Road User Charging: Acceptability and Effectiveness

by

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

One of the major barriers to implementation of road user charging is how to design a scheme that is simultaneously acceptable to the public and effective in achieving its objective. The aim of this research was to study how road user charging can be designed to achieve acceptability and effectiveness. Acceptability was reflected by voting behaviour, in which individuals were asked whether they were willing to vote for charging schemes. Effectiveness in reducing congestion was evaluated by mode switching of commuters. The research demonstrated the effects of the system benefits (car and bus travel time reduction, environmental improvement and revenue use) and the system features (charging levels, charging methods, charged times and charged areas). It also investigated the impacts of personal characteristics and perceptions. The research also examined the effect of selfish and social perspectives, reflected by the perceptions of benefits to self and to society, on acceptability.

Paper based SP questionnaires were distributed to residents and employees in Leeds and London between November 2000 and March 2001. A total of 830 responses were received. The analysis technique was based on random utility theory, which was used to formulate the multinomial-logit based models. The standard logit model was used to demonstrate the overall effects of variables for the whole sample. The segmentation model, based on the incremental factors, was used to identify the different effects for different groups of people. The random parameters logit model was used to examine taste variations (heterogeneity) among individuals from unobserved factors, which were unable to be captured by the segmentation model.

The study found that although more highly effective charging schemes (with higher levels of charge) were less acceptable, while more highly acceptable schemes (with lower levels of charge) were not substantially less effective. In other words, effective charging schemes were not always unacceptable.

Acceptability varies substantially across system characteristics. Acceptable road user charging schemes can be designed by limiting the area of charge to within the city centre and having a fixed charge per day. Support would be increased significantly if the scheme was expected to bring substantial environmental improvement. Over 50% of people would vote for this scheme, if the charging level is less than £3 per day in Leeds, and less than £7 per day in London.

Effectiveness in reducing car use had a small variation across the factors. Overall, any charging system is relatively effective in reducing car commuting. Even at £1 per day, over 20% of car commuters in Leeds and about 30% in London would switch to non-car modes or uncharged times. When the charge rises to £7 per day, the reductions would increase to around 40%. A small number of non-car users would change to use cars because of car delayed-time reductions.

The acceptability and effectiveness can be improved by provision of clear information on the principles and objectives of charging, on the severity of congestion and pollution, on the adverse effects of car use, and on the effectiveness of road user charging in reducing the problems. In addition, individuals need to be convinced that road user charging will provide benefits both to themselves and to society as a whole.

In brief, this research suggests that the relationship between acceptability and effectiveness of road user charging schemes is not high. It is not simply the case that highly effective schemes are less acceptable. Road user charging can be designed to achieve high acceptability and effectiveness.

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Chapter 1

Introduction

1.1 Background

Generally, increasing car use leads to more problems; for example, increased congestion and damage to the environment, which in turn lead to a decrease in the quality of life. Therefore it has been suggested that car use should be controlled (Goodwin et al., 1991). One transport policy to do this is road user charging. It has been widely suggested by transport economists and planners for several years. The great interest in road user charging for various governments has been mainly stimulated by the desire to find new sources of revenue for transport projects, and by the failure of alternative policies to cope with the growth of traffic congestion (Small and Gomez-Ibanez, 1998).

However, it is not readily acceptable to the public. Public acceptability is probably the greatest barrier to the implementation of road user charging (Jones, 1998). Even though during last ten years there has been a great deal of research into how to increase the acceptance of road user charging, there is still doubt about how to design the scheme to be acceptable and effective. A fundamental question can be set as "... is it possible to design an urban road pricing scheme that is both publicly/politically acceptable and effective at meeting policy objectives?" (Jones, 1998).

This is difficult to answer because it is not very clear how people will perceive the benefits and respond to different road pricing systems. In general, the benefits of a road user charging scheme are not appreciated by all individuals. People may feel they lose because of the charge (Small and Gomez-Ibanez, 1998). They may not want to pay for what was free (Giuliano, 1992; Small, 1992). Many car users also see themselves as 'captive' to the charge and do not perceive personal benefits (Giuliano, 1992). However, individuals are likely to be willing to pay for things they wish to acquire (Jones, 1998). These considerations lead to a hypothesis that road pricing would not be acceptable to the public, especially to car users who face the charges, unless some benefits are perceived as either benefits to the individuals (self benefits) or community benefits, or both. If pricing is to be introduced, car users will have to be convinced that its benefits are worth paying for (Giuliano, 1994). In other words, people may vote for a policy that makes them better off; makes their lives easier, more comfortable and less stressed; improves the environment; and makes the economy more efficient (Goodwin, 1997).

The features of a road user charging scheme are likely to directly influence individuals' travel behaviour; through variations in charging levels, charging methods, charged periods of time and charged areas. Some car users may respond to a charging system by paying and driving. Some may respond by changing travel behaviour; for example, using another mode, changing their route, changing time of travel and so on. Public acceptance of the system would relate to whether they are satisfied with these responses. In summary, the details of the scheme: how charging is administered and how the benefits are returned to the public, will affect both the public's attitude towards the scheme and their behaviour.

In addition to charging system characteristics, acceptability is likely to be influenced by individuals' preferences. Some people may not accept the policy because they lose benefits even though the public gain. On the other hand, some people may accept it because society as a whole is better off. These perspectives may be called selfish and social perspectives, which relate to perceptions of benefits to self and to society. These perspectives may deeply influence individuals' propensity to accept and support the policy. For example, some people may be willing to pay to preserve a service that benefits others or society as a whole (Bonsall et al., 1992).

1.2 Objectives and Methodology

The research aims to examine the impacts on acceptability and effectiveness, in order to help in the design process of road user charging schemes. It also investigates the relationship between acceptability and effectiveness. The main research question is: *how can road user charging schemes be designed to be simultaneously acceptable to the public and effective in achieving their objective?* The conceptual framework of the study is illustrated in Figure 1.1.

Therefore the objectives of study are to:

- examine the effects of road user charging characteristics, benefits and system features, on acceptability and effectiveness;
- examine the impacts of personal characteristics and perceptions on acceptability and effectiveness;
- study the effects of selfish and social perspectives on acceptability; and

- investigate whether acceptable systems are effective in reducing car use.

The four main factors examined include road user charging benefits, system features, personal perceptions and socio-economic characteristics. The basis for these is established in Section 2.5. Briefly the key characteristics considered are: (a) Benefits of road user charging include: car and bus travel time reduction, environmental improvement and revenue allocation. (b) System features involve: level of charge, method of charge (fixed charge per day, time-based, distance-based and delay-based), and time and area of charge. (c) Individual perceptions are related to some hypotheses that:

- When the public perceive their current travel situations as acceptable, it would be difficult to encourage them to support charging schemes and change their behaviour.
- When transport problems (congestion and pollution) are not perceived as serious, this is a problem for introducing charging schemes.
- When road user charging is not perceived as an effective solution in reducing the problems, it is unlikely to be acceptable.
- When individuals have a strong dislike of charging, road user charging would be difficult for these people to accept.

(d) socio-economic characteristics include travel mode used, income, gender, age and household location.

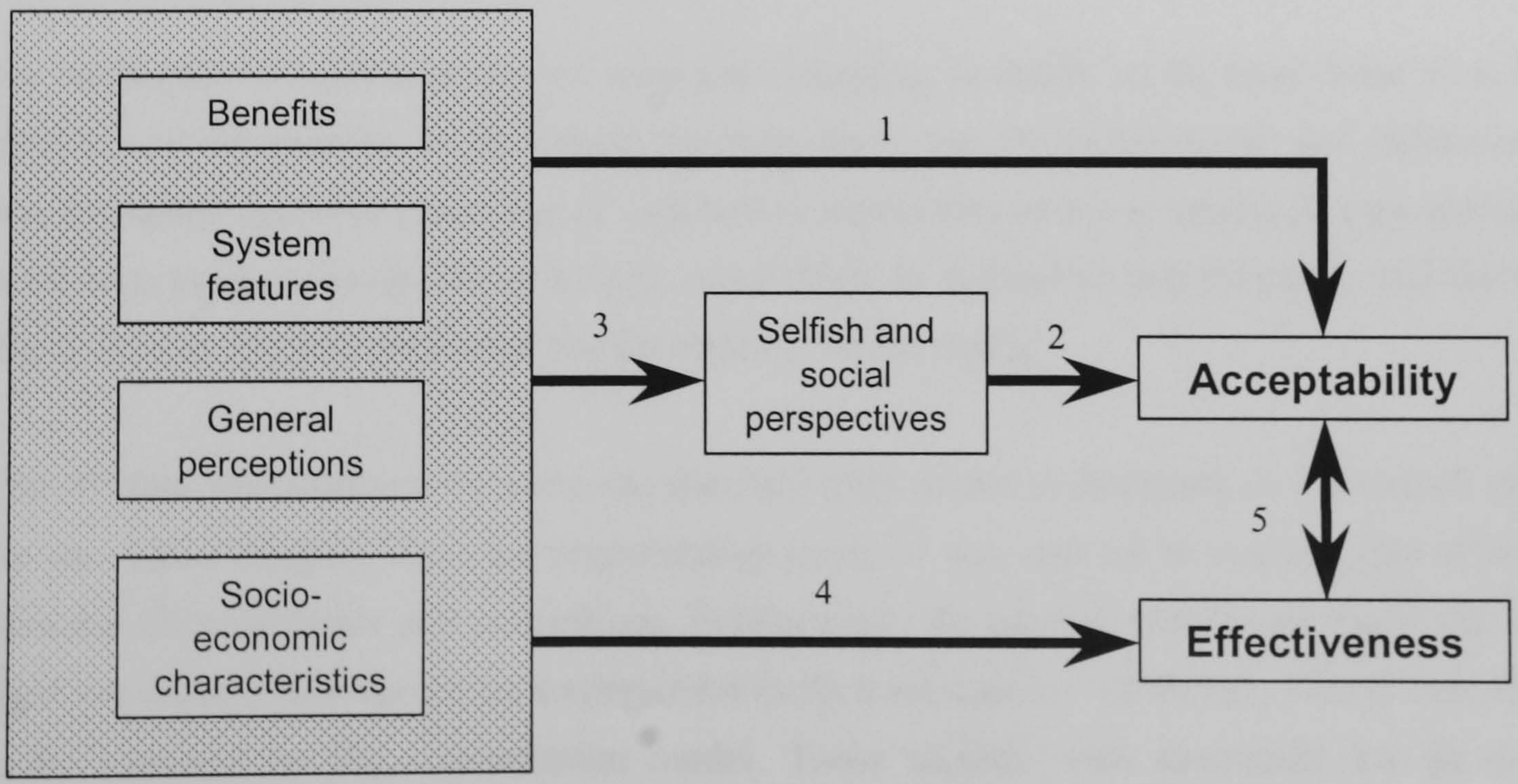

Figure 1.1 Conceptual framework for the study of acceptability and effectiveness

Five hypotheses of the study are identified in Figure 1.1 and tested in data analysis:

(1) The four factors have direct effects on acceptability of road user charging (tested in Chapter 6).
(2) Acceptability is influenced by selfish and social perspectives (tested in Chapter 7).
(3) These perspectives are results of individuals' evaluations of the charging characteristics (tested in Chapter 7).
(4) The factors affect travel behavioural responses which influence effectiveness of road user charging schemes in reducing car use (tested in Chapter 8).
(5) Acceptability has some relationship with car use reduction. Car commuters may not accept the scheme if they have to change from using their car to other modes (low acceptance, high effectiveness). On the other hand, they may accept it if they perceive some benefits from paying without changing behaviour (high acceptance, low effectiveness) (tested in Chapter 9).

To examine these hypotheses, the stated preference (SP) technique was used. The SP exercises were designed and developed through a set of pilot surveys. Hypothetical charging scenarios were presented to respondents, following by the questions to measure acceptability and behaviour responding to each scenario.

Acceptability was measured by voting behaviour, in which individuals were asked whether they are willing to vote for charging schemes. Selfish and social perspectives were reflected by perceptions of benefits to self and to society.

For evaluation of effectiveness of road use charging, it needs to be clear what is a main objective of the scheme. In this study, the main focus was for reducing car use. Effectiveness was evaluated by mode switching of commuters responding to the scenarios. It was specific to work trips because mode choice is very much likely to depend on trip purposes, and the work trip is seen as the most important for the majority of the public.

The SP data was analysed by using the standard logit model to demonstrate the overall effects for the whole sample. Then the segmentation analysis was applied to examine the effects of personal characteristics and perceptions. Furthermore, the random parameters logit model was used to examine taste variations among individuals from unobserved factors, which were unable to be captured by the segmentation model. These models were developed for the voting behaviour and mode choice models, which were then used for predictions of levels of acceptance and levels of car use reductions for different charging schemes.

In summary, in order to assess how to design road user charging schemes that are acceptable to the public and effective in achieving their objective, this research examines not only the effects of the charging systems characteristics, but also the effects of intrinsic motivations of individuals.

1.3 Outline of Thesis

The thesis is written in the order of the research process. A graphical presentation of the thesis's outline is in Figure 1.2.

The first part, Chapters 1 to 3, explains the construction of the study's framework. This chapter, Chapter 1, presents the objectives and hypotheses, which were set up from the literature review in Chapter 2. Then Chapter 3 introduces the SP technique, which was used in this study.

The second part of the research involves the design of SP questionnaire survey as shown in Chapter 4. The design and development of SP exercises, through four pilot surveys, is described. This chapter also explains the data collection process, and presents the sample characteristics from Leeds and London.

The third part, Chapter 5 to 10, comprises the analysis of results and conclusions. Chapter 5 reports the data of current travel situations, such as journey time and delayed-time. It presents results of the general perceptions including: the perception of the current situation, transport problems (congestion and pollution), and effectiveness of road user charging in reducing the problems. It also summarises general comments which respondents provided in space provided in the questionnaire.

Chapter 6 demonstrates the *direct* effects of the charging system characteristics, and personal characteristics and perceptions on acceptability. The voting behaviour model was developed for predictions of acceptance levels of different road user charging schemes.

Chapter 7 demonstrates the *indirect* impacts on acceptability. It shows that acceptability is highly influenced by the selfish and social perspectives. These perspectives are the results of individuals' evaluations of the system characteristics, and are influenced by personal characteristics and perceptions.

Chapter 8 demonstrates that effectiveness of road user charging is affected by some charging system features, and personal characteristics and perceptions. The effectiveness of charging schemes is focused on levels of car commuting reduction. The mode choice model was developed for the predictions of car commuting reductions responding to different road user charging schemes.

Chapter 9 illustrates the forecasts of acceptance levels of different groups of people for various road user charging schemes. These results were created from the voting behaviour models in Chapters 6 and 7. This chapter also illustrates the forecasts of levels of car use reduction, produced from the use of the modal choice model in Chapter 8. Then the relationships between acceptability and effectiveness are demonstrated.

Finally, Chapter 10 draws together a summary of the research objectives and methodology, and the main findings on how to design acceptable and effective road user charging schemes. It also provides some suggestions for further studies.

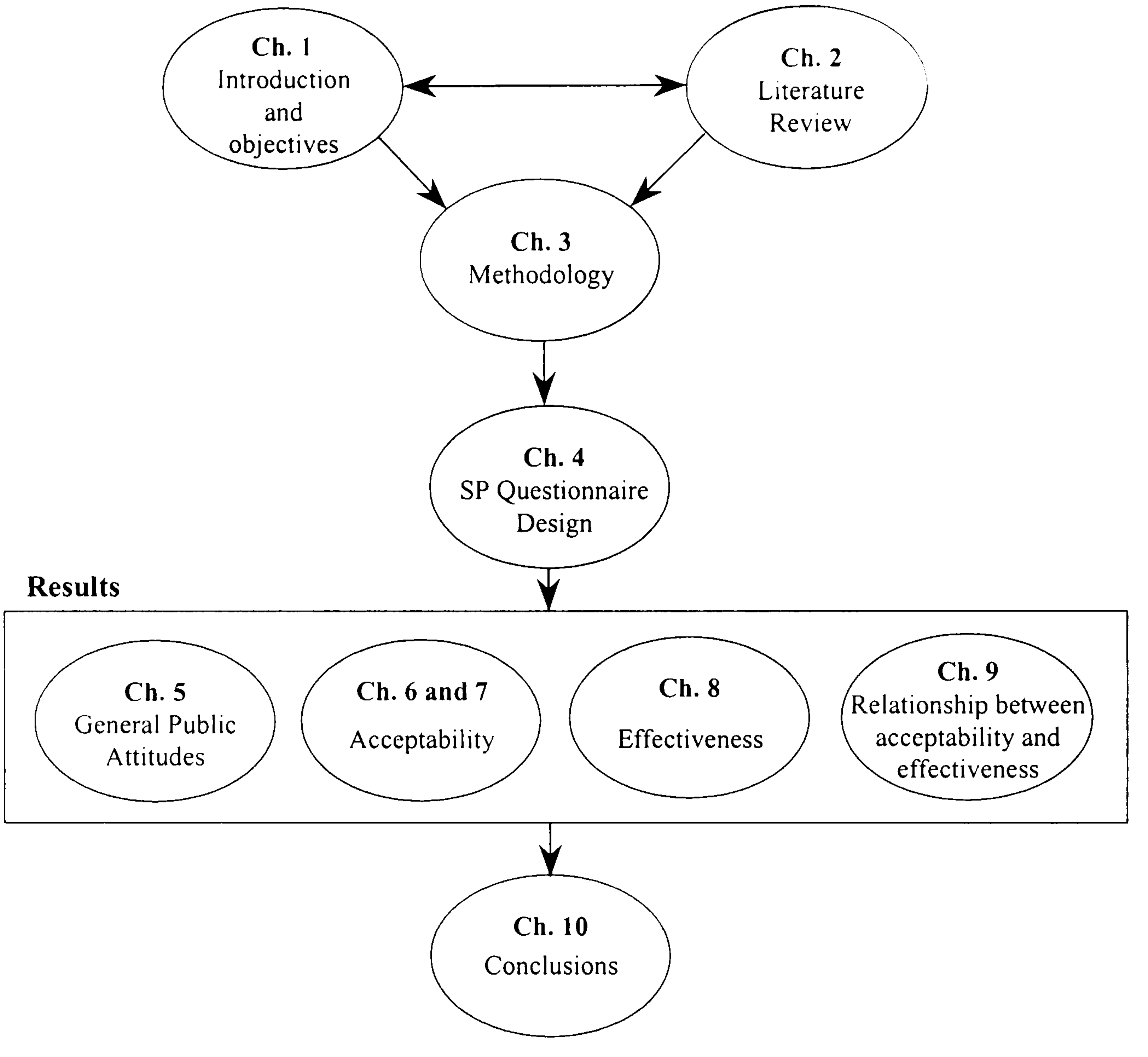

Figure 1.2 Outline of the thesis

Chapter 2

Review of Road User Charging

2.1 Introduction

The objective of this chapter is to provide an overview of road user charging and a review of relevant previous studies. It includes general background: definitions, objectives and development history in Section 2.2, and economic background in Section 2.3. The design of road user charging schemes is presented in Section 2.4. Then Section 2.5 reviews previous studies of acceptability of road user charging and the factors affecting acceptability towards ways to improve it. Section 2.6 reviews its effectiveness from experiences of implemented schemes and studies of pre-implementation places. Next, Section 2.7 presents a review of the relationship between acceptability and effectiveness. Finally, Section 2.8 summarises some implications of the literature review for this study.

2.2 General Background of Road User Charging

This section provides an overview about road user charging. This includes definition and objectives of the policy. Different terms have been used with the same or similar meaning as road user charging. Different goals can be set for different schemes. The development history of road user charging is also briefed in this section.

2.2.1 Definitions and objectives

Road pricing, in general, is a transport policy for charging motorists a fee for using their vehicles within specific areas or on specific roads. The main concept of road pricing can be defined in two ways by Jones and Hervik (1992). Firstly, by traffic engineers and transport planners it refers to the imposition of direct charges on road use, with a variety of objectives. These are for managing travel demand in order to alleviate traffic congestion and to reduce the environmental impacts from traffic, and for generating revenue to finance transport services and infrastructure. Secondly, by economists road pricing is referred to as the setting of pricing equal to the difference between the social marginal cost and the marginal private cost of a journey. It is a means of achieving what economists define to be optimal.

The term road pricing has been used to cover any fiscal form of traffic restraint (Thompson, 1990) including both direct and indirect charges of road users (Ministry of Transport, 1964; Lewis, 1993). However, various terms have been used in parallel with the term road pricing, e.g. road user charging and congestion charging (in UK) and congestion pricing (in USA), and the specific terms, e.g. road tolling, value pricing, variable pricing and peak period pricing.

In UK during 1990s, the term *road user charging* was widely used for specifying direct charge schemes and formally used by the government, but since 2000 it has been called *congestion charging*. In the USA, one particular form of road pricing called *congestion pricing* is only used for the objective of reducing congestion (Giuliano, 1992) by charging each motorist a fee that is directly related to the amount of congestion he or she causes in using a road; as a result motorists are encouraged to travel during less congested time, by less congested routes or by alternative modes, or not to travel at all (Gomez-Ibanez and Small, 1994). The Transportation Research Board (1994) also states that "congestion pricing would charge a premium to motorists who wish to drive during peak travel periods through strategies that could include tolls on roads or bridges, fees to enter congested areas, or changes in the structure of parking and transit pricing". The terms *variable pricing* and *peak period pricing* are sometimes used to specify that a charge is varied by time of day, in order to shift demand from peak periods to off-peak periods or other modes.

Road tolling is defined as road tolls or charges imposed by governments or private investors to finance the construction of new roads and maintenance of old roads where the objective is to maximise revenue (Luk and Chung, 1997). *Value pricing* was first introduced by the private operators of the SR91 Express Lanes in California. The term is defined by the Institute of Transport Engineers (ITE, USA) as a "system of optional fees paid by drivers to gain access to alternative road facilities providing a superior level of service and offering time saving compared to the free facility" (cited in Orski, 1998). Road tolling and value pricing are slightly different from the concept of road pricing. They may charge motorists for financing the construction costs or for providing better service, and may not be necessarily implemented on congested roads.

2.2.2 Development history in transport planning

The concept of road pricing was initially mentioned in the middle of the 18^{th} century (see Section 2.3). In the UK, the Smeed Report (Ministry of Transport, 1964) was the first full contribution of the theory of road pricing to policy implementation, which seemed to be a catalyst of interest in road pricing studies. Subsequently, the first practical road pricing scheme was applied in 1975 through the Area Licensing Scheme (ALS) in Singapore to reduce traffic congestion. Another country, which has successfully implemented road pricing, is Norway. Toll rings were installed to raise revenue for transport projects around Bergen in 1986, Oslo in 1990, and Trondheim in 1991. Many other countries are also interested in implementation of road pricing. In 1985 an electronic road pricing was on trial in Hong Kong. In 1988 the Netherlands Government developed a proposal for a road pricing implementation in the region called 'Randstad'. In 1991 the Swedish Government created a proposal for introducing tolls around Stockholm. In UK several local authorities, e.g. Bristol, Cambridge, Derby, Durham, Edinburgh, Leeds, and London, are interested in road pricing since the central government gave new powers to decide whether they want to implement road user charging and to provide them to use the revenue for investment (DETR, 1998). The most recent proposal (GOL, 2000; GLA, 2001) was prepared for London. More details of these schemes including implemented and pre-implemented cases are reported in Section 2.6.

In summary, so far the only successful implementations of urban road pricing are in Singapore, which replaced the manual (ALS) system by an electronic road pricing system in 1998, and Norway. Other countries are still studying road pricing and trying to gain support from the public.

2.3 Economic Background of Road User Charging

Over 200 years ago Adam Smith (1776a), a Scottish economist, already mentioned the principles of efficient provision of 'public good' (e.g. roads, bridges, canals and harbours). Smith argued that services should be paid for by those who benefit from them. Dupuit (1844), a French engineer, by using a simple example of the imposition of a toll on a footbridge, demonstrated efficiency of pricing, for which the benefit to users of the bridge was greater than the revenue collected from the users.

A substantial studies of the economics of road user charging, based on the marginal pricing concept pointed out by Marshall (1890), has been led by Pigou (1920) and Knight (1924). They introduced the simple two-road example and argued that by imposing a toll-tax on a congested road, total travel time would be reduced and encourage the more efficient use of road space, so that society's welfare would be enhanced. Walters (1954) clearly suggested that "motor taxation should be levied so that the marginal private cost of vehicle operation is brought nearer to the marginal social costs and the degree of congestion on our roads is reduced". Vickrey (1955) also stated that marginal cost should be concerned in an elaboration of any scheme of prices in order to achieve the efficient utilisation of facilities. However, this has not happened in practice. He believed that in "no other major area are pricing practices so irrational, so out of date, and so conducive to waste as in urban transportation" (Vickrey, 1963).

Since the cost rises as traffic speed falls, an extra cost is imposed on the average cost of all users when an individual driver is added to a road network. The average cost is slightly higher than before the individual joined, because of increase of travel time and pressure from other vehicles. This concept was mentioned by Walters (1961), Beesley and Roth (1962) and the Smeed Committee (Ministry of Transport, 1964).

A basic representation of the concept is presented in Figure 2.1. The demand curve represents the decreasing flow with increasing cost. The average cost curve shows an increasing cost as flow increases. The intersection of the demand curve with the average cost curve (point A) represents the equilibrium condition where flow is Q_0. The marginal cost curve illustrates the extra costs imposed on itself and other vehicles by the addition of one extra vehicle. If travel costs are increased by a road user charge CB, the flow of traffic reduces from Q_0 to Q_1 (optimal flow in which there is no extra cost imposed with an extra vehicle), where the demand curve intersects the marginal cost curve. With this charge, overall welfare of society would be improved, from which revenue plus benefits of those who are willing to pay for delayed-time reduction is higher than the loss of those who stop using the network.

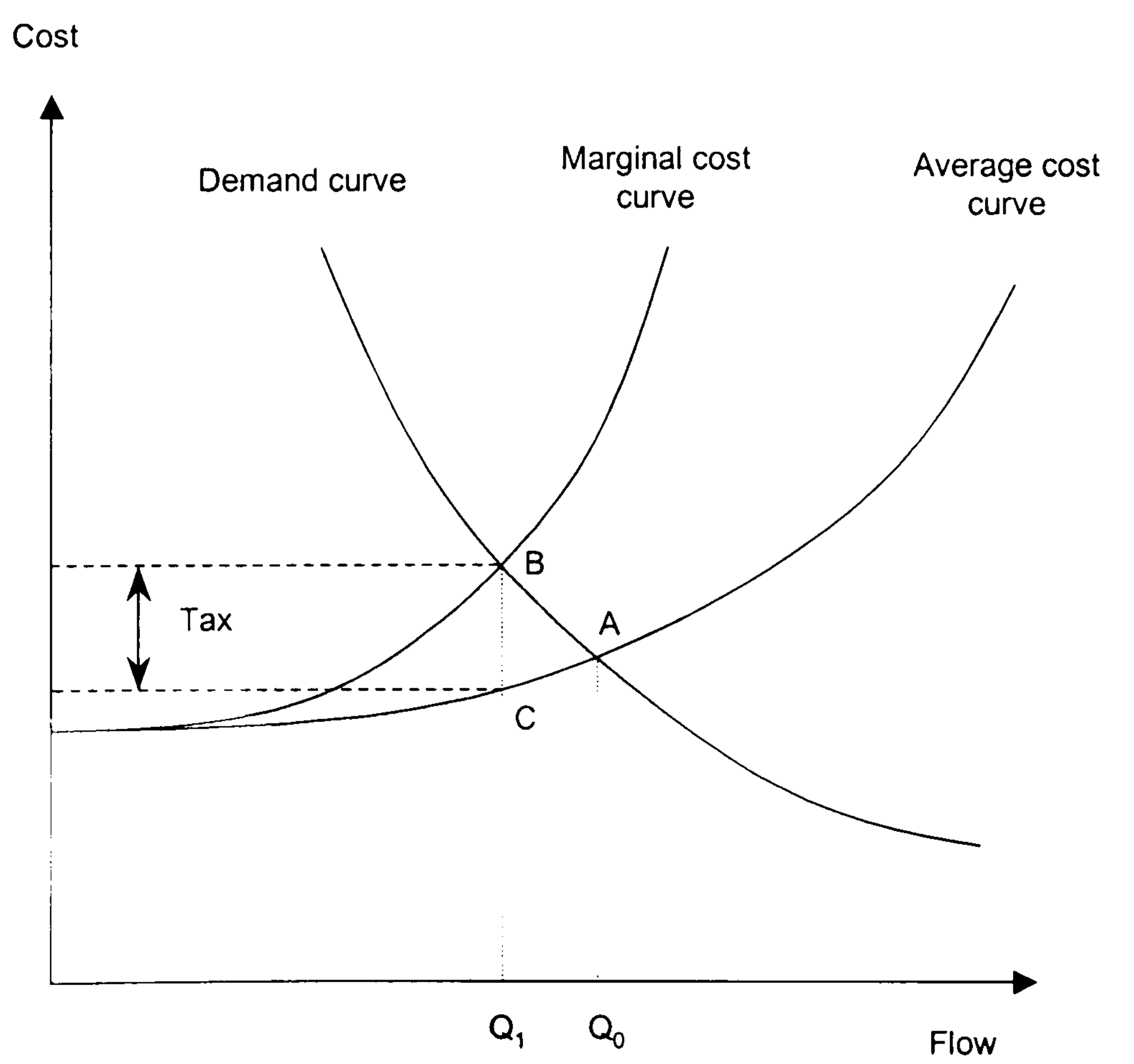

Figure 2.1 The simple economics of road user charging

The marginal cost function can be related to objectives of the charge. Firstly, if the objective is concerned only with congestion, the marginal cost curve will include the extra cost of delay, which vehicles impose on each other. Secondly, the curve will be different, if the objective is also concerned with other external costs e.g. air pollution, noise and accidents. Furthermore, in the case of maximising revenue, the curve is not taken into account. The level of charge is dependent upon the elasticity of the traffic demand.

