TRAFFIC MANAGEMENT WITH CONGESTION CHARGING IN DIFFERENT ENGLISH TOWNS

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INTRODUCTION

Good transport policy requires balancing a number of conflicting objectives. Governments are almost invariably required to provide road transport infrastructure (with the possible exception of concessioned interurban roads in some countries). Efficiency requires the right level of capacity provision for each mode (road, rail, etc.), and the efficient use of that capacity. Efficiency in use requires that all, and only, those trips whose value exceeds the social cost caused by the trip are undertaken, where these social costs include not only the private cost borne by the transport user, but any external costs. In addition, transport policy must be politically sustainable, that is, it must command an adequate level of political support. One measure of its success is whether policies can endure over reasonable periods of time, and particularly during periods of stress. If not, then policies may have to adapt to a new balance of interests. A good recent example was the acceptance, for a remarkably long period, of the annual real fuel price escalator, designed, so it was claimed, to discourage profligate energy use, to make the polluter pay, and to help meet carbon dioxide targets in the UK. The policy was tolerated while world oil prices fell in real terms during the 1990s, but was immediately upset once oil prices more than doubled in 2000.

Political sustainability requires a complex balancing of various interest groups, notably when new roads or by-passes are proposed to relieve generalised congestion, but to the detriment of particular local interest groups. In the present context it arises in setting the various taxes and charges on road users. Britain (and most European countries) have moved far beyond the point where road taxes were conceived to be primarily intended for financing the road system. The old concept of a Road Fund was abandoned once the revenues looked set to substantially exceed the costs of building and maintaining the road network, though its formal suspension was delayed until 1955 (Teja and Bracewell-Milnes, 1991), some twenty years after its de facto suspension. Road taxes are now set partly to reflect different road user costs (notably for vehicles of different damaging capacity, through the highly differentiated vehicle excise duty, or VED), partly to cover other investment and operating costs (though not the full resource costs), but increasingly to finance general government expenditure, defended in part as a pollution tax, partly by willingness-to-pay, (or at least political acquiescence), and most recently as necessary for the proper finance of the health and education commitments of the current Government.

Over time, successive UK Governments of both parties have probed the limits of how much revenue can be extracted from road users without losing too many votes, and how little money can be spent on transport infrastructure without arousing too great despair over the poor quality of the resulting transport system. Periodic shocks to the system, such as rail privatisation, the Hatfield rail crash of 2000, the petrol blockade, as well as the steady increase in inter-urban and urban congestion, cause periodic reappraisals of transport policy, and the quest for a new equilibrium to balance the competing claims on the public purse and the various interest groups in society.

Equity can be seen primarily as a political constraint on certain types of intervention, though not necessarily insurmountable. Taxing rural motorists, even though they are poorer, is also acceptable as they count for few votes. Fuel taxes are regressive over the car-owning population, though not over the whole population, and are primarily defended as sin taxes rather than redistributive taxes. But *changes* that impact excessively and obviously on the poor will be resisted. Road prices have certainly been opposed on those grounds, and their distributional impact should therefore be explored.

The conflict between efficiency and political sustainability is particularly acute when attempting to use the price system to correct the various market failures in transport. The standard economic approach to the presence of external costs is to internalise the externality by imposing corrective taxes or charges. The taxation of road transport may be used to address the different social costs generated by road vehicles: environmental, congestion and accidents and road infrastructure (Smith, 1995). The two main candidates for such road charges are pollution and congestion (leaving aside accidents, which deserve to be investigated separately). While pollution can be dealt with using the existing array of road tax instruments, congestion cannot, and instead some form of road pricing would be needed to address this market failure.

However, if road taxes reflect the complex political economy suggested above, it may be hard to reconcile the general revenue raising objectives with the more targeted approach required to internalise externalities. Specifically, any attempt to impose additional pollution taxes or road prices to reflect external costs may be perceived as a thinly disguised attempt to increase the overall tax take. If, as seems to be the case in the UK by the year 2000, there is growing acceptance that the overall tax collected from road users has reached or even surpassed an acceptable level, then it will require delicate balancing to introduce new corrective charges or taxes. This may be possible if there is some mechanism to cap total revenue from road users, in which case any new taxes or charges would require that existing road taxes (VED and/or fuel duties) be reduced. That is certainly not the approach taken by the current government in the UK. The recently passed Transport Act (Acts of Parliament, 2000) authorises local authorities to introduce road user charges and workplace parking levies to help tackle congestion in towns and cities. In other words, local authorities now have the power to impose an even heavier burden on motorists. Not a word in the Act indicates any intention from the Government to reduce any road tax.

