ROAD USER CHARGING AND SOCIAL EXCLUSION: THE IMPACT OF CONGESTION CHARGES ON AT-RISK GROUPS

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Abstract

The paper discusses the link between social exclusion and transport, indicates which groups in society are most particularly at-risk of transport-related exclusion, and highlights the importance of social exclusion and equity in the evaluation of congestion charging schemes.

A new technique with which to quantify the impact of congestion charges on at-risk groups is introduced and discussed. It uses iterative proportional fitting and monte-carlo simulation to "generate" the characteristics of travellers and then uses select-link-analysis to identify which drivers would be affected by a given policy. The methodology allows the spatial incidence of impacts on at-risk groups to be clearly demonstrated and allows the user to examine how the severity and incidence of impact varies with the definition of at-risk groups and the charging scheme.

The technique is used to establish the impacts on at-risk groups, defined with reference to their income and other socio-economic characteristics, of a £2 charge on drivers entering the central area of Leeds during the morning peak hour. The distribution and severity of the impacts are seen to depend crucially on the precise definition of the charge area and the basis of the charges (cordon-crossing, time-based or distance-based) and, of course, on the extent of any exemptions. Using the new technique, it is possible to see how the impact on at-risk groups could be minimized without compromising the overall objectives of a charging scheme.

The paper concludes with a discussion of potential further applications of the new technique.

Keywords: Road pricing; Social exclusion; Equity; Synthetic population
Topic Area: H9 Implementation of Pricing in Transport

1 Road user charging and social exclusion

1.1 Introduction

Our investigation of social exclusion and equity issues in the context of road user charging was stimulated by the observation that current government policy contains elements from two contrasting ideologies. On the one hand government is placing increased emphasis on the needs and rights of vulnerable groups, and on the other hand it is contemplating the widespread use of increased charges as a means of managing the demand for travel. The introduction of charges gives additional choice to affluent groups but may present serious problems to those for whom the new charges represent a significant part of their available income.

1.2 Road user charging

The idea that road users should be charged for their use of the road network at the point of use has a long history and is the norm in many countries for use of interurban motorways, bridges and tunnels. The current interest in urban road charging is associated with theoretical arguments about system efficiency and the need to charge users the full

cost of the congestion and other externalities, which they cause. The success of the Singapore scheme and the development of technologies which allow automatic collection of tolls put the idea very firmly on the traffic engineer's agenda. The revenues generated by the Norwegian toll rings put it on the political agenda and the initial success of the scheme introduced in London in Spring 2003 (TfL,2003) has given it a very high profile. Several UK local authorities beginning to consider the introduction of charging schemes in their areas and the UK government is letting it be known that it is seriously considering the introduction of a national scheme, based on GPS technology, within the next ten to fifteen years. This surge of interest makes it important to consider issues such as the impact on equity and social exclusion before plans become too concrete.

1.3 Social exclusion and transport

The modern concept of social exclusion was developed in France from the 1960s onwards and has recently become a central concern of social policy in many European countries and, increasingly, in other parts of the world (Rodgers et al, 1995). Social exclusion has long been a concern in the UK but its current political profile dates from the election of the Labour Government in 1997 and their establishment of a Social Exclusion Unit close to the heart of government. Social exclusion has been variously described but most definitions stress that it is a multi-faceted phenomenon and that it implies an inability to participate fully in the life of the community. Poverty, ill-health, unemployment, physical isolation, lack of education and lack of confidence often occur together and may be a particularly debilitating combination if they affect people whose membership of a social or linguistic minority further restricts their participation in society.

Lack of access to good transport can exacerbate or trigger social exclusion. Hine and Mitchell (2003) suggest that people on low incomes, women, the elderly and people with health problems face particular difficulties accessing transport and that this can restrict their participation in society. Many of the most vulnerable people suffer from multiple deprivations and loss of access to transport can be particularly serious for them.

This paper is concerned with the identification of people for whom the introduction of road user charging would restrict their participation in society. Kenyon et al's (2001) definition of mobility-related exclusion is particularly relevant: '*the process by which people are prevented from participating in the economic political and social life of the community because of reduced accessibility to opportunities, services and social networks….*'. Church et al (2001) identify physical, economic, fear-based, institutional and spatial factors as contributors to mobility-related exclusion. The Social Exclusion Unit (2003) have recently identified major barriers which restrict people's use of local public transport systems. Their list includes: the unavailability or physical inaccessibility of transport; the lack of safety and security when traveling; the cost of transport; and the limited availability of information about services. These problems are compounded by individuals' limited travel horizons and the distant location of many services.

It is often assumed that the existence of public transport avoids mobility-related social exclusion. However, not only are public transport services often limited or deficient, but as highlighted above, many of the most vulnerable groups may have difficulties in making use of it.

1.4 The implications of road user charging for social exclusion

The introduction of road user charges will immediately make it more difficult for some people to drive – particularly those on low incomes. However, if the revenues are used to improve the transport system, to provide alternative modes of transport or to provide alternative means of participating in the normal activities of society, this immediate effect

may be offset and the net effect may even be to reduce the number of people who are socially excluded.

It is often suggested that, since car owners are generally more affluent than non-car owners, and since road charges will be imposed only on car users, the main effect of road charging will be to remove income from the more affluent members of society and to re-distribute it, via public spending, to the less affluent. This view of road charging as a tax on those most able to pay is something of an over-simplification! Not all car owners are affluent. Recent evidence (DfT, 2002) indicates that 38% of households in the lowest quintile income group have access to a car (an increase from 26% in 1985/86).

The car certainly offers convenience and flexibility but the old view of the car as a luxury item is misplaced. Many motorists can only just afford to run a car but have little alternative if they are to continue to function in society. Jones (2001) identifies a particular problem for people on low incomes who need to use a car to access their work.

In a perfectly free market, drivers faced with a new charge would have the option of paying it or making alternative arrangements. It is suggested that those with high values of time will be happy to pay the charge because it would buy them access to less congested roads, while those with low values of time will make alternative arrangements. Richer people, the argument runs, will have higher values of time and so will pay the charge while poorer people with lower values of time will seek to travel less frequently or at other times, by other modes, and to other destinations. So far so good, but many of those for whom the charge would be an imposition may not be able to make alternative arrangements without compromising their participation in society.