Following the development of the basic charging concept, various studies have contributed to the economic theory of road pricing; for example, by Vickrey (1969), Walter (1987), Newbery (1990), Small (1992), Verhoef (1996) and Hau (1992a, 1998). The more recent development of the fundamental analysis involves the specification of demand and supply for congested networks. One theory is that the average cost curve can be bent backward when demand exceeds the maximum capacity of the network and speed falls with flow (hypercongestion). Nevertheless, there is still an on-going debated among researchers, who have still not agreed on the fundamental analysis.

The initial analysis (see e.g. Hau, 1992a; Verhoef, 1999) used a static model with the flow-based approach to explain the several points of intersection between the demand function and the backward-bending supply function. This supply function is derived from the relationship between average network speed and traffic flow for a given time period, in order to represent performance of the network. This is based on an assumption that congestion on a network is stable with continuous demand.

The flow-based approach is criticised by Hills and Gray (2000) who believe the backward-bending curve of cost/flow over simplifies the actual traffic network, in which traffic flow performs differently across different times and segments of network. By using a micro-simulation approach, May et al. (2000) addressed the behavioural responses relating to the spatial change (route choice) and the temporal change (departure time choice), whereas the costs to users were measured by tracking individual vehicles through the network, not cutting them in a given time period (as done for the performance curve).

This issue was investigated in detail based on micro-simulations in a DETR project 'Analysis of Congested Network' (2001) carried by ITS (University of Leeds), TORG (University of Newcastle upon Tyne), John Bates' Services (Consultant) and TRL (Transport Research Laboratory). They demonstrated that the use of performance curves to estimate supply curves is unreliable, and will generally overestimate the flow levels at which congestion charging is the first justified and underestimate its benefits. They claimed that *"once demand and supply have been properly defined and the dynamic complexity of congestion properly represented in a model of a suitable specification, then the impact on supply/demand interaction of any change (whether in pricing, regulation or investment) could be analysed in the normal way"*. However, this has not been achieved. Some further interesting studies are suggested by the project, for example exploration of dynamic rescheduling and route-choice behaviour, extension of modelling to include vehicle-occupancy and other important behavioural responses (e.g. shifts in mode, destination and frequency) to changes in trip costs, exploration of more complex networks and the incorporation of different journey-purposes and multiple user-classes.

2.4 Design of Road User Charging Schemes

In this section, the design of road user charging systems is presented. This includes general criteria of design and main structure of the systems.

2.4.1 General criteria of design

For the design of road user charging, although each city and country has its own constraints, some general criteria should be considered (Ministry of Transport, 1964; Thompson, 1990; Hau, 1992a):

- *fairness*, the charges should be perceived as fair by most travellers. This may involve basis of charge (e.g. based on quantity of road use), charged areas, time periods, and the travellers who are charged;
- *simplicity*, the charging system should be easy to understand by the public;
- *accuracy*, the charging system should always be accurate and be able to be verified by users;
- *enforcement*, the system should be capable of protecting against fraud and evasion;
- *privacy*, the system should be designed to protect users' privacy;
- *flexibility*, the system should be able to integrate with other systems, e.g. driver information system and roadside information system, etc.;
- *technology*, to achieve all above issues technologies should be appropriately applied.

These cover the four characteristics of a 'good' tax proposed by Smith (1776a) in his book 'The Wealth of Nations', in which the objectives of a good tax should be considered as equity, certainty, convenience and efficiency.

Furthermore, The High Level Group on Transport Infrastructure Charging (1998), convened by the European Commission, in considering the general concept of charging, commented that "the consequence of introducing the proposed charging systems should be to reduce rather than to increase total transport related costs to the economy as a whole". This decrease of overall costs could be achieved because the charge should increase efficiency of operation and use of infrastructure, and the 'external' costs which are incurred somewhere in the economy will be paid directly by those who cause them.

2.4.2 Structure of road user charging system

Various road user charging features have been studied; for example, those reviewed by May et al. (1991), May (1992), Hau (1992b), Lewis (1993), Gomez-lbanez and Small (1994), and Small and Gomez-lbanez (1998). These show many practical features of road pricing. In addition to setting objectives of the system, there are five key issues, which need to be addressed when designing a road pricing system (Jones, 1998):

- type of traveller/vehicle to be charged;
- charged area;
- charged period;
- charging level;
- charging basis.

Type of traveller/vehicle to be charged

To classify categories of travellers to be charged, the objectives of the scheme should be specified. Jones (1998) suggests that exemption of some types of traveller or vehicle can be made; for example: of pedestrians, cyclists and drivers of electric vehicles, when pollution reduction is an objective of the scheme; of pedestrians, cyclists and public transport users, when congestion reduction is an objective of the scheme; and of disabled drivers and goods vehicles, according to 'need' to use vehicles. Moreover, occasional users, visitors, high occupancy vehicle users and residents in the charged area should also be considered when designing the system. However, designers of the system needs to be concerned that if residents in the charged area were exempt from the charge, this is likely to affect the effectiveness of the scheme.

Charged area

Evidence from road pricing studies and implementation has shown various scales of implementation that can be divided into three (Decorla-Souza, 1993; Bhatt, 1993). Firstly, single facility pricing (small scale) involves charging for use of a segment of motorway or bridge, e.g. in USA, UK and France. Secondly, area-wide pricing (medium scale) involves charging within a small area such as a city centre or a central business area. For example, this has been implemented in Singapore and Norway's cities and also researched for Hong Kong, Cambridge, Stockholm, Leeds and London. Finally regional-wide pricing (large scale) involves charging within a regional area covering urban areas and road networks; for example, studied for Randstad region (Netherlands).

The design of road pricing scales is dependent on the objectives of the scheme, and local geographical factors. For example, when the objective is to reduce congestion the scale of charged area (covering a congested area) may be smaller than when the objective is to reduce pollution (Jones, 1998). Single facility pricing may be for the objective of covering the construction costs or reducing congestion on a particular section. If the objective is to generate revenue, the scale should be adequate to prevent 'rat running' and bypassing.

Charged period

The charged period is closely related to the objectives of the scheme (Jones, 1998). Many time periods could be used. A charge could be installed 24 hours a day when revenue raising is a major issue; for example, in Oslo. It could be applied only to the daytime for reducing congestion and pollution. At weekends some reasons for having no charge are that there are fewer problems and the scheme can gain more public acceptance (MVA, 1995).

Charging level

The level of charge is dependent on the policy objectives and local circumstances (Jones, 1998). For example, a low charging level could be applied for generating revenue, e.g. in Norway's cities, while a high charging level could be used for reducing traffic and pollution, e.g. in Singapore (Small and Gomez-lbanez, 1998), as well as social benefit optimality. The level of charge could vary by categories of user or vehicle (e.g. high charge for vehicles which cause the problem, and low or free for others), by time of day (e.g. same charge all day, charge peak time only, or charge all day with higher charges in peak times), by areas (e.g. high charge in the central area and low charge in the suburbs), and by direction of traffic (e.g. inbound only or both directions).

Charging basis

Two broad charging bases are categorised in the design: point-based and area-based (MVA, 1995; Milne, 1992; Jones, 1998). There are two types of point-based charging: cordon-based and cellular system, while there are five types of area-based charging: supplementary licence, time-based, distance-based, congestion-based and externality-based. These are described as follows.

Firstly, for point-based charging, drivers are charged when entering specific areas, defined by a single or series of boundaries. The charge is directly dependent on the number of boundary crossings made by the vehicle (Milne, 1992). Two types of point-based charging: cordon-based and cellular systems are suggested (MVA, 1995). Cordon-based systems involve one, two or more boundary lines around a specified area, and sometimes with screen lines. For example, single toll cordons have been implemented around three Norwegian cities. Cellular systems include many cells; for example, a system of hexagonal cells, each with a radius of about a mile.

Secondly, for area-based charging, many types have been considered.

- A supplementary licence system requires a licence to be purchased for and displayed on any vehicle used within a charged area (May, 1975). This system had been used in Singapore since 1975, before being replacing by an automatic point-based charging system, electronic road pricing (ERP) in 1998 (see URL: www.lta.gov.sg/erp/index.html). While the original Singapore scheme used manual enforcement, enforcement can now be achieved by video or digital camera studied for Leeds (Richards and Harrison, 1999) and London (GOL, 2000).

- Distance-based charging involves a charge calculated from the distance travelled within a charged area. This charging basis would be predictable based on route choice, and would not lead to dangerous driving behaviour (Milne, 1992; MVA, 1995).

- Time-based charging involves a charge calculated from the time spent travelling within a charged area. This charging method is perceived by the public as a fair system (Thorpe and Jaensirisak, 1998). However, it leads to fast driving, which in turn may induce unsafe driving behaviour (Bonsall and Palmer, 1997).

- Congestion-based (delay-based) charging is that vehicle users are charged when using their vehicles on a congested road in a charged area but they are not charged when the road is not congested. For example in the study for Cambridge, a congested road is specified as being when a vehicle using the road has four stops within 0.5 km, or when the time taken to travel any 0.5 km is above three minutes (Oldridge, 1995). The delay-based charging is related to congestion levels, so the charge tends to be difficult for users to predict. This regime also may induce unsafe driving behaviour (Bonsall and Palmer, 1997).

- Externality-based charging involves a charge linked directly to the negative impact being caused by the vehicle (Jones, 1998); for example, the charge could be related to exhaust emissions from vehicles.

2.5 Review of Acceptability

This section reviews previous studies of acceptability of road user charging. This includes the public attitudes in general from attitudinal surveys and the factors affecting acceptability. It also explains how acceptability relates to individuals' selfish and social perspectives. Finally, it presents a summary of general guidelines to improve acceptability.

2.5.1 Acceptability of road user charging

In psychology, it is stated that an attitude of a person is expressed by some degree of favour or disfavour (Eagle and Chainken, 1993). A number of studies in transport have used attitudinal approaches for assessing acceptance of new transport policies and systems. Acceptance of a system can be defined as the willingness to accept the proposed system (van der Loop and Veling, 1994).

Several attitudinal surveys towards road user charging have been carried out in the UK during the last decade. The results are presented in Table 2.1.

Table 2.1 Review of acceptability of road user charging in UK

Case study	Source	Year of survey	Results
Nationwide	Jones (1991)	1991	30% support
	Taylor and Brook (1998)	1993, 1995, 1996	18% in favour of road pricing in city centre (1993) 25% in favour of road pricing in city centre (1995) 30% support charging motorists £2 for entering a city centre at peak time (1996)
	CfIT/MORI (2000)	2000	27% support
	CfIT/MORI (2001)	2001	37% support
London	NEDO (1991)	1991	43% acceptance
	Halcrow Fox and Associates (1992)	1992	37% acceptance in car users
	GOL (2000)	1999	53% of respondents agreed it was a "good thing" 30% of car users agreed it was a "good thing" (a daily charge of £5 for driving within Central London and £2.50 for Inner London)
	London First (1999)	1999	76% support the system proposed by the London First (a £5 daily charge for cars, between 7am and 7pm, inside the Inner Ring Road, with discount for residents)
Other UK cities			
Cambridge	Thorpe et al. (2000)	1994	34% acceptance of charging for car use within the city centre (73% of respondents travelled into the city centre once a week or less)
Bristol	Collis and Inwood (1996)	1996	32% acceptance
Leeds	Bonsall et al. (1998)	1997	30% thought that it would 'be a good idea to charge people for using roads at busy times of day'
Newcastle upon Tyne	Thorpe et al. (2000)	1998	48% acceptance of charging for car use within the city centre (71% of respondents travelled into the city centre once a week or less)
Leeds	Schlag and Schade (2000)	Unknown	8%-16% support for different charging regimes: distance-based pricing, congestion pricing and cordon pricing
York	Schlag and Schade (2000)	Unknown	10%-23% support for different charging regimes: distance-based pricing, congestion pricing and cordon pricing

The results show that public acceptability of road user charging in UK is generally low. Among the surveys, the results are different. This is likely to be partly because of different groups of sample. For example, for the surveys in Cambridge and Newcastle, acceptance is higher than the other surveys outside London because there were high proportions of respondents who were less frequent (once a week or less) travelling into the charged area. In London, charging is more acceptable than others, probably because of a high proportion of non-car users. GOL (2000) reported that only 30% of car users felt that road pricing was a good thing, but 54% of the whole sample did, when non-car user were included. The higher acceptance in London is also possibly because there is higher congestion level than in other cities.

However, the differences of levels of acceptance is likely to be mainly because there were different charging features presented and no information at all about charging system. For some surveys, respondents were asked about attitudes to road user charging by a simple question without presenting system characteristics. Although, the results are slightly different from each other, with charges supported by about a third of respondents for the nationwide surveys and the surveys in cities outside London: Bristol and Leeds (reported by Bonsall et al., 1998), they are different from the surveys for which some charging characteristics were presented, for example the surveys in Leeds and York (reported by Schlag and Schade, 2000).

Different charging systems are also considerably different in levels of acceptance. For London surveys in 1999, the results reported by the Government Office for London (GOL) show that a daily charge of £5 for driving within Central London and £2.50 for Inner London is supported by about a half of the respondents (53%). In the same year, the survey by the London First found that three quarters (76%) of respondents supported the presented scheme, which is a charge of £5 per day for cars between 7am and 7pm, inside the Inner Ring Road, with a discount for residents (£104 per annum without extra charge). This scheme is substantially more acceptable than the charge proposed by GOL, possibly because of the smaller charged area and the discount for residents.

Furthermore, acceptability of congestion pricing in other countries is also generally low. As reviewed by Luk and Chung (1997), support amongst the public is in the range of 15% and 50%, except in Singapore in which support is higher than 50%.

The lesson from Oslo shows that acceptance has increased over time after implementation, from 28% responding positively in 1989 to 40% in 1995 (Odeck and Brathen, 1997), and then to 46% in 1998 (Harsman et al., 2000). Moreover, the case of value pricing in California, which is acceptable to the public, is interesting. The evidence suggests that people are willing to pay for a better service, faster and more predictable trips, and do not oppose the scheme as long as they have a free alternative route (Orski, 2000).

2.5.2 Factors affecting acceptability

Factors that are likely to directly affect acceptability of road user charging can be divided into two main groups relating to characteristics of road pricing. These two factors can be controlled in the process of road user charging design, in order to improve the acceptability.

The first relates to benefits of the scheme, which may include journey time reduction, environmental improvement and revenue generation. In other words, the scheme must make clear what is the main objective, and meet public concerns. This was recommended from the London congestion charging study (Sheldon et al., 1993), the experiences of Oslo toll ring

(Odeck and Brathen, 1997) and the TransPrice project (Schlag and Schade, 2000). However, it is uncertain that travel time reduction and environmental improvement are perceived by the public to be worthwhile enough to compensate for the charge. Giuliano (1992) believed that in the case of road pricing, individuals would not trade off between time and money (although time has a monetary value in the economic theory), because charging is immediate and tangible while time savings are not (Button, 1984). A result from Harrington et al. (2001) supported that time saved is not significant in improving voting for congestion pricing.

In order to improve the public acceptance, many studies suggested that the revenue should be used for improving public transport and/or reducing tax (e.g. Jones, 1991; CfIT/MORI, 2000; GOL, 2000; Thorpe et al., 2000). For example, support for road pricing increased from 30% of respondents to 57% supporting a package of road pricing with revenue raised to improve alternatives (Jones, 1991). Recent surveys by MORI in 2000 found that the 27% accepting road pricing alone rose to 39% if revenue is invested in public transport, and to 41% if revenue is used to reduce road and fuel taxes (CfIT/MORI, 2000). In the 2001 survey, 37% supporting charges for driving into city centre increased to 54%, if revenue was invested in public transport (CfIT/MORI, 2001). However, no study indicates whether proportion of revenue use is importance. Harrington et al. (2001) found that although the acceptance is related to tax reduction, the variations of percentage of revenue used in this way were not significant. Furthermore revenue used in improving the environment is also rather highly supported by the public (Stokes, 1996; Thorpe et al., 2000).

Secondly, acceptability is affected by scheme features including, e.g. the level of charge, the method of charging, charged areas and the times of charging (Section 2.4.2). It was found that complex systems such as time-based and delay-based charging may not be accepted (Sheldon et al., 1993), and a system with a known charge is preferable over a system with an uncertain charge (Bonsall and Cho, 1999). The results of TransPrice project (Schlag and Schade, 2000) also showed variations in the acceptability for different methods of charge. In London, London First (1999) found that a majority of people preferred charges in only Central London to charges in larger areas, they also preferred changes between 7am-7pm to shorter or longer period charges, and they thought that a charge at £5 per day for cars was acceptable.

These findings are useful in the design of road user charging schemes. However, it has not been clear how people value the benefits and how acceptability varies across different combinations of these system features. More details need to be studied; for example, effects of each system feature and benefit on acceptability.

Moreover, acceptability relates to other factors, which are not in the design process. It involves personal attitudes and perceptions; for example, attitudes to transport problems and the perceived effectiveness of the scheme (van der Loop and Veling, 1994; Schlad and Toubel, 1997; Rietveld and Verhoef, 1998). People who perceive serious transport problems and perceive charging as an effective solution tend to support road user charging schemes.

Acceptability is influenced by attitudes relating to the environment, the hazards of traffic and the car (Nilsson and Kuller, 2000). Those who are concerned about quality of the environment and negative effects from traffic are likely to accept charging more easily than others. On the contrary, those who have good images of cars tend to oppose charging. Some people use their cars because they enjoy doing so, rather than through necessity; this leads to resistance against policies aimed at reducing car use (Steg and Tertoolen, 1999; Tertoolen et al., 1998).

Acceptability also involves psychological issues, for example perception of freedom and fairness (Baron, 1995; Jakobsson et al., 2000), concern on equity issues (Giuliano, 1992, 1994), as well as the self and social interest of individuals (see the next section, 2.5.3). In addition to personal benefits, people consider whether charging can provide benefits to different groups of society equally.

Acceptability is likely to relate to personal characteristics and constraints, which may include income, age, education, transport mode used, frequency of car use, the availability of alternative modes, location of household and workplace, household type, and life style (Stokes and Taylor, 1995; Odeck and Brathen, 1997; Rietveld and Verhoef, 1998; Harrington et al., 2001).

Furthermore, in general, road user charging is not acceptable to the public, for the simple reason that some people misunderstand the concept (Giuliano, 1992). For example, they respond that road user charging is another form of taxation and they believe that they already pay a lot of money to use cars.

2.5.3 Relevance of selfish and social perspectives to acceptability

In psychology, it is believed that people who hold positive attitudes tend to support the attitude object, while people who hold negative attitudes tend to oppose the object (Eagle and Chaiken, 1993). However in some contexts, such as public policies, individuals may have a conflict between positive and negative attitudes in their mind for different perspectives. For example, if action A has greater utility for a person than action B but simultaneously action B makes society better off, then the person may not always choose action A; this means that the well-being of others must be guiding the individual's choice (Dawes, 1980). In other words, people may still be willing to do something that does not directly benefit them, but benefits the community. This concept is called 'Social Dilemmas' in which Dawes proposed two defining characteristics:

> "(a) each individual receives a higher payoff for a socially defecting choice than for a socially cooperative choice, no matter what the other individuals in society do, but
> (b) all individuals are better off if all cooperate than if all defect."

In politics, concern on individual impacts to and from other people may be a common issue for living in society, as stated by Pitkin (1981):

> "Drawn in to public life by personal need, fear, ambition or interest, we are there forced to acknowledge the power of others and appeal to their standards, even as we try to get them to acknowledge our power and standards. We are forced to find or create a common language of purposes and aspirations, not merely to clothe our private outlook in public disguise, but to become aware ourselves of its public meaning. We are forced ... to transform 'I want' into 'I am entitled to', a claim that becomes negotiable by public standards."

In political and social science, many papers in Mansbridge (1990) demonstrate a critical importance of motivations that go 'Beyond Self-Interest'. Mansbridge believed that:

> "... when people think about what they want, they think about more than just their narrow self-interest. When they define their own interests and when they act to pursue those interests, they often give great weight both to their moral principles and to the interests of others."

In economics, there is a considerable literature suggesting that individuals' preferences are not derived only from their own well-being, but also of others. Smith (1776b) called this nature of humans "fellow-feeling pleasure" in 'The Theory of Moral Sentiments'. This concept was generally called 'The Economics of Altruism' by Zamagni (1995).

Sen (1977), in 'Rational Fools', criticised the rational choice theory on the basis that individuals' preferences would be influenced not only by self-interest, but also by other motivations: sympathy for other people and commitment, which involves counterpreferential choice. Collard (1978) argued, in 'Altruism & Economy', that "human beings are not entirely selfish even in their economic dealings", though "practically the whole of (neoclassical) economic theory is built upon self-interested individuals maximising utility". However, he also believed that altruistic feelings might be too weak to lead to action. Coleman (cited in Margolis, 'Selfishness, Altruism, and Rationality', 1982) also suggested that the classical economic theory, which always assumes that the individual will act as self-interest, is simply a convenience, without theoretical foundation. He also stated that in many cases people do not only vote for their own interest, but also for the interest of society. In other words, they attach some weight to the interest of other people and take it into account (see section 3.3). These led Frey (1997) to develop the crowding-out theory in 'Not Just for the Money', in which he believed that all economic activities depend on both "extrinsic motivation" and "intrinsic motivation".

In transport studies, selfish and social perspectives are considered in two areas as follows.

(a) Studying the effects on behavioural change. This attempts to assess the effects of the conflict between self and public interest on car use, for example studied by Steg and Vlek (1996), Gärling and Sandberg (1997) and Kitamura et al. (1999). They found that individuals hold conflicting attitudes between positive and negative effects of car use on themselves and society, which tend to underlie their behaviours on whether to travel by car. Van Vugt et al. (1995, 1996a, 1996b) and van Vugt (1996) studied the effects on mode choices between car and public transport by dividing people into pro-self (individualist), who are primarily concerned with their own well-being, and pro-social (co-operator), who are primarily concerned with the well-being of society. Their experimental results show that the pro-social group would be more likely to commute by public transport than the pro-self group.

(b) Studying the effects on individuals' valuations of transport schemes, which in turn affect their decisions on whether or not to support the implementation. This examines the effects of selfish and social perspectives at the individual level. For example, Bristow et al. (1991) studied the effects on willingness to pay for preservation of local bus services. Hopkinson et al. (1992), Hopkinson (1994), and Daniels and Hensher (2000) studied the effects of selfish and social perspectives on individuals' valuations of road schemes. They found that individuals are likely to have two different viewpoints for evaluating the schemes; one concerned their own benefits and the other concerned benefits to society.

These studies confirm that people tend to hold two points of view (in their decision process) on an issue, which particularly has effects on both themselves and society, before making a decision to do something, e.g. travelling by a car, paying to preserve a service, and accepting or supporting a scheme.

As with other public policies (or issues in which the public are involved), the selfish and social perspectives are likely to influence individuals' propensity to accept and support road user charging. The concept extends the point made by Giuliano (1992) in which individuals would strongly oppose road pricing because they would not personally benefit from it. Rietveld and Verhoef (1998) and Rienstra et al. (1999) found that people have both individual and social perceptions of transport problems which affect support for policy measures, and their concerns about social issues would be more significant than about individual disutility. They believed that people are not always guided by self-interest, but they also take a social perspective into account.

Furthermore, as a separate issue, the concept of selfish and social perspectives can help to explain another reason of unacceptability of road user charging in which people concern equity of its impacts. This is because individuals often compare their rewards and costs with those of others (Berkowitz, 1970). This may be a small problem for altruistic people. For example in an extreme case, if A is very altruistic but B is egoistic, there would be perfect consensus in favour of allocating almost all output to B and very little to A (Collard, 1978). In fact, this would be seen as 'unfair' for selfish perspective. Therefore, if people in a society are concerned more about benefit to society than about disbenefit to themselves, the equity problem may be less important. (This issue was not examined in the study here).

2.5.4 Ways to increase acceptance of road user charging

Several ways have been suggested to increase acceptance of road user charging schemes from a number of previous studies; for example: by Giuiano (1992), May (1992), Sheldon et al. (1993), Ison (1995), TransPrice project (Schlag and Teubel, 1997; Schlag and Schade, 2000), Jones (1998), Reitveld and Verhoef (1998), Whittles (1999), and PRIMA project (Gueller, 2000; Hårsman et al., 2000). These are useful in implementation of road user charging schemes. The suggestions are summarised as follows.

- *Benefits and objectives* need to meet the public concern. It is found that using the scheme as a financial instrument is more easily to be acceptable than using it for demand management.
- *System characteristics* need to be simple to understand for the public. A scheme would also be preferable if the charge can be predicted.
- *Revenue allocation* needs to meet the public preference. The most frequent suggestions are using revenue to improve public transport and reduce tax.

- *Equity issues* need to be considered. This relates to the distribution of cost and benefits. If road user charging is perceived as unjust and unfair, acceptance will be difficult to achieve. It must also not be perceived as a kind of punishment. This issue can be added by revenue distribution.
- *Alternatives* need to be available. This must be part of a policy package, which can compensate those who cannot afford the charge, as well as contribute to perception of freedom of choice.
- *Communication and marketing strategy* can be of use to improve public understanding. It also can be used to create public awareness of the transport problems, and then to enable a scheme to be perceived as effective solution.

2.6 Review of Effectiveness

This section reviews the effects of road user charging on overall traffic reduction, environmental improvement, raising revenue and individual behaviour from previous studies. It also reviews some experiences of implemented and pre-implementation cases of urban road pricing systems. Finally, this section reviews the previous research about demand elasticities with respect to road user charging, as well as fuel price, parking charges and tolls.

2.6.1 Effects of road user charging

How the effectiveness of a road user charging is measured largely depends upon the objectives of the scheme. Travel behavioural response is one of the indicators for reflecting the effectiveness of traffic reduction. Many methods have been used to investigate behavioural responses to road-pricing schemes before their implementation; for example: network modelling, SP survey, attitude survey, driving simulator and field trials. The results are summarised in Table 2.2.

Table 2.2 Review of studied effectiveness of road user charging

Case study	Source	Method	Charging level	Results
Nationwide	Taylor and Brook (1998)	Attitudinal survey	£2 entering city centre	35% give up or reduce significantly their reliance on cars
London	NEDO (1991)	Attitudinal survey	50 p/hour	27% switch to public transport or un-charged period
	MVA (1995)	Modelling	£2 per crossing	8% reduction of total vehicle kilometres
			£8 per crossing	22% reduction of total vehicle kilometres 21% increase in use of public transport
	LEX (1999)	Attitudinal survey	£3 per day	30% switch to public transport
			£6 per day	39% switch to public transport
	GOL (2000)	Attitudinal survey	£5 per day	30% not by a licence (over half switch to public transport)
		Modelling	£5 per day	20% reduction in overall car trips within the central area 30% reduction in home-based commuting trips 10-12% reduction in total traffic level
Leeds	Richards and Harrison (1999)	Modelling	£2 peak time and £1 off peak	11% overall traffic reduction within the city centre
	Bonsall et al. (1998)	Route choice simulator	£1 charge within city centre	74% "pay up and continue to travel", in turn 26% are expected to travel in un-charged periods or by other modes
	May et al (1998)	Stated preference	£0.50	25% car use reduction
			£1.00	54% car use reduction
			£2.00	90% car use reduction
Liverpool	Stokes (1996)	Attitudinal survey	£1 per day	Just under a quarter (of 456 car users) would switch to public transport
			£3 per day	Just over a third (of 456 car users) would switch to public transport
Bristol	CONCERT-P (1998)	Modelling	£2.5 - £4.5 cordon	15% reduction of car trips
Edinburgh	Edinburgh City Council (2000)	Modelling	£1 per crossing	5% increase in use of public transport
			£4 per crossing	15% increase in use of public transport
Leicester	Smith and Burton (1998)	Field trial	£1.50 tolling 7:45-8.45am	20% car use reduction
			£3.00 tolling 7:45-8.45am	18-22% car use reduction
			£3.00 tolling 7:00-10:00am	29% car use reduction
Dublin	O'Mahony et al. (2000)	Field trial	Average 6.4 Euro per trip	22% trip reduction from suppression and switch to public transport (responding to distance- and time-based charging)

In charging systems, effects on overall traffic reduction can be expected. For example, transport modelling studies indicated that a significant proportion of car users would transfer to bus or change their time of travel to outside the charged time, if cordons around Central London were implemented. The London Congestion Charging Research Programme (MVA, 1995) found that an inbound charge of £2 and £8 for Central London between 7am and 7pm would provide 8%

and 22% reductions of total vehicle kilometres, respectively. Among those who altered their behaviour, the greatest responses would be a switch to buses. At a charge of £8, a 16% increase was predicted in the number of bus passengers entering Central London in the morning peak period, and 3% and 4% increases in rail and Underground passengers, respectively. The modelling results from GOL (2000) are that car journeys to/from within the central area would reduce by 20% overall, and 30% for home-based commuting trips.

A 15% reduction in car use was predicted in Bristol with an all day cordon-based charge of £2.50-4.50 (CONCERT-P, 1998). For road pricing in Leeds, MVA consultancy (Richards and Harrison, 1999) found that a morning peak charge of £2 and an off-peak charge of £1 could reduce overall traffic within the city centre by 11%. In the Dublin trial, based on distance and time-based charging, a significant reduction (22%) in the number of peak period trips was expected from trip suppression and switching to alternatives (O'Mahony et al., 2000).

At the individual level, various responses to road pricing can be expected, mainly including: mode switching, re-timing, re-routeing, re-locating, and trip frequency reduction. In UK, attitude surveys have found that motorists would reduce car use if they were charged for entering a city; most of them would switch to use public transport or change travel time. For example, the British Social Attitudes surveys in 1996 found that 35% would give up or significantly reduce their reliance on cars, if they were charged £2 each time they entered a city (Taylor and Brook, 1998). NEDO (1991) claimed that if a charge of 50p per hour at peak times were implemented in the centre of London, 27% of those who had travelled by car into the area said they would avoid using their cars by switching to public transport (14%), using cars in off-peak (10%) and not making the journey (3%).