Bearing this in mind, it might take some time before congestion charges are introduced in the UK. Leaving the problem of political acceptability aside, there is the practical question of what type of scheme and level of charges would need to be implemented. Cordon tolls seem to be a simple, yet effective, way of charging road users and have for that reason been chosen in this study. In a cordon-toll scheme a trip maker is charged a fixed amount to enter and/or leave the charged area at all or only some times of the day. The charge does not depend on the time taken or distance travelled within the charged area nor on levels of prevailing congestion. Cordon tolls have been already tested in Singapore, Oslo, Trondheim and Bergen. Other systems would be more expensive, more complex, and would have less predictable effects.

The aims of this paper are to compute the optimal cordon toll in eight English towns and assess the costs and benefits of the introduction of such a toll. The optimal cordon toll is computed as the toll that maximises the increase in social surplus. Costs and benefits of both drivers and the local authority are assessed under the assumption of the simplest and cheapest technology. In most cases benefits exceed costs by enough to suggest these towns for possible field trials.

PROGRAMS USED

The potential impacts of the schemes were estimated using results from SATURN (Simulation and Assignment of Traffic to Urban Road Networks) and its batch file procedure to simulate road pricing, SATTAX. SATURN, developed at the Institute for Transport Studies at University of Leeds, simulates and assigns traffic in towns and iterates until it finds the equilibrium, defined as the situation when no trip maker can reduce his or her generalised cost. The generalised cost of a trip is defined as the sum of both the time cost and the vehicle operating cost:

$$GC_{ij} = VOT \times time_{ij} + VOC \times dist_{ij} \tag{1}$$

where GC_{ij} is generalised cost in pence per PCU to go from origin zone i to destination zone j, VOT is value of time in pence per PCUmin, $time_{ij}$ is the time taken to complete the trip in minutes, VOC is vehicle operating cost in pence per PCUkm, and $dist_{ij}$ is the distance travelled to go from origin zone i to destination zone j, in km. Time and distance vary according to the route chosen to go from origin zone i to destination zone j but in equilibrium no trip maker can reduce his or her GC_{ij}.

SATTAX is a batch file procedure, also developed at the Institute for Transport Studies at University of Leeds, that can be added to SATURN in order to simulate road charging (Milne and Van Vliet, 1993). It simulates driver responses to road pricing. These can be classified in two main types: change of route and transfer off the road.

For each link on the simulation network, there is usually an associated fixed travel time, with delays treated as taking place at junctions. This fixed travel time can be increased to emulate road charging. SATTAX is based on the assumption that trip makers consider tolls alongside and in equal weight to the costs of running a car and the value of their time. If the cost for a driver to go from origin zone i to destination zone j is £10 ($14.6) including both time and distance (vehicle operating) costs and a toll of £2.5 ($3.7) is introduced in the central area of town which he has to enter to reach his destination, the total cost of his trip will now be increased to £12.5 ($18.3) in the first instance. After adjustments are made however some drivers will be ‘tolled-off’ and some drivers will change route, and with fewer vehicles in the charged area, travel times will be lower and the total cost of the trip will be less than £12.5 ($18.3).

If a cordon toll is introduced in the central area of a town, an extra delay is added on to the fixed travel time to traverse the appropriate link or turn. The magnitude of the additional cost is computed from the VOT assumed, which in this case was 23.4 pence per PCUmin (34.2 cents per PCUmin)[1]. The VOT varies with user's income, time of the day and trip purpose. For simplification a weighted average representative of the morning peak was taken. This average was computed according to the guidelines of the Highways Economics Note N°2 (Highways Agency *et al*, 1996). Average wages and value of leisure time were taken into account as well as vehicle type, vehicle occupancy and trip purpose in urban areas in England during the morning peak, 8 to 9AM.

