhD Dissrtation, University of California Los Angeles.

Knight, F.H. (1924). Some fallacies in the interpretation of social costs, *Quarterly Journal of Economics,* 38: 582-606.

Kraus, M. C. (1981). Indivisibilities, economies of scale, and optimal subsidy policy for freeways, *Land Economics*, 57: 115-121.

Lam, T.C. and Small, K.A. (2001). The value of time and reliability: measurement from a value pricing experiment, *Transportation Research E*, 37: 231-251.

Larsen, O.I., (1988) The toll ring in Bergen Norway – the first year of operation, *Traffic Engineering and Control,* 22: 216–22.

Lay, M.G. and Daley, K.F. (2002) The Melbourne Link project, *Transport Policy*, 9: 261-268.

Layard, R. (1977). The distributional effects of congestion taxes. *Econometrica,* 44: 297-304.

Lee, D.R. 1997. Overcoming taxpayer resistance by taxing choice and earmarking revenues. In W. Shughart (ed). *Taxing Choice*, Independent Institute, Oakland

Lewis Berger Group, Inc. (2001) *Innovative Road policies in the United States: A Report from Washington DC, Chicago, and Los Angeles, Appendix A: Background Reports from US Urban Areas – Washington DC Region*. Washington DC.

Lex Services (1998). *Lex Report on Motoring: Driving for the Future,* Lex Service PLC, Buckingham.

Li, J. (2001) Explaining high-occupancy-toll lane use, *Transportation Research D*, 6: 61-74

Lindsey, R. and Verhoef, E. T. (2000). Congestion Modeling. In D.A. Hensher and K.J. Button (eds) *Handbook of Transport Modelling*, Pergamon: Oxford.

Lindsey. R. and Verhoef, E. (2001) Traffic congestion and congestion pricing, in K.J. Button and D.A. Hensher, (eds) (eds) *Handbook of Transport Systems and Traffic Control*, Pergamon, Oxford.

Liu, L.N. and McDonald, J.F. (1999). Economic efficiency of second-best congestion pricing schemes in urban highway systems. *Transportation Research B,* 33, 157-188.

Mackie, P., Jara-Díaz, S. and Fowkes, A. (2001). The value of travel time savings in evaluation, *Transportation Research E,* 37: 91-106.

Mackie, P., Wardman, M., Fowkes, A., Whelan, G., Nellthorp, J. and Bates, J. (2003). *Values of Travel Time Savings in the UK*: Report to the Department of Transport. Institute for Transport Studies, University of Leeds.

Major of London (2003) *Congestion Charging 6 Months On*, Transport for London, London.

Marchand, M. (1968). A note of optimal tolls in an imperfect environment, *Econometrica*, 36: 575-581.

May, A.T. (1975) Supplementary licensing; an evaluation, *Traffic Engineering and Control*, 16: 162-167.

May, A.T., Guest, P.W. and Gardner, K. (1990) Can rail-based policies relieve urban traffic congestion, *Traffic Engineering and Control*, 31: 406-407.

Mills, D.E. (1981). Ownership arrangements and congestion-prone facilities, *American Economic Review*, 71: 493-502.

Minard, J. (1850) Notions élémentaires d'économie politique appliquée aux travaux publics, *Annales des Ponts et Chaussés: Mémoires et Documents*, 2d ser, 19: 1-125.

Ministry of Transport (1964). *Road Pricing: The Economic and Technical Possibilities*. Her Majesty's Stationary Office, London.

Mohring, H. (1970). Urban highway investments. In R. Dorfman (ed) *Measuring Benefits of Government Investment,* The Brookings Institution, Washington DC

Mohring, H. and Harwitz, M. (1962). *Highway Benefits*, Northwestern University Press, Evanston

Morrison, S.A. (1986) A survey of road pricing, *Transportation Research,* 20A: 87–97.

National Economic Development Office (1995) *A Road User's Charge – Londoners Views,* NEDO, London.

Newbery, D.M.G. (1988) Road user charges in Britain, *Economic Journal Supplement*, 98: 161-76.

Newbery, D.M.G. (1989). Cost recovery from optimally designed roads. *Econometrica,* 56: 165-185.

Newbery, D.M.G. (1990). Pricing and congestion: economic principles relevant to pricing roads. *Oxford Review of Economic Policy*, 6: 22-38.

Newbery, D.M.G. (1994). The case for a public road authority, *Journal of Transport Economics and Policy,* 28: 235-253.

Pigou, A. (1920) *The Economics of Welfare*, Macmillan, London.