LEX (1999) also reported that if a £3 daily charge were implemented within a city centre, 30% of car commuters would change to use public transport, and 39% would switch at a £6 daily charge. Basing on the attitude survey, ROCOL (GOL, 2000) found that if a £5 daily area licence were introduced within Central London between 7am and 7pm on weekdays, 30% of car users said they would not buy a licence. Over half of them would switch their modes of travel. In Leicester, 20-30% were expected to switch from car to alternatives (Smith and Burton, 1998). For the Edinburgh charging scheme, Edinburgh City Council (2000) reported that a city centre cordon of £1 and £4 would encourage an increase in the use of public transport by 5% and 15%, respectively.

Based on a stated preference study by May et al. (1998), 90% of car users would avoid using their cars, if a £2 cordon-based charge was introduced in Leeds city centre between 7:30am and

9:30am with a free park and ride service. Over half would change to travel in uncharged times, and others would switch to use alternative modes or park and ride.

Moreover, it is believed that there are hierarchical levels of individuals' behavioural responses. Giuliano (1994) divided them into three levels. The first is that of household characteristics, how an individual can adapt personal and other members' activities. The second one is the workplace, e.g. changing work schedules, or departure and arrival times. The final level is switching to alternative transport modes.

Raux et al. (1998) reported two main responses. One is immediately conceivable changes e.g. activity timetable changes, route changes, cancellations or postponement of some trips. The other one is "extraordinary" adaptation, e.g. switching to public transport and changing job or home. These emphasise that individuals' last travel behavioural response is a change of transport mode. The results of a study by May et al. (1998) and Bonsall et al. (1998) supported that the theory that car users are much more likely to avoid the charge by considering alternative routes and times rather than to changing mode. They reported that preferences for behavioural changes were in order:

- to take a different route,
- to travel earlier (before charged time),
- to travel later (after charged time),
- to use park and ride (or walk),
- to use public transport,
- to use car share and to relocate.

Reduction of car use is not only dependent on the levels of charges, but also on trip purposes. The ROCOL (GOL, 2000) study showed that reduction of car use for work trips is higher than the reduction for other purposes. Thorpe and Jaensirisak (1998) and Gärling et al. (2000) also found that switching to public transport is the most likely choice for work trips. This is possibly because for each individual commuting trips are usually more frequent and less flexible to change destinations than other trips, such as shopping and leisure trips; to avoid the charge car users would switch modes and times, rather than reduce numbers of trips or change destination.

Reduction of traffic and travel time on a network is also dependent on charging regimes. May and Milne (2000) examined four charging systems based on cordons crossed, distance travelled, time spent in travelling and time spent in congestion by using a SATURN application on the

Cambridge road network. They found that congestion-based pricing is the most effective in increasing network speed, but less effective in reducing distance travelled because it encourages use of longer routes and minor roads. They concluded that, overall, time-based charging performs better than other systems on most indicators.

As a result of traffic reduction, pollution problems would be reduced. Daniel and Bekka (2000) studied the effects of congestion pricing on emissions for the US highway network. Their results confirmed that congestion pricing can produce environmental benefits: clean air and less energy consumption. The US Environmental Protection Agency (EPA, 1997) also found that pricing measures had an advantage of reducing congestion and emissions faster than building facilities or changing vehicles.

Another major objective of road user charging is to generate revenue to finance other transport projects. It was claimed that road user charging could create substantial revenue for the government. For example, the study of road pricing in Leeds found that the charge within the Inner Ring Road between 6am-6pm on weekdays could generate an annual net revenue of £25 million, if the level of charge is £2 in the morning peak time and £1 in the off-peak time (Richards and Harrison, 1999). The London charging scheme of a £5 daily charge operating between 7am and 7pm on weekdays within Central London could raise £230m-£270m per year net revenue (GOL, 2000).

In brief, the effects of urban road user charging systems are likely to relate to characteristics of the system and local circumstances, e.g. congestion level and the availability of alternative transport modes, in addition to personal adjustments. The following sections review, case-by-case, previous studies from different countries on the effectiveness of road user charging systems. The studies can be divided into two groups: implemented and pre-implementation cases.

2.6.2 Experiences of implemented cases

In practice, currently, only two countries, Singapore and Norway, have successful introduced urban road pricing measures. They have demonstrated different objectives and system designs. Thus they have different effects on traffic and travel behaviour.

Singapore

Singapore was the first country to introduce urban road user charging. Initially, the objective was to restrict traffic at peak periods into the Central Business District in order to alleviate congestion. The system applied was called Area-Licensing Scheme (ALS), covering most of the central area in peak morning hours. The system was paper-based, and enforcement was effected by observers posted at each of the 22 entrance-points to the Restricted Zone (over 5 kilometres square). Each vehicle entering this zone had to display an area licence on windscreen.

As a result of the scheme, traffic volumes during the morning peak hours fell almost immediately by 45% (against the goal 25-30%) and average speeds increased from 18 to 35 km/h (Holland and Watson, 1978). Though the ALS had achieved more than the target, it was argued that the price of an ALS licence had been set too high; thus causing less than optimal use of available road space in peak hours (Wilson, 1988; McCarthy and Tay, 1993).

In 1998 the ALS was replaced by Electronic Road Pricing (ERP) (Menon, 2000). The objective of the system was changed to improve travel speeds in the road network. Vehicles to pass through the area, during 7:30am and 7:00pm on weekdays and 7:30am and 2:00pm on Saturday, must have an electronic In-vehicle Unit in which a smartcard with positive cash balance has been inserted. The toll applying at the particular time when the vehicle passes under each of the 33 gantries is automatically deducted without the driver having to slow down. Prices applied under ERP do not fluctuate directly with actual traffic volumes, but they are subject to maintain traffic speeds of 45-65 km/h on expressways and 20-30 km/h on arterial roads. The tolls would be varied according to the average speed on the network.

Advantages of the ERP over ALS are mentioned as being that it is more efficient, flexible, reliable and convenient, though with higher initial investment costs (Foo, 2000). From data one year after the implementation, Luk (1999) by using the short-run price elasticities showed that the scheme would be twice as effective as a petrol price increase in reducing car travel, but that they were similar in inducing mode shift to public transport. It would appear that ERP was not intended to force a transfer from cars to other modes, although some traffic reduction is measured (Menon, 2000).

It should be noted from the experiences of Singapore that the road pricing scheme is successful because the system is a part of a policy package, including e.g. substantial improvement of public transport, high parking charge and additional registration fee, and vehicle quota system. Singapore can easily implement the 'stick' policies because there is no political problem; the government is strong and people believe in the government's policies. Moreover, surprisingly, the restraint policies have no major negative side effect on economic growth; on the contrary, they have generated substantial funds for the improvement of social welfare (Willoughby, 2001).

Norway

In Norway, three cities are implementing cordon pricing. Bergen was the first city to introduce the scheme in 1986, followed by Oslo in 1990 and Trondheim in 1991. The systems involve charging all vehicles entering the cities. In Bergen, the toll system operates between 6am and 10am on weekdays. In Oslo, it is 24-hours operation on both weekdays and weekends. In Trondheim, the time of charge is between 6am-5pm, with discount after 10am, on weekdays.

In these cases, the main objective of the toll rings was to raise revenue to finance road projects. The scheme was not designed to reduce traffic. Nevertheless, the experiences of the toll rings suggest that although the demand management was not among the objectives of the schemes, some impacts on travel behaviour and traffic volume were found. The results of before-and-after survey showed that in Trondheim about 40% of the public indicated effects on their travel behaviour, e.g. changing mode, time, route, destination and frequency, on the contrary, in Oslo and Bergen the impacts on travel behaviour were relatively small (Meland and Polak, 1993). In terms of the number of trips in the toll periods, the inbound car trips decreased by 6-7% in Bergen, 8% in Oslo, and 10% in Trondheim (Larsen, 1995).

2.6.3 Studies of pre-implementation cases

Governments of some countries introduced proposals of urban road user charging schemes. Although the studies of the impacts of the schemes demonstrated that the design could achieve their objectives, they have not yet been implemented, as presented below for example.

Hong Kong

The first Hong Kong pilot of Electronic Road Pricing System (RRP) was undertaken between 1983 and 1985. The system was based on the automatic toll collection, billing and enforcement. Three schemes with different levels of charge, number of zones and geographical coverage were tested. Vehicles' owners would receive a bill with details of their use of the network at the end of each month (see Catling and Harbord, 1985).

The effects of the schemes were predicted (by a traffic simulation model) to reduce total daily car trips by 9-13% and peak-period trips by 20-24% (Harrison, 1986). Economic evaluation found that net benefits of the schemes were satisfactory (Gomez-Ibanez and Small, 1994). Nevertheless, the schemes were not implemented. One of the main reasons was the public concern about the potential intrusion of privacy by 'big brother', in addition to political and economic problems (Hau, 1992b).

After the failure of the attempt, road pricing was studied again in the mid 1990s. This involves assessing the requirements for an ERP system in Hong Kong, as well as the public acceptability (Opiola, 1998). (So far no result has been found reported in academic publications.)

Netherlands

During the late 1980s, the Dutch government developed a road pricing proposal for the Randstad region. This covers four big urban areas (over 2,000 square miles) including Amsterdam, Rotterdam, Hague and Utrecht. The objective was to manage travel demand and raise revenue to finance transport project. The plan involved charging points every 10 km based on £1 peak-period charges and 10p off-peak period charges, by using SMART card technology with infra-red or microwave communications (May et al., 1991). The scheme was expected to reduce vehicle travel by 17% during peak hours (Small and Gomez-Ibanez, 1998). Nonetheless, it was rejected in 1990 because of public concerns about technical feasibility, invasion of privacy and prevention of traffic spilling over to local streets.

In 2001, new charging scheme was proposed by the Dutch Ministry of Transport, Public Work and Work Management, in 'The National Traffic and Transport Plan' proving a vision for traffic and transport in 2020 (see URL:www.minvenw.nl/nvvp). It included the mileage charge scheme, in which private cars would be charged a per-kilometre fee for using their cars in the Randstad area. This was based on the principle "the more you drive the more you pay". The charges will include environmental tax and vary with peak and off-peak periods. The scheme is expected to introduced around 2010, reduction of regular taxes. However, the experimental peak levies and pay-lanes will start in 2002, to investigate the effects of road pricing.

Stockholm

The road pricing system for Stockholm was proposed in 1991. The objective was primarily to reduce air pollution, traffic noise and congestion. The charging system was based on pre-purchased licences. The charge would have operated on weekdays by using £30 monthly cards or £2.50 daily cards (May et al., 1991). These have been predicted to reduce traffic by 10% and 6-8%, respectively. However, in 1997 the proposal was suspended by the government because of political problems and opposition by the business community (Ahlstrand, 2001).

In 1999, a new study of road pricing for Stockholm was carried out by the Swedish Institute for Transport and Communications Analysis (SIKA), a governmental agency. It was claimed that road pricing would be able to reduce the number of private cars struck in the morning peak period by 90-95%, compared to the current situations, and to decrease car traffic in the Stockholm region between 1998 and 2010 by 9% in the morning peak time (Ahlstrand, 2001).

London

The first proposal for London road pricing was during the 1970s by the Greater London Council (GLC). The charging system was 'supplementary licensing', in which every vehicle was required to purchase a daily licence to drive in the Inner London area. These charges were expected to reduce traffic substantially and to increase speeds by about 40% during peak period (May, 1975). However, the proposal was rejected by the GLC in 1975.

During the early 1990s, 'The London Congestion Charging Research Programme' was sponsored by the Department of Transport in UK (MVA, 1995). The research studied various charging systems. The simplest scheme was a single cordon charge around central London. The most complex schemes involved three cordons and screen-lines. The levels of charges were different for each cordon and screen-line and time period. The study found that the charging schemes were relatively effective in reducing car use. For example, for a single cordon charge around central London at £8 per crossing, 22% reduction of total vehicle kilometres could be expected. Nevertheless, the schemes were very much likely to be opposed by the public. At the end the systems were postponed by the government.

In 1999, new legislation created the Greater London Authority (the first Mayor was elected in May 2000). The Mayor produced the 'Transport Strategy for London', which included congestion charging (GLA, 2001). Charging schemes suggested were based on the 'Road Charging Options for London' study, which was produced by an independent group of transport professionals (called Review of Charging Options for London (ROCOL) Working Group) and supported by Government Office for London (GOL, 2000).

The scheme was based on the area licence enforced by using digital cameras to check number plats against the database. The £5 daily charge operated between 7am and 7pm on weekdays within Central London would produce net economic benefits of £95m-£160m per year. (The effectiveness in traffic reduction are reported in Table 2.2) The survey by MORI (GOL, 2000) found that the scheme is supported by majority of the public, particularly when the revenue is proposed to be used for public transport improvement (Section 2.5). The scheme is planned to be introduced in the early 2003, according to the Transport Strategy for London (GLA, 2001) and the announcement by the Mayor of London (Mr. Livingstone) on 26 February 2002.

2.6.4 Demand elasticities

This section reviews elasticities of road user charging from previous research. Although there are a limited number of studies directly about road pricing, evidence about increases of fuel price, parking charges and tolls is also reviewed as this, to some extent can be transferable to indicate effects of road user charging.

A study of road pricing in London by Halcrow Fox and Associates (1992) was based on a stated preference survey in 1992. The scheme involved car trips inside the M25 charged on a distance basis. They reported that for 'radial' (travelling into the city centre) work journeys the elasticities with respect to 5, 15 and 35 p/mile (based on zero charge) are -0.11, -0.38 and -0.52, respectively. For 'orbital' (roughly parallel to the cordon) work trips, the elasticities with respect to 5, 15 and 35 p/mile (based on zero charge) are -0.06, -0.12 and -0.41, respectively. The higher values for radial journeys are because public transport provides a better alternative to car users for these journeys than for orbital journeys.

The ROCOL study (GOL, 2000), based on a stated preference survey in London, found that elasticities for home-based work (HBW) trips by area licence holders with respect to a £2.50 daily charge within the Inner Ring Road are -0.03 and -0.07 for high and low income groups, respectively. The elasticities for a £10 charge are -0.09 and -0.27 for high and low income groups, respectively. Based on the AREAL model (a strategic model developed by the Government Office for London with the aim of evaluating the impacts of alternative charging options in the Greater London area), ROCOL found that elasticities for work trips with respect to £2.50 and £10 charges are -0.17 and -0.27, respectively.

The elasticities for the low level of charge from the Halcrow Fox and Associates study are somewhat similar to the value from the ROCOL study, but for the higher levels of charge they are slightly higher (in absolute terms). This is probably because the areas of charge are different. Charging schemes covering larger areas are likely to have higher impact than ones covering small areas.

Comparing the studies in London to evidence of road pricing in Singapore and tolls in Norway and USA, the elasticities are broadly similar. For the original area licensing scheme (ALS) in Singapore, Luk (1999) estimated that toll elasticities in reducing car travel varied between -0.19 to -0.58, with an average of -0.34, which is about twice as effective as petrol price increases. However in inducing mode shifts Luk found that road pricing was as effective as petrol price increases. After the replacement of the ALS with electronic road pricing (ERP) in 1998, Menon (2000) reported that a short run elasticity of demand was between -0.12 and -0.35 for the morning peak period. This is also rather similar to the experience in Norway, in which the elasticities were -0.22 for the Oslo cordon and -0.45 for the Ålesund toll station (Jones and Hervik, 1992). In their review of toll increases on six bridges and two tunnels in New York, Hirschman et al. (1995) found that the average elasticity of traffic volumes was -0.10, with the highest value -0.50.

Reviews of elasticities by Goodwin (1992) and Glaister and Graham (2000) found that the short run elasticity of traffic levels with respect to petrol price was -0.15, and the one for petrol consumption was -0.30. This led the National Economic Research Associates (NERA, 2002) to use elasticities of around -0.1 and -0.3 in their modelling process to predict traffic levels in response to the charging scheme based on distances travelled and levels of congestion ("Paying for Road Use" reported to the Commission for Integrated Transport in February 2002). Although there is no evidence to confirm that the effects of petrol price and road user charging are similar, they are unlikely to be substantially different. This is based on the assumption that some people may be able to mitigate the effect of charges by switching to uncharged periods, without reducing car use; on the other hand, they may drive more efficiently to mitigate the impact of fuel price changes (NERA, 2002).

Although there is limited evidence of the impact of road pricing, Jong et al. (1999) suggested that area-based (or cordon-based) road pricing can be evaluated using parking charge elasticities, because the price to be paid is a more or less fixed amount per trip, and does not vary with distance travelled as does fuel price. They found that average parking charge elasticity for the number of trips in European countries is -0.10. However because many commuters may have free parking spaces provided, parking charge elasticity may be expected to be lower than area-based pricing elasticity. Both elasticities could be similar, if those commuters with free parking spaces provided had their area licence charge subsidised by their employers.

Jong et al. (1999) also claimed that the fuel price effect could be used for evaluating distance-based charges. Nevertheless, the reviews of the impacts of fuel price increases on car traffic appear to be broadly similar to the impacts of parking charge increases and road user charging. A recent review of evidence from European countries by Jong et al. (1999) and Jong and Gunn (2001) reported that the fuel price elasticity of the number of car commuting trips was -0.20 in the short run. A review of Australian evidence by Luk and Hepburn (1993) concluded that the short-term elasticity of traffic levels with respect to fuel costs was -0.1. For a review of a number of US cases, Lee (1998, cited in Dargay and Goodwin, 2000) found that the fuel price elasticity was -0.16 in the short run.

2.7 Review of Relationship between Acceptability and Effectiveness

It is important for the implementation of any transport policy to know whether the policy is simultaneously effective in achieving its objectives and acceptable to the public. A study on 'carrot' and 'stick' policies clearly found that 'sticks' are likely to be more effective at changing behaviour than 'carrots', but they are less popular (Pharoah, 1993; Stokes, 1996; Anderson et al, 1998).

In the case of road user charging, a number of researchers felt that road user charging is effective in reducing car use but less acceptable to the public, for example they stated that:

> "...there is a trade off between methods of road user charging which are less effective but more acceptable, and those which are more effective but less acceptable" (NEDO, 1991);
>
> "Although many transport and planning professions are agreed that some form of road pricing is likely to be the most effective and flexible way of coping with the growth in urban traffic problems, it is clearly one of the least popular measures among the public at large" (Jones, 1991);
>
> "...it can easily be shown that congestion pricing is the first-best solution for efficiently dealing with congestion, this instrument cannot yet boost much public and political support" (Emmerink et al, 1995);
>
> "At this moment road pricing would appear to offer the best option for tackling the problem and a powerful economic case can be made for its introduction, but the evidence suggests it is the least popular option" (Ison, 1995);
>
> "Charging entry into town centres was also seen as effective in reducing car congestion, but was not popular" (LEX, 1998);
>
> "Urban road charges, which are rather unpopular, might induce a substantial minority to give up or reduce significantly their reliance on cars" (Taylor and Brook, 1998);
>
> "Travel demand management by road pricing is especially difficult, because prices that would be effective are not accepted, and what is accepted is not effective" (Gueller, 2000).

These opinions do not seem to be supported by the results from the attitudinal surveys in Cambridge and Newcastle by Jaensirisak (1998) and Thorpe et al. (2000). They examined the public acceptability of packages of travel demand management measures and effectiveness of the packages in reducing frequency of car use into the city centre. They found that the combination of road user charging and public transport improvement was more acceptable and also more effective than other combinations (e.g. combinations between increased parking charges and improving public transport, and between road user charging and increased parking charges). However, the study involved the comparisons among packages of policies. It is still not clear among different road user charging schemes whether more highly acceptable schemes would be highly or less effective.

In general, it is agreed that there is a negative relationship between acceptability and effectiveness of road user charging. However, this has not been focused on by any research so far in order to find out whether it is possible and how to make road user charging acceptable and effective.

2.8 Summary and Implication for this Research

This chapter has presented general background and reviewed previous studies of road user charging. Various terms relating to road user charging were explained. The development history and economic background was summarised. The general criteria and the charging system features, which are important in the design, were described. More importantly, this chapter has reviewed previous studies on acceptability and effectiveness of road user charging. This led to the study aims, objectives and conceptual framework (presented in Chapter 1).

The review of actual and studied cases of road user charging systems has demonstrated that it is not difficult to design effective systems to achieve objectives. Road pricing systems can be designed to have significant impacts on travel behaviour, leading to less traffic and pollution. In addition, they would generate substantial revenue for improving alternative modes and road networks. However, the impacts can be expected to depend directly on the system characteristics of the system, e.g. charging level, charging regime, charged area and charged time. Thus, knowing the effects of these features on car users' travel behaviour would be useful for the design of a road pricing scheme to achieve objectives.

One of the main problems and reasons why the studied charging systems have not been implemented is that they are not widely acceptable by the public. Many researchers also agreed that in general road user charging is effective, but less acceptable. Thus, the main aim of the study here is to examine how to design acceptable and effective schemes.

The review has also shown that acceptability and effectiveness are affected by the charging system characteristics, and personal perceptions and characteristics. The system characteristics include, for example delay-time reduction, revenue allocation, charging levels, charging methods, charged areas and charged times. The personal perceptions and characteristics relate to e.g. perceptions of transport problems, perceptions of effectiveness of charging, gender, income and age. These factors were found to have influences on public attitudes and behaviour. Nevertheless, it has not been clear how much these factors have impacts, relative to each other, and how acceptability and effectiveness would be changed regarding to these factors.

Moreover, the research took the concept of self- and social-interest into account for explaining acceptability of road user charging. The viewpoint concerning mainly on self interest is called *selfish perspective*, on the other hand, concerning mainly on social interest may be called *social perspective*. It can be assumed that utility of an individual for supporting a charging scheme includes both self and social preferences. Different people are likely to have different weights for their preferences (see Section 3.5).

Chapter 3

Methodological Issues

3.1 Introduction

In Chapter 1, the objectives and hypotheses were presented, based on the literature review in Chapter 2. To achieve the objectives and test the hypotheses, the methodological process is set as follows.

1. Constructing the framework of the study (Section 1.2) from the literature review (Chapter 2);
2. Specifying the method and analysis (Sections 3.2 - 3.5);
3. Designing the survey form and SP experiment. This involves an iterative process, in which the questionnaire and SP experiment were tested and developed through a set of pilot surveys until they were adequate for the use in the main data collection stage (Sections 4.2 - 4.5);
4. Conducting data collection (Section 4.6);
5. Analysing the data (Chapters 5 - 9);

The objective of this chapter is to introduce the stated preference (SP) technique and data analysis method. Section 3.2 presents the reasons for choosing the SP method. Section 3.3 presents the SP method: its main features, design process and possible sources of error in SP data. Then Section 3.4 explains the technique of SP data analysis, involving the random utility theory and logit model. Finally, Section 3.5 presents the development of the utility function for demonstrating the effects of the individuals' selfish and social perspectives.

3.2 Choosing the Method of Research

In order to achieve the objectives and test the hypotheses of the study (presented in Section 1.2), a research method used should be able:

a) to deal with various charging scenarios;
b) to measure public acceptability and behavioural responses;
c) to examine the effects of charging characteristics (benefits and charging features);
d) to examine the effects of personal characteristics and perceptions;
e) to predict acceptability and behavioural responses of different charging systems.

Revealed preference (RP) information, relating to actual preferences and behaviour, is impossible to be used simply because there is no road user charging system in UK. A few methods were considered including stated preference (SP) techniques, attitudinal surveys, and activity-based approaches.

Stated preference (SP) techniques involve studying individuals' preference and behaviour in responding to hypothetical scenarios. These are characterised by important attributes which are likely to affect the preference and behaviour (further detail is explained in the next section). This method was considered as the most appropriate in which it could achieve all the criteria listed above.

Nonetheless, the SP techniques assume that people answer honestly what they think and will attempt to do what they intend to do (although there are some possibilities of response biases; discussed in Section 3.3.3). It might be suspected that people may not do (actual behaviour) what they said (intention).

The assumption that intentions correspond closely with behaviour is supported by psychological studies that have examined the relationship between behavioural intention and actual behaviour (e.g. Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1980; Ajzen, 1985, 1988, 1991; Conner and Sparks, 1996; Gärling et al., 1998). They found that the relationship is relatively high; individuals tend to behave in accordance with their intentions. Although individuals' intentions could change over time (the longer the time interval, the lower the relation between behaviour and intention), aggregate intentions for a group of people are apt to be much more stable over time than individuals' intentions (Ajzen and Fishbein, 1980). Furthermore, the strength of relationship between intention and behaviour could be improved, if the behaviour is planned, rather than habitual or impulsive (Gärling et al., 1998).

In the study here, therefore, public acceptance and travel behavioural intentions measured were reasonably reliable to represent actual behaviour, in which the intentions dealt with individuals' planned travel behaviour (for journeys to work), and the models developed were used to predict acceptance and behaviour at the aggregate level.

The other concern for the use of SP methods in demand forecasting is related to imprecise coefficients in estimated models, due to random error in SP responses. This is called the scale factor problem (see Wardman, 1991). This scale factor cannot be estimated separately from the coefficients. The problem could be overcome by re-scaling the model using revealed preference (observed) data. Unfortunately, this is not available for this research. Nevertheless using the random parameters logit model (Section 3.4.3), which allows the parameters vary across individuals, should improve the coefficients, and in turn lead to more reliable prediction results.

The other methods considered have some drawbacks, as a result of which they were not suitable for this study. Conventional attitudinal surveys with descriptive statistic analyses can be used to investigate general attitudes and responses to road user charging (e.g. in NEDO, 1991; Stokes, 1996; Taylor and Brook, 1998; Thorpe et al., 2000). The analyses are able to test what factors (charging characteristics and socio-economic factors) influence the attitudes and behaviours significantly. However, the analysis results do not explain the effects of road user charging system characteristics in quantitative terms. Thus, they cannot be used to predict preferences and behavioural responses to alternative charging schemes which are not presented to respondents.

Activity-based approaches (see Jones, 1990; Ettema and Timmermans, 1997) can be used to describe not only which responses individuals pursue, but also details of how each individual and his/her family change their travel times, routes and destinations. Data collection is usually based on a travel diary, which can provide a rich source of data. Data analysis can examine the interactions among activities, times and spaces, from which individuals respond to a road user charging scheme. Nevertheless, the data collection gathers a lot of information from each respondent for one charging scenario, it is not appropriate to examine various charging systems at the same time, and thus not possible to be used in forecasting behavioural responses to different charging schemes. In addition, the methods are expensive to collect a large sample.

In brief, the different methods can be used for different purposes. Attitudinal surveys are used to examine factors affecting attitudes and behavioural responses in general. Then these factors can be examined by using SP techniques, which are able to measure the effects of the factors in quantitative terms, for which a main advantage is in predicting preferences and behaviours of different combinations of charging characteristics. This is useful in designing acceptable and effective schemes. Activity-based approaches are suitable to investigate further detail, e.g. how people will respond to a designed charging system and why they choose the responses.

3.3 Stated Preference (SP) Method

In this section, an overview is given of SP methods covering: main features, design process and sources of error in SP data. The technique for analysis of the SP data will be explained later in Section 3.4.

3.3.1 Main features and process of design

Stated preference (SP) methods are well known and widely used in transport studies. They are especially useful for studying non-existing market situations, such as road pricing. They have been used to evaluate the effects of relevant attributes of a system on individuals' responses and provide forecasts of changes in demand and travel behaviour. The techniques are based on individuals' preferences and/or behavioural responses elicited when facing a set of hypothetical scenarios, set up by researchers. Good guidelines for SP experiment design can be found in greater detail in Bradley (1988), Fowkes and Wardman (1988), Pearmain and Kroes (1990), Hensher (1994), Louviere et al. (2000), and Louviere and Hensher (2001).

Stated preference techniques are based on the presentation of hypothetical scenarios to respondents. These scenarios need to be plausible and realistic for respondents. Each scenario represents a package of different attributes. The design process of an SP experiment can be summarised in four steps.

(a) *Selection of a set of attributes.* The characteristics of the hypothetical scenarios are represented by attributes that influence preferences. Attributes can be selected from a preliminary survey (e.g. pilot survey or focus group) and a literature review of previous studies, and can be included factors (e.g. road pricing characteristics as in this research) which are interested by the researchers. For example, in mode choice studies SP exercises usually include in-vehicle time, out-of-vehicle time, cost and quality of transport modes as attributes for each mode. In this study, the attributes include the benefits and system characteristics of road user charging (see Chapter 4).

(b) *Specification of the number and magnitude of attribute levels.* As the number of the specified attributes and their levels increases, the number of the combined scenarios (such as from a fractional factorial design) also increases. If there are too many attributes in an SP exercise, individuals may ignore some attributes to simplify the task (Fowkes and Wardman, 1988; Bates, 1998). Pearmain and Kroes (1990) suggested that in an exercise attributes should be limited at six or seven per alternative, and less if it includes unfamiliar variables. In order to keep a limited number of attributes, a set of separate SP designs is useful, in which at least one common attribute (e.g. cost and time) is included in every exercise. This attribute(s) would allow comparisons of relative preferences across all the attributes.

Furthermore, variations of attribute values across scenarios need to be large enough for respondents to trade-off, otherwise they may be ignored. This may be tested by the simulation of responses (see Section 3.3.2), which allows the designer to improve the values of attributes before collecting real data. However, the simulation test cannot guarantee that the design will have no problems, particularly where there is a lack of previous information about magnitudes and ratios of coefficients in the study (Tudela, 2000). The simulation also cannot test whether individuals find the exercise realistic. At least one pilot survey is necessary; not only for testing the design, but also for guiding how individuals respond to the survey as a whole (e.g. format, questioning, presentation, survey conducting and response rate).

(c) *Experimental design: combination of the attribute levels.* Design of the hypothetical scenarios is based on an experimental design, which is usually fractional factorial rather than complete factorial. A complete factorial design is a design in which each level of each attribute is combined with every level of all other attributes. In other words, it contains all possible combinations of attribute levels. On the other hands, a great advantage of the fractional factorial design is that the number of scenarios can be dramatically reduced from the full factorial design, while it still ensures that the main effects of attributes are independent from the significant interaction effects, so that the main effects can be estimated efficiently. For designing fractional factorial experiments, the catalogue of experimental plans provided by Kocur et al. (1982) can be employed.