The time penalty required to reflect a toll of £2.5 ($3.7) per crossing with an assumed VOT of 23.4 pence per PCUmin is 641 seconds. This delay is added onto the links leading to the charged area. The tolls assumed in this study are therefore effectively tolls per PCU to cross the cordon. In particular, a lorry with a PCU value of 2.5 will pay two and a half times the toll a car would pay and a light good vehicle with a PCU value of 1.5 will pay one and a half times the toll a car would pay. The same reasoning applies for buses. If the local authority wishes to get people out of their cars and to use public transport, it may decide to exempt buses from paying the toll.

As stated above, the SATTAX model has two responses:

- Route choice
- Transfer off the road

Transfer off the road includes all trips that for one reason or other are dropped from the original trip matrix for the time period under study. The reasons for these trips to be excluded include:

- Change of departure time, provided it is outside the time period modelled
- Change of mode (including car pooling)
- Cancellation of the trip.

This model considers only one time period. It takes into account the reduction of traffic linked to changes in departure time but it does not take into account the increase of traffic at other time periods. The resulting increase in traffic at other time periods could be modelled by running the model for other times and including the trips that would change departure time.

The elasticity level of the demand response relationship in SATTAX represents all likely travel choices that would reduce the volume of motorised vehicle trips in the time period represented. The demand function assumed was the constant elasticity

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[1] PCU stands for passenger car units. It is the weight given to each vehicle type according to the disruption it causes to the network. A car for example, has a PCU rating of 1, whereas a van has a PCU rating of 1.5, and a lorry has a PCU rating of 2.5 or 3, according to its size.

demand. The independent variable was number of trips (measured in PCUs per hour). The demand elasticity was defined as:

$$\eta = \frac{d \ln Q(P)}{d \ln P}$$

where *Q(P)* is demand for trips at price *P*, with both *Q* and *P* referring to a particular origin and destination and time. The constant elasticity demand function is

$$Q(P) = Q_0 * \left(\frac{P}{P_0} \right)^{\eta}$$

and its inverse is

$$P(Q) = P_0 * \left(\frac{Q}{Q_0} \right)^{1/\eta}$$

Three elasticities were assumed: -0.2, -0,4 and -0.7, spanning the plausible range of values.

THE CORDONS

The physical location of the roadside sensors determines the boundary of the charged area and defines the cordon. The decision of where to put the cordon was based on two main considerations: what seems to be the most congested area in the town in question, and what cordon would not allow too many alternative routes. If too many alternative routes were available for drivers, congestion would be shifted to these routes and the problem would not be solved. In many cases the local authorities were contacted for advice. The cordon was often placed just inside what the local authority defines as the inner ring road.

Finally, only inbound cordons were simulated. Bi-directional cordons could have also been considered. With an inbound cordon, some people reverse commuting from the city centre to the area outside the cordon may cross the cordon outbound during a peak period, generating congestion, and cross it inbound during a non-congested period paying only a small charge or even no charge at all. Bi-directional cordons are an answer to this problem. However, this problem would only exist if congestion during the morning peak were serious outbound as well as inbound. In general inbound roads are congested during the morning peak and outbound roads are congested during the evening peak. In such cases, inbound cordon tolls should be sufficient to improve efficiency. During the off-peak hours, if the level of traffic does not lead to congestion, as is the case in the towns studied, there should be no charge to cross the cordon.

OPTIMAL TOLLS

The criterion used to assess the benefits from a cordon toll was the increase in social surplus. We define social surplus as the trip makers' surplus, which can be expressed as:

Social surplus = Sum of individual utilities – Sum of individual costs

In the case of a unique origin-destination pair, the utility of driving is the integral under the inverse demand function between zero and the actual level of traffic. Individual social costs are the generalised costs defined in equation (1) adjusted to make them net of VAT and fuel duties. They are expressed in equation (2).

$$SC_{ij} = VOT * time_{ij} + (VOC - VAT - duty) * dist_{ij}$$

where SC_{ij} is the social cost in pence per PCU to go from origin zone i to destination zone j, VAT is a weighted average of the Value Added Tax on fuel and duties and *duty* is a weighted average of the average fuel duty paid by trip makers exclusive of VAT on duties. VAT and *duty* in this study were assumed to be 0.82 and 4.3 pence per PCUkm (1998 prices). The sum of all SC_{ij} can also be represented by the integral of the marginal social cost (MSC) between zero and the actual level of traffic.