For those drivers who have no viable alternative to use of the car, road user charging will increase social exclusion if their participation in society is compromised either because they have to stop using their cars or because they have to make economies elsewhere.

The existence of viable alternatives to the car is thus an important part of the case for road charging. However, as we have seen, public transport can never hope to provide the standard of convenience offered by the private car and so, at the margin, there will always be people for whom the car is essential to their current pattern of participation in society.

The impact of road user charging on at-risk groups may differ depending on the arrangements adopted for paying the charges, for example, if charges have to be paid as a lump sum in advance this could be problematic for people on low incomes. Similarly if lack of access to a bank account or credit facilities makes the process of paying more onerous this could disadvantage those at the fringes of society. The choice of technology used to collect the charges, be it smart-cards, beacons or GPS could also be problematic for low-income drivers if they are expected to pay to have their vehicles equipped.

In addition to what might be termed the first-order effects of road charging there are a number of impacts which come about in consequence of people's responses to the charges. The second-order effects include problems caused by diversion onto roads just outside the charge areas or parking outside the charge area to avoid paying the charge and changing to another mode. Third-order effects might include land-use changes stimulated by changed travel patterns – for example the closure of some shops within the charge zone. The second and third order effects could impact on social exclusion if they disadvantage at-risk groups – for example if rat-running traffic or out-of-zone parking causes environmental degradation in low-income neighbourhoods, if public transport becomes so crowded with people from distant suburbs that those who wish to board in the inner suburbs find it impossible to do so or if the city centre shops accessible to non-car owners are replaced by other in out-of-town retail parks.

1.5 The identification of at-risk groups

The key statistics used to assess whether a road user charging scheme is successful include revenues, traffic speeds and volumes, but these tell us nothing about the people affected by the charge, where they live, whether they could afford the charge, the purpose of their journey… etc. Information at this level of detail would help the local authorities to introduce measures to reduce the unwanted impacts of the scheme on vulnerable groups.

The literature identifies a number of groups who are potentially at-risk from the introduction of road charges. The main one will be those low-income drivers who either have to stop travelling, so lowering their mobility levels, or have to pay the charge (if they have no alternative) so putting an extra strain on their already limited resources. Whilst a low income would leave people particularly vulnerable to the introduction of road charges it is clear that the presence of other factors could change a mild inconvenience into a major problem. Difficulty or inability to use public transport would make a driver particularly vulnerable to the introduction of road charges. Thus one might regard the following drivers as being particularly at-risk: those suffering from disabilities (access problems), elderly people (access problems and security fears), females (potential security fears), ethnic minority groups (potential security fears and inability to understand how to use public transport) and, of course, those whose trip is not served by public transport.

The seriousness of the impact of road charging might also differ depending on the individual's journey purpose. The introduction of a charge might be of little consequence to those who could simply reschedule their trip to avoid the charge period or substitute an alternative destination which avoids entering the charge area. However there will be trips, particularly for work and education, but also for other purposes such as hospital appointments and even some important shopping trips, where there is no such flexibility. Drivers who are responsible for transporting others may also find that they have little flexibility on trip timing or destination. Rajé's (2003) study of public responses to road user charging suggested that passengers who relied on others for lifts to destinations such as doctor's appointments, work and foods shops might not be able to justify the expense that the driver would incur if a charge were in operation.

1.6 Methods of ameliorating the impact on at-risk groups

One of the main reasons for identifying the at-risk groups before implementing a road user charging scheme is that it might be possible to modify the scheme design so as to reduce the likelihood of these people becoming socially excluded. If it is possible, by moving the boundary, by redefining the basis for the charge, by allowing different methods of paying the charge, by providing exemptions for certain groups or by using the revenues to improve the provision of alternative modes of travel, to reduce the impact on at-risk groups then this should seriously be considered right from the outset.

The definition of the charge area may be crucial – for example if there is a major hospital or other social-service facility in the charge area then thought might be given to seeking to re-draw the boundary so as to exclude it. Similarly the operating hours and charge-basis could perhaps be adjusted to avoid catching night-shift workers traveling against the peak flow.

One of the simplest ways of protecting at-risk groups may be to provide exemptions for them – although this would reduce the effectiveness and profitability of the scheme and might not be an effective way of targeting the relief. The London congestion charging scheme includes exemptions or discounts for licensed taxis; disabled drivers with blue (orange) badges; residents (90% discount); certain NHS staff and certain NHS patients; buses, coaches, two wheeled vehicles and alternative-fuelled vehicles; and vehicles used by the emergency services, the armed forces or breakdown organizations (for a comprehensive list see TfL, 2003). A number of other groups argued that they should also

be exempt from the charge and these included low-paid workers who travel at unsocial hours (e.g. cleaners, market porters, theatre staff) and emergency service staff who live outside the charge area. It was decided that these workers would not be exempt – it being argued that their employers ought to be prepared to pay the charge. Clearly the choice of groups to receive an exemption or discount is a political matter!

As an alternative to the provision of exemptions for at-risk groups, a more positive option might be to ensure that alternative modes are available. Cycling and walking might be relevant in some circumstances and improvement of facilities for cyclists and pedestrians may make these modes feasible options for some drivers affected by the introduction of charges. More generally it is likely that improving the public transport service and making it more accessible for the at-risk groups will be a more efficient use of resources. Given the profile of the at-risk groups, the improvements might include increased provision of early-morning and late-night services, increased penetration of services – perhaps involving the expansion of demand-responsive services, more disabled-friendly vehicles, more generous concessionary fares for elderly, disabled or unemployed people, and improved information about services in all relevant languages. Where public transport is not a viable option then thought might also be given to the encouragement of other alternatives such as car sharing and community-based transport. The London scheme included considerable investment in improved public transport services – particularly through an expansion in capacity and operating hours.