Pitfield, D. and Watson, R. (2001) High-occupancy routes and truck lanes. In K.J. Button and D.A. Hensher (eds) *Handbook of Transport Systems and Traffic Control*, Elsevier, Oxford.

RAC Foundation for Motoring (2003) *Making the Most of Britain's Roads,* RAC London.

Ramjerdi, F. (1994) The Norwegian experience with electronic toll rings, *in Proceedings of the International Conference on Advanced Technologies in Transportation and Traffic Management*, Nanyang Technological University, Singapore.

Richardson, H.W. (1974) A note on the distributional effects of road pricing, *Journal of Transport Economics and Policy,* 8: 82–5.

Robbins, L. (1932) *Essay on the Nature and Significance of Economic Science*, Macmillan, London.

Roy, R. (1998) *Infrastructure Cost Recovery under Allocatively Efficient Pricing*, UIC/CER Economic Expert Report.

Samuel, P., Poole, Jr., R.W., and Holguin-Veras, J. (2002) *Toll Truckways: A Path Toward Safer and More Efficient Freight Transportation*, Policy Study 294, Reason Public Policy Institute, Los Angeles.

Santos, G. and Rojey, L. (2004). Distributional impacts of road pricing: the truth behind the myth. *Transportation,* forthcoming.

Schoenberger, C.R. (2002) Stop and go, *Forbes*, May 13.

Seah, C.M. (1980) Mass mobility and accessibility: transport planning and traffic management in Singapore, *Transport Policy and Decision Making*, 1: 55-72.

Segal, D. and Steinmeir, T.L. (1980). The incidence of congestion and congestion tolls, *Journal of Urban Economics,* 7: 42-62.

Sharp, C.H. (1966) Congestion and welfare: an examination of the case for a congestion tax, *Economic Journal,* 76: 806–17.

Sherman, R. (1971). Congestion interdependence and urban transit fares, *Econometrica,* 39: 565-576.

Small K.A. (1992) Using the revenues from congestion pricing. *Transportation,* 19: 359-381.

Small, K.A. (1982). The scheduling of consumer activities: work trips. *American Economic Review,* 72: 467-479.

Small, K.A. (1983). The incidence of congestion tolls on urban highways, *Journal of Urban Economics,* 13: 90-111.

Small, K.A. (1992) Using the revenue from congestion pricing, *Transportation*, 19: 359-381.

Small, K.A. (1999). Project evaluation. In J. Gómez-Ibáñez, W. Tye and C. Winston (eds) *Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Meyer,* The Brookings Institution, Washington DC

Small, K.A. and Chu, X. (1997). Hypercongestion. Department of Economics, University of California at Irvine, Working Paper 97-98-12.

Small, K.A. and Gomez-Ibanez, J.A. (1999) Road pricing for congestion management: the transition from theory to practice. In K.J. Button and E. T. Verhoeff (eds) *Road Pricing, Traffic congestion and the Environment, Issues of Efficiency and Social Feasibility*, Edward Elgar, Cheltenham.

Small, K.A. and Yan, J. (2001). The Value of "Value Pricing" of Roads: Second-Best Pricing and Product Differentiation. *Journal of Urban Economics,* 49: 310-336.

Small, KA. and Gomez-Ibañez, J.A. (1998) Road pricing for congestion management: the transition from theory to policy, in Button, K.J. and Verhoef, E. (eds) *Road Pricing, Traffic Congestion and the Environment*, Edward Elgar, Cheltenham.

Smith, A. (1776) *An Enquiry into the Nature and Causes of The Wealth of Nations*, Prometheus Books, Anherst.

Solheim, T. (1990) The toll-ring in Oslo, paper to the Ecology and Transport Conference, Gothenburg.

Starkie, D. (1982). Road Indivisibilities: Some Observations. *Journal of Transport Economics and Policy,* 16: 259-266.

Starkie, D. (1986) Efficient and politic congestion tolls, *Transportation Research*, 20A: 169-173.

Stern, E. (1998), Travel choice in congestions: modeling and research needs, in Garling, T., Laitila, T., and Westin, K. (eds.), *Theoretical Foundations of Travel Choice Modeling*, Elsevier, Oxford.

Stockton, W., Benz, R, Rilett, L. Skowronek, D. Vadaki, S. and Daniels, G. (2000). *Investigating the General Feasibility of High Occupancy/toll Lanes in Texas*, Texas Transportation Institute, College Station.

Strotz, R. H. (1965). Urban transportation parables. In J. Margolis (Ed) *The Public Economy of Urban Communities*, Resources for the Future, Washington, DC.