(d) *Design of response measurement.* Respondents are asked to state their preferences towards each scenario by either ranking, rating or choosing. These responses are able to provide information based on how individuals evaluate the attributes in the designed scenarios. A ranking response requires respondents to order preferences of the hypothetical options presented. This method has been rarely used. It may not correspond to what respondents face in real life (Pearman and Kroes, 1990). It is also been questioned in terms of reliability (Ortuzar and Garrido, 1991). A rating response requires respondents to express their degree of preference on a scale (e.g. 5, 10 or 100 point scale). This provides the richest form of data. However, binary choice data is the most realistic and simplest in making decisions, the simplest in data analysis and use for prediction, and the most often used in SP studies. It requires respondents to choose between usually two options.

In addition to the SP experiment, other components are also needed in a survey, e.g. questions gathering individuals' actual travel situations, which are relevant to the study context, questions about the attributes of existing choice alternatives, questions about attitudes to alternatives and personal details (Bradley and Kroes, 1992). These additional data are useful in analysis of SP data and explanation of the behavioural responses.

3.3.2 Simulation test

SP experimental designs may be tested by a simulation test (Fowkes and Wardman, 1988). This would allow the design to be improved in specifying magnitude of attribute levels and combining the levels, before being used in data collection. The simulation is based on the discrete choice theory (Ben-Akiva and Lerman, 1985), in which the random utility is a function of measurable utility and random error, ε (see Section 3.4).

The simulation mimics individual's choices from the measurable (known) utility function (usually linear) of variables in SP experiment, a set of reasonable (known) coefficients (from previous studies) of the variables and a random error. The known coefficients are usually based on values of time, in which the coefficient of cost is set to one; hence the coefficient of time is known. Following random utility theory, the error (ε) is assumed to be Gumbel distributed, in which $\varepsilon_i = Ln[-Ln(random)]/\lambda$; where random number is generated between 0 and 1, and λ is known as the scale factor. $\lambda = \pi/(\sqrt{6}\cdot\sigma)$; where σ is standard deviation of the error ε_i (see Ben-Akiva and Lerman, 1985; Fowkes and Wardman, 1988; Tudela, 2000). The scale factor is determined by selecting a standard deviation of the error to give a Rho-squared about what we expect. This is usually around 0.1.

Synthetic responses are produced based on the assumption of utility maximisation in that option i with respect to option j will be chosen if the utility of option i is higher. This process is repeated many times to achieve a number of responses. These simulation responses are analysed and then the estimated coefficients are compared with the adopted ones. A good design should achieve a small difference. Simulation test should also check that standard errors (t ratios) are acceptable and that they cannot be improved substantially by changing the design.

3.3.3 Sources of error in SP data

There are several sources of error in SP data that need to be considered when the SP techniques are applied. The first and most important bias could be from the design and presentation used because these can give misleading results (Ampt et al., 1995; Bates, 1998; Widlert, 1998). A major cause of this problem is that respondents tend to simplify the task and some factors may be ignored. This usually occurs in complex SP exercises. The design needs to be concerned about number of attributes in an alternative, the number of alternatives presented to a respondent, and how to present the attributes (for example, in percentage or absolute changes).

The other sources of error could be from unreliable data. The data error is due to 'wrong' answers from respondents (see Bonsall, 1985; Wardman, 1987; Bonsall et al., 1992; Ampt et al., 1995; Swanson, 1998). The responses may be provided by intention for some reasons, such as policy response bias (respondents may attempt to influence the policies studied), affirmation bias (respondents may adjust their response according to the aim of the study), habit or status-quo bias (respondents may tend to choose the option which is close to the actual situation, or which they are currently doing), and rationalisation bias (respondents may provide artificial responses in order to rationalise their current behaviour).

The wrong answers may also be given unintentionally, for example through misunderstanding (respondents may not fully understand SP and/or they may be fatigued from doing the exercise), unconstrained response bias (respondents may fail to consider all relevant constraints on their choices), lexicographic answer (respondents may sort the alternatives according to the value of one variable because they find the task too difficult or because one factor actually is more important to them than the others), and ability to report behaviour (respondents may have some difficulties to answer about their likely behaviour).

All sources of error need to be carefully considered when designing the SP experiment. Developments of the methodology (in Chapter 4) were needed before using the SP technique in this study in order to be sure that the design is appropriate to explain the public's preferences and behaviours responding to road user charging. Furthermore, the error could naturally occur from the SP data in model analysis including taste variations among individuals (heterogeneity; accounted in this research) and repeated measurement (further discussed in Section 3.4).

3.4 Analytical Issues

This section presents a brief description of the SP data analysis based on the random utility theory and logit model, which is explained in full in Ben-Akiva and Lerman (1985), Ortuzar and Willumsen (1994), and the most recent and comprehensive details in Louviere, Hensher and Swait (2000). This method of analysis has been widely used in analysing and forecasting economic consumer behaviour in a wide variety of applications, including marketing research, travel demand, residential location choice, environmental economics and health economics. Moreover, this section also presents the current development of the analysis technique to cope with taste variation among individuals and repeated measurement problem in SP data.

3.4.1 Random utility theory

An analytical method used for explaining choice behaviour is discrete choice analysis based on the random utility theory (Domencich and McFadden, 1975). An individual's choice is assumed to depend on 'utility' representing the satisfaction or benefits to the person from each alternative. If individuals act rationally, they are assumed to always choose the option with the highest utility to them. For example, if utility of alternative i is higher than utility of alternative j, alternative i will be chosen. However, it is impossible for the analyst to know the precise utility of each alternative, so the random utility (U_i) applied by the individual is broken down into a measurable part (V_i) and a random part (ε_i):

$$U_i = V_i + \varepsilon_i \qquad \text{(Equation 3.1)}$$

The measurable part (V_i) is a function of the measured attributes of the alternative and is commonly specified as a linear function shown in Equation 3.2; where θ_{ik} are the parameters or utility weights of the k attributes, X_{ik}, for alternative i.

$$V_i = \sum_k \theta_{ik} X_{ik} \qquad \text{(Equation 3.2)}$$

The random part (ε_i) reflects a non-measurable (unknown and/or unobservable to the analyst) part, which comes from four distinct sources: unobserved attributes, unobserved taste variations, measurement errors, and model specification error (Manski cited in Ben-Akiva and Lerman, 1985). The taste variation can be coped with by segmentation analysis and alternative specific functions (see Section 3.4.3). However, other errors are still assumed to be in the single additive element ε_i, with assumed known distribution.

3.4.2 Conventional logit model

Based on the random utility maximisation theory, an individual will choose alternative i rather than alternative j from a choice set C_n (n alternatives available), if

$$U_i > U_j \quad \textit{for all } j \neq i \in C_n \qquad \text{(Equation 3.3)}$$

From Equations 3.1 and 3.3, alternative i is chosen if

$$V_i + \varepsilon_i > V_j + \varepsilon_j \qquad \text{(Equation 3.4)}$$

The exact sizes of the random terms ε are unknown because of uncertainty and complexity of human behaviour. They vary across alternatives and individuals. Therefore, a distribution for them is assumed and only a choice probability of occurrence can be obtained, that:

$$P_i = Pr\,(V_i + \varepsilon_i > V_j + \varepsilon_j) \quad \textit{for all } j \neq i \in C_n \qquad \text{(Equation 3.5)}$$

$$P_i = Pr\,(V_i - V_j > \varepsilon_j - \varepsilon_i) \quad \textit{for all } j \neq i \in C_n \qquad \text{(Equation 3.6)}$$

An assumption that the random term (ε) is independently and identically distributed (IID) with a Weibull (also called Gumbel) distribution leads to the derivation of the multinomial logit model (MNL; Equation 3.7), in which the probability of choosing an alternative i (P_i) is that (Domencich and McFedden, 1975):

$$P_i = exp(V_i) \,/\, \Sigma_{j \in Cn}\, exp(V_j) \qquad \text{(Equation 3.7)}$$

The estimation process of utility parameters (θ_{ik}) of the MNL model is widely based on the maximum likelihood estimation. This estimator is based on the idea that the values of parameters are most likely to occur for the observed sample. The utility parameters (θ_{ik}) can be interpreted as an estimate of the weight of attributes in the utility function of alternative i. They can be allowed to vary across the groups of the public: for example according to socio-economic characteristics, and even vary across individuals as random parameters (described in Section 3.4.3).

As parameters estimated have associated standard error, a parameter is considered to be significantly different from zero at the 95% confidence level when its corresponding t-ratio (the ratio of the mean parameter to its standard error) has an absolute value greater than 1.96. Values of t-ratio as low as 1.6 are sometimes accepted representing the 90% confidence level, if the sign is correct and magnitude (e.g. implied values) seems plausible.

The overall model goodness-of-fit is indicated by likelihood-ratio index, ρ^2, which is parallel to the R^2 for a linear regression model. The ρ^2 values between 0.2 and 0.4 are considered to indicate an extremely good fit (Louviere et al., 2000). For SP studies, the values around 0.1 are typical. These results of the estimation process: values of parameters, their t-ratios and likelihood indexes can be estimated using available computer software programmes, for example ALOGIT (Hague Consulting Group, 1995) and LIMDEP (Econometric Software, 1999).

3.4.3 Taste variation among individuals

In the random utility, one of the sources of the random error is from taste variations among respondents (response heterogeneity). The standard logit model can cope with this variation, but only with respect to observed factors (commonly socio-economic factors and trip characteristics), by using segmentation analysis. However, this cannot handle unobserved or purely randomly variables (Train, 1986). Instead, the random parameters logit model is used.

Segmentation analysis

Segmentation techniques are used to explore differences between personal characteristics of respondents. This can be done by two methods. The first is by estimating separate models for each group (for example, used in Preston and Wardman, 1991 and Accent and HCG, 1994). With a small number of observations available for each segment, this technique would reduce the significance of coefficients (MVA et al., 1987). It would estimate all coefficients separately for every segment, even where some coefficients do not vary importantly across segments.

The second is by using incremental factors (MVA et al., 1987), as used in this study. The incremental factors allow different marginal utilities across segments of the sample (for example, used in Wardman et al., 1998). They can be specified as:

$$\sum_{y=1}^{n-1} \gamma_y \; d_{ky} \; X_{ik} \qquad \text{(Equation 3.8)}$$

Where γ_y is an incremental factor for the k^{th} attribute (X_k) and d_{ky} is a dummy variable denoting whether an observation is in y^{th} group of n groups in a category. If so, d_{ky} is equal to one, otherwise zero. One of the groups in the category is arbitrarily chosen as the base. The incremental effects for other groups are relative to this base, so only n-1 dummy variables are defined. The utility function of alternative i is:

$$V_i = \sum_k \theta_{ik} X_{ik} + \sum_{y=1}^{n-1} \gamma_y d_{ky} X_{ik} \qquad \text{(Equation 3.9)}$$

Thus, in Equation 3.9, the coefficient of the base group would be θ_{ik}, and the coefficient of X_{ik} for the y^{th} group in the category would be $\theta_{ik} + \gamma_y$. This approach can indicate the sign and size of any effect from the segmentation variable, provide its statistical significance, and can be tested on the fit of different models, for example between the basic model and the segmentation model or among the different segmentation models (Wardman et al., 1998).

In order to test the fit between the models, the likelihood ratio test is used given that the un-segmented model is a special case of the segmented one. The test is that twice the difference between the log likelihood values (LL) at convergence of the restricted and unrestricted models, -2(LL(R)-LL(U)), is higher than a χ^2 critical value of the chi-square distribution with M degrees of freedom. This degree of freedom is the number of extra parameters imposed on the model.

Random parameters logit model

One of the restrictions of the standard logit model is that the coefficients of the variables are assumed to be the same for all people. Though the segmentation analysis allows different coefficients for different groups of people, it is still assumed that different people with the same observed characteristics have the same values of parameters. Thus, variation of tastes of individuals (heterogeneity) may still be included. To deal with this problem, a random parameters logit model can be used. This model allows coefficients of observed variables to vary randomly across observations rather than being fixed. Some recent empirical studies can be found in e.g. Bhat (1998a, 1998b), Revelt and Train (1998, 1999), Train (1998), Brownstone and Train (1999), McFadden and Train (2000), and Hensher (2001a, 2001b, 2001c).

In general, the model specification is the same as the standard logit model, except that one or more coefficients (as well as alternative-specific constants, ASCs) vary across the population rather than being fixed. The coefficients are commonly assumed to be either normally or log-normally distributed. The selection of the distributions is still a major ongoing research area since no one distribution has all of the desirable behavioural properties; for example, with normal distribution both positive and negative values are produced across the parameter distribution, and with the log-normal distribution the values are constrained to be one sign but have a long tail of distribution that is behaviourally implausible for valuation (Hensher, 2001b).

When a coefficient is normally distributed, it is specified as $\theta_n = b_n + s_n\mu$, where μ is an independent standard normal distribution (mean zero and standard deviation one). b_n and s_n, therefore, represent the mean and standard deviation of θ.

The lognormal distribution is used if coefficients need to be the same sign for all observations; for example, the coefficient of cost should be always negative. The coefficient is expressed as $\theta_l = \exp(b_l + s_l\mu)$, where b_l and s_l represent the mean and standard deviation of $\ln\theta_l$. Therefore,

The median of θ_l	$= \exp(b_l)$	(Equation 3.10)
The mean of θ_l	$= \exp[b_l + (s_l^2/2)]$	(Equation 3.11)
The standard deviation	$=$ *(the mean of* θ_l*)* $\times \sqrt{[\exp(s_l^2) - 1]}$	(Equation 3.12)

The estimation results of mean, standard deviation of random coefficients, as well as individuals' specific coefficients, can be obtained by using e.g. LIMDEP and ALOGIT4. The estimation procedure for the random parameters logit model is based on simulated maximum likelihood. Simulation methods can be the random draws (pseudo-random Monte Carlo) or Halton draws (quasi-Monte Carlo). Nevertheless, Train (1999) and Bhat (2001) found that using the Halton draws method is vastly superior to using random draws (pseudo-random Monte Carlo). They showed that the simulation error in the estimated parameters was lower using 100 Halton numbers than 1000 random numbers, and the estimation procedure is faster for the Halton method (because of higher convergence rate). Revelt and Train (1998) suggested 100 Halton draws are sufficient for the estimation of a random parameters logit model. (See also Train (2002) for further detail of the estimation process and its simulation methods)

3.4.4 Repeated measurements effect

A nature of SP data is that multiple responses are obtained from each respondent. The data analysis assumes that these responses are independent. This may lead to a problem known as the 'repeated measurements' effect, when there is correlation between the responses within individuals, for example unobserved factors are specific to individuals. The problem tends to grow with increasing number of observations per respondent.

It is believed that this problem results in the upward biased values of the t-ratios (under-estimating the standard errors), but does not affect considerably the estimated parameter values of logit models. Until recently, the problem has usually been ignored in practice (Bates and Terzis, 1997). The simplest solution for correcting the t-ratios involves dividing the t-ratios by a correction factor. The first factor suggested is the square root of the number of observations per individual (Kocur et al., 1982). This most conservative factor would be correct, if the errors were perfectly corrected within individuals, which is unlikely (Bradley and Daly, 1993). The factor tends to be too high; some other factors mentioned are the third root (Bates and Terzis, 1997) and the fourth root (Ortúzar et al., 1997) of the number of repeated questions per individual.

In the study here, four observations (see Chapter 4) were obtained for each individual, so the correction factor using the fourth root of four would be 0.71. This would increase the critical value for testing significance at 95% confidence level from 1.96 to 2.76.

Moreover, some more complicated methods to cope with the problem have been suggested. Cirillo et al. (1996) applied re-sampling techniques, called Bootstrap and Jackknife, to examine how the estimated coefficients vary with different sizes of sub-sample. They found that the estimated coefficients were slightly changed, and the t-ratios were smaller, but did not fall as much as the simple correction factors (even the 'fourth root' factor). Ouwersloot and Reitveld (1996) divided the sample into sub-samples, taking only one observation from each respondent for each sub-sample, in order to avoid correlation between the responses. Models were analysed for each sub-sample, and then a final model for the whole sample was achieved later by using a complex algorithm called 'minimum distance' estimator. Although they found that in their data the repeated measurements effect was modest and statistically insignificant, further empirical studies are needed to examine the problem and solution.

These two methods were examined by Ortúzar et al. (1997) who found that neither was reliable. They found that the coefficients in some cases changed considerably, and their t-ratios did not decrease consistently, particularly for specific constants in the utility function. They mentioned that the problem is still far from solved.

In brief, in general it has been currently believed that the repeated measurements effect does not significantly affect values of coefficients in the logit model, and only has a small effect in reducing the significance of variables in the model. In turn, this is less likely to have considerable effects on predicted results of the model (main use in the study here).

More recently, to deal with the repeated choices by each respondent, Train (2002) suggests[1] that the coefficients should be treated as varying over people but being constant over choice situations for each person (a random parameters logit with repeated choices).

3.5 Development of Utility Function for the Individuals' Perspectives

The previous section has presented the analysis method for SP data, based on the random utility theory. The utility represents preference of an individual for a chosen option, according to its attributes. The choice is based on an assumption that the individual maximises his/her own utility. This almost implies that individuals' behaviour is motivated by self-interest. However, the literature review in Section 2.5.3 suggests that it is also influenced by social-interest, particularly on issues in which the public are involved. Hence, this section develops the utility function to measure the self and social preference.

Many studies argued that a utility function can contain both self- and social-interest components. For example, Margolis (1982, 1990) introduced the 'dual utilities' model: $W = G / S$ where W is the ratio (weight) between the value of group-interested and self-interested. S is the utility of self-interest and G is the utility of group-interest. The bigger the ratio for a person is, the more likely the person will be to cooperate in group-interest.

Mueller (1986) suggested a framework to explain and predict decisions, such as voting. He assumed that each individual maximises an objective function (O_i), which is a weighted sum of his/her utility (U_i) and the utilities of the other individuals (U_j). That is $O_i = U_i + \theta \sum_{j \neq i}^{n} U_j$. If θ = 1, an individual gives equal weight to the group's utility as to his/her utility. If θ = 0, the individual ignores the utility of others in his/her own objective function.

Hudson and Jones (1995), by expanding Mueller's concept, assumed that general attitudes to tax and public expenditure (TA^g) are determined by a weighted average of people's perceptions of their own interests (TS^s) and their perceptions of public interest (TA^p): $TA^g = \alpha . TA^p + (1-\alpha) . TA^s$. The α, lying between 0 and 1, can be considered to be a measure of 'altruism' and can be

[1] Unfortunately, the suggestion by Train (2002) has not been addressed by LIMDEP (a statistical analysis package) which was used to analysis the data in the study here. In addition, with a limit of time the study did not examine the repeated measurement effect. Nonetheless, with the four observations per person the effect was expected to be low.

referred to as the 'coefficient of altruism'. α is equal to zero, if individuals are entirely selfish; on the other hand, if they are entirely altruistic α is equal to 1.

Similar concepts to these studies are also suggested. For instance, Holmes' (1990), 'conceptual voting model', introduced a utility function representing an individual's egoistic and altruistic motivations. This concept is similar to Isaac's (1997), called 'multiple-utility representations', in which individuals' utility is related to self-interest and morality. Gupta et al. (1997) added an evidence to enlarge the paradigm of individual utility maximisation by explicitly taking into account group preference, in addition to self preference.

These concepts can be applied to this study. The utility function can be based on the assumption that the individuals' utility is not purely from self-interest or selfish perspective; it is partly from the social-interest and partly from the social perspective. Individuals have a trade-off between benefits to themselves and to society when deciding whether to vote for a scheme. Thus, utility of 'yes' vote for road user charging schemes contains utilities of benefits to self and to society.

$$U_{yes} = \beta_{self} U_{self} + \beta_{society} U_{society} \qquad \text{(Equation 3.13)}$$

Utility of benefits to self (U_{self}) and to society ($U_{society}$) were measured directly from individuals by asking how much they perceive benefits of a scheme to themselves and to society (see Section 4.5.1). These were separately indicated by rating on a scale defined between very detrimental and very beneficial. By using the utility function with the standard logit model (Equation 1), estimation coefficients of utility of benefits to self (β_{self}) and to society ($\beta_{society}$) can demonstrate whether both selfish and social perspectives of individuals influence acceptability of road user charging and how much weight they have for each perspective, and can also be used to forecast voting.

3.6 Summary

This chapter has presented the related methodological issues used in the research. The stated preference (SP) method was used to examine the impact of charging system characteristics on acceptability and effectiveness. The reasons for choosing the method have been discussed. Then this chapter presented the general background about SP methods covering processes of design and possible sources of error, which may incur in the SP data. The analysis technique of discrete choice data was also presented. It is based on the random utility theory, in which individuals are assumed to maximise their utility by choosing the option with the highest utility to them. The analysis method used is based on the logit model. This involves the standard logit model, in which the overall effects of variables are demonstrated for all samples. The segmentation model, based on incremental factors, is used to show different effects for different groups of people. The random parameters logit model can be used to examine the taste variation among individuals (heterogeneity), which is from unobserved sources and unable to be captured by the segmentation of respondents. Finally, this chapter has reviewed the utility functions, which included the effects of both self and social preferences, from various previous studies. This led to the development of the utility of voting for charging schemes, which is the function of the perceptions of benefits to self (from selfish perspective) and to society (from social perspective).

Chapter 4

Survey Design and Data Collection

4.1 Introduction

In the study, the SP technique was used (see Chapter 3). A paper-based SP questionnaire was designed and developed throughout a set of pilot studies. Four pilot surveys, varying in their design of presentation and measurement, were undertaken. The first version of the questionnaire and SP exercise was piloted in August 1999, with further pilots conducted in December 1999, March 2000 and July 2000. The main purposes of the pilot studies were: to test the presentation of SP attributes and levels; and to test the measurement of studied behaviours: acceptability, selfish and social perspectives, and effectiveness of charging schemes. The final version of the SP questionnaire was used for the main survey conducted in Leeds and London during November 2000 and March 2001.

In this chapter, the developments of the SP experiment and data collection are presented. Instead of presenting details of each pilot survey, the development of the key elements: attributes, their levels and behaviour measurements in the SP experiment are described. Section 4.2 presents the characteristics of the survey form. Section 4.3 presents the design of the SP experiment, involving the attributes and their levels used in the main survey. Section 4.4 explains the development of presentation of the attributes. Then Section 4.5 explains the development of measurement of the studied behaviours. Finally, Section 4.6 describes the main data collection procedures and presents respondents' characteristics.

4.2 Survey Form

A paper-based questionnaire was designed for the data collection. An example of the questionnaire is shown in Appendix A. It contains four main parts. The first part was designed for gathering general attitudes about transport problems and road user charging. The questions were how serious congestion and pollution is in the cities. Respondents could respond on a four-point scale: no problem, slight, serious and very serious. The other questions were whether they think road user charging is effective in reducing congestion and pollution. Respondents can answer yes or no. This part was also designed for gathering general information on travel to work (for commuters only). The questions involved travel mode for work and non-work trips, frequency of work trips, journey time, cost and distance travelled to work.

The second part focused on work and non-work trips within the specified areas of charge. These areas were within the Outer Ring Road of Leeds, and the North/South Circular Roads of London (a map was provided to each respondent with the questionnaire; shown in Appendix B). Respondents were asked to provide their journey travel time and delayed-time within the area for work trips and non-work trips when they travelled by car and bus. (Delayed-time was defined as "the time spent moving slowly or stopped in congested traffic, at traffic lights, or bus stops.") They were also asked whether they find their current travel situations acceptable.

The third part presented an SP exercise including hypothetical charging scenarios (see Section 4.3). Four scenarios were presented to each respondent, definition of road user charging was given to respondents in which "road user charging involves drivers being charged a fee for using their vehicles within specific areas (e.g. within the city centre), or on specific roads (e.g. on motorways), in order to reduce congestion, improve the environment, and/or generate revenue to be spent on transport projects and/or social projects". Following the charging scenarios, three questions were posed which measured individuals' responses about selfish and social perspectives, acceptability and mode choice (see details in Section 4.5).

The final part included some questions asking personal characteristics: gender, age, annual household income and number of cars in household. Furthermore, at the end of the questionnaire an open space was provided for respondents to add any comments which they had.

4.3 Design of Stated Preference (SP) Exercises

In the study, the two main key influences on acceptability (Section 1.2) in the design process are the benefits and the system features of road user charging schemes. These were used as attributes in the SP experiment. The benefits include: car travel time reduction, bus travel time reduction, environmental improvement, and benefits from use of revenue. The system features include: charging level, charging method, charged time period and charged area.

If all attributes were presented in one exercise, respondents might have ignored some attributes because there were too many variables to consider. To overcome the problem, separate designs were used. Five SP exercises were designed. Each exercise contained four attributes: three basic attributes that were charge, car travel time reduction and bus travel time reduction, plus an additional attribute.

- Exercise 1: charge, car travel time reduction, bus travel time reduction and *environmental improvement.*
- Exercise 2: charge, car travel time reduction, bus travel time reduction and *revenue allocation.*
- Exercise 3: charge, car travel time reduction, bus travel time reduction and *charged area.*
- Exercise 4: charge, car travel time reduction, bus travel time reduction and *charged time period.*
- Exercise 5: charge, car travel time reduction, bus travel time reduction and *charging method.*

Levels of the SP attributes were developed through the four pilot surveys (see the next section, 4.4). The set of attribute levels presented in Table 4.1 and 4.2 was found to be satisfactory in the pilots, and then was used in the main surveys (Jaensirisak, 2001).

Table 4.1 Attributes and their levels in SP exercises 1 - 4 (EX 1-4) in the main survey

Attributes[1]	**Levels**			
	0	**1**	**2**	**3**
Basic attributes				
Charge	£1	£3	£5	£7
Car delayed-time reduction	A quarter	A half	Three quarters	-
Bus delayed-time reduction	A quarter	A half	Three quarters	-
Additional attributes				
Environmental improvement (EX1)	As now	Slight	Substantial	-
Revenue allocation to Public transport : tax reduction (EX2)	50 : 50	Public transport only	Tax Reduction only	-
Charged area (EX3)	Wide area[2]	Small area[2]	-	-
Charged time (EX4)	7am – 7pm	7am – 10am	-	-

Note: 1. Attributes in each exercise are three basic attributes plus an additional attribute.
2. Wide and small areas are within the North/South Circular Roads and Inner Ring Road for London, and the Outer Ring Road and Inner Ring Road for Leeds.

Table 4.2 Attributes and their levels in SP exercise 5 (EX 5) in the main survey

Attributes	Levels			
	0	1	2	3
Charge levels (depended charging method)				
Fixed charge (per day)	£1	£3	£5	£7
Distance-based charge	10 ppmile[1]	30 ppmile	60 ppmile	100 ppmile
Time-based charge	2 ppmin[2]	5 ppmin	8 ppmin	12 ppmin
Delay-based charge	5 ppdm[3]	15 ppdm	25 ppdm	40 ppdm
Car delayed-time reduction	A quarter	A half	Three quarters	-
Bus delayed-time reduction	A quarter	A half	Three quarters	-

Note: 1. ppmile is pence per mille, 2. ppmin is pence per minute,
3. ppdm is pence per delayed-minute

For each SP exercise, the fractional factorial design (Section 3.3) was used for selecting a subset of a full factorial design. Exercises 1 - 4 have 16 charging scenarios each based on four attributes (charging, car and bus travel time reduction, and another additional attribute). In order to minimise effects of response fatigue, each respondent was presented only one SP exercise with four charging scenarios (see an example in Appendix A). These were random out of 16 scenarios.

For exercise 5, there were three attributes (charging, and car and bus travel time reduction). Charging was based on a fixed daily charge (as in Exercises 1-4) and the three variable charge (distance-based, time-based and delay-based) which were defined in the questionnaire for respondents as follows.

- "Distance-based charge is a charge related to the *distance* spent travelling on roads inside (but not including) the Outer Ring Road during 7am-7pm."
- "Time-based charge is a charge related to the *time* spent travelling on roads inside (but not including) the Outer Ring Road during 7am-7pm."
- "Delay-based charge is a charge related to the *delayed-time* spent travelling on roads inside (but not including) the Outer Ring Road during 7am-7pm."

The SP exercise was separately designed for each method. Each method of charge has 16 scenarios, there were totally 64 scenarios (for four charging basis). For the variable charges, respondents needed to estimate their daily charges based on their distance travelled, journey time or delayed-time to/from work. Only four charging scenarios were presented to each respondents, in which two scenarios were based on fixed daily charge and the other two scenarios were based on one of the variable charges. Thus, each respondent needed to calculate the charges for only two scenarios (the same charging method). They were also asked to provide the estimated charges.

4.4 Presentation of SP Attributes

This study used the SP technique to examine the effects of road user charging on acceptability and effectiveness. Since it was quite different from typical uses of the technique, this application of SP needed to be developed in order to be appropriate for the study. Presentation of the SP attributes and their levels was initially developed by guidance from previous studies and then tested in the series of pilot studies.

4.4.1 Presentation of levels of charge

Levels of charge are presented in the SP exercises 1 - 4 as fixed daily charges of £1, £3, £5 and £7 (shown in Table 4.1), which are likely to be suitable for both Leeds and London residents. The levels of charge for the time-based and distance-based charge (shown in Table 4.2) are presented as rates of charge, estimated by applying average daily travel time between home and usual work place (52 minutes to the conurbation centre) and average journey length (8.3 miles), from the National Travel Survey 1996/98, to the basic fixed charge per day. For the delay-based charge, the levels of charge were produced from the average delayed-time from the pilot surveys, which was about a third of journey time. Thus, the average daily delayed-time was assumed to be 17 minutes (a third of 52 minutes).

The levels of charge used are reasonable in comparison with the previous studies, presented in Table 4.3. They are rather different for the delay-based charge. This is possibly because the studies have different definitions of delayed-time.