There may be situations in which the best way to limit the impact of the introduction of road charging on at-risk groups might have little or nothing to do with transport. For example it might be that be, by relocating key facilities (such as benefit offices or budget shops) outside the charge area, the at-risk groups would no longer need to travel into the charge zone.

Of course all such measures whether they be changes to the scheme design, provision of exemptions or provision of alternative modes/destinations, would have to be carefully assessed to determine whether they make a real difference to the at-risk groups, whether the impacts on the overall effectiveness of the scheme are justified and whether the proposed measures represent an efficient use of scarce resources. In order to do this it is important to have a good picture of the numbers of at-risk people affected by the proposed schemes including details of their personal circumstances and travel patterns. The next section of the paper will discuss the methodology that has been developed at Leeds to provide such a picture.

2 The Popgen-T methodology

2.1 General description

The Popgen-T methodology, described in more detail in a separate report uses iterative proportional fitting and monte-carlo simulation to “generate” the characteristics of travellers from probabilities derived from a variety of sources but most particularly the small-area-statistics available from the census. The method then uses select-link-analysis and other routines from a standard traffic assignment package to identify which individuals would be affected by a given policy. The tool is designed to facilitate investigation of the extent and spatial incidence of policy impacts on members of a population, and the way in which the severity and incidence of impact varies with the definition of the at-risk groups and of the policy being tested.

The original concept was of a six-stage process:

1. Estimate, using a variety of sources, the occurrence probabilities of key characteristics in the population.

2. Where not available from published sources, use appropriate software to estimate the joint probabilities of occurrence of key characteristics (i.e. of particular combinations of characteristics) in the population.
3. Create, using Monte Carlo selection from the occurrence probabilities, a synthetic population of travellers, defined in terms of key characteristics,.

And then, for each policy to be tested:

4. Conduct a select link analysis to identify how many travellers between each pair of zones are affected by the policy being tested.
5. Select this number of travellers, randomly, from the population associated with each zone pair.
6. Examine the characteristics of this sample of travellers.

The individual characteristics generated by Popgen-T include age, gender, employment status, occupation (if employed), income, car availability, disability, lone-parenthood and membership of an ethnic minority. These characteristics were chosen such that, between them, they would provide an indication of people who might be particularly at-risk from the introduction of road user charges. The method could of course be revised or expanded to consider other characteristics such as educational attainment, literacy, and mobility difficulties short of disability. Data exists to support all of these, and more besides, but the computing facilities available to us at the start of the project would have made their inclusion difficult.

Characteristics are assigned to individual travellers (defined by their origin and destination zones) using the known characteristics of the origin and destination zone (e.g. the characteristics of residents and employees and details of the land-uses within the zone). The number of travellers between each pair of zones is derived from a trip matrix, and a trip purpose is assigned to each trip on the basis of the zonal characteristics and information about the distribution of trip purposes within the study area.

Popgen-T does not seek to predict how individuals might respond to a given policy, merely to describe the characteristics of those who are affected by it. Although it would be possible to extend the method to allow for second-order effects due to changes in behaviour following introduction of the policy, we have chosen to restrict our attention to the first-order impacts (in the case of road user charges this is the charges that drivers would incur if they continued with their previous pattern of behaviour). The implications of this restriction are discussed in a later Section of this paper.

2.2 Related methodologies

The use of synthetic populations in transport policy analysis has been fairly common since the 1970s. Most of the early work was associated with attempts to overcome the bias inherent in more aggregate forecasting methods (see for example, Koppleman, 1974). Much of this work involved sample enumeration - the generation of a sample of the full population in order that disaggregate choice models could be applied to individuals or groups within that sample such that, with appropriate weighting of the results for individuals or groups, a forecast for the entire population can then be produced. Although some early practitioners sought to enumerate the entire population, this was generally thought unnecessary and, with the then available computing power, was not an attractive prospect (see Dunne, 1985). One of the early examples of complete enumeration was that by Bonsall (1980,82) in his model of an organized car-sharing scheme – in which context the representation of market clearing mechanisms was thought to require a full representation of that market.

The use of synthetic populations, or samples, thereof, as a basis for predictive modeling has become increasingly popular. Its use by Purvis (1994) in his car ownership models and by Hensher and Ton (2002) in their strategy simulator, indicate the range of applications.

Its use by Beckman et al (1996) as the foundation for the microsimulation of activity and travel behaviour in the TRANSIMS project is particularly noteworthy, not least because of the scale of the investment in this approach.

Popgen-T differs from most of the previous examples in that it is not primarily designed as an input to a predictive modeling exercise. Rather, it seeks simply to synthesise a population which can then be examined as if it were the real thing. Examination of the synthetic population is analogous to conducting surveys among specified subpopulations. Popgen-T thus has something in common with the "simulated household activity/travel survey" developed by Stopher et al (2001) and with the method used by Rees et al (2003) and Boyle et al (2001,3) to study migration patterns and social deprivation / long-term illness respectively. What makes Popgen-T unique is its use of a transport demand model, in the current example it is an assignment model, to define the individuals who are affected by a given policy.

A variety of methods have been used to generate synthetic sample populations (see for example: Bonsall, 1980; Beckman et al, 1996; Greaves, 2000; Ton and Hensher, 2001; Norman, 1999; and Adams et al, 2003) but most are based, as is Popgen-T, on the use of iterative proportional fitting or monte carlo simulation on probabilities derived from published census material. The work by Greaves and Stopher (2000) and by Adams et al (2003) is interesting because they demonstrate the use of sample surveys to enrich published census data. Both use regression to analyse sample survey data (travel surveys and health surveys respectively) and so derive an association between a dependent variable (self-reported travel patterns and health condition respectively) and independent variables (commonly occurring socio-economic characteristics). The regression coefficients are then used to infer the incidence of the dependent variable within the wider population.