Sullivan, E. (2000). *Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes*, California Department of Transportation, Sacramento.

Sunnucks, M. (2001) Glendening extinguishes HOT lanes proposal, *Washington Business Journal*. June 18.

Supernak, J. (2001) *I-15 Congestion Pricing Project Monitoring and Evaluating Services. Phase II year 3 Overall Report*, San Diego State University, San Diego.

Surface Transportation Policy Project and Center for Neighborhood Technology (2000) *Driven to Spend: The Impact of Sprawl on Household Transportation Expenses.* Washington, DC.

Texas Transportation Institute (2001) *2001 Urban Mobility Study*. Texas A & M University System, College Station.

Thomson. M.E. (1974) *Modern Transport Economics*, Penguin, Harmondsworth.

UK Department of Environment, *Transport* and the Regions (2000) *Breaking the Logjam, The Government's Response to the Consultation*, HMSO, London.

UK Ministry of Transport (1964) *Road Pricing: The Economic and Technical Possibilities*, London, HMSO.

Van den Bergh, C.J.M., Button, K.J., and Verhoeff, E.T. (1997) Transport, spatial economy and the global environment, *Environment and Planning A*, 29:1195-1213.

Verhoef, E. T. (1999). Time, speed flows and densities in static models of road traffic congestion and congestion pricing, *Regional Science and Urban Economics,* 29: 341-369.

Verhoef, E.T. (2000). The Implementation of Marginal External Cost Pricing in Road Transport: Long Run vs Short Run and First-Best vs Second-Best. *Papers in Regional Science 79*, 307-332.

Verhoef, E.T. (2002a) Second-best congestion pricing in general static transportation networks with elastic demands, *Regional Science and Urban Economics,* 32: 281-310.

Verhoef, E.T. (2002b). Second-best congestion pricing in general networks – heuristic algorithms for finding second-best optimal toll levels and toll points, *Transportation Research B,* 36: 707-729.

Verhoef, E.T. (2003) *Speed-Flow Relations and Cost Functions for Congested Traffic: Theory and Empirical Analyses*, Tinbergen Institute, Discussion Paper TI 2003-064/3, Amsterdam-Rotterdam.

Verhoef, E.T., Nijkamp, P. and Rietveld, P. (1995). The Economics of Regulatory Parking Policies: The (Im)possibilities of Parking Policies in Parking Regulation. *Transportation Research A 29*, 141-156.

Verhoef, E.T., Nijkamp, P. and Rietveld, P. (1996). Second-best congestion pricing: the case of an untolled alternative. *Journal of Urban Economics,* 40: 279-302.

Verhoef, E.T. (1996) *The Economics of Road Pricing,* Edward Elgar, Cheltenham.

Verhoef, E.T., Rouwendal, J. and Rietveld, P. (1999) Congestion caused by speed differences, *Journal of Urban Economics,* 45: 533-556.

Vickery, W.S. (1969) Congestion theory and transport investment, *American Economic Review (Papers and Proceedings)*, 59: 251-260

Vickrey, W.S. (1959). *Statement on the Pricing of Urban Street Use*. Hearings, US Congress Joint Committee on Metropolitan Washington Problems, Washington DC.

Vickrey, W.S. (1963). Pricing in urban and suburban transport. *American Economic Review,* 53: 452-465.

Vickrey, W.S. (1968) Congestion charges and welfare, *Journal of Transport Economics and Policy*, 2: 107-118.

Vickrey, W.S. (1969). Congestion theory and transport investment. *American Economic Review*, 59*:* 251-260.

Walters A.A.(1961) The theory and measurement of private and social cost of highway congestion, *Econometrica*, 29: 676-697.

Walters, A.A. (1968) *The Economics of Road User Charges*, Johns Hopkins Press, Baltimore.

Wardman, M. (1998) The value of travel time: a review of British evidence. *Journal of Transport Economics and Policy,* 32: 285-316.

Washington State Department of Transportation (2002) *Regional Toll Revenue Feasibility Study*, Urban Corridors Office, Seattle

Wheaton, W.C. (1978). Price-induced distortions in urban highway investment. *Bell Journal of Economics and Management Science,* 9: 622-632.

Whelan, G. and Bates, J. (2001). Market Segmentation Analysis. *ITS Working Paper 565.* Institute for Transport Studies, University of Leeds.

Willoughby, C. (2000) *Singapore's Experience in Managing Motorization and its Relevance to Other Countries*, The World Bank. TWU Series. Washington, DC.