Only the fixed charge per day is straightforward for presenting in the SP experiment. The rates of charge for the variable charging methods are quite difficult for the public to understand and estimate the charge, particularly because time-based and delay-based charges involve travel time, which is reduced because of reduced traffic.

In order to help respondents to know how much the charge would be, Bonsall et al. (1998) provided both rates of charges and estimated charges for respondents in their SP exercises, which were based on the hypothetical situation (knowing journey time and length), for example 2 pence per minute is £0.15 - £0.25 per journey. However, this is not realistic for respondents. In practice (if the variable charges were implemented), only rates of charges are given to the public, vehicle users have to estimate the charge themselves.

Table 4.3 Review levels of charge used in previous studies

Source	Study area	Methods of charge				
		Cordon (pence per crossing)	Fixed (pence per day)	Time-based (pence per min.)	Distance-based (pence per mile)	Delay-based (pence per delay min.)
This study	Leeds and London	-	100 - 700	2 - 12	10 - 100	5 - 40
NEDO (1991)	London	-	-	0.8 - 8	-	-
Sheldon et al. (1993)	London	50 - 200	500	1.5 - 12	10 - 40	-
Milne et al. (1993)	Cambridge	10 - 100	-	5 - 21	16 - 64	60 – 600
Fowkes et al. (1993b)	London (Central)	100 - 800	-	-	-	-
Fowkes et al. (1995)	Edinburgh	25 - 200	-	-	-	-
MVA (1995)	London (Central)	200 - 1000	-	-	64 - 256	-
Palmer and Bonsall (1997)	Simulation	-	-	3 - 36	-	12 – 150
Ghali et al. (1998)	Leeds and York	5 - 200	-	1-22	1.6 - 35	5 – 110
Cho (1998)	Leeds	70 - 150	-	2 -8	-	7 – 12
Richards and Harrison (1999)	Leeds	-	100 - 200	-	-	-

To make the SP exercise realistic, in this study, charging levels for each method were presented as rates of charge, such as pence per minute, pence per delayed-minute or pence per mile depending on charging method, even though it would be quite difficult for them to work out the charge. To check whether respondents understood the charging regimes and were able to estimate the charge, they were asked how much they would be charged. The pilot surveys showed that the majority of respondents were able to estimate their own charge. This was probably because only two variable charging scenarios, which used the same method of charge, were presented to each individual who received SP exercise 5.

4.4.2 Presentation of travel time reduction

In an SP exercise travel time changes are usually presented as absolute values. This is inconvenient for a paper-based survey where travel time reductions in the SP exercise are based on individuals' current travel time, because various sets of travel time and travel time change need to be prepared for different travel circumstances, and it may still imply unrealistic percentage changes for some respondents. Moreover, this requires much more time to distribute the survey forms because of the need to check that each individual receives the appropriate form. A computer-based survey is very much more flexible in presenting suitable travel time reduction as absolute values for each individual. However, this study did not use this method because it was costly, particularly when a number of respondents was needed for segmentation analysis. Therefore, the study should consider whether it is appropriate to present travel time reductions to respondents in other forms (e.g. percentage changes), rather than absolute changes.

In addition, another issue needed to be considered is whether time reductions (offered in the SP exercises) should be related to times reduced in current travel time (free flow travel time plus delayed time) or only in delayed-time. (Delayed-time is defined as the time spent moving slowly or stopped in congested traffic, at traffic lights, or bus stops.) This is important since the free flow time and delayed-time have different values (see Wardman, 2001a). In practice, if a charging scheme was introduced, the delayed-time reduction would be a direct benefit of the charge, which in turn results in reduction of total travel time. Therefore, reduction in delayed-time would be a more suitable measure for the study. This can also avoid unrealistic presentation of travel time reduction, in which travel time reduction offered may be higher than delayed-time perceived by an individual.

In the pilot surveys, in order to get a suitable form of presentation of travel time reduction, different forms were designed to test: (a) whether proportionate changes could be used instead of absolute changes, and (b) whether reduction of delayed-time was understandable by respondents and could be used instead of reduction of travel time. There were three forms of presentation: as absolute values (e.g. reduced by 10 minutes), percentage changes (e.g. reduced by 20%), and descriptions of proportionate changes (e.g. reduced by a quarter).

For the percentage and proportionate changes, each form has only one set of SP exercises. The percentage changes were presented in reductions of travel time, while the proportionate changes were in reductions of delayed-time in which travel time reductions. For the absolute changes, the study needed to provide a suitable survey form for each respondent. One set of travel time reductions was designed for each range of current travel times, for example for those who travel time 20-40, 41-60, 61-90 and over 90 minutes per day.

It was quite difficult to decide which form of the travel time reductions was the best for presenting in the SP exercises because of the limited sample size. Overall, the results showed that the description of proportionate changes in delayed-time (reduced by a quarter, a half and three quarters) could be used for the main data collection because:

- it presented realistic travel time reductions for everyone; (total travel time, for which delayed-time was deducted from current travel time, would not be lower than free-flow travel time)

- it was convenient for data collection; (survey forms can be handed to people without asking their current travel time)
- it was more familiar to the public than the percentage change;
- the model estimation results in the pilot studies using this approach showed no problem;
- respondents seemed to understand delayed-time relatively well; most of them were able to estimate their own delayed-time.

4.4.3 Presentation of environmental improvement

The presentation of environmental variables is one of the main difficulties of SP design. In previous SP surveys, there are various methods to present the environmental change in SP exercises. Firstly, the improvement is presented as categorical variables, such as 'slight' and 'significant' improvement (Thorpe and Hills (1992) studying preferences on road pricing schemes). Secondly, it is introduced as percentage change in improvement, e.g. 50% improvement, or in deterioration, e.g. 50% worse (Wardman et al. (1997) examining the impacts on location decisions), or as percentage reduction, such as the pollution reduced by 20% (Sælensminde (1999) investigating willingness to pay to reduce environmental problems). Thirdly, it is based on location specific descriptions that involve offering individuals different levels of environmental quality by referring to a range of locations with which the respondents would be familiar (Wardman et al., 1997), or by referring to different positions of respondents' households, e.g. noise levels varying due to distance from a source of the noise (Arsenio et al. 2000). Finally, it is presented in quantity of households affected, such as "number of households moderately to highly affected by traffic noise", or in amount of space lost expressed in "football field equivalents" (Daniels and Hensher (2000) valuing environmental impacts of road projects).

The previous studies show that the presentation design depends on what the objective of the study is, and how detailed the environmental valuation is. The design needs to bear in mind that the more details presented the more complicated the survey to the respondent, and this may affect valuations of the other variables. The last two methods of presentation (referring to specific locations and referring to amount of measurable effects) are more likely to be suitable for great detail in the valuation of the environmental impact. The first two approaches (categorical description and percentage charge) are simpler and easier to use in trading-off with other variables.

In the pilot studies, therefore, the two simple forms of environmental improvement presentation were tested: percentage change and description of improvement ('slight' and 'substantial'). There was no problem for respondents in responding to the charging schemes presented.

Nonetheless, in the main survey the description was used, because it was likely to be more understandable for respondents than the percentage improvement, which was in numerical terms.

4.4.4 Presentation of revenue allocation

Suggestions for revenue allocation have been made by Goodwin (1989) and Small (1992). Goodwin claimed that revenue of road pricing should be spent equally (a third each) for improving public transport, including in general tax revenue (either to reduce taxes or to increase social spend), and building and maintaining new road infrastructure. Small argued that this spending was too much for road projects. He suggested slightly differently a revenue allocation of one-third to reimburse to traveller, one-third to substitute general taxes and one-third to fund new transportation services (road network and public transport). However, it was not quite clear why revenue should be split equally among these projects.

The effects of the revenue uses on public acceptability were studied by many attitude surveys (e.g. Jones, 1991; Nevin and Abbie, 1993; CfIT/MORI, 2000; GOL, 2000; Thorpe et al., 2000). These found that acceptance of road user charging would be significantly improved when its revenue was spent on either public transport improvement or tax reduction.

In an SP survey, Thorpe and Hills (1992) examined the effects of revenue use on acceptability by presenting levels of public transport investment as 'slight' and 'significant', and presenting levels of annual vehicle tax reduction as 'unchanged' and 'reduced'. These presentations are simple and may be able to show some effects of revenue use on acceptability. However, it is difficult to know whether proportion of allocation of revenue to public transport and tax reduction significantly influences acceptability.

Since it was quite clear that these revenue uses could improve acceptance, this study examined whether proportions of revenue use are important. In the pilot surveys, the proportions were presented as 'revenue allocation to public transport : tax reduction' with three levels: '50:50', '75:25' and '25:75'. In the other version the levels tested were '50:50', 'public transport only' and 'tax reduction only'. These were simpler than the first one for respondents to understand; thus, they were used in the main survey to examine whether spending revenue on only improving public transport or only reducing tax are significantly different in improving acceptance from spending equally.

4.4.5 Presentation of systems features

System features: charging method, charged area and time, were unlikely to be a problem for presentation in an SP exercise. Definitions of charging methods were given to respondents that the charge was related to the distance, time or delayed-time spent travelling on the roads inside the charged area (described in Section 4.3). To indicate the areas of charge, a map (shown in Appendix B) was provided for each respondent. Times of charge were presented as 7am-10am and 7am-7pm. All these presentations were understandable for respondents, as shown by results from the pilot surveys.

4.5 Measurement of Behaviours

In the study, behavioural responses to the charging scenarios included: what they think about the schemes from their own and social preferences, whether individuals accept the schemes, and whether they intend to change mode for journey to work. To measure these, a set of questions was tested in the pilot surveys.

4.5.1 Measurement of selfish and social perspective

So far only a few studies in transport (see Section 2.5.3) have been involved with the self- and social-interest at the individual level. They examined the effects of the individuals' perspectives on travel behaviours and attitudes to transport projects. This study examined the individuals' preferences as influences on acceptability of road user charging. This was based on a hypothesis that people are not concerned only with benefits to themselves, but also benefits to society as a whole. A major barrier of the study was that there was no consensus on how to set questions that were able to distinguish selfish and social perspectives in each individual. The design for measurement of these perspectives needs to be varied depending on the context and objective of the study.

For example, Bristow et al. (1991) studied individuals' willingness to pay to preserve local bus services from three different aspects: (a) when respondents need to use the bus, (b) when respondents are concerned for others in their household, and (c) when respondents are concerned for the community as a whole. These can reflect personal preferences from self-interest to social-interest.

Hopkinson (1994) studied the public attitudes to transport projects, e.g. road widening and bypass building. The attitudes were measured from two perspectives: personal and social. These involve: (a) "benefit me personally as a resident", (b) "benefit me personally as a road user", (c) "benefits to residents as a whole", (d) "benefits to road users as a whole". These can reflect individuals' perceptions of benefits to themselves and to society, and also individuals' perspectives when they are in different positions, as users and residents.

Furthermore, Daniels and Hensher (2000) also studied the public valuation of environmental impacts of road construction for the selfish and social perspectives by asking respondents: (a) "from individual perspective..." and (b) "from community perspectives...". They believed that each individual has the two different perspectives, so these were asked directly of respondents.

In this study, a set of questions was designed to gather the individual's selfish and social perspective, and was tested in the pilot surveys. Three versions of the questions were designed to distinguish the two perspectives. In the first version, two questions used were:

- "How acceptable do you think the charge situation would be *for yourself*?"
- "How acceptable do you think the charge situation would be *for society as a whole*?"

Responses were provided on a 5-point scale, between very unacceptable and very acceptable. The majority of respondents answered the same to both the questions. This was possibly because the phrases 'for yourself' and 'for society as a whole' were not very clear to the respondents.

In the second version, the questions were:

- "From *your point of view*, would the situation be acceptable?"
- "From the point of view of the *well-being of society*, would the situation be acceptable?"

Respondents can only respond 'yes' or 'no'. It appeared that respondents either were unable or had no option to differentiate the two perspectives since most respondents gave the same answers for these two viewpoints.

In the last version, the questions were:

- "How much do you find each situation would benefit *yourself*?"
- "How much do you find each situation would benefit *society*?"

Respondents were asked to indicate their answers on an 11-point scale, -5 to 5, defined between very detrimental and very beneficial. Overall, respondents seemed to easily distinguish their attitudes; most of the respondents stated different perceptions between the two perspectives. This was possibly because the phrase 'benefit' was clearer than the previous questions and the scale allowed a wider range of response options. Therefore, this version was used for the main data collection. The pilot studies also found reasonable results in that the average of the perception of benefits to self was negative but to society was positive when rating was given by car users; while both were positive when rating was given by non-car users. Correlation between the two perspectives was quite low for car users, but high for non-car users.

4.5.2 Measurement of acceptability

Acceptance of road user charging has long been studied by attitudinal surveys. Many terms have been used for reflecting the acceptability. The most direct one is 'acceptable' (used in NEDO, 1991, Thorpe et al., 2000; Ison, 2000). Some other general terms are 'support/oppose' (in Jones, 1991, 1995; LEX, 1998, 1999; Taylor and Brook, 1998; CfIT/MORI, 2000), 'in favour/against' (in Seale, 1993; Taylor and Brook, 1998), 'good/bad thing' (in GOL, 2000). The other term, which is direct and meaningful, is 'vote for' (in Jakobsson et al., 2000).

Though all these terms are clearly understandable, they are slightly different in some senses. For example, some people might think it is good, but not vote for it because they do not want to happen. Or some might vote for it (for some reason), even though they feel it is not good for them. 'Acceptable', 'good' and 'in favour' can reveal general attitudes. 'Support' and 'vote for' may imply more sense in terms of implementation support or political support. 'Vote for' also lets people become more involved in the decision-making process.

In the pilot surveys, there were attempts to use both terms 'acceptable' and 'vote for'. The first was:

> *"Which situation do you consider most acceptable?*
> *Current situation or with-charging situation"*

The second was:

> *"Which situation would you vote for?*
> *Current situation or with-charging situation"*

Although both 'acceptable' and 'vote for' seemed to be understandable to respondents, 'vote for' was selected for use in the main survey because it was more a precise measure of whether people would accept the schemes to implementation. The term 'acceptable' was rather too general.

Furthermore, in some cases the choices offered (current situation and with-charging situation) cannot provide clear information because a selected answer was compared to the other. For example, if the current situation was unacceptable and the charging system was considered more acceptable than the current one, it was not clear whether the charging system was acceptable.

In order to make it simple for respondents, the final version of the measurement was:

> *"Would you vote for situation A? (If there was a local referendum)*
> *Yes or No"*

This question was clearer and simpler than the previous ones in measuring whether individuals accept and support the charging schemes to be implemented. Hence, it was used in the main survey.

4.5.3 Measurement of effectiveness

In order to evaluate the effectiveness of road user charging schemes, the main objective of the scheme needs to be specified, either for traffic relief, environmental improvement or revenue generation. The study focused on car use reduction. To reflect this, car users' behavioural responses to the schemes could be measured by their intention to reduce car use or to change behaviour. For example, car users could be asked to indicate a number between 0-100 corresponding to their intended car use when facing charging schemes, where zero means no car use at all and 100 means the same extent of car use as now (Jakobsson et al., 2000). This method is fairly crude. Car users can just indicate their overall level of car use, for whatever purposes, but they may use different modes for different trips. Alternatively, car use reduction can be measured by travel mode switching. Car users can be asked to indicate a behavioural change by selecting from a presented set of choices, for example, including pay and drive, travel earlier or later, change transport mode, move house and change job or destination. This measurement should be used to allow car users to indicate the change for different trip purposes because they are likely to change their behaviours in different ways for different trip purposes.

In this study, the SP exercises were designed to examine individuals' mode choice response to the charging scenarios for their work trips. Respondents were offered four choices: car, car earlier/later (travelling by car before and/or after the charged time), bus, and other (specified by respondents). This question is straightforward. The results from the pilot studies indicated no sign of a problem for respondents to answer the question.

4.6 Data Collection and Respondents' Characteristics

The main data collection was conducted in Leeds and London during November 2000 and March 2001 by self-completion questionnaires. In this section, the process of the data collection is described, sample characteristics are presented, and problems found in the main data collection are discussed.

4.6.1 Data collection process

The designed SP questionnaires were distributed to the public in general without identifying specific groups. There were 830 respondents in Leeds and London in total. The sample was collected from two sources: household surveys and employee surveys. The household survey forms were distributed by Royal Mail to residents' households inside and outside the Inner Ring Roads of Leeds and London in selected postcode areas. Respondents replied by using freepost envelopes provided. There were 572 respondents from Leeds (11.4% response rate) and 159 from London (3.2% response rate).

For the employee survey, several private companies and local government organisations in Leeds and London were contacted to ask for cooperation in distributing the questionnaires to their staff. A few organisations agreed to help. Their staffs were given the self-completion questionnaires. Respondents replied either by using freepost envelopes, or by collection within their firms. There were 88 replies from Leeds (14.7% response rate) and 11 from London (6.5% response rate).

4.6.2 Problems in the data collection

For the household survey, the low response rates particularly from London were probably due to the survey method (self-completion) and its lack of personal contact. Another possible reason was that the questionnaires were delivered by Royal Mail to every household in the selected postcode areas, although some households had no occupants. It may also be because it was clearly stated that the questionnaires were carried out for a PhD research in the University of

Leeds, so people were less interested to complete the survey form, particularly in London. They may believe that the results will not influence any change.

For the employee survey, most companies only cooperated in distributing the survey forms to their staff, but the response was dependent on their employees who can individually reply by using freepost envelopes provided. Thus, the response rates on average are just a little better than the household survey. Some companies have no response at all, but some have over 50% response rate. Moreover, the main problem of this survey was the difficulty to get cooperation from both private and public organisations. They may not see any benefit to themselves. On the other hand, the survey may disturb their staff work.

The survey method, self-completion and mail-back questionnaire, was used because it was less time and cost consuming than face-to-face interview, in order to achieve the same sample. Although, the response rates are low, it was less likely to have biases from non-responses, as long as the respondents' characteristics are not very far from the Census. It was also less likely to have the policy bias from those who have strong attitudes against the policy, because it was clear to respondents that the questionnaires were carried for university research.

4.6.3 Respondents' characteristics

There were 830 respondents in the sample, of which 660 were from Leeds and 170 were from London. Sample characteristics are given in Table 4.4. There was a high proportion of car users from Leeds, but a high proportion of non-car users from London, as expected. (Note that car user is defined as those who usually use their cars for either work or non-work trips.)

Table 4.4 Characteristics of respondents from Leeds and London residents

Characteristics	Leeds 660	London 170
Mode use		
Car*	522 (80%)	69 (41%)
Bus	113 (17%)	47 (28%)
Other mode	25 (4%)	54 (32%)
Gender		
Female	237 (36%)	79 (47%)
Male	399 (61%)	83 (49%)
No answer	24 (4%)	8 (5%)
Household income per annum		
Less than £10,000	71 (11%)	19 (11%)
£10,000 - £19,999	111(17%)	23 (14%)
£20,000 - £29,999	132 (20%)	31 (18%)
£30,000 - £39,999	80 (12%)	19 (11%)
£40,000 - £49,999	58 (9%)	21 (12%)
£50,000 - £59,999	36 (6%)	14 (8%)
£60,000 or more	46 (7%)	20 (12%)
No answer	126 (19%)	23 (14%)
Age		
24 or below	8 (1%)	6 (4%)
25-34	77 (12%)	58 (34%)
35-44	137 (21%)	41 (24%)
45-54	174 (26%)	27 (16%)
55 or more	248 (38%)	31 (18%)
No answer	16 (2%)	7 (4%)
Number of car in household		
0	66 (10%)	68 (40%)
1	337 (51%)	79 (47%)
2	224 (34%)	11 (7%)
3 or more	22 (3%)	4 (2%)
No answer	11 (2%)	8 (5%)

* Note: car user is defined as those who usually use their cars for either work or non-work trips

The data of the 1991 Census for gender and age can be accessed. The distribution of the sample from London is slightly different from the census. The Leeds sample included a higher proportion of men and a slightly higher proportion of respondents over 55 than expected from the Census figures, in which men are 47.3% and the 55 or older age group are 34.3% of those who are 18 or over.

In the questionnaire, respondents were asked to indicate their general perceptions relating to: current travel situation, transport problems (congestion and pollution) and effectiveness of charging schemes in reducing the problems. They were also given space for comments. From these comments, some respondents were identified to have a strong dislike of charging. This includes opinions mentioning that car users already pay enough, charging is not a solution, and some stating directly that they were against the charge. The statistical results of the perceptions are shown in Table 4.5. Greater details of these perceptions are presented and discussed in the next chapter.

Table 4.5 General perceptions of respondents from Leeds and London residents (% of respondents)

Perceptions	Leeds	London
Perception of current travel situation		
Acceptable	372 (56.4%)	56 (32.9%)
Not acceptable	177 (26.8%)	72 (42.4%)
No comments	111 (16.8%)	42 (24.7%)
Perception of congestion problem		
No problem	8 (1.2%)	1 (0.6%)
Slight	135 (20.5%)	4 (2.4%)
Serious	377 (57.1%)	62 (36.5%)
Very serious	134 (20.3%)	102 (60.0%)
No comments	6 (0.9%)	1 (0.6%)
Perception of pollution problem		
No problem	12 (1.8%)	0 (0%)
Slight	167 (25.3%)	9 (5.3%)
Serious	359 (54.4%)	67 (39.4%)
Very serious	111 (16.8%)	93 (54.7%)
No comments	11 (1.7%)	1 (0.6%)
Perception of effectiveness in reducing congestion		
Yes	225 (34.1%)	93 (54.7%)
No	407 (61.7%)	72 (42.4%)
No comment	28 (4.2%)	5 (2.9%)
Perception of effectiveness in reducing pollution		
Yes	221 (33.5%)	91 (53.5%)
No	422 (63.9%)	73 (42.9%)
No comment	17 (2.6%)	6 (3.5%)
Dislike of charging		
Strong dislike of charging	215 (32.6%)	19 (11.2%)

4.7 Conclusion

This chapter has presented the process of survey development. The questionnaire and SP exercises were designed and tested by a series of pilot surveys between August 1999 and July 2000. The last pilot survey showed that the designed questionnaire and SP exercises were suitable for use in the main data collection. The main survey was conducted between November 2000 and March 2001 in Leeds and London by the household and employee surveys.

Throughout the pilot studies, many developments of the questionnaire and SP exercises were produced. The formats of questionnaire and SP exercises were changed until they were the least complicated for the public and were still capable to of producing all the information needed in the analyses. Attributes and their levels in the SP exercises were designed. Delayed-time was proved to be understandable to respondents. Presentation of delayed-time reductions in terms of proportions (a quarter, a half and three quarters) was satisfactory and gave some advantages over the presentations of travel time reduction in terms of absolute number and percentage change. Selfish and social perspectives were distinguished by public perceptions of benefits to themselves and to society. Voting for the schemes was used for reflecting acceptability. Effectiveness was measured in terms of mode choice for travel to work.

Results of the data analyses are presented and discussed in the next five chapters, Chapters 5 – 9. Chapter 5 looks at the descriptive analysis results about public's general attitudes to transport problems and road user charging. In Chapter 6, voting behaviour is analysed to show how acceptability is influenced by the system characteristics, as well as respondents' characteristics. Chapter 7 reports on the effects of selfish and social perspectives on acceptability. Chapter 8 investigates the effects on effectiveness. Then in Chapter 9, the relationship between acceptability and effectiveness of the policy is examined.

Chapter 5

General Public Attitudes to Road User Charging

5.1 Introduction

In chapter 4, the design of the questionnaire for the main data collection was described. It was designed for gathering three main elements of data:

- general public attitudes to transport problems and road user charging;
- individuals' current travel situations;
- the SP data, which was analysed and is reported in the next three chapters.

Moreover, space was provided at end of the survey form for respondents to add their comments.

The objective of this chapter is to present and discuss the data about the general attitudes and current travel situations. A summary of the comments is also provided. Although Table 4.5 has presented the statistical results of the general attitudes, this chapter provides greater details. Section 5.2 reports the perceptions of current travel arrangements, such as journey times, delayed-time and the acceptability of the current situation. Section 5.3 describes the perceptions of transport problems: congestion and pollution. Then, Section 5.4 demonstrates the relationship between the perception of the current travel situation and the perception of the problems. The perceptions of effectiveness of road user charging in reducing the problems are presented in Section 5.5, while Section 5.6 summarises the general comments from respondents, and identifies respondents who have a strong dislike of charging. Section 5.7 ends the chapter with conclusions about general public attitudes towards transport problems and road user charging.

5.2 Perception of Current Travel Situations

One of the main elements of the data from questionnaire is about individuals' current travel arrangements within the inner areas of Leeds and London. For Leeds, the area is specified as the area inside the Outer Ring Road and for London as within the North/South Circular Roads (shown in Appendix B). Respondents were asked to estimate their daily journey time and delayed time within these areas, if they travelled or were to travel by car and bus for work and non-work trips. They were also asked whether they found their current travel arrangements in their city acceptable.

5.2.1 Current journey time

Average daily journey times to work per day for commuters in Leeds and London using their current mode and assessed for the alternative mode are shown in Table 5.1. The average journey times to work for both car and non-car users in London are higher than those in Leeds. This is partly because in London people live further from work places than in Leeds (from the data, average daily travel to and from work is 22.1 miles in London and 18.7 miles in Leeds). It is likely to be mainly because in London congestion is higher[1].

In both cities, car users expected that their journey time to work by bus would exceed car journey time. Non-car users also believed that their journey time would be less if they travelled by car, even in London. Perceived delayed-times are relatively large, particularly for bus.

Table 5.1 Average journey times (standard deviation) for work trips within Leeds and London

Sample	Average car journey time (mins. per day)	Average car delayed-time (mins. per day)	Average bus journey time (mins. per day)	Average bus delayed-time (mins. per day)
Leeds				
Car users	35.6 (26.1)	16.8 (14.6)	69.3 (44.2)	32.3 (27.1)
Non car users	51.1 (51.0)	25.7 (21.5)	66.5 (40.4)	29.6 (26.4)
London				
Car users	83.8 (87.1)	37.7 (36.6)	150.2 (114.5)	68.7 (72.0)
Non car users	66.5 (69.7)	35.0 (32.2)	95.2 (75.2)	47.1 (41.5)

In order to see how perceptions of car and bus journeys differed, calculations were made for each individual of the ratio of bus journey time to car journey time, as well as the ratio of delayed-time to total journey time for both bus and car journeys. The average of these ratios for work trips are reported in Table 5.2.

The average ratios of bus journey time to car journey time are relatively high for car users. In Leeds, on average, journey time to work by bus is expected to be double that of the car journey, and almost double in London. The difference between car and bus journey time for non-car

[1] From the Transport Statistics Great Britain 2001, average time taken to travel between home and usual place of work is 42 minutes in London and 25 minutes in West Yorkshire.

users is lower than for car users. This is probably because car users have less experience and poorer perceptions of using the bus, so they are likely to overestimate bus journey times.

The average ratios of the delayed-times to journey times for car and bus are slightly different. In Leeds, the ratios are similar between car and non-car users. In London, the ratios of delayed-time to journey time are slightly higher for non-car users than for car users. For car users, the delayed-times are perceived as almost a half of journey times, but over a half for non-car users.

Table 5.2 Average ratios of travel times (standard deviation) for work trips within Leeds and London

Sample	Average ratio of bus journey time to car journey time	Average ratio of car delayed-time to car journey time	Average ratio of bus delayed-time to bus journey time
Leeds			
Car users	2.02 (0.99)	0.42 (0.24)	0.46 (0.19)
Non car users	1.66 (1.01)	0.43 (0.17)	0.46 (0.28)
London			
Car users	1.87 (0.92)	0.43 (0.16)	0.48 (0.24)
Non car users	1.51 (0.69)	0.58 (0.32)	0.55 (0.29)

Average daily journey times for non-work trips perceived by both commuters and non-commuters in Leeds and London are shown in Table 5.3. As with work trips, the average journey times of non-work trips in London for both car and non-car users are higher than in Leeds. Car users expected that journeys by bus would be longer than by car. Non-car users also thought that journeys by car would be quicker. Perceived car and bus delayed-times are relatively large, particularly in London.

Table 5.3 Average journey times (standard deviation) for non-work trips within Leeds and London

Sample	Average car journey time (mins. per day)	Average car delayed-time (mins. per day)	Average bus journey time (mins. per day)	Average bus delayed-time (mins. per day)
Leeds				
Car users	36.5 (49.2)	14.4 (15.5)	82.3 (72.9)	29.3 (35.9)
Non car users	39.1 (39.8)	18.9 (14.2)	76.8 (93.9)	20.6 (15.5)
London				
Car users	49.4 (65.0)	25.5 (21.2)	82.6 (54.7)	43.8 (29.7)
Non car users	44.4 (48.4)	32.9 (28.2)	82.1 (57.0)	39.9 (32.3)

Comparisons between car and bus journey times and between delayed-time and journey time for non-work trips are presented in Table 5.4. The bus is still perceived as having longer journeys time than the car, particularly for car users in Leeds. In Leeds, the car and bus delayed-times, compared to the journey times, are not as high as for work trips. The delayed-times of non-work trips are perceived as only about a third of journey times. In London, the ratios for non-work trips are slightly different from work trips, with non-work delayed-times about a half of journey time.

Table 5.4 Average ratios of travel times (standard deviation) for non-work trips within Leeds and London

Sample	Average ratio of bus journey time to car journey time	Average ratio of car delayed-time to car journey time	Average ratio of bus delayed-time to bus journey time
Leeds			
Car users	1.93 (1.33)	0.29 (0.21)	0.36 (0.22)
Non car users	1.63 (1.72)	0.35 (0.16)	0.31 (0.17)
London			
Car users	1.52 (0.71)	0.39 (0.14)	0.51 (0.20)
Non car users	1.53 (0.96)	0.56 (0.33)	0.51 (0.25)

5.2.2 Acceptability of current travel situations

Figure 5.1 shows the analysis of the answers to the question about attitudes towards the current situation. Individuals were asked whether they found their current travel situation 'acceptable' or 'unacceptable'.