Spatial analysis of published census data is another tradition, rather different in style, to which Popgen-T is related. This tradition is well-established among social geographers and is commonly used by government agencies. It is typified by Hine and Mitchell's (2001) work on the distribution of various indicators of deprivation in Scotland, by a recent report from Friends of the Earth (2001) which seeks to map the distribution of transport-related social exclusion in Bradford and by work by Camara et al (n.d.) which maps social exclusion in developing countries. This tradition is almost as old as geography itself but has become easier and quicker with the development of Geographical Information Systems (GIS) and associated mapping tools and databases. Most of the applications are relatively simple but they can be a very effective means of transmitting a message. Chapleau (2003) has demonstrated some of the strength and sophistication of the tools now available. Popgen-T does not claim any sophistication in its display of spatial data but is perhaps unique in the way in which it processes census data prior to display.

3 The use of Popgen-T to study road user charging in Leeds

3.1 Study Area

This application of Popgen-T relates to the city of Leeds, which sits on The River Aire in the County of Yorkshire in northern England. The study area covers approximately 552 square kilometres and has a resident population of some 715 thousand. The city centre is located to the north of the River Aire. It is a major source of employment for the region and attracts shoppers from a large catchment area. Leeds has two universities who, between them, have 65 thousand students – education-related trips are thus an important component of the traffic in Leeds. Leeds has a ring-and-radial road network with a motorway standard ring road running round the city centre. Another ring road runs round the city some 6 kilometres from the city centre. The morning peak period is characterised by congestion and the mode split is approximately 61 % car.

3.2 Data sources

The data sources used in this application include the Household Census, the National Travel Survey, the Journey to Work Census, the Household Income Survey, The Household Expenditure Survey, the New Earnings Survey and a number of local travel surveys. The data for this study were compiled in early 2001 from sources that were readily available at that time. This timing was unfortunate because the results of the 2001 Census were not due to be published for some time and a revalidation of the local trip matrix was overdue. We had to rely on local area statistics from the 1991 Household and Journey to Work Censuses and on a trip matrix based on detailed studies in the late 1980's – all be it adjusted to reflect observed flows in 1993. Although it would have been possible to update these data sources using an appropriate combination of trend extrapolation, matrix manipulation and Bayesian updating, we concluded that this could not be justified given that the publication of the 2001 Census was imminent.

Although most of our data relates to the situation in Leeds in the early 1990s, we thought it appropriate to use more up-to date (late 1990s) information on incomes and total trip volumes and to base our tests on the network which is being used by the local authority and its consultants. The absence of a unique time base for our work is excusable given the fact that our policy tests were primarily for demonstration purposes but would clearly not be acceptable if the method were being used to test a "real" policy option. These data problems notwithstanding, we suggest that the results of our analysis can be regarded as indicative of the impacts on at-risk groups in Leeds were a road charging scheme to be introduced.

3.3 The charging schemes tested

We have tested the effect of six different charging schemes: cordon crossing charges at each of three cordons, distance-related charges within two charge areas, and time-related charges within the same two charge areas.

The location of the cordons and charge areas is shown in Figure1. *Cordon A* encloses an area about 1.8 Kilometres across and runs for much of its length just inside the Leeds Inner Ring Road. The area within cordon A is predominantly business and commercial but contains a large hospital, a university, civic facilities and the bus and rail stations. *Cordon B* is similar to cordon A except that it excludes the area of light industry and commerce to the south of the River Aire. It is thus more closely focussed on the commercial, civic and retailing heart of the city. *Cordon C* runs just inside the Leeds outer ring road and thus encloses an area some 11 kilometres across. Although this includes the majority of the built-up area of Leeds, there is a substantial inward flow of commuter traffic across this cordon during the morning peak period.

The six polices are:

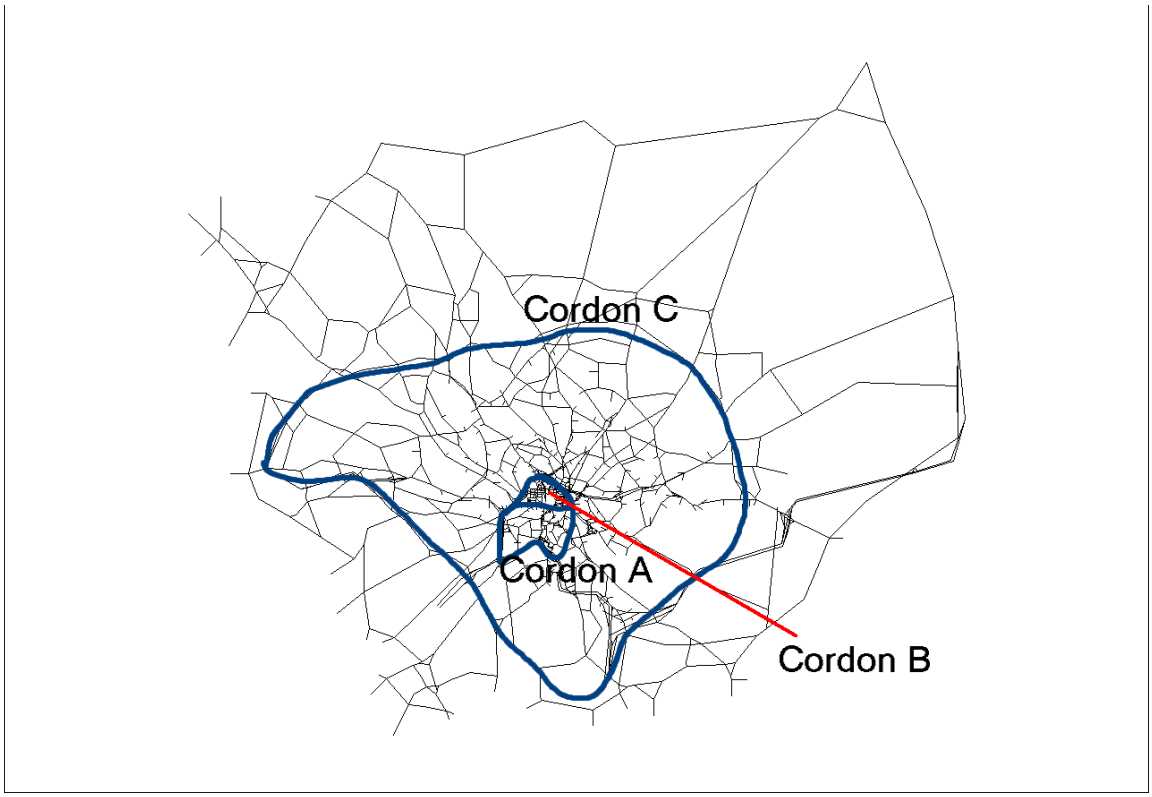
Policy 1: a charge levied on inbound traffic at *cordon A* during the morning peak hour (8am to 9am). This policy is based on the scheme considered by consultants advising Leeds City Council and the West Yorkshire Passenger Transport Executive in 1999 (MVA consultancy and Institute for Transport Studies, 2000).