It should be noted that the meaning of the term 'individual' is different from the meaning of the term 'private'. Individual refers to trip from origin zone i to destination zone j. Private and social refer to the inclusion and exclusion of VAT and duties.

The difference between ij drivers' utility before and after the introduction of the toll was computed. That was done for each origin-destination pair and then all the changes in utilities were added up to get the overall change in utility. The change in total costs was obtained directly from the new cost matrix produced by SATTAX, adjusted to exclude VAT and fuel duties.

Total social costs should also include costs of pollution and accidents. However, these costs are small compared to total costs. Moreover, there are important variations between the different estimates of the costs of pollution. The effects of a toll on accidents are also controversial for reasons discussed below. Neither of these costs was included in the analysis.

SATTAX was used to simulate different tolls. The optimal toll was chosen between the options simulated and therefore is a constrained optimal toll. This constrained optimal toll was chosen as the toll for which the increase in social surplus, defined as the difference between the sum of individual utilities of making trips *minus* the sum of individual costs, reaches a maximum.

SATTAX was run for different levels of charges ranging from £0.25 in steps of £0.25 to £5 ($0.4 to $8). Three different demand elasticities were considered in this study: -0.2, -0.4 and -0.7, using the constant elasticity function. The towns for which the cordon toll was simulated are Cambridge, Northampton, Kingston upon Hull, Lincoln, Hereford, Bedford, Norwich and York. The model was run for the morning peak (8.00 to 9.00 am).

The main results are presented in Table 1. The annual gross revenues were computed as the number of vehicles that would cross the cordon multiplied by the toll that they would pay and by the number of working days (assumed to be 250) per year.

Table 1: Main results (1998 US dollars)

Town	η	Optimal toll	Annual ΔSS ($ million)	Annual gross revenues ($ million)	Ratio of revenues to ΔSS
Northampton	-0.2	4.38	3.46	12.05	3.5
	-0.4	4.38	4.83	11.61	2.4
	-0.7	5.11	7.08	12.15	1.7
Kingston upon Hull	-0.2	3.65	4.73	11.23	2.4
	-0.4	4.38	6.51	12.51	1.9
	-0.7	5.11	7.50	13.21	1.8
Cambridge	-0.2	1.10	0.66	2.56	3.9
	-0.4	1.46	1.33	3.17	2.4
	-0.7	2.19	1.85	4.09	2.2
Lincoln	-0.2	0.37	0.64	0.76	1.2
	-0.4	0.73	0.76	1.39	1.8
	-0.7	1.46	0.79	2.28	2.9
Norwich	-0.2	0.73	1.31	1.81	1.4
	-0.4	0.73	1.34	1.81	1.3
	-0.7	1.10	1.88	2.44	1.3
York	-0.2	1.10	1.05	1.77	1.7
	-0.4	1.10	1.23	1.69	1.4
	-0.7	2.19	1.27	3.26	2.6
Bedford	-0.2	0.73	0.76	1.77	2.3
	-0.4	0.37	0.16	0.89	5.5
	-0.7	2.19	0.51	3.94	7.7
Hereford	-0.2	5.11	0.77	6.22	8.0
	-0.4	2.56	1.12	3.21	2.9
	-0.7	2.19	1.24	2.66	2.1

Source: Table 2 (Santos, Newbery and Rojey, 2001).