From the whole sample, 52% replied that their current travel situation was acceptable and 30% unacceptable (the others did not answer). However, there were differences between respondents in Leeds and London, and between car and non-car users. In London, less than a third of non-car users (27%) thought their current situation acceptable, while 40% of car users did. In Leeds, the majority of car users (60%) thought their current situation acceptable, and 42% of non-car users did.

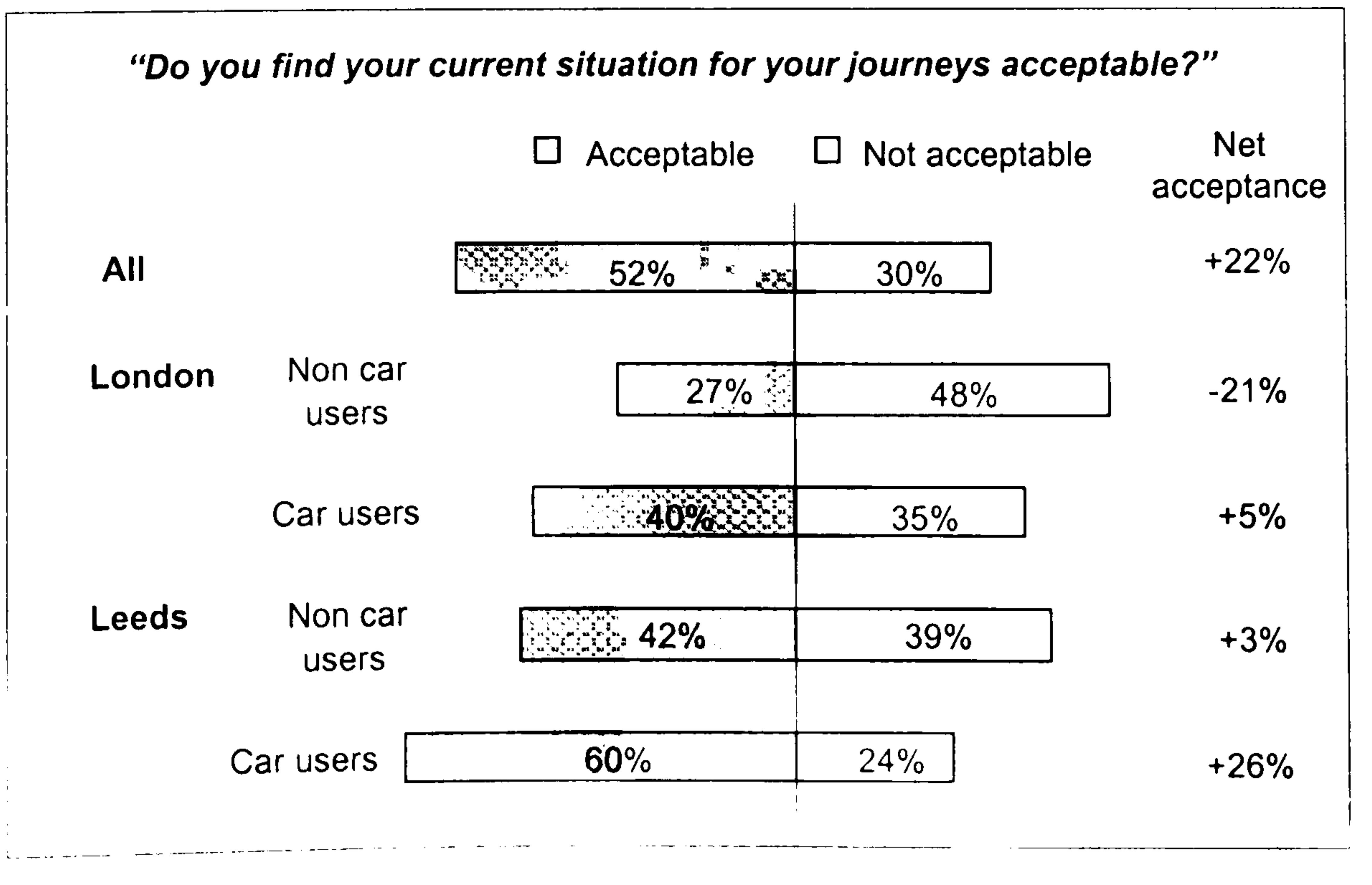

Figure 5.1 Acceptability of current travel situations by car and non-car users

Overall, the current situation is more acceptable to car users than to non-car users, and to respondents from Leeds than from London. Non-car users may not be satisfied with public transport services, as well as other non-car modes. In London, transport problems of congestion and pollution are likely to be perceived as more serious than in Leeds (see Section 5.3).

5.3 Perception of Transport Problems

In this section, the results are presented from questions asking respondents how serious they perceive traffic congestion and pollution to be in their city. Responses were indicated separately for the level of congestion and pollution on a four-point scale: no problem, slight, serious and very serious.

Overall, the majority saw the problems as 'serious' or 'very serious', 81% for congestion and 76% for pollution, with minorities rating them 'slight' and 'no problem', as shown in Figure 5.2. Correlation (Kendall's tau-b coefficient[2]) between the perceptions of the level of congestion and pollution is moderate (0.64). This indicates that when respondents perceive one problem as serious, they also tend to perceive the other as serious too.

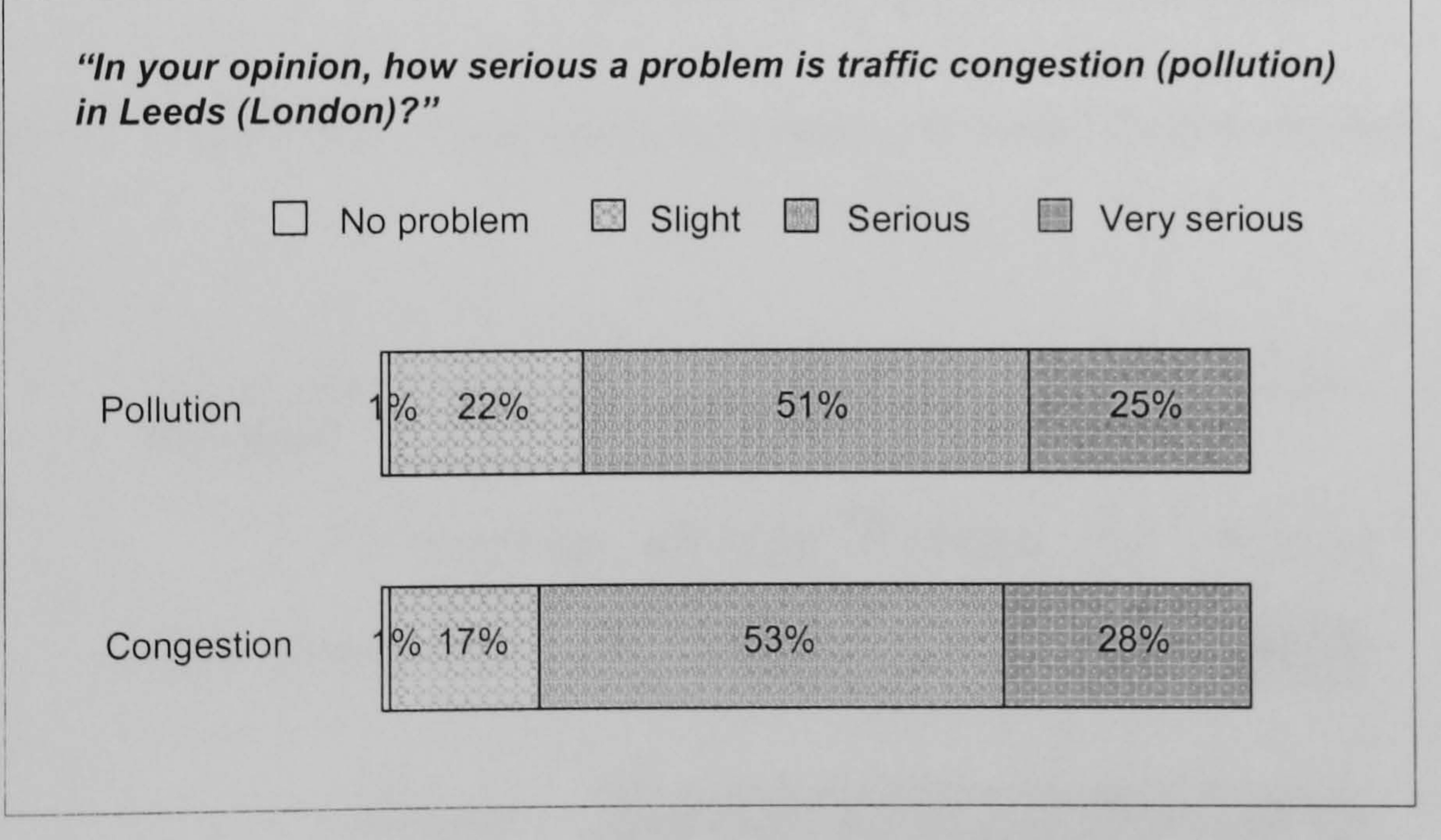

Figure 5.2 Perceptions of congestion and pollution by all respondents

It was found that the perceptions of the transport problems ware different between respondents who are from Leeds and from London, and between car and non-car users. Figure 5.3 shows the

[2] Kendall's tau-b coefficient varies between −1 and +1 to indicate the strength and direction of relationship between two ordinal variables (Bryman and Cramer, 1997). Its interpretation is identical to Pearson's r coefficient, which is for interval data.

perception of congestion of car and non-car users in Leeds and London. Nearly all London respondents, 97% of non-car users and 96% of car users, felt that congestion was serious or very serious. These figures are slightly lower for non-car users (89%) in Leeds, and lower (75%) for car users in Leeds. Between these cities, although the proportions of perceiving 'serious' or 'very serious' in Leeds are not substantially different from in London, the proportions of 'very serious' alone in London are very much higher than in Leeds.

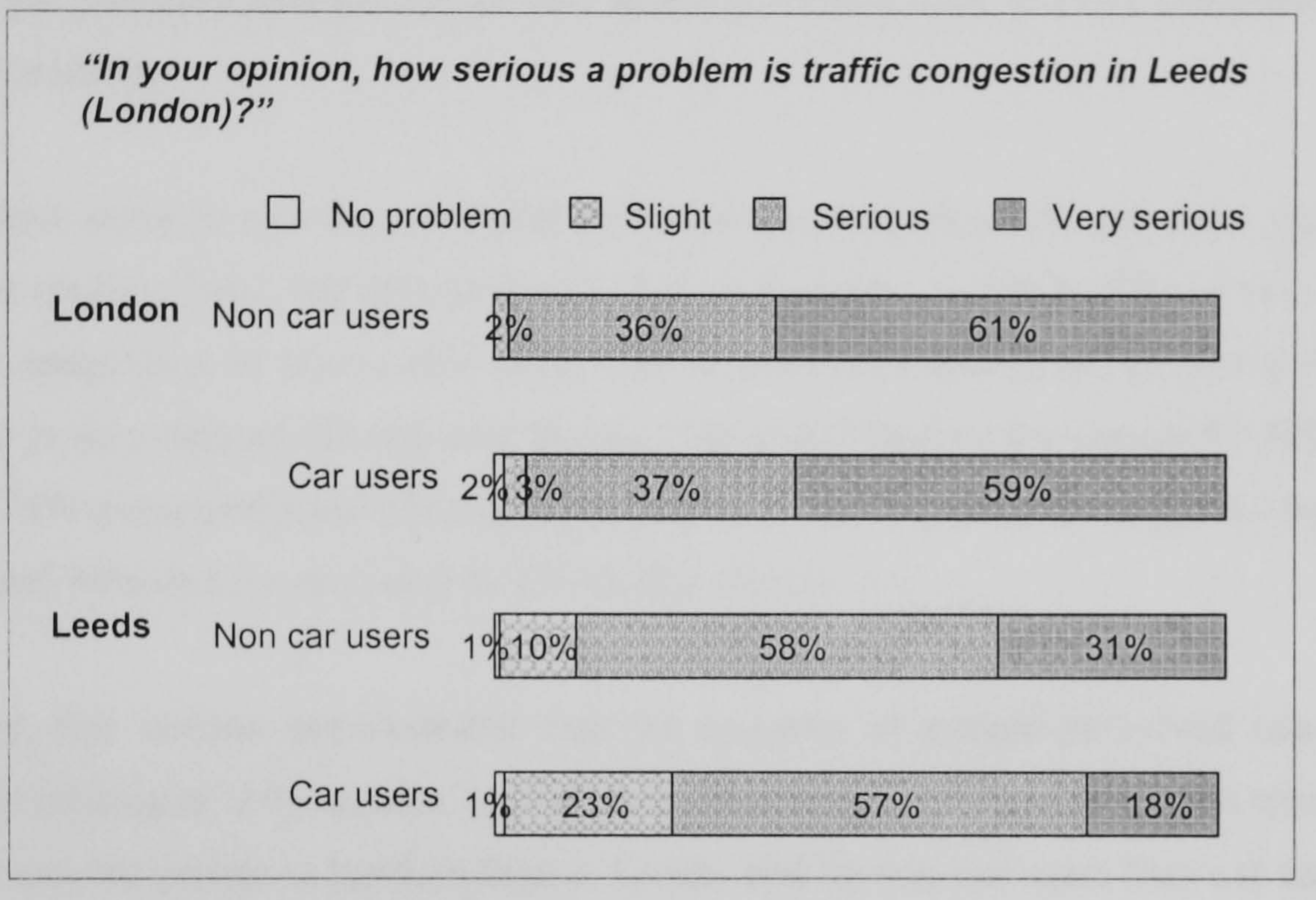

Figure 5.3 Perceptions of congestion in London and Leeds by non-car and car users

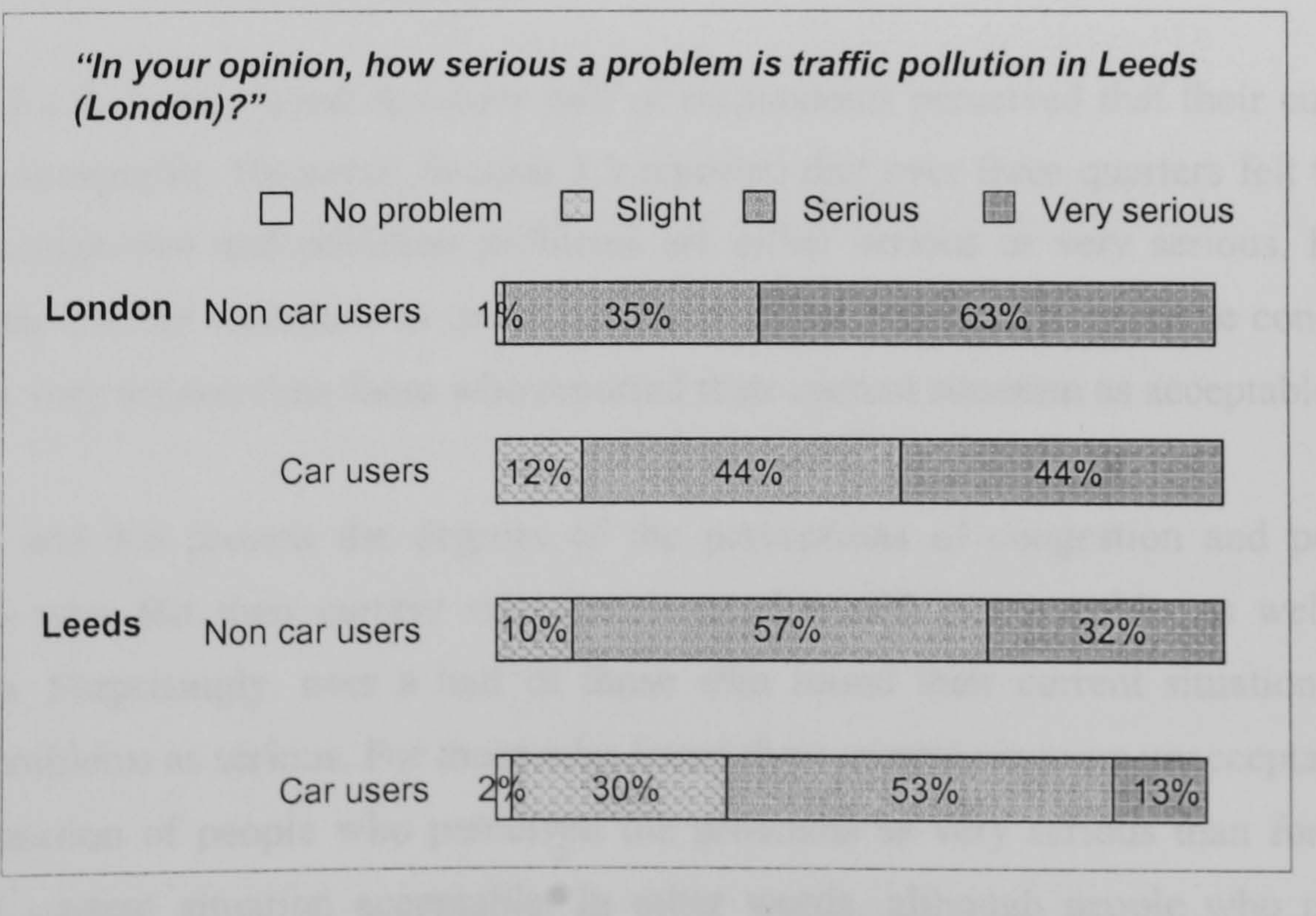

Figure 5.4 Perceptions of pollution in London and Leeds by non-car and car users

Figure 5.4 shows the perception of pollution for respondents in Leeds and London by car and non-car users, which is quite similar to the perceptions of congestion. A very high proportion of non-car users (98%) of London perceived pollution as serious or very serious. This proportion is slightly lower for car users in London (88%) and non-car users in Leeds (89%). The perception of pollution for car users in Leeds is relatively lower than the others. Two thirds of car users in Leeds thought pollution was serious or very serious, while a third felt that pollution in Leeds is slight or no problem.

Other previous surveys also found similarly that the majority of public perceive congestion and pollution as serious. From the British Social Attitudes survey in 1995, 50% of respondents felt that traffic congestion in towns and cities was *very* serious and 63% felt that exhaust fumes from traffic is *very* serious (Taylor and Brook, 1998). In London, the survey by MORI in 2001 found that 74% perceived level of congestion was fairly or very poor, 51% did for motor vehicle pollution, and 69% did for emission (CfIT/MORI, 2001).

In summary, this section demonstrated that the majority of people perceived congestion and pollution as serious or very serious, as found in other surveys. These problems were perceived as more serious by people in London than in Leeds, and by non-car users than car users.

5.4 The Relationship between the Perceptions of the Problem and Current Travel Situation

In Section 5.2.2, it was found that over half of respondents perceived that their current travel situation is acceptable. However, Section 5.3 reported that over three quarters felt that in their local area congestion and pollution problems are either serious or very serious. People who reported their current situations as unacceptable could be expected to perceive congestion and pollution as very serious than those who reported their current situation as acceptable.

Tables 5.5 and 5.6 present the degrees of the perceptions of congestion and pollution for respondents who felt their current situation acceptable and unacceptable, as well as for all respondents. Surprisingly, over a half of those who found their current situation acceptable perceived problems as serious. For those who found their current situation unacceptable, there is higher proportion of people who perceived the problems as very serious than for those who found their current situation acceptable. In other words, although people who perceive the problems as very serious tended to find their current situation unacceptable, the majority of people who perceive the problems as serious felt their current situation acceptable.

The correlations (Cramer's V coefficient[3]) between the rating of their current travel situation and the perceptions of the severity of the congestion problem (0.43) and pollution problems (0.29) are rather low. In addition to the perceptions of these problems, it is likely that there are other factors affecting the perceptions of the current situation, e.g. journey time, reliability of journey time, road condition, public transport services, facilities of walking and cycling, etc.

Table 5.5 Cross-tabulation between the perception of congestion and current situation

Perception of Congestion	Perception of current situation		Total
	Acceptable	Not acceptable	
No problem	9 (2.1%)	0 (0.0%)	9 (1.3%)
Slight	109 (25.8%)	10 (4.0%)	119 (17.8%)
Serious	237 (56.2%)	109 (44.0%)	346 (51.6%)
Very serious	67 (15.9%)	129 (52.0%)	196 (29.3%)
Total	422 (100%)	248 (100%)	670 (100%)

Table 5.6 Cross-tabulation between the perception of pollution and current situation

Perception of Pollution	Perception of current situation		Total
	Acceptable	Not acceptable	
No problem	11 (2.6%)	1 (0.4%)	12 (1.8%)
Slight	123 (29.3%)	24 (9.7%)	149 (22.0%)
Serious	212 (50.5%)	130 (52.6%)	342 (51.3%)
Very serious	74 (17.6%)	92 (37.2%)	166 (24.9%)
Total	420 (100%)	247 (100%)	667 (100%)

5.5 Perceptions of Effectiveness of Charging

In this section, the results presented are from questions asking whether respondents agree that charging would be effective in reducing congestion and pollution. Responses, either 'yes' or 'no', were made for assessment of effectiveness in reducing congestion and pollution. The results are presented in Figure 5.5.

[3] Cramer's V coefficient varies between 0 and 1 to indicate the strength of relationship between two nominal variables that have more than two categories (Bryman and Cramer, 1997).

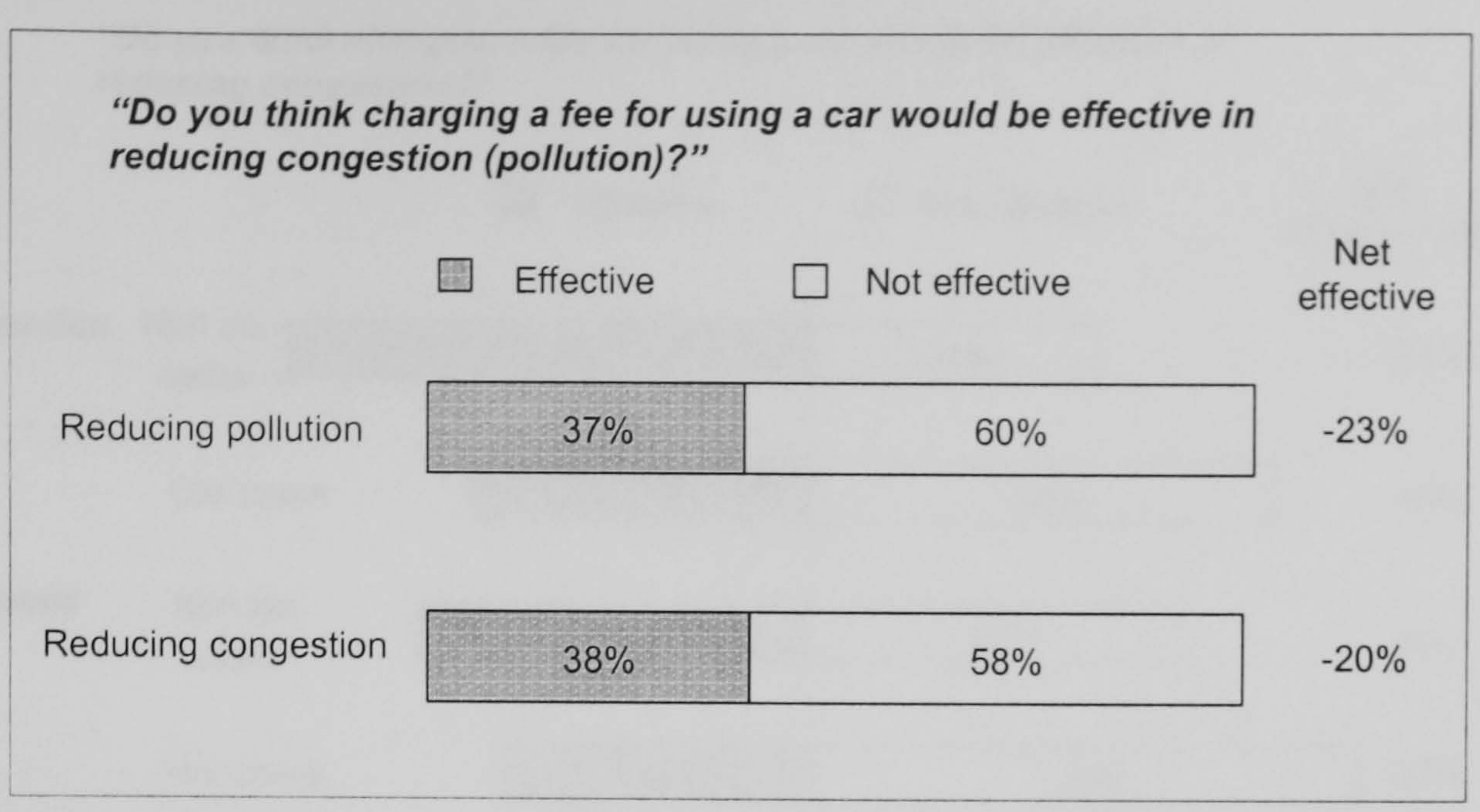

Figure 5.5 Perceptions of effectiveness of charging in reducing congestion and pollution by all respondents

From all respondents, most respondents (almost two thirds) believed that charging a fee for using a car would not alleviate the problems. Only 38% and 37% of them agreed that the charge would be effective in reducing traffic congestion and pollution, respectively. The correlation (Phi coefficient[4]) between the perceptions of effectiveness of road user charging in reducing congestion and pollution is high (0.87). This indicates that when respondents perceive effectiveness in reducing one problem, they also tend to perceive the same for the other.

There were differences in proportions with each perception between car and non-car users, and between respondents from Leeds and London. Figure 5.6 shows the perception of effectiveness in reducing congestion for respondents in Leeds and London by car and non-car users. In London road user charging is perceived as effective by almost two thirds of non-car users (63%), but only 40% of car users. In Leeds these proportions are lower. Almost half of non-car users perceived effectiveness, but only 37% of car users did.

Among car users there are lower proportions of those who perceived charging as effective than among non-car users. This may represent protest responses from some car users. They may be against charging, and thus claim that charging is ineffective in reducing the problems. In London, charging is perceived as more effective than in Leeds. This may be because charging has been on the public agenda for longer in London, so it is more familiar to the public.

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[4] Phi coefficient varies between 0 and 1 to indicate the strength of relationship between two nominal variables that have two categories (Bryman and Cramer, 1997).

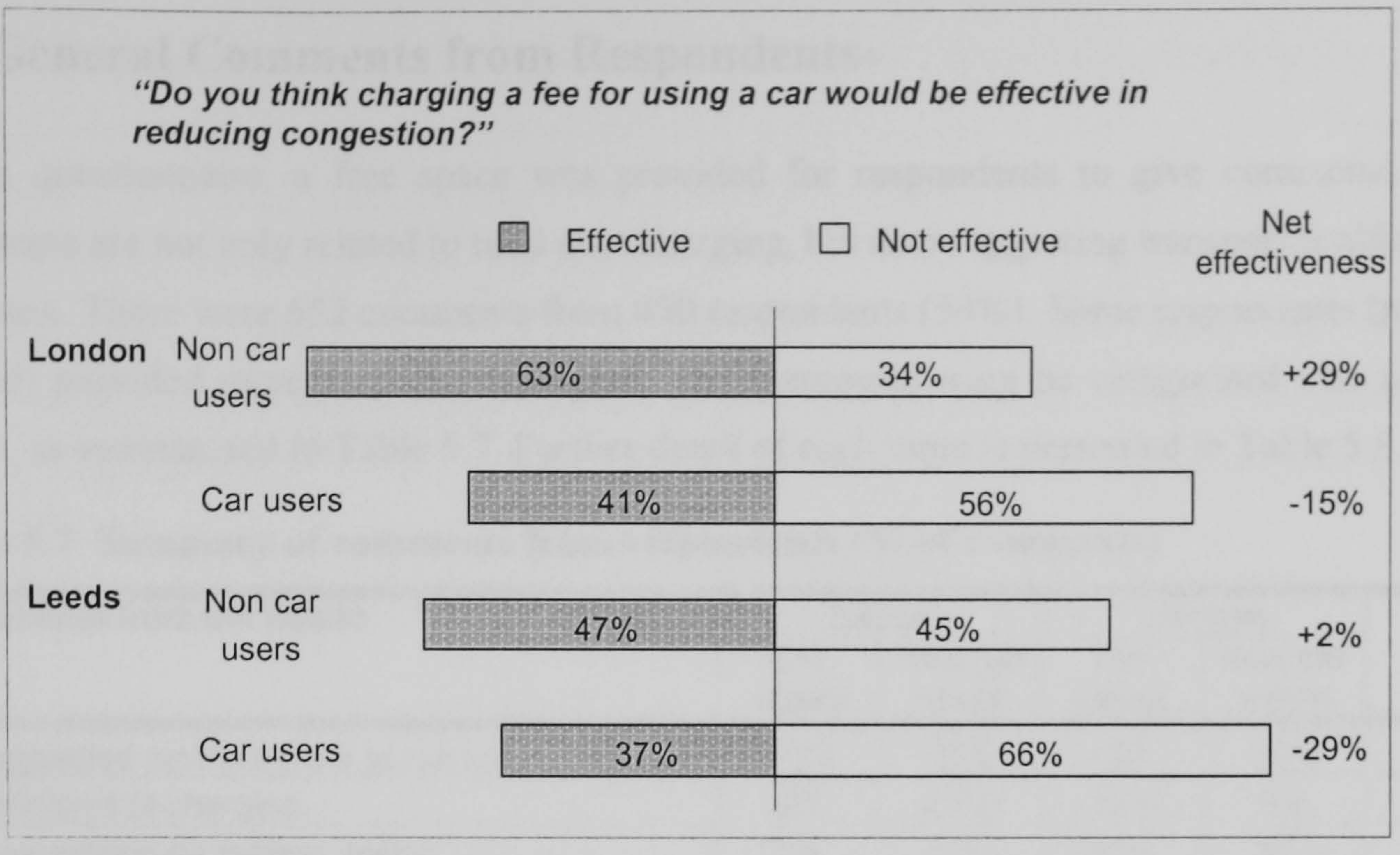

Figure 5.6 Perceptions of effectiveness of charging in reducing congestion in London and Leeds by non-car and car users

Figure 5.7 shows the perception of effectiveness in reducing pollution for car and non-car users in Leeds and London. These results are quite similar to the results of the perceptions of effectiveness in reducing congestion.