Policy 2 : a charge levied on inbound traffic at *cordon B* during the morning peak hour.

Policy 3: a charge levied on inbound traffic at *cordon C* during the morning peak hour.

Policy 4: distance-related charges applied to traffic within the area surrounded by *cordon A* The charge is levied on the basis of the total distance travelled within the cordon. This policy differs from *Policy 1* in that it seeks to charge all traffic within the designated area, not just that which enters it, and, since the charges reflect the distance travelled, it will fall hardest on those who drive furthest.

Policy 5 distance-based charges applied to traffic within the area surrounded by *cordon C.*



Area within *Cordon A*

Area within *Cordon B*

Figure 1: The location of the three charge cordons

Policy 6 time-based charges applied to traffic within the area surrounded by *cordon A*. The charges are proportional to time spent on the network rather than to distance travelled. This will mean that drivers who use slow routes will pay proportionately more than those who use fast routes (supporters of this charging regime point out that, by charging people more for using slow links, the incidence of charges will be close to that of congestion and that this will prompt more efficient behavioural responses).

The charges under *Policy 1* are £2.00 (approx 3€) per day. The charges under policies 2-6 are set so as to maintain approximately the same total revenue as is achieved under *Policy 1*. (see later). We have initially assumed that all drivers have to pay the charges but will explore the consequences of allowing exemptions for disabled drivers, residents and hospital visitors.

3.4 Impacts of the policies

Results for Policy 1 Table 1 details the characteristics of drivers affected by *Policy 1*.

Table 1: Characteristics of drivers subject to a charge under *Policy 1.*

Characteristic	Number of drivers		Drivers with an annual income of less than £10,000		
	n	%	n	as % of all such drivers	as % of drivers in this category
Total drivers	15372	100	1165	100	8
Travelling to work	12978	84	409	35	3
Travelling on employer's business	115	1	11	1	10
Escorting someone (social purpose)	128	1	66	6	52
Escorting someone (to school)	509	3	188	16	37
Travelling to hospital (other than for work)	212	1	86	7	41
Travelling to Shops	261	2	102	9	39
Travelling to college or university	278	2	120	10	43
Travelling on personal business	462	3	173	15	37
Returning home	429	3	142	12	33
Female	4922	32	457	39	9
Age 16-30	5012	33	365	31	7
Age 31-60	8701	57	801	69	9
Age 61+	1659	11	541	46	33
Member of Non-white ethnic group	976	6	201	17	21
Disabled	561	4	48	4	9
Lone parent	180	1	8	1	4
Annual income[1] under £10,000	1165	8	1165	100	100
Annual income[1] £10,001-£15,000	5128	33	0	0	0
Annual income[1] over £15,000	9112	59	0	0	0
Registered disabled and lone parent	17	neg	1	neg.	6
Registered disabled and female	204	1	26	2	13
Registered disabled and non-white	60	neg	3	neg.	5
Over 60 and female	799	5	184	16	23
Over 60 and non-white	180	1	11	1	6
Lone parent and non-white	14	neg	0	0	0
Registered disabled, female and non-white	28	neg	5	neg.	18

[1] For people in work, these incomes are based on their personal income before tax. For people not in work they are based on household incomes deflated to allow for multiple person households (on average we equate an annual personal income of £10,000 with an annual household income of £10,400).

The table includes some general characteristics but emphasises those which, sole or in combination, might be thought to indicate some vulnerability to the imposition of charges. Particular emphasis is therefore placed on drivers who have an annual income of less than £10,000 (14,000€). The figure of £10,000 was chosen because, for these people, a daily charge of £2 would amount to almost 5% of their income. The reasons for including disablement, old age and lone-parenthood in the list are, we assume, self-evident. Inclusion of gender (female) and ethnicity (non-white) might be justified by concerns for personal security.

It is clear from column 1 that, of the 15372 drivers who would be subject to a morning peak cordon charge around the city centre, almost 85% would be on their way to work, around two thirds of them would be male, about 60% would have annual incomes above £15,000 and more than half would be aged 31-50. None of which appears to raise any particular concerns for social exclusion.

However, it is apparent that around 8% of the people affected by the cordon charge would have annual incomes below £10,000, around 41% would have annual incomes of

less than £15,000 and around 10% would be aged over 60. A small proportion, but still a significant number, would be disabled, engaged in hospital trips, escort trips and members of non-white ethnic minorities.

Columns 3, 4 and 5 of Table 1 provide more information about the 1165 affected drivers whose annual income is less than £10,000. It can be seen from column 4 that, among these people, the work journey is still the predominant purpose but that other purposes are much more evident. The proportions who are over 60, female and/or members of a non-white ethnic group are significantly higher than they are among the whole population of affected drivers. Column 5 shows that the affected escort trips, hospital trips and trips to college or university are trips are particularly likely to be by people on low incomes. The figures in column 5 could be used to indicate how much "leakage" there might be if an exemption were targeted at the specified group. For example, if an exemption were provided for disabled people, only 9% of them would have annual incomes below £10,000. If an exemption were provided for hospital visitors some 41% of the recipients would have incomes below £10,000 but 59% would have incomes above this level.

Table 1 quantifies the number of people whose participation in society might be particularly compromised by the introduction of the cordon charge. As we will see later, more detailed investigation can indicate such details as where they live.