Note: η: elasticity, ΔSS: increase in social surplus

COST-BENEFIT ANALYSIS

Costs

The costs of a cordon toll scheme for each town considered in this study are presented in Table 2. The number of inbound tolled crossings per day was assumed to be 3.7 times that during the morning peak, 8 to 9AM. The number of intra-vehicular units (IVUs) to be installed was assumed to be three times the daily number of cordon crossings. The IVUs' implementation costs, £15 ($22) for the tag, which is currently the cheapest option available on the market (Cheese and Klein, 1999), were multiplied by the number of IVUs required in each case. Infrastructure costs, of £45,300 ($66,100) per point (Cheese and Klein, 1999)[2], were multiplied by the number of cordon points. One fourth of the cordon points were assumed to be dual lane, and would therefore require gantries. According to Cheese and Klein (1999), the cost of one gantry is £97,000 ($141,600).

Operating costs, which include all costs of running the tolls, such as labour costs, costs of maintenance and costs of operating the infrastructure, were estimated using data from the Norwegian Public Roads Administration. These are in the order of seven pence (ten cents) per transaction at most. This figure was therefore multiplied by the number of transactions per day and by the number of days on which the scheme would operate per year, assumed to be 250. The IVUs were assumed to have a life of six years. The electronic devices in the infrastructure were assumed to have a life of five years and a value of £18,765 ($27,400) per cordon point (Cheese and Klein, 1999). The rest of the infrastructure was assumed to have the same life as the equipment.

The present value of the costs presented in Table 2 are presented in Table 3. The scheme was assumed to last 30 years. The 1998 Treasury test discount rate of 6% was used. In the case of Cambridge a second alternative entailing two cordons instead of one was also tried. It was found that while one cordon around the city centre would not be worth implementing, a double cordon scheme, one in the city centre and one for virtually the whole town, would be worth implementing, with benefits being considerably higher than costs.

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[2] MVA (1995) estimates infrastructure costs at £110,000 per point. Cheese and Klein's (1999) estimate was chosen instead because it is more recent and prices for this type of equipment are likely to decrease with time and technological progress.

Table 2: Implementation and operation costs of a cordon toll in different towns (1998 US$)

Town		Number of vehicles crossing the cordon between 8 and 9AM	Number of Crossings per day	Number of IVUs	Number of cordon points	Implementation costs ($ million at 1998 prices)		Operating costs ($ million at 1998 prices)
						IVUs	Infrastructure	
Cambridge	*One cordon*	10,527	38,950	116,850	16	2.56	1.62	0.99
	Two cordons	17,074	63,174	189,521	27	4.15	2.74	1.62
Northampton		14,189	52,499	157,498	12	3.45	1.21	1.34
Kingston upon Hull		14,529	53,757	161,272	14	3.53	1.42	1.37
Hereford		6,494	24,028	72,083	8	1.58	0.82	0.61
Lincoln		9,074	33,574	100,721	20	2.20	2.03	0.86
Bedford		10,335	38,240	114,719	14	2.51	1.42	0.98
Norwich		12,164	45,007	135,020	22	2.96	2.23	1.15
York		6,444	23,843	71,528	21	1.56	2.13	0.61

Source: See text

Note: IVUs and infrastructure costs are capital one-off costs that take place in year zero. IVUs and infrastructure will need to be replaced every five and six years. Operating costs are annual costs.

Table 3: Present value of the different costs (1998 US$ million)

Town		Implementation Costs (IVUs + Infr.)	Replacement IVU (every six years)	Replacement Infrastructure (every five years)	Operating costs	Total costs
Cambridge	*One cordon*	4.2	5.4	1.0	13.0	23.5
	Two cordons	7.1	8.9	1.7	21.6	39.3
Northampton		4.7	7.3	0.7	17.4	30.1
Kingston upon Hull		5.0	7.4	0.9	17.8	31.1
Hereford		2.3	3.4	0.4	8.0	14.2
Lincoln		4.2	4.7	1.3	11.1	21.2
Bedford		3.9	5.3	0.9	12.7	22.8
Norwich		5.3	6.1	1.3	14.9	27.7
York		3.7	3.2	1.3	7.9	16.2

Source: Own calculations

Note: elasticity assumed: -0.2, test rate: 6%, project life: 30 years

Benefits

The benefits are simply the increase in social surplus. They are presented in Table 4. The increase in social surplus for a whole day was assumed to be three times the increase in social surplus from 8 to 9AM. This is a conservative but reasonable assumption. The scheme would also improve social welfare in the shoulder peaks, i.e., the congested time-periods that surround the morning and evening peaks. Therefore, to assume that the introduction of a cordon toll during the morning and evening peaks and shoulder-peaks would yield an increase of only three times the increase in social surplus during the hour 8 to 9 may be an underestimate. At this stage it is preferable to underestimate benefits, particularly bearing in mind that calculations for other times of the day cannot be done due to lack of data.