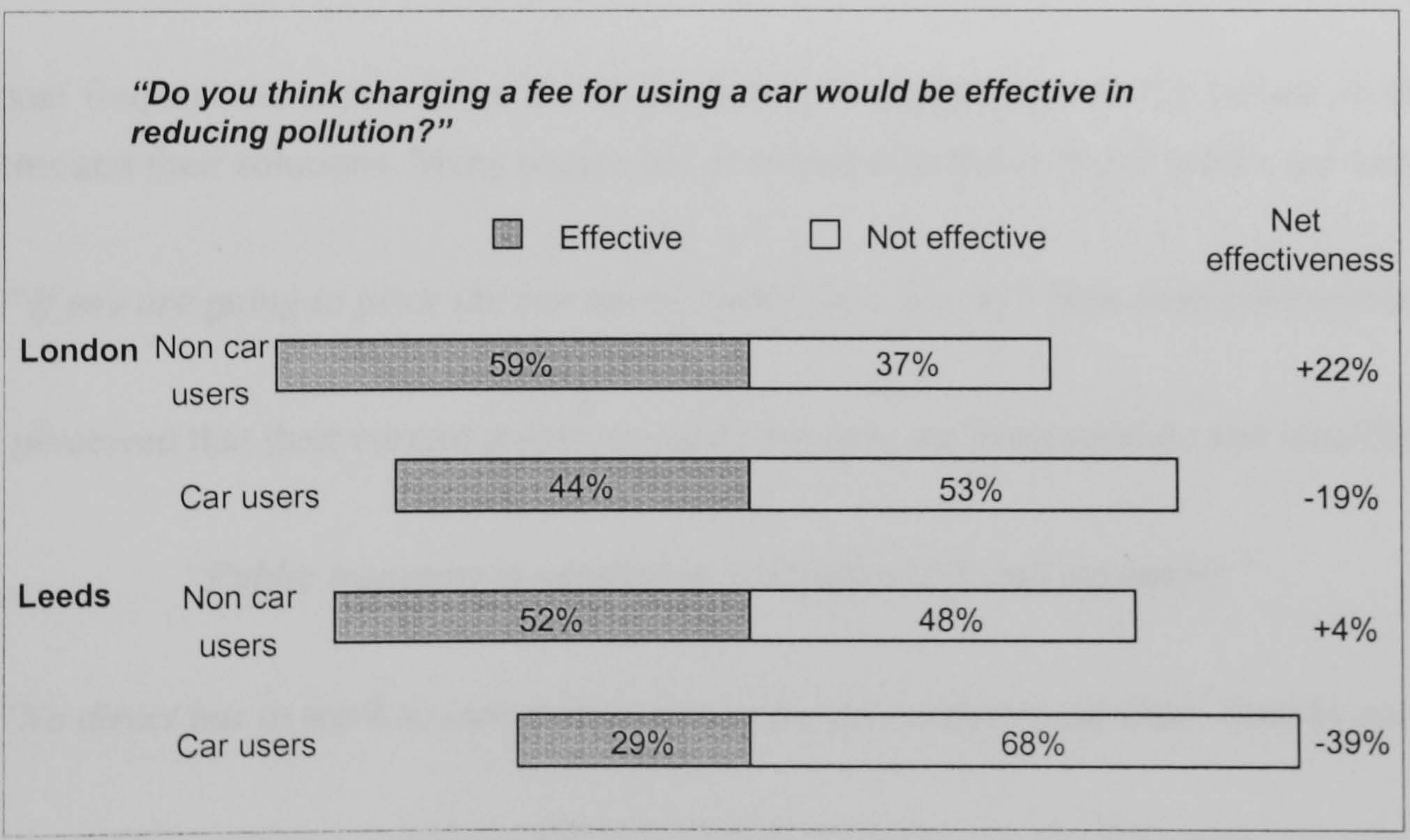

Figure 5.7 Perceptions of effectiveness of charging in reducing pollution in London and Leeds by non-car and car users

5.6 General Comments from Respondents

In the questionnaire, a free space was provided for respondents to give comments. These comments are not only related to road user charging, but also suggesting transport problems and solutions. There were 652 comments from 450 respondents (54%). Some respondents (just over a third) provided more than one comment. The comments were be categorised into six main topics, as summarised in Table 5.7. Further detail of each topic is presented in Table 5.8.

Table 5.7 Summary of comments from respondents (% of comments)

Comments from the public	Leeds		London		All
	Car users	Non car users	Car users	Non car users	
a. Suggested problems and solutions	45%	48%	45%	61%	47%
b. Criticisms of charging	35%	27%	22%	6%	30%
c. Suggestions on system design	5%	7%	22%	19%	8%
d. Preferring car use	10%	0%	2%	0%	7%
e. Effects of charging	4%	12%	2%	6%	5%
f. Reasons for support	1%	6%	8%	9%	3%
Total number of comments	445	90	51	66	652
Total number of respondents giving comments	313	62	33	42	450
Total number of respondents in the study	522	138	69	101	830

a. Suggested problems and solutions

The most frequent comments from the respondents are suggestions on the causes of transport problems and their solutions. Many people believed that alternative travel modes are needed:

"If you are going to price the car out of town –fine- but let's have real alternative."

Some perceived that their current public transport services are inappropriate and insufficient:

"Public transport is unreliable, uncomfortable and expensive."

"No direct bus to work so currently would take even longer to get there than by car."

Some also believed that transport problems would be eased by improving public transport:

"A reliable bus service with comfortable and clean buses driven by drivers who know how to accelerate and brake for the comfort of their paying passengers would go a long way to solving the problem."

It is not surprising that many people mentioned their need of alternatives. In attitudinal surveys, public transport is always the most preferred solution of congestion for the public (e.g. Cullinane, 1992; Stokes and Taylor, 1995; CfIT/MORI, 2000, 2001). There are three possible reasons behind these comments on public transport. Firstly, some people may really need alternative modes. They would use public transport if services were satisfactory. Secondly, some people may just attempt to justify their rejection of charging or excuse for using their car. Finally, some people may expect others to use alternatives and relieve the roads for them.

Some people felt that traffic congestion is partly because of parents escorting their children to school:

"Volume of traffic shows a marked decrease during school holiday time, which indicates the number of school-run cars on the road during term time."

Furthermore, a few comments suggested that congestion can be reduced by other policies, e.g. enforcing the ban on cars on bus lanes, giving priority to pedestrians and cyclists, increasing parking charges, banning cars from the city centre and so on.

b. Criticisms of charging

Many respondents believed that charging for using cars is not a solution for transport problems. They thought people will not stop using their car; they will do what they want:

"It would never happen, people won't change the habits of a lifetime even if the ultimate reward would be faster journeys and less pollution. It's human nature. We are utterly selfish."

"Pricing people out of car is not the way to go."

One common reason for being anti-charging is that people felt that they already paid enough tax for using a car, and road user charging was just another tax to raise revenue by the government. Thus, they thought they should not pay any more for using a car.

"I pay Road Tax, this would mean an extra tax."

"I do not agree to any road user charging system in principle. Within Europe alone we have the highest fuel tax."

"Motorists pay enough."

"Why should I pay more for using roads?"

"I will not support any proposal that makes life more difficult or costly."

These people are unlikely to agree with the principle of charging, which requires them to pay more for using cars. They may not understand the reasons why they should pay more. Moreover, a few people also mentioned that charging is unfair for some groups of the public, e.g. disabled people, those who use cars very little, those on low income and pensioners.

c. Suggestions on system design

Some respondents provided suggestions about charging system features, which they would like to see. Some responses mentioned the benefits of charging: reducing pollution and spending the revenue for improving public transport and reducing tax. Some respondents suggested levels of charge and exemptions for specific groups e.g. high occupancy vehicles and residents in charged areas.

"I think a charge will be a great way to get our pollution down."

"We would prefer a better environment for our children."

"Benefits would come through subsiding to bus companies that provide services from outside Leeds."

"Using the revenue to create proper bike and bus lanes which cars cannot park."

d. Preferring car use

Some car users felt that the car is essential for their life. They would have some difficulties without cars. They need it for many purposes, e.g. journey to work, taking children to school and going shopping, for which they may not prefer to use public transport.

"We have to accept that the car is the king and one's lifestyle is geared to its use."

"I am an essential car user."

"The car is a beautiful freedom."

"I have to drop my daughter off at nursery."

These people are less likely to give up using cars. They are dependent upon their car. In turn they may be less likely to accept any policy that make difficulty for car use.

e. Effects of charging

Some people felt that road user charging would have detrimental effects on others, e.g. on businesses, increasing public transport fares and increasing accidents. They were uncertain about the indirect impacts of charging.

"If it (road user charging) was introduced, it would have detrimental effects on my business."

The schemes will jeopardise those business based in the city centre."

It will drive away business and jobs."

"Would buses have to pay the fares? If so bus fares would increase."

"The proposal would result in being congested on the Outer Ring Road."

f. Reasons of support

Some respondents stated that they supported road user charging because something has to be done and because they believe charging can tackle transport problems.

"We have got to have a system of costing cars out of central town."

"Please do something about traffic congestion and especially pollution, I worry for my children's health."

"I think a charge of any kind will be a great way to get our pollution down and to stop roads being as built up with traffic."

These suggest that in order to improve acceptance of road user charging, the public need to be convinced that charging is an effective solution in reducing transport problems, e.g. congestion and pollution. Chapter 6 looks at whether those who perceive charging as an effective policy tend to accept road user schemes.

Summary

In summary, the comments can be put into three categories.

- Firstly, those who suggested solutions to transport problems (Comments a; 47% of comments);
- Secondly, those who made suggestions about the design of charging systems and those who gave reasons why they support charging (Comments c and f; 11% of comments). Their acceptance of charging systems was likely to depend on the benefits and characteristics of the systems;
- Finally, those who objected to being made to pay more for using cars, those who were concerned about the indirect effects of charging and those who had a high preference for car use (Comments b, d and e; 42% of comments). These people were likely to have stronger feelings of dislike of charging than the first two groups and respondents who did not made any comments.

The respondents who have a *strong dislike of charging* may be expected to have lower rates of acceptance than other groups. They may also evaluate and respond to charging systems differently from others. These hypotheses are tested in the following chapters (Chapters 6-9).

In total 450 respondents (of 830, 54.2%) provided comments in the open space provided. Of these, 234 respondents (52.0% of those who provided comments and 28.2% of the total number of respondents) criticised charging in principle and the detrimental effects of charging, or showed a high preference for car travel.

The perception of strong dislike of charging was examined whether it was related to the perception of current travel situation, the perceptions of transport problems, the perceptions of effectiveness, and personal characteristics. The results of the correlation analysis demonstrated that the relationship was very low (the Cramer'V coefficients are less than 0.2).

Table 5.8 Comments from Leeds and London residents by car and non-car users (% of comments)

Comments from the public	Leeds		London	
	Car users	Non car users	Car users	Non car users
a. Suggested problems and solutions				
Alternatives are needed	22%	20%	18%	27%
Current public transport is not good enough	10%	4%	10%	9%
Public transport would solve transport problems	6%	10%	8%	6%
Congestion is from school trips	2%	6%	6%	2%
Current traffic network should be improved	2%	-	2%	-
Buses make more congestion and pollution than cars	1%	-	-	-
There is less congestion and pollution	1%	-	-	-
More restriction for using or parking cars on bus lanes	-	-	-	8%
Flexible working hours	1%	1%	-	-
Increasing parking charging	1%	-	2%	-
Banning cars from city centre	-	4%	-	-
Priority for pedestrians and cyclists	-	-	-	5%
Encouraging car sharing	-	1%	-	2%
Encouraging motorbike	-	-	-	3%
Increasing road tax and fuel tax	-	1%	-	-
b. Criticisms of charging				
Charging is not solution for transport problems	12%	11%	14%	5%
Paying enough taxes already or just another tax	9%	3%	2%	2%
Against charging or not willing to pay	6%	-	-	-
Concerns for disable people	2%	1%	-	-
Concerns for less frequent car users	2%	2%	-	-
Concerns for low income people	1%	2%	-	-
Concerns for pensioners	-	1%	-	-
Unfair	1%	-	4%	-
Constraining personal freedom	1%	-	-	-
How does charging system work?	-	3%	2%	-
Charging system is expensive to install and operate	-	2%	-	-
c. Suggestions on system design				
Pollution has to be reduced	2%	-	-	3%
Revenue should be spent on tax reduction	1%	-	2%	-
Revenue should be spent on public transport	1%	2%	4%	6%
Combining with public transport improvement	-	-	6%	-
Charging only on peak time	1%	1%	-	-
Low level of charge	-	3%	-	3%
High level of charge	-	-	-	3%
Charging only on solo drivers	-	1%	-	2%
Discount for residents	-	-	6%	-
Exemption for residents	-	-	4%	-
Exemption for motorbikes	-	-	-	2%
d. Preferring car use				
Car is essential	9%	-	2%	-
Charging is a punishment to car users	1%	-	-	-
e. Effects of charging				
Affects business	3%	6%	-	-
People will move out or avoid getting into charged areas	1%	-	-	-
Charging will cause an increase of bus or taxis fares	-	4%	2%	2%
Charging will have some indirect effects to other groups	-	2%	-	3%
Charging will cause more accidents	-	-	-	2%
f. Reasons for support				
Agree because something has to be done	-	-	8%	9%
Agree because charging will tackle transport problems	1%	6%	-	-

5.7 Conclusions

This chapter has presented general public attitudes towards transport problems and their current travel situations for car and non-car user in Leeds and London. These related to perceptions of current travel situations, perceptions of transport problems (congestion and pollution), and perception of effectiveness of charging.

Overall, most respondents perceived that congestion and pollution problems in their cities are serious or very serious, particularly in London. However, many people still perceived their current travel situations as acceptable. This perception is also likely to be influenced by other factors, not only the perceptions of congestion and pollution. Furthermore, the majority of car users did not perceive that charging is an effective solution in reducing congestion and pollution. On the other hand, it was perceived as an effective solution by a majority of non-car users.

From the general comments, it was found that one main concern was about public transport and alternatives. Many respondents felt that provision of alternative means of travel is currently not sufficient and needs to be improved. Furthermore, some respondents who have a strong dislike of charging were identified. They include those who criticised charging as a solution of transport problems, those who objected to being made pay more for car use, those who were concerned at the indirect effects of charging and those who had a high preference for car use. These respondents were assumed to be more opposed to charging than those who did not provide any comments or who commented on other issues.

In the following three chapters, the perceptions and the strong dislike of charging were examined to assess whether they influence acceptability and effectiveness of road user charging schemes. This was based on the hypothesis that those who perceived their current travel situations as unacceptable, who perceived the transport problems as serious, who perceived charging as effective and who did not demonstrate a strong dislike of charging were more willing to support charging schemes and to reduce their car use than others.

Chapter 6

Public Acceptability and System Characteristics

6.1 Introduction

In this research, the questionnaire (described in Chapter 4) was designed to collect the data. This included the general public's attitudes towards transport problems and road user charging (presented in Chapter 5), and the SP experiment to examine the impacts on acceptability and effectiveness. The results of analyses of the SP data are presented in this chapter and Chapters 7 and 8.

The objective of this chapter is to test the first hypothesis presented in Chapter 1 (Figure 1.1), in which acceptability of road user charging is influenced by the benefits and system features of the charging scheme, as well as personal characteristics and perceptions. The acceptability of road user charging as influenced by these factors is presented. The logit model (Section 3.3) was used for analysing the SP data. Acceptability was measured by whether respondents would vote for schemes. This directly measures whether people would support the schemes for implementation (Section 4.5.1).

The results of voting behaviour based on the conventional logit model are shown in Section 6.2. The basic model presented was estimated from all respondents from Leeds and London. Section 6.3 demonstrates the effects of personal characteristics and perceptions on the voting. This explores the extent to which results differ among groups of the public. Section 6.4 examines variation among individuals which is from unobserved sources and unable to be captured by the segmentation of respondents according to socio-economic and trip characteristics. This is achieved through the use of the random parameters logit model. Section 6.5 ends the chapter with conclusions about the acceptability of road user charging as affected by the system characteristics, and personal perceptions and characteristics. A preferred voting model developed will be used later in Chapter 9 to predict acceptance levels of different groups of people for various road user charging schemes.

6.2 Acceptability Influenced by the System Characteristics

Voting behaviour was analysed using the standard logit model (Section 3.4.2) in order to explain the effects of the characteristics of road pricing systems. Hypothetical charging scenarios were presented to respondents. For each scenario, they were asked whether they would vote 'yes' or 'no' (Section 4.5). The utility function of vote 'yes' is set as a function of the alternative specific constant (ASC) and the system characteristics, whilst the utility function of vote 'no' is zero, as follows:

$$U_{YES} = ASC + \theta_1\ (charge) + \theta_2\ (car\ delayed\text{-}time\ reduction) + \theta_3\ (bus\ delayed\text{-}time\ reduction) + \theta_4\ (environmental\ improvement) + \theta_5\ (revenue\ allocation) + \theta_6\ (area\ of\ charge) + \theta_7\ (time\ of\ charge) + \theta_8\ (method\ of\ charge)$$

$$U_{NO} = 0 \qquad \text{(Equation 6.1)}$$

ASC is included in order to allow for a preference effect for one alternative over the other, all other things equal. This ensures that the model can replicate the observed market share, which is often not equally split between options. In this case, the sign of ASC is expected to be negative because people are likely to dislike any charge regardless of the level that the charge takes. Level of charge is in units of pence per day. Car and bus delayed-time reductions are measured in minutes per day.

The remaining variables are categorical data, whose effects can be represented by dummy variables, relative to a base scenario. If a variable has n categories, n-1 dummy variables would be used. The value given to the dummy variables is one if an observation corresponds with a specific category, otherwise zero. Environmental change is represented by two dummy variables: slight and substantial improvement. These would be based on the current situation 'as now'. For the revenue use, there are two dummy variables: revenue allocated to public transport (100%) and tax reduction (100%). These are compared with the base of equal (50:50) distribution. The dummy variable of area of charge is the small area; the base is the wide area. A dummy variable of time of charge is the morning peak time (7am-10am), relative to the all day base (7am-7pm). For method of charge, there are three dummy variables for distance-based, time-based and delay-based charge, and the base method is the fixed charge per day.

Table 6.1 reports the coefficients and t-ratios of the variables in the utility function of 'yes' vote. The results were analysed from the combined data of the five SP exercises[1]. This included all 830 respondents from Leeds and London (sample characteristics were presented in Section 4.6). Two models were estimated. Model 1 includes all variables as shown in Equation 6.1. In Model 2, some coefficients which do not have significant effects on the voting are excluded. However both models are similar.

Table 6.1 Basic standard logit model of voting behaviour

Variables	Model 1 Coefficient (t-ratio)	Model 2 Coefficient (t-ratio)
ASC – vote 'yes'	**-0.4577 (-4.5)**	**-0.4371 (-4.6)**
Charge	**-0.0020 (-9.9)**	**-0.0020 (-9.9)**
Car delayed-time reduction	**0.0210 (5.8)**	**0.0210 (5.8)**
Bus delayed-time reduction	-0.0031 (-1.7)	-0.0031 (-1.7)
Environmental improvement: based on as now		
Environment: dummy for slightly improved	-0.0103 (-0.1)	
Environment: dummy for substantially improved	**0.6415 (3.7)**	**0.6190 (3.7)**
Revenue allocation: based on 50:50		
Revenue: dummy for public transport only	-0.0880 (-0.4)	
Revenue: dummy for tax reduction only	0.1694 (0.9)	
Area of charge: based on wide area		
Area: dummy for small area	**0.5610 (4.0)**	**0.5385 (4.0)**
Time of charge: based on all day		
Time: dummy for peak time	0.1255 (0.9)	
Method of charge: based on fixed charge		
Method: dummy distance-based	**-1.2713 (-3.8)**	**-1.2926 (-3.9)**
Method: dummy time-based	**-0.8805 (-3.3)**	**-0.9017 (-3.4)**
Method: dummy delay-based	**-0.6598 (-2.5)**	**-0.6811 (-2.6)**
No. of observation	2887	2887
ρ^2 with respect to constants	0.0498	0.0493
Log likelihood at convergence	-1636.9940	-1637.8406

The results show that the ASC has negative sign, indicating that in general the charging system is not acceptable to the public. Even at a very low level of charge, for example at 1p per day, the model predict that 39% would vote for the base scheme. This may be because some people disagree with the principle of the policy, so there are protest responses.

The level of charge has a significant negative effect on the acceptability, as expected. Road user charging systems would be less acceptable if the level of charge increases. Its t-ratio is very

[1] A model was analysed for data from each SP exercise. This found that the scales were similar for the constrained variables (charge and car and bus delayed-time reductions); it was appropriate to combine the models.

high, significant at even at 99% confidence level. It is the most precisely estimated effect in the model.

With regard to the benefits of the system, car delayed-time reduction has a positive significant effect at 95% confidence level. When the charge increases by £1, the decrease in the acceptance level can be compensated by 9.5 minutes per day of car delayed-time reduction, giving the value of delayed-time equal to 10.5p per minute. This value is relatively close to the value of time reviewed by Wardman[2] (2001b).

The effect of bus delayed-time reduction was expected to be of positive sign, but was in practice negative. This is possibly because some people, e.g. car users, may not accept that car use is charged in order that bus journey time is reduced, in other words they may not accept reducing bus journey time reduction as a legitimate goal of car use charging and may not perceive any personal benefits. Some may feel that reduction in bus times can only be achieved by limiting car use and space; this would be detrimental to them. However, the effect is not significant at 95% confidence level.

Although the effect of a slight improvement in the environment does not significantly improve acceptability, substantial improvement has a significant positive effect. This improvement is valued as equal to 321p per day. This implies that, on average, people are willing to accept a charge up to 321p per day if the environment is significantly improved.

The effects of using the revenue for public transport (100%) and tax reduction (100%) are not significantly different from the effect of the base scenario in which revenue is equally allocated (50%:50%). Although previous research found that revenue used both to improve public transport and to help to reduce tax is significant in increasing acceptance levels (CfIT/MORI, 2000, 2001), the result here shows that different proportions of use of revenue for public transport improvement and tax reduction are not significantly different in affecting acceptability. This is possibly because people have different opinions in using the revenue; there is no consensus on a single use. The result is similar to a study in USA by Harrington et al. (2001), who found that support for charging schemes does depend on tax rebate, but does not vary across percentages of revenue return.

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[2] Wardman (2001b) provides a model (formed by a meta-analysis from a large number of previous studies) for estimating UK values of time. Based on this model, the value of time is 6.8 p/min in year 2000 for commuters travelling 10 miles. The value of delayed-time is about 1.4 times higher than the value of time (Wardman, 1991, 2001a), so the value of delayed-time should be around 9.5 p/min.

For other system features, small-area charges (within the Inner Ring Road) positively affect public attitudes, compared to wide-area charges (within the Outer Ring Road for Leeds and the North/South Circular Roads for London). This indicates that a charge in a small area is more acceptable than a charge in a wide area. This is possibly because people feel that it is only the city centre that is congested and there is no need to charge car use in the whole city. Some people who can avoid travelling in the small area may also expect some benefits to themselves without being charged.

For the effect of charged time, support for the morning peak-period (7am-10am) charge is not significantly different from support for the all day (7am-7pm) charge. This may be because most car commuters would find it difficult to avoid the charge in these time periods and non-car users would find no difference between the times of charge.

The effects of the three variable charging methods have negative signs and significant differences from the effects of the fixed charge. This indicates that the fixed charge is the most acceptable form of charging. This is probably because people prefer to know how much the charge would be before travelling, as found by Bonsall and Cho (1999). Some people may be concerned on safety for time-based and delay-based charges which tend to influence speeding, in turn increasing risk of accidents, as found by Bonsall and Palmer (1997).

6.3 Acceptability Variation among Groups of the Public

In Section 6.2, the model was analysed for the whole sample. However, different groups of people are likely to respond differently when they evaluate charging schemes (for example car users are expected to be more opposed to the charging systems and also more sensitive to increases of charging levels). To test this, segmentation analysis was applied on the basic model in Table 6.1. Incremental effects (Section 3.4.3) for each group of respondents on the basic effects were estimated. Respondents were segmented by personal characteristics (Table 4.4): mode use, household income, age, gender and location. They were also categorised by personal perceptions (Table 4.5) on: the current situation, congestion and pollution problem, effectiveness in reducing congestion and pollution, and the strong dislike of charging.

The incremental factors, representing the differences among the segments, were applied in Equation 6.1. Three models separately identified the potential effects in the ASC alone, in coefficients of the charging system characteristics (X_k) alone, and in both the ASC and coefficients of the characteristics.

The effects in ASC

The differences between groups of respondents could appear in the constants of model; each group has its own constant, indicating its specific preference, as shown in Equation 6.2. ASC_b is a constant for a base group, while ASC_y is the incremental factor for a specific group y. The d_y is the dummy variable to identify observations. If an observation is categorised as y, d_y is one and otherwise is zero. Therefore, ASC for the group y is $ASC_b + ASC_y$.

$$U_{YES} = \{ASC_b + \sum_{y=1}^{n-1} ASC_y \,.\, d_y\} + \Sigma_K\, \theta_k \,.\, X_k \qquad \text{(Equation 6.2)}$$

The effects in coefficients of the charging system characteristics

Different groups of people also could have different coefficients for the variables representing the charging system characteristics (X_k). Each group has its own coefficients, indicating different degrees of sensitivity to the variables, as shown in Equation 6.3. The γ_y is the incremental factor for the specific group y. Thus, the coefficient of variable X_k for the group y is $\theta_k + \gamma_y$. This can be applied to every variable in the model.

$$U_{YES} = ASC + \{\Sigma_K\, \theta_k \,.\, X_k + \sum_{y=1}^{n-1} \gamma_y \,.\, d_y \,.\, X_k\} \qquad \text{(Equation 6.3)}$$

The effects in both the ASC and coefficients of the charging system characteristics

The third model combines the first two models together, in order to present the effects of personal characteristics and perceptions in both the ASC and coefficients of the charging system characteristics, as shown in Equation 6.4.

$$U_{YES} = \{ASC_b + \sum_{y=1}^{n-1} ASC_y \,.\, d_y\} + \{\Sigma_k\, \theta_{ik} \,.\, X_{ik} + \sum_{y=1}^{n-1} \gamma_y \,.\, d_y \,.\, X_{ik}\} \qquad \text{(Equation 6.4)}$$

The first two models (Equations 6.2 and 6.3) were used to estimate the potential effects for each segment separately. Table 6.2 summaries the results of the model goodness-of-fit indexes (ρ^2). The table also illustrates which incremental factors are significantly different (at least at 90%

confidence level) from a base group for each personal characteristic and perception, indicating by '✓'. Between the two models for each segmentation, the results indicate that the model showing the effects in the constants is as good as the model showing the effects in the variables (ρ^2 are only slightly different). They show that the personal characteristics, except income, and the perceptions can help to improve the basic model in explanation of the voting behaviour (the ρ^2 increase from 0.0498 which is the ρ^2 of the basic model). This demonstrates that, besides the system characteristics, acceptability is also influenced by the personal characteristics and perceptions, particularly mode use, the perceptions of the problems and the perceptions of the effectiveness of the schemes (all of which provide a substantial increase in the ρ^2).

These models identified separately the potential effects of personal characteristics and perceptions on voting, and distinguished separately the effects in the ASC and charging characteristics. By using the combined model (Equation 6.4) the effects were presented in a model. This was done step by step. First, only the significant effects of the personal characteristics were included. Second, only the significant effects of the perceptions were included. Then all were combined. For each combination, three models were estimated. One addressed the effects of segmentation in the constant and another one in the variables. The third model dealt with both at the same time. This combined model is based on Equation 6.4, in which the incremental factors are included for both the ASC and charging characteristics.

Table 6.2 Effects of segmentation in constant and coefficients of variables in the voting model (the basic model: $\rho^2(c) = 0.0498$)

Segmentation	For effects in ASC (using Equation 6.2)		For effects in variables (using Equation 6.3)								
	ASC	$\rho^2(c)$	Charge	Car delayed-time reduction	Bus delayed-time reduction	Environment	Revenue	Area of charge	Time of charge	Method of charge	$\rho^2(c)$
Personal characteristics											
Mode use	✓	0.1206	✓		✓					✓	0.1132
Having car(s) in household	✓	0.0898	✓							✓	0.0842
Location	✓	0.0725	✓							✓	0.0745
Income		No effect									No effect
Age	✓	0.0583	✓							✓	0.0574
Gender	✓	0.0558				✓		✓			0.0553
Personal perceptions											
Perception of current situation	✓	0.0756	✓							✓	0.0738
Perception of congestion problem	✓	0.0846	✓								0.0681
Perception of pollution problem	✓	0.1042	✓							✓	0.1000
Perception of effectiveness in reducing congestion	✓	0.1341	✓			✓		✓		✓	0.1288
Perception of effectiveness in reducing pollution	✓	0.0531								✓	0.0513
Strong dislike of charging	✓	0.0860	✓		✓					✓	0.0825

Note: 1. ✓ indicates having significant effect at least at 90% confidence level.
2. The models were separately estimated for each segment and also distinguished the effects of segmentation in the constant and variables.

Table 6.3 presents the ρ^2 of models when combining the effects of personal characteristics and perceptions. The combined models are very much better in explaining the voting behaviour than the basic model (indicating by substantial increases of the ρ^2). The ρ^2 of models combining the personal perceptions are more than the ρ^2 of models combining the personal characteristics, indicating that the perceptions have more influence on acceptability than the characteristics. The models are even better when both are included. The results also demonstrate that the models in which the incremental effects based on the constants and variables are better than those based on either of them alone. In conclusion, the combined model reflecting the effects of both personal characteristics and perceptions in both the constant and variables is the best (achieving the highest ρ^2 at 0.2107). The likelihood ratio test (Section 3.4.3) also confirmed that this model is significant better than the other combined models.