Table 2: Summary Statistics for Six Policies

	Number of affected drivers (italicised figures indicate what % this is of number affected under policy 1)				
	Policy 1	*Policy 2*	*Policy 3*	*Policies 4 and 6*	*Policy 5*
Total number of drivers	15372	11603 *75*	9439 *61*	16460 *107*	19624 *128*
Average household income (£k p.a.) of non-workers	17.4	17.6	17.5	17.5	17.4
Average personal income (£k p.a.) of workers	17.5	17.8	17.6	17.7	17.6
N drivers with annual income of less than £10,000[1]	1165	969 *83*	908 *78*	1247 *107*	1389 *119*
N disabled drivers	561	410 *73*	316 *56*	610 *109*	634 *113*
N lone-parent drivers	185	136 *74*	95 *51*	185 *100*	196 *106*
N drivers aged over 60	1659	1401 *84*	1226 *74*	1812 *109*	1860 *112*
N female drivers	4922	3853 *78*	3013 *61*	5324 *108*	6102 *123*
N drivers from non-white ethnic minorities	976	734 *75*	362 *37*	1041 *107*	1339 *137*
N drivers en route to work	12978	9335 *72*	7600 *59*	13822 *107*	15818 *122*
N drivers not en route to work	2394	2268 *95*	1839 *77*	2625 *110*	3956 *165*
N drivers on school escort trips	509	490 *96*	422 *83*	561 *110*	598 *117*
N drivers visiting hospitals	212	201 *95*	137 *64*	238 *112*	278 *131*

as defined in footnote to Table 1.

Summary Statistics for the Six Policies

Table 2 summarises, for each of our six policies, the characteristics of the car drivers who, unless they changed their travel patterns, would be required to pay a charge.

By comparing the numbers of affected drivers in each category for each policy, it is possible to see how the incidence of specific characteristics differs between the policies. Thus, compared to *Policy 1*, it is clear that:

- Policies 2 and 3 affect progressively fewer drivers (this is because the *Policy 2* cordon is round a smaller area and so fewer people need to cross it, and because the *Policy 3* cordon is so far out from the city centre, most drivers start their journeys inside it and so do not need to cross it);
- drivers affected by *Policy 2* have slightly higher average incomes (this reflects the fact that *Policy 2* targets drivers working in that part of the city characterised by highest salaries);
- Policies 2 and 3 affect fewer drivers in any of our at-risk groups (this simply reflects the lower number of drivers affected);
- Policies 4-6 affect more drivers in all of our at-risk groups.

The italicised figures in Table 2 indicate the number of affected drivers as a percentage of the number affected under *Policy 1*. By comparing a figure in a given column in any row with that in the first row of a given column, it is possible to see whether, for that policy, the characteristic to which the row relates is over- or under-represented. It is apparent that, compared to *Policy 1*:

- drivers affected by policies 2 and 3 include a higher proportion on the lowest incomes (reflecting the fact that policies 2 and 3 include a higher proportion of non-workers);
- drivers affected by policies 5 and 6 include a *lower* proportion of people on the lowest income
- drivers affected by *Policy 2* include a higher proportion of drivers who are over 60, and making trips other than to work - particularly school escort and hospital visiting (reflecting the location of the main hospital and a university within cordon *B*);
- drivers affected by *Policy 3* include a higher proportion of drivers who are on low incomes, over 60, and making trips other than to work (particularly school escort), but that they include a smaller proportion who are disabled, lone parents or members of non-white minorities.
- drivers affected by policies 4 and 6 include a higher proportion of drivers who are not en route to work (particularly hospital visiting and school escort), a marginally higher proportion who are over 60 or disabled, but otherwise the affected population is very similar to that for policy 1**;**
- drivers affected by *Policy 5* include a lower proportion of drivers who are on low incomes, disabled, lone parents, over 60, or female.

Consideration of the absolute numbers might lead to the conclusion that polices 2 and 3 are to be preferred (because they affect fewer people in our at-risk groups) while consideration of the relative proportions of at-risk people among the affected drivers would suggest that *Policy 5* should be preferred (because the at-risk drivers make up a smaller proportion of the drivers affected). In fact neither of these analyses tells the whole story because they do not take account of the fact that not all affected drivers would be affected to the same extent.

Assuming that the local authority wished to derive approximately the same revenue from each of the six policies, the charge would be set to reflect the number of drivers who

would be "caught" and, for policies 4-6, the extent of their exposure. Examination of the relevant data suggests that, in order to achieve the same daily revenue (£30,744) as is achieved under *Policy 1* from a £2.00 charge at cordon *A*, the charges would have to be set as shown in Table 3. Table 3 provides some information on the implications of these charges on the at risk groups identified.

It is immediately clear that the average charges payable under policies 4-6, which relate to all people driving within the cordons rather than simply to those who drive across them, are substantially lower than those for policies 1-3. The charge payable under *Policy 3* is the highest of all the policies tested and this reflects the fact that it affects the smallest number of people.

Under policies 4-6, drivers will pay a charge proportional to the distance, or time, travelled in the charge area. A wide range of charges would be paid, for example, the highest charge payable under *Policy 4* is £8.64 (£6.64 higher than the fixed charge under *Policy 1*) while that payable under *Policy 5* is only £3.84. The lower charges per unit distance (or time) under *Policy 5* (at cordon *C*) mean that the maximum charges payable are lower than under the equivalent policies at Cordon *A* – despite the potential for longer journeys within cordon *C*.

Although *Policy 4* requires some people to pay £8.64, 64% of the drivers under this scheme would be paying less than the £2 charge under *Policy 1*. Under *Policy 5* very few drivers would pay the maximum charge and 75% of the drivers will be paying less than £2.

If the number of low-income people required to pay £2.00 or more is regarded as an indicator of potential increase in social exclusion then the policies which involve a charge per unit time or distance would be preferred to those which involve a charge to cross a cordon. *Policy 5* would be preferred over all others since it only affects 182 drivers to this degree – about 15% of the number who would pay £2.00 under *Policy 1* and about 20% of the number who would pay £3.26 under *Policy 3*.