Benefits increase with the elasticity, so at the assumed value of -0.2 they are likely to be underestimated. If a scheme is worthwhile with this value, then it will certainly be worthwhile with other higher elasticity values.

Table 4: Annual benefits of implementing a cordon toll in different towns in $ million at 1998 prices

Town		Increase in social surplus morning peak	Total increase in social surplus
Cambridge	*One cordon*	0.6	1.9
	Two cordons	2.5	7.5
Northampton		3.4	10.1
Kingston upon Hull		4.5	13.9
Hereford		0.7	2.2
Lincoln		0.6	1.9
Bedford		0.7	2.2
Norwich		0.9	2.6
York		1	3.1

Source: Own calculations done with SATURN outputs

Note: elasticity assumed: 0.2, total increase in social surplus assumed to be three times the increase in social surplus during the morning peak

Comparison of costs and benefits

In order to decide whether a scheme is worthwhile or not we have compared the net present value (NPV) of the streams of costs and benefits that would derive from a cordon toll scheme in the different towns considered in this study. The main benefit would be the increase in social surplus. Revenues are not benefits and therefore do not enter the calculations. There would also be some other benefits linked to the reduction in emissions, but these have not been included in the final estimates of NPV. Finally, there would perhaps be a benefit resulting from fewer accidents. Traffic accidents, however, are related to both speed and traffic volume. If road charging increased speeds, accidents would increase, but since road pricing reduces traffic volumes, accidents would decrease. If a cordon toll increased speeds not by increasing running speed but by reducing queuing delays, the number of accidents would probably decrease (MVA, 1995), but the remaining accidents would (perhaps) be more severe. We have ignored this benefit as well as we believe a separate careful study would have to be conducted to arrive at a robust estimate.

Ideally, a comprehensive cost-benefit analysis should also include the impacts on the urban economy. The MVA study of road charging in London (MVA, 1995) considers four classes of impact: those on employees, on costs of the inputs of organisations, on costs of outputs of organisations, and on organisations' customers. We have only included the direct transport cost changes, and ignored indirect effects arising from such changes, as they are not modelled by SATURN.

There is a further problem in the analysis, which can only be solved by using a more comprehensive model that would account for longer term changes. SATURN and the batch file procedure SATTAX are medium-run models in that they hold constant car ownership and use, and specifically the pattern of origin and destination of trips, and therefore medium-run elasticities have been used. We have assumed that the changes in social surplus computed for the first year would hold during the whole life of the project. This is of course unrealistic. In the long run higher elasticities should be used as people and businesses might relocate and even more, there could be changes in the local authorities' land use plans. We are unable to allow for those responses in a model that only accounts for time or route switching, which are clearly medium run responses. The stream of costs and benefits we are comparing therefore may help to give an idea of what the result of a cost benefit analysis would be, but it should not be taken as definitive. To assess the real impact of a scheme a more complex model would need to be used so that all possible responses could be taken into account. It would be possible to make cruder forecasts of traffic growth, but it is likely that traffic management arrangements would be adapted to deal with such growth and our model would no longer give an accurate measure of congestion costs. Our defence of this simplifying assumption is that the long-run impacts of relocation caused by road pricing are likely to reduce traffic, while economic development is likely to increase traffic, making a no-change assumption not unreasonable. If anything, it is likely to underestimate the benefits of road pricing.

To estimate the costs the toll was assumed to operate from 7 to 10 AM and from 4 to 7 PM. The toll should depend on the level of congestion and should be set lower at the shoulder-peak hours, 7 to 8 and 9 to 10 in the morning, and 4 to 5 and 6 to 7 in the afternoon.[3] The number of vehicles crossing the cordon during this time period was deduced from the number of vehicles crossing the cordon between 8 and 9AM using SATTAX and from the daily traffic distribution inbound on Cambridge radial routes.[4] The number of transactions per day was estimated to be 3.7 times the number of transactions between 8 to 9AM. As argued above, the daily benefits are taken as three times those measured for the period 8 to 9AM, erring on the side of under-estimating benefits (as is the case for valuing the results at an elasticity of -0.2).