Table 6.3 ρ^2(c) of voting models segmented by personal characteristics and perceptions

Combining the effects	ρ^2 (c)		
	Combining the effects in the ASC alone	**Combining the effects in the variables alone**	**Combining the effects in both the ASC and variables**
Combining the effects of personal characteristics	0.1334	0.1338	0.1443
Combining the effects of personal perceptions	0.1590	0.1753	0.1894
Combining the effects of both personal characteristics and perceptions	0.1911	0.1952	**0.2107**

Table 6.4 presents the preferred model of voting behaviour segmented by personal characteristics and perceptions. This model, which identifies sources of differences across the respondents, is substantially better than the basic model in explanation of the voting behaviour (shown in Table 6.1). This is indicated by the increase of ρ^2 from 0.0498 to 0.2107. The likelihood ratio test (Section 3.4.3) was used to compare the segmentation model in Table 6.4 and the basic model in Table 6.1. The test is that twice the difference between the log likelihood values of the models at convergence (for example for Model 1: 2[(-1074.1301) - (-1636.9940)] = 1125.7) is higher than a χ^2 critical value of 18.5 for 7 degrees of freedom (the number of parameters imposed on the basic model is restricted to being equal to zero under the null hypothesis), indicating that the segmentation model is statistically superior even at the 99% confidence level.

Table 6.4 Standard logit model of voting behaviour segmented by personal characteristics and perceptions

Variables	Model 1 Coeff. (t-ratio)	Model 2 Coeff. (t-ratio)
ASC-base	**-1.0471 (-6.8)**	**-1.0014 (-6.9)**
+ *incremental effects*		
If individual is non car user	**0.8363 (6.9)**	**0.8379 (7.0)**
If current situation is perceived as unacceptable	**0.3837 (3.3)**	**0.3868 (3.4)**
If congestion is perceived as very serious	**0.7089 (3.3)**	**0.7048 (3.3)**
If the scheme is perceived as effective in reducing congestion	**0.5018 (2.3)**	**0.5024 (2.4)**
If individual has strong dislike of charging	**-0.5645 (-4.1)**	**-0.5567 (-4.1)**
Charge-base	**-0.0027 (-9.4)**	**-0.0027 (-9.4)**
+ *incremental effects*		
If age is 55 or over	**-0.0015 (-5.0)**	**-0.0015 (-5.0)**
If pollution is perceived as very serious	**0.0020 (7.7)**	**0.0020 (7.8)**
Car delayed-time reduction	**0.0120 (2.4)**	**0.0119 (2.4)**
Bus delayed-time reduction	-0.0023 (-1.0)	-0.0022 (-1.0)
Environmental improvement: based on as now		
Environment: dummy of slightly improved	0.0790 (0.3)	
Environment: dummy of substantially improved	**0.6721 (3.0)**	**0.6230 (2.9)**
Revenue allocation: based on 50:50		
Revenue: dummy for public transport	-0.0473 (-0.2)	
Revenue: dummy for tax reduction	0.2831 (1.2)	
Area of charge: based on wide area		
Area: dummy for small area	**0.7507 (4.2)**	**0.7015 (4.1)**
Time of charge: based on all day		
Time: dummy for peak time	0.1975 (1.1)	
Method of charge: based on fixed charge		
Method: dummy distance-based	**-1.1508 (-2.8)**	**-1.1966 (-3.0)**
Method: dummy time-based	**-1.1974 (-3.4)**	**-1.2441 (-3.5)**
Method: dummy delay-based	**-1.0617 (-3.4)**	**-1.1077 (-3.5)**
No. of observation	2277	2277
ρ^2 with respect to constants	0.2107	0.2098
Log likelihood at convergence	-1074.1301	-1075.3054

Two models were estimated. Model 1 includes all variables as shown in Equation 6.1. In Model 2, some coefficients which do not have significant effects on the voting are removed. However both models are similar.

The estimation model shows that the incremental effects of some segments are significant for the alternative specific constant (ASC) and the charge. The incremental effects which were not significant at the usual 95% confidence level were excluded from the model.

In the segmentation model, the effects of the system characteristics shown are generally similar to their effects shown in the basic model. Moreover, the segmentation model also presents the effects of personal characteristics and perceptions.

The model shows that the ASC has a negative effect. This indicates that in general charging is not preferred by the public. However, the effects are different for different groups of respondents. The incremental factors show that some people have a less negative attitude to the charging systems, but some have a more negative attitude. The results reasonably demonstrate that charging would be more acceptable to non-car users, who would not be charged. It is also more acceptable to respondents who find their own current travel situation unacceptable, who perceive the congestion problem as very serious, and who perceive the charging schemes as effective in reducing congestion. These people would expect some benefits from the charging schemes. However, as expected, charging is less acceptable to people who have a strong dislike of charging, since they may oppose the principle of charging, as well as object to paying more for using their car.

Increasing charging levels would clearly have a negative effect on acceptability. However, some groups have different sensitivities to the charges. At the same rate of increasing the charge, when all other things are equal, those who are 55 or older are more averse to charging than others, but those who perceive pollution as very serious are less sensitive. This means that in order to retain the same acceptance level elderly people would need more compensation, but people who perceive pollution as very serious need less than the others.

Acceptance levels would fall in elderly people more than in other groups, when the charge increases. Most of them do not travel to work and have a higher proportion in the low income group than other ages. Acceptance levels in people who perceive pollution as very serious are less sensitive to the charge than other people, possibly because they agree that the policy needs to be implemented in order to reduce the problem.

Surprisingly, different groups of income have no different sensitivity to the charge, though ones might expect that higher income people are less sensitive than lower income people. This may be the case only if higher income people expect higher benefits. However in the next chapter, Section 7.3.2, the result shows that there is no (significant) income effect on the perceptions of both personal and social benefits.

The rest of the charging system characteristics retain similar effects on voting as in the basic model (discussed in Section 6.2). Only the effects among the variable charges on acceptability are slightly different. This result does not confirm the results in the previous section in that distance-based charges are the least acceptable. It is uncertain which method is the most unacceptable; nevertheless, it is certain that they are all considerably less acceptable than fixed charges.

Some factors: having car(s) in household, location of respondents household and perception of effectiveness in reducing pollution do not show significant effects on the acceptability, though their effects are significant in the separate segmentation models (shown in Table 6.2). This is because they correlate with the other factors, so that there are cross-effects. For example, having car(s) in households show a significant effect in the separate model, but the effect is not significant in the segmentation model. This is because most of those who have car(s) are car users. Thus, the effect of having car(s) in the separate model is actually reflected by the effect of mode use (the model segmented by mode use has higher ρ^2 than the model segmented by having car(s)). When they are combined in one model, only the effects of mode use are included (giving the best fit model). Similar to the other factors, there is also a high correlation between mode use and location (high proportion of car users in Leeds, but low in London), and between the perceptions of effectiveness in reducing congestion and pollution. Their effects on acceptability can be expected to be similar.

Furthermore, the effects of some system characteristics (bus delayed-time reduction, environmental improvement, area of charge and method of charge) are different among different groups of people in the separate models (shown in Table 6.2). However, when the separate effects in the ASC and in the variables are combined in the final model (in Table 6.4), the effects on the variables are not significantly sensitive to the different personal characteristics and perceptions. Only the effects in ACS are significant. This is because different groups are not different in evaluating the charging characteristics, but they are different in assessing charging schemes in overall, indicated by the significant effects of the incremental factors of the ASC. Except for the effect of charging levels, there are differences between the age groups and between the perceptions of congestion problem.

In summary, the results demonstrate that acceptability is clearly more influenced by personal perceptions than personal characteristics. In addition to mode use and age, other personal characteristics: location of respondents' household, gender and surprisingly even income do not have significant effects on acceptability. On the other hand, acceptability is highly influenced by personal perceptions including: perception of current situation, perception of transport problems, perception of effectiveness of charging and the strong dislike of charging. These results are similar to the findings of Rienstra et al. (1999) in their study of the support for transport policies in the Netherlands, and Schade and Schlag (2000) who examined the acceptability of transport pricing in European cities (AFFORD Project), in which support for charging is clearly influenced by perceptions of problem and effectiveness, and to a lesser extent by personal characteristics (including income).

6.4 Acceptability Variation among Individuals

In the previous section, variation of voting behaviour among respondents was addressed by the segmentation analysis. Some sources of differences from personal characteristics and perceptions were identified. The segmentation model in Table 6.4 was substantially improved from the basic standard logit model in Table 6.1. However, taste variation among individuals from unknown sources may still be included in the model.

To cope with this, the random parameters logit model is applied to the segmentation model. The random parameters logit model allows coefficients to vary across individuals within the sample. Mean coefficients, assuming a normal distribution, and standard deviations of random parameter distribution were estimated. The standard deviation is for indicating whether a parameter significantly varies among respondents. (Greater details about the model are explained in Section 3.4.3.)

However, all variables in model should not be treated as random. Ruud (1996) pointed out that the random parameters logit model tends to be unstable when all parameters are allowed to vary. This led Revelt and Train (1998) and Hensher (2001c) to avoid the instability by fixing coefficient of cost, while allowing the other coefficients vary. They chose to fix the cost parameter because it is convenient for interpretation of the model, in which a value of time would be distributed the same as the parameter of travel time.

The random parameters logit model (obtained from the LIMDEP programme) is shown in Table 6.5. This model is based on the segmentation model, but explores variations of parameters across individuals. The coefficient of the charge is fixed, while the others are random. Overall, this model is not significantly different from the segmentation logit model in Table 6.4. The goodness-of-fit index (ρ^2) increases slightly from 0.2107 to 0.2129. The likelihood ratio test (Section 3.4.3) is that twice the difference between the log likelihood values of the models (5.9) is not higher than a χ^2 critical value of 18.55 for 12 degrees of freedom, indicating that the random parameters logit model is not statistically better than the segmentation model at even the 90% confidence level.

Table 6.5 Random parameters logit model of voting behaviour segmented by personal characteristics and perceptions (based on 100 Halton draws)

Variables	Coeff. (t-ratio)	Std. (t-ratio)
ASC-base	**-1.2597 (-4.4)**	0.9803 (1.6)
+ *incremental effects*		
If individual is non car user	**0.9467 (5.8)**	-
If current situation is perceived as unacceptable	**0.4459 (3.1)**	-
If congestion is perceived as very serious	**0.7480 (2.9)**	-
If the scheme is perceived as effective in reducing congestion	**0.5608 (2.2)**	-
If individual has strong dislike of charging	**-0.7534 (-2.4**	
Charge-base	**-0.0030 (-6.8)**	-
+ *incremental effects*		
If age is 55 or over	**-0.0017 (-4.5)**	-
If pollution is perceived as very serious	**0.0023 (6.0)**	-
Car delayed-time reduction	**0.01438 (2.2)**	0.0016 (0.1)
Bus delayed-time reduction	-0.0027 (-0.9)	0.0009 (0.1)
Environmental improvement: based on as now		
Environment: dummy of slightly improved	-0.1206 (-0.3)	1.1522 (1.1)
Environment: dummy of substantially improved	**0.7906 (2.7)**	0.1761 (0.3)
Revenue allocation: based on 50:50		
Revenue: dummy for public transport	-0.3279 (-0.6)	1.6000 (1.4)
Revenue: dummy for tax reduction	0.1674 (0.5)	1.2417 (1.3)
Area of charge: based on wide area		
Area: dummy for small area	**0.8474 (3.3)**	0.7140 (0.8)
Time of charge: based on all day		
Time: dummy for peak time	0.1669 (0.6)	0.6494 (0.8)
Method of charge: based on fixed charge		
Method: dummy distance-based	**-1.5032 (-2.1)**	0.8385 (0.6)
Method: dummy time-based	**-1.4345 (-3.0)**	0.1031 (0.1)
Method: dummy delay-based	**-1.3795 (-2.7)**	0.7518 (0.7)
No. of observation	2277	
ρ^2 with respect to constants	0.2129	
Log likelihood at convergence	-1071.163	

The results show that no standard deviations of the random parameters distributions are significant at 95% confidence level, indicating that the parameters' coefficients do not vary significantly across the individuals. Furthermore, the analysis also attempted to test whether there is a taste variation in the charge parameter. When the charge parameter was allowed to vary and the time parameter was fixed instead, the standard deviation of the charge parameter distribution was also not significant. Therefore, a significant taste variation among individuals in evaluating the charging characteristics was not found. The interpretation of the model results for the effects of the variables on acceptability is the same as of the segmentation model.

Nevertheless, the standard deviation of distribution of the ASC is relatively high, compared to its coefficient. The t-ratio of the standard deviation is also not very low, though it is not significant at 95% confidence level. The distribution of the ASC indicates that acceptability in general is fairly different among individuals. Furthermore, the analyses also tested for the case that only the ASC was allowed to vary and other parameters were fixed. It found that the results were similar to the model reported in Table 6.5.

In addition, a log-normal distribution was applied to the coefficient of car delayed-time reduction, which can be expected to be always positive. The results of its mean coefficient and t-ratio retained similar as assumed to be normally distributed. Its standard deviation was even lower. Overall this model was similar to the model in Table 6.5.

In summary, the results of the model show that the taste variation among individuals is not significant. By using the likelihood ratio test, it is found that the random parameters logit model is also not significantly different from the segmentation model in Table 6.4. Therefore the segmentation model with fixed coefficients can be used in prediction of acceptance levels of road user charging schemes (in Chapter 9).

6.5 Conclusions

This chapter has tested the hypothesis that the acceptability of road user charging is influenced by the benefits and system features of the charging scheme, as well as personal characteristics and perceptions. The results presented are from the analyses of the SP data based on the logit models. Not surprisingly, it was found that acceptability is highly sensitive to the level of charge: the higher level of charge, the lower acceptance. However, this can be improved by increasing the levels of environmental improvement and car delayed-time reduction. Bus delayed-time reduction was found to have no significant influence on acceptability. Charge within the city centre is more acceptable than in the wide area. A fixed charge also is significantly more acceptable than the variable: distance-based, time-based, and delayed-based charges. For time of charge, there is no difference between acceptability of the charge during the morning peak-time and all day.

It was also found that personal characteristics have some effects on acceptability. Mode use has a significant effect on acceptability; acceptance in car users is much less than in non-car users. Elderly people are highly sensitive to the charging level. However, other socio-economic characteristics: gender and income, surprisingly, do not affect acceptability.

On the other hand, attitude to road user charging is highly affected by personal perceptions. Individuals tend to accept a charging scheme if they perceive their current travel situation as unacceptable, if congestion and pollution problems are regarded as being very serious, and if the scheme is perceived to be effective in reducing the problems. However, those who have a strong dislike of charging are, not surprisingly, more opposed to any charging scheme.

In brief, acceptable road user charging schemes can be designed by limiting the area of charge within the city centre and basing it on a fixed charge per day. These schemes would be even more supported by convincing the public that the scheme will provide substantial environmental improvement and car delayed-time reduction. Moreover, acceptability could be influenced by externality factors encouraging personal perceptions of congestion and pollution problems, and perceptions of the effectiveness of road pricing in reducing the problems.

The preferred voting model developed in this chapter will be used later in Chapter 9 to predict acceptance levels of different groups of people for various road user charging schemes. The next chapter will present the influence of selfish and social perspectives on acceptability. These perspectives are reflected by individuals' evaluations of their own and social benefits, respectively.

Chapter 7

Public Acceptability and Selfish and Social Perspectives

7.1 Introduction

In Chapter 6, voting behaviour model was presented as a function of road user charging characteristics. It demonstrated that acceptability is influenced by the system characteristics, as well as personal characteristics and perceptions. The objective of this chapter is to test the second hypothesis in Section 1.2 in which the influence of individuals' selfish and social perspectives on acceptability are separated out. These two perspectives were reflected by the perception of benefits to self and to society as a whole, respectively (described in Section 4.5.1). The results are presented in Section 7.2.

This chapter also aims to test the hypothesis that the selfish and social perspectives are results of individuals' evaluations of the system characteristics and influenced by personal characteristics and perceptions, the third hypothesis in Section 1.2. The effects of the charging system characteristics and personal characteristics on these perspectives and how the public differently evaluate the system characteristics for their own benefits and social benefits are demonstrated in Section 7.3. Finally, conclusions on the selfish and social perspectives influencing acceptability of road user charging are provided in Section 7.4.

7.2 Selfish and Social Perspectives Affecting Acceptability

This research studies the influence of individual preferences or interests, from both selfish and social perspectives, on acceptability. Some people may not accept the policy because they lose benefits even though the public gain. On the other hand, some people may accept it because society as a whole is better off. These perspectives may influence individuals' propensity to accept and support the policy (Section 2.5.3). These perspectives were represented by the perception of benefits to self and to society. They were measured by the rating on an 11-point scale, -5 to 5 representing 'very detrimental' to 'very beneficial' (as described in Section 4.5.2), responding to the charging scenarios presented.

On the 11-point scale, it can be summarised that rating on the positive side (between 1 and 5) means that the scheme is perceived as beneficial, on the negative side (between -1 and -5) it is perceived as detrimental, and zero is neither. The overall perceptions of benefits to self and to society without taking into account the different system characteristics are demonstrated in Table 7.1. The results were analysed from 830 respondents in Leeds and London (sample characteristics were presented in Section 4.6). Each individual was presented an SP exercise with four charging scenarios.

Table 7.1 Perceptions of benefits to self and to society by all observations

Perception on road user charging	To self	To society
Beneficial	30%	56%
Neither	19%	15%
Detrimental	51%	29%

Base: 2473 observations

The results show that over a half of the observations (56%) felt that road user charging is beneficial for society as a whole, but only less than a third (30%) perceived benefits to themselves. The majority (70%) believed that the policy is either not beneficial or detrimental for them. In general, the results demonstrate that although most respondents did not perceive benefits to themselves, they still believed that there would be some benefits to society. However, when respondents rated on the scales, there was some positive correlation (Kendall's tau-b coefficient[1] = 0.45) between the perceptions of the benefits to self and to society. This means that if a rating is high on one scale, it tends to be also high on the other. Nonetheless, the correlation is not particularly high[2].

In the remainder of this section, the effects of selfish and social perspectives on the acceptability of road user charging are examined. This demonstrates how much each perspective influences acceptability. There are three sub-sections. First the overall results are analysed from the whole sample. The second shows the differences between groups of the public, according to socio-

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1 Kendall's tau-b coefficient varies between -1 and +1 to indicate the strength and direction of relationship between two ordinal variables (Bryman and Cramer, 1997). Its interpretation is identical to Pearson's r coefficient, which is for interval data.

2 This is good from the perspective of modelling, in which the separate effects of the selfish and social perspectives on voting are appropriate to be represented in a model (see Section 7.2.1).

economic characteristics and personal perceptions. Finally, taste variations among individuals are investigated.

7.2.1 Weights of selfish and social perspectives in overall respondents

The analysis, using the standard logit model, is based on the utility function developed in Section 3.5. The utility function of a 'yes' vote is expressed as a function of the perception of benefits to self and to society, while the utility of 'no' vote is equal to zero. The basic model, without the effects of personal characteristics, is shown as Equation 7.1. The coefficients of selfish (θ_1) and social (θ_2) perspectives indicate how much weight people put on each perspective when they decide to accept the charging schemes presented. The alternative specific constant (ASC) represents effects of unknown factors, which are not included in the model. It also allows the model to replicate the observed market share, in the case where the perceptions of both benefits are zero and voting is not 50:50 because of some protest responses.

$$U_{YES} = ASC + \theta_1 \text{ (perception of benefits to self)} + \theta_2 \text{ (perception of benefits to society)}$$

$$U_{NO} = 0 \qquad \text{(Equation 7.1)}$$

Table 7.2 reports the coefficients and t-ratios of the selfish and social perspectives in the utility function of 'yes' vote (Equation 7.1). These results were analysed from the whole sample, 830 respondents in Leeds and London (see sample characteristics in Section 4.6).

The model goodness-of-fit index (ρ^2) is very high (0.3158) for the logit model; the model explains the choices very well. The results demonstrate that the perceptions of the benefits to self and to society have highly significant positive effects (at 99% confidence level) on the vote.

Table 7.2 Standard logit model of voting behaviour as a function of selfish and social perspectives

Variables	Coefficient (t-ratio)
Alternative specific constant (ASC) – Yes	-1.0563 (-15.4)
Perception of benefits to self	0.3452 (17.6)
Perception of benefits to society	0.2554 (10.7)
No. Observations	2440
ρ^2 with respect to constants	0.3158
Log likelihood at convergence	-1030.562

The coefficient of the perception of benefits to self is higher than the coefficient of perception of benefits to society. The ratio of the coefficients of the selfish and social perspectives is 1.35.

This indicates that on average people perceived benefits to self as more important (35%) than benefits to society, as expected. People were required to pay for car use; they would expect direct benefits to them. Nevertheless, acceptability is not totally influenced by the perception of personal benefits, but also the perception of social benefits.

The ASC representing unmeasured effects has a negative sign. This indicates that if individuals do not perceive any benefits to themselves and to society from a charging system (i.e. if the perceptions were zero in the models), this system would attract support from less than 50% of the voters (the utility of 'yes' vote is less than the utility of 'no' vote which is zero). More precisely, the predicted 'yes' vote is 25.8%, calculated from the standard logit model: $P_{yes} = e^{U_{yes}} / (e^{U_{yes}} + e^{U_{no}})$. In other words, without taking account of system features, road user charging would be unacceptable to the majority of the public (three quarters), if the public did not perceive any benefits to them or to society, and even if they did not perceive any detriments. This is possibly because they disagreed with the principle of charging and provided protest responses.

In order to make a charging system gain a vote up to 50%, the perception of benefits to self needs to be 3.1 (1.0563/0.3452) out of a five-point positive scale if the perception of benefits to society is zero. On the other hand, the perception of benefits to society has to be 4.1 (1.0563/0.2554) out of a five-point positive scale if the perception of benefit to self is zero.

7.2.2 Weights of selfish and social perspectives variation among groups of the public

The basic model was analysed for the whole sample. It is very likely that there are taste variations between groups of respondents; for example car users and non-car users are likely to have different weights for the perspectives. Segmentation analysis (Section 3.4.3) was applied on the basic model in Table 7.2, in order to demonstrate whether different groups have different weights for the benefits to self and to society.

The analysis technique was similarly used as in Chapter 6. The analysis began with analysing a separate model for each segment in order to identify the potential sources of the differences between groups. Incremental effects of variables and ASCs in the models were estimated. Then only significant incremental effects were taken forward to be included in a combined segmentation model.

The results of the significant incremental effects for some groups of individuals are presented in Table 7.3. This segmentation model identifies some sources of differences across the sample. The explanatory power of the model is improved, in that the goodness-of-fit index increases from 0.3158 in the basic model to 0.3343. A likelihood ratio test (Section 3.4.3) was used to compare the segmentation model in Table 7.3 and the basic model in Table 7.2. The test is that twice the difference between the log likelihood values of the models (123.7) is higher than a χ^2 critical value of 16.8 for 6 degrees of freedom (the number of parameters' coefficients imposed on the basic model is restricted to being equal to zero under the null hypothesis), indicating that the segmentation model is statistically superior, at the 99% confidence level.

Table 7.3 Standard logit model of voting behaviour as a function of selfish and social perspectives segmented by personal characteristics and perceptions

Variables	Coefficient (t-ratio)
Alternative specific constant (ASC) – Yes	-1.0015 (-14.1)
Perception of benefits to self	0.3692 (12.5)
+ *incremental effects*	
If bus user	-0.3009 (-4.5)
If female	0.1033 (2.4)
If very serious pollution problem	-0.1613 (-3.6)
Perception of benefits to society	0.2008 (6.4)
+ *incremental effects*	
If bus user	0.3357 (4.9)
If age 55 or over	-0.1497 (-3.5)
If very serious pollution problem	0.2096 (4.6)
No. Observations	2335
ρ^2 with respect to constants	0.3343
Log likelihood at convergence	-968.7055

Similar to the basic model, the coefficients of the perceptions demonstrate that both benefits to self and society significantly influence acceptability. The ASC has a negative sign. This indicates that a charging system would attract support from less than 50% of the voters, if individuals do not perceive any benefits or disbenefits to themselves and to society. The incremental effects are not significant in the ASC, only in the perceptions of benefits to self and to society.

The incremental effects show that some groups of people have significantly different weights for their own benefits and social benefits from the others. The coefficients and their ratios for different groups are summarised in Table 7.4. This was worked out from the coefficients in Table 7.3 in which a coefficient for a particular group is equal to the base coefficient plus its incremental effects.

Table 7.4 Coefficients and ratios of the perceptions of benefits to self and society for different groups

Segmentation	Perception of benefits to self (1)	Perception of benefits to society (2)	Ratio (1) / (2)
Base	0.3692	0.2008	1.84
Bus user	0.0683	0.5365	0.13
Female	0.4725	0.2008	2.35
Age 55 or older	0.3692	0.0511	7.23
Perceiving pollution as very serious	0.2079	0.4104	0.51

The variation of the ratios between the perceptions of benefits to self and to society among the groups of the public is very high. For the base group who are car and other mode (non-bus) users, males, those younger than 55 and those who do not perceive pollution as very serious, their acceptability is influenced by both the perceptions of benefits to self and to society. However, their concern with their own benefits is almost twice as important as concern with social benefits when they vote for a charging scheme, indicated by the ratio of the perceptions of benefits to self and to society which is 1.84.

Bus users have just a little interest (0.3692 - 0.3009 = 0.0683) in the benefits to themselves, which is very much lower than the self-interest of car users. However, they have relatively high interest in benefits for society (0.2008 + 0.3357 = 0.5365), which is almost three times higher than the social-interest of the base group. The ratio of the perceptions of benefits to self and to society is very low. This suggests that acceptability of charging for bus users mainly depends on whether they perceive benefits to society. They will hardly vote for a scheme if they are not convinced that the scheme will provide benefits to society. This is possibly because they are not required to pay for the charges, so they do not expect the charging schemes to offer direct benefits to themselves. On the other hand, if the schemes provide benefits to society, they would also be better off.

Surprisingly, the segmentation model did not find that there are significant differences between the coefficients for car users and the other (non-bus) mode users. This seems to indicate that those who usually travel by rail, walking, cycling and other modes (except bus users) are concerned for their own benefits more than social benefits when they vote for a scheme, as with car users. This may be because there is a small sample size of these users (10% of respondents), so little confidence can be placed in the results.

In contrast with bus users, elderly people (55 and older) have very low concern for benefits to society (0.0511). They are mainly interested in their own benefits, seven times more so than social benefits. This is probably because most of them are pensioners. In the sample, most of them do not travel to work and have lower income than other younger groups. They will vote for a scheme if they are convinced that they will be better off.

For females, although both selfish and social perspectives influenced on their voting as for males, their self-interest was slightly larger than males' self-interest. Females' self-interest was over double that of their social-interest.

Those who perceive pollution as a very serious problem are twice as interested in social benefits as the base group. They weighed for their self-interest only half of their social-interest; on the contrary, the base group weighed for their self-interest almost twice their social-interest. Those who perceive pollution as very serious may be more aware of the problem to society. They are more likely to vote for a scheme if society is better off, but less likely than others to vote for it on the ground of its selfish benefits. This supports the finding in Chapter 6 in that charging schemes are more acceptable to these people than others.

Although the effects of having a car in the household and the perception of congestion problem are excluded from the model, there are also significant differences between respondents who have a car in their household and those who do not, and between those who perceive congestion as serious and those who do not. These differences are represented by the effects of mode use and the perception of pollution. This is because there are close correlations between having a car(s) in household and mode use, and between the perception of congestion problem and of pollution problem.

For other personal characteristics and perceptions: income, the location of respondents, the perception of effectiveness and the strong dislike of charging, there is no significant difference between different groups. To vote for a charging scheme, people are generally concerned for their own benefits more than for social benefits. There is no evidence to suggest that people who live in London, who perceive charging to be effective, who have a stronger dislike of charging or who have higher incomes are any more likely to value social benefits more than their own benefits than those who live in Leeds, perceive charging as ineffective, have a weaker dislike of charging or have lower incomes.

7.2.3 Weights of selfish and social perspectives variation among individuals

The segmentation model showed that different groups of people have put different weights for the benefits to themselves and to society. However, within each group taste variations among individuals from unknown sources (in addition to the personal characteristics and perceptions) may still be included. The random parameters logit model (Section 3.4.3), which allows coefficients to vary across individuals within the sample, is applied to the segmentation model in Table 7.3.

In order to test whether there are taste variations among individuals in the coefficients of the perceptions of benefits to self and to society, these coefficients are treated as random, allowing coefficients to vary across individuals within the sample. The ASC in the model was treated as non-random, because the model was unstable when all parameters were random.

In the random parameters logit model, coefficients of parameters are typically assumed to be normally and log-normally distributed. When a coefficient is normally distributed, it is specified as $\theta = b + s\mu$, where μ is an independent standard normal distribution (mean zero and standard deviation one). b and s, therefore, represent the mean and standard deviation of θ. When a coefficient needs to be the same sign for all observations, it is assumed to be log-normally distributed. The coefficient is expressed as $\theta_l = \exp(b_l + s_l\mu)$, where b_l and s_l represent the mean and standard deviation of $\ln\theta_l$. (Greater detail of the random parameters logit model is explained in Section 3.4.3.)

The results of the random parameters logit models (obtained from the LIMDEP programme) are shown in Table 7.5. Two models are presented. In Model 1, both the random coefficients of the perceptions of benefits to self and to society are treated as normally distributed. The standard deviations of both coefficients are significant; the coefficients are likely to have taste variations among individuals. The standard deviations are relatively high, compared to their means.

In reality, both coefficients of the perceptions of benefits to self and to society should be of positive sign. For the coefficient of the perception of benefits to self, 6% of the population are of negative sign. For the coefficient of the perception of benefits to society, 21% of the population are of negative sign. This large proportion of the negative coefficients indicates that the normal distribution is not appropriate for the coefficient of the perception of benefits to society. The log-normal distribution, in which means