Table 3 shows that, although *Policy 5* performs well in not requiring many low-income drivers to pay more than £2.00, it is not so successful in avoiding requiring such payments from drivers over 60 years of age; *Policy 4* does better in this respect. The data in table 3 could, of course, be further disaggregated to show any combination of characteristics and charges that is thought particularly interesting or sensitive. The results would then help to determine which policy would be best implemented in terms of the at-risk groups.

3.5 The spatial distribution of drivers affected by the charges

The spatial distribution of the origins or destinations of trips affected by the charges can be very helpful in understanding the distribution of impacts. Figure 2 shows the location of origins of trips by drivers whose annual household income less than £10,000 and who are affected by the charge envisaged under *Policy 1*. It is clear that these drivers are spread quite sparsely across the built up area.

Table 3: incidence of charges

	Policy 1	*Policy 2*	*Policy 3*	*Policy 4*		*Policy 5*		*Policy 6*	
Fee charged (£)	2.00	2.64	3.26	1.08 per 500 metres		0.12 per 500 metres		0.50 per 30 seconds	
Average Fee paid (£ per day)	2.00	2.65	3.26	1.86		1.56		1.86	
Maximum fee paid (£ per day)	2.00	2.65	3.26	8.64		3.84		8.50	
	Total no. affecte	Total no. affecte	Total no. affecte	No. paying < £2	No. paying	No. paying 1<£2	No. paying >£2	No. paying	No. paying
Total number of drivers	15372	11603	9439	10593	5867	14769	4855	8458	8002
drivers with annual income less than £10,000	1165	969	908	753	494	1207	182	632	615
disabled drivers	561	410	316	377	233	480	154	332	278
lone-parent drivers	185	136	95	120	65	146	50	80	105
drivers aged over 60	1659	1401	1226	1135	677	946	914	958	854
female drivers	4922	3853	3013	3272	2052	4373	1729	2613	2710
drivers from non-white ethnic minorities	976	734	362	655	386	987	352	569	472
drivers en route to work	12978	9335	7600	8958	4864	12521	3297	7163	6658
drivers not en route to work	2394	2268	1839	1643	982	2334	1622	1298	1327
drivers on school escort trips	509	490	422	334	227	353	245	337	224
drivers visiting hospitals	212	201	137	127	111	122	156	96	142

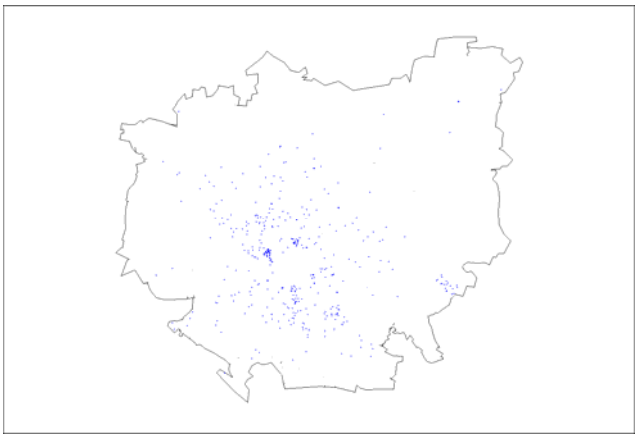


Figure 2: Origins of low income drivers who would be subject to charges envisaged under *Policy 1* (each dot indicates a separate origin)

This suggests that spatially-specific "solutions" to the problem of potential social exclusion - for example via the provision of additional bus services or park and ride facilities or by the provision of discounts for drivers living within or just outside the cordon – are unlikely to be effective.

Figure 3 is equivalent to Figure 2 but relates to *Policy 3* (which envisages a charge at cordon *C*). It shows that most of the affected drivers originate just outside the charge cordon; which suggests that, for this policy, spatially-specific solutions might be worth considering.

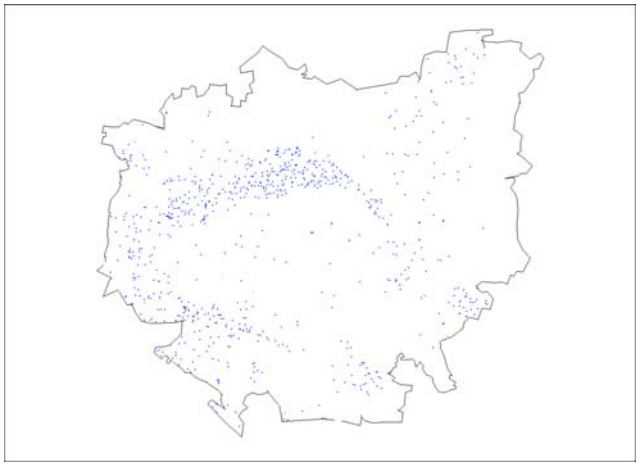


Figure 3: Map showing origins of low income drivers who would be subject to charges envisaged under *Policy 3* (each of the dots represents 1 trip)

Maps such as those in Figures 2 and 3 could clearly provide a basis for planning additional public transport services or for determining the boundary of an area whose residents might be offered a discount. The investigation of the spatial incidence of potential problems could of course be further pursued. For example, if a map of the origins of trips by drivers who are disabled lone parents on low incomes revealed spatial concentrations of such people, thought might be given to making special provision for this group (in fact a map of this particular combination of characteristics revealed that the few drivers affected by *Policy 5* who exhibit this particular combination of characteristics are fairly evenly spread across the city).

3.6 Implications for the design of road charging schemes.

Variants on the policies described in Section 3.3 above might be able to reduce the impact on at-risk groups. The decision on whether to adopt any of these variants would, quite properly, be political but our methodology can help to inform such a decision.

We have already discussed the possible role of additional public transport services targeted to serve the needs of the at-risk groups and have shown how our methodology might be used to help plan such measures.