Table 5 summarises the costs and benefits were a cordon toll implemented in the towns in question.

Table 5: Net Present Value of a cordon toll in different towns in $ million at 1998 prices

Town		Total cost	Benefit	Net Present Value	Benefit/Cost
Cambridge	*One cordon*	23.5	24.2	0.7	1.0
	Two cordons	39.3	95.0	55.7	2.4
Northampton		30.1	131.4	101.3	4.4
Kingston upon Hull		31.1	180.3	149.2	5.8
Hereford		14.2	28.5	14.3	2.0
Lincoln		21.2	24.8	3.5	1.2
Bedford		22.8	29.1	6.3	1.3
Norwich		27.7	34.9	7.2	1.3
York		16.2	40.0	23.8	2.5

Source: Own calculations

Note: discount rate: 6%, benefits assumed to be constant throughout the 30 years

A comparison of costs and benefits indicates that road pricing would be very beneficial in Kingston Upon Hull and Northampton, and to a lesser extent in Hereford

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[3] A sophisticated toll would increase gradually from zero to the prescribed level and back over the shoulder periods to prevent bunching of trips around the beginning and end of the charged periods.

and York. Conservative estimates were used. These schemes would become more beneficial if costs proved to be lower than the ones used or if the elasticity of the demand proved to be higher than 0.2.

Two cordons in Cambridge, one inner and one outer, at £1 ($1.5) per crossing yield a benefit-cost ratio well over 1. This shows that where a single cordon scheme might not be worthwhile, a double cordon scheme could be. Changing from one to two cordons could therefore change the policy decision. On the other hand, a second cordon would increase costs. The ratio would only increase if the increase in benefits were greater than the increase in costs. This kind of analysis is therefore worth doing before deciding on the desirability of a road pricing scheme in any one town.

CONCLUSIONS

The paper estimated optimal peak hour cordon tolls to reduce urban traffic congestion. Optimal tolls are computed as the tolls that maximise social surplus after allowing for a response from drivers who may decide to reduce the number of trips, change the time of their trips to avoid tolls (and congested periods) or use a different non-tolled route. SATURN and SATTAX were used to simulate and assign traffic and simulate cordon tolls in eight English towns. The trip demand function was assumed to be of constant elasticity, but three different elasticity values were assumed, covering the plausible range of travel responses. It was found that in all cases the introduction of the optimal cordon toll would increase social surplus.

The cost-benefit analysis shows that even with the cheapest available technology, which was the one assumed in this study, there may be some borderline cases with cost-benefit ratios just above one. This is the case of Lincoln, Bedford, Norwich and Cambridge (with a single cordon). If a more expensive technology were used, a cordon pricing scheme in these towns could well yield losses. Another option for those towns in which the scheme would not have a positive net present value is to introduce a second outer cordon. Such is the case of Cambridge, where with one cordon only around the city centre electronic road pricing would not be worthwhile, whereas with two, it would. York and Hereford are towns with positive net present values. However they do not have much margin. Finally, there are two unambiguous cases: Northampton and Kingston upon Hull, where the benefit cost ratio is well above one, regardless of the technology used.

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[4] We are indebted to James Lindsay, from WS Atkins, who provided us with data on vehicle counts in Cambridge.

Back-office costs are the most significant usage-related cost. It may be that these costs can be substantially reduced by improved electronic processing. If so, more schemes will become socially desirable. In the mean time, the most important lesson to draw from this study is that trials should be carefully targeted at the few towns (such as Kingston upon Hull and Northampton) that appear to have a considerable excess of social benefits over costs. These trials should be studied closely, to validate the travel responses upon which the benefits and costs so sensitively depend and to validate the estimates of implementation and operating costs. That knowledge will allow subsequent schemes to be better-designed and subsequent cost-benefit analyses more accurately undertaken.

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