Another possibility might be to offer reduced charges or exemptions to some of the more vulnerable groups. The financial implications of such actions, and the number and type of people affected, can be calculated quite simply. Table 4 presents some summary statistics in respect of possible exemptions under each the six policies. It is clear that the "same" amendment has quite different consequences under the different policies. For example, a decision to provide exemption permits for disabled drivers would cost much more (in terms of revenue forgone) under *Policy 4* than under any other policy, and although *Policy 5* affects more disabled drivers than any other policy, it would be less expensive, in terms of revenue foregone, to provide these people with exemption permits.

If exemption permits were issued for hospital visitors then, under *Policy 5* this would result in 238 people being provided with permits at a cost of £674 a day. In terms of revenue foregone this is only 2% of the total. Under *Policy 6* the same 238 permits would imply a reduction of daily revenue of only £588. The minimum loss of revenue would be under *Policy 1* (£424 per day – not much more than 1% of revenue).

The degree of "leakage" (defined as exemptions which benefit people who are not on the lowest incomes) that would arise from various exemptions was identified, for *Policy 1*, in Table 1 and was discussed earlier in Section 3.4. Table 4 now shows, for two potential exemptions, how the extent of leakage differs under different policies. It shows that the high level of leakage associated with exemptions for disabled drivers under *Policy 1* are also present under policies 2-6. However, it appears that an exemption for hospital visitors would give much lower leakage under *Policy 3* than under any of the other policies, and that it would be greatest under *Policy 2.*

Table 4: Effect of specified amendments to the policies

	Policy 1	*Policy 2*	*Policy 3*	*Policy 4*	*Policy 5*	*Policy 6*
Exemption for disabled drivers						
Number of drivers affected:						
total	561	410	316	610	634	610
annual income less than £10k	48	40	30	56	66	56
Leakage (%)	91	90	91	91	90	91
Revenue foregone (£ per day)	1122	1082	1030	1537	1011	1239
Exemption for hospital visitors						
Number of drivers affected:						
total	212	201	137	238	278	238
annual income less than £10k	70	64	61	83	101	83
Leakage (%)	67	68	55	65	64	65
Revenue foregone (£ per day)	424	530	447	674	601	588

It is often argued that residents of any charge zone should not pay the charge as they have no option but to travel in their local area. Calculations, not shown in Table 4, indicate that this would be a very expensive option – particularly in policies 4 and 6 and even more so for *Policy 5*. The revenue loss in policies 1 and 2 would, by contrast be very modest at around 3% of total revenue. This policy would also result in a high level of leakage.

4 Summary and conclusions

4.1 Road user charging and social exclusion

If road user charging is introduced some drivers will reduce their car use due to the charge and others will have to make economies elsewhere. Either eventuality could have serious consequences for some people and could make it difficult for them to continue to participate in society.

The groups who are most at-risk from road charges are those on low incomes who have no realistic alternative to make particular journeys by car. Such people may be car-captive because of the absence of a viable alternative mode. Their trip may be too long, or their health insufficient, to allow them to contemplate walking or cycling, public transport services may be non-existent or inaccessible to them and their trip may not be substitutable. In addition to low income, the indicators for being at-risk include disability, age, gender, membership of a social minority and responsibilities for the transportation of others.

Although the provision of exemptions, and the use of revenues to improve the mobility of at-risk groups, could go some way to ameliorating these problems it could prove very difficult to target the help effectively. The methodology presented in this paper is designed to inform decision makers where these people are located and advise on which form of road user charging would result in the least number of them being affected.

4.2 The Leeds case study

The Leeds case study has highlighted that the impact on at-risk groups differs depending on the location and extent of the charge area and the basis of the charge. Different schemes require different charges to maintain the same revenue and the charges which result affect can be of very different sizes. The various at-risk groups are affected to different extents by each of the policies tested and the financial implications of providing exemptions are markedly different – as is the efficiency with which exemptions can be targeted on the most vulnerable groups.

Application of the Popgen-T methodology has highlighted the differences between the policies in terms of their impact on at-risk groups. It appears that a policy under which charges are proportional to distance driven within the charge area would have less serious consequences for at-risk groups and that, although the number of affected drivers is higher when the charge area covers a large area of the city, the number of low income drivers having to pay significant daily charges is less than when the charge area is restricted to the city center. If the charge is to be based on drivers crossing a cordon then the situation is reversed - a tight cordon affects more people but to a lesser extent.

4.3 Further development and application of the method

Popgen-T has proved a useful tool for examining a range of road charging schemes in Leeds. The same methodology could, of course, be used to study similar schemes elsewhere. The further development and wider application of Popgen-T is discussed in more detail in our final report to sponsors where we identify three possible extensions of our work:

- revision of the software to deal with a wider range of characteristics;
- extension of the method to investigate behavioural response, and thus to allow consideration of the second-order impacts of policies;
- investigation of a wider range of road charging options in the Leeds study area; and
- investigation of a wider range policies in Leeds or elsewhere.

. The inclusion of a wider range of characteristics is conceptually simple and is only constrained by the availability of suitable data. The possibility of adding characteristics derived from sample surveys could prove particularly rewarding.

The extension of the method to investigate behavioural responses by the affected drivers would require considerably more work and, by introducing more uncertainty and speculation into the analysis, could actually reduce the value of the output. The richness of information about individual travellers would make prediction of their behavioural responses easier than is often the case, and it would certainly be useful to be able to explore and quantify the second and third order impacts of policies (including such things as the effect of rat-running on residents, the effect of increased overcrowding on people wanting to board busses in the inner suburbs, and the effect of changes in retail patterns on non car owners). The prediction of response would however bring an additional issue to the fore, namely are travellers who change their behaviour in response to the policy gain or lose more, or less, than those who, because they regard the alternatives as less desirable, choose to retain their existing pattern of behaviour?

The investigation of a wider range of road charging options in the Leeds study area would be relatively straightforward and could shed light on issues such as the equity implications of different balances between fuel tax, vehicle ownership taxes and charges at the point of use.

Popgen-T could be used to investigate a policy other than road charging (for example: to investigate the impact of the removal or enhancement of a particular bus service; or to study the impact of a reallocation of road space on a particular link). Any such work could be done using our existing database but it would obviously be desirable to update it to take advantage of recently published census data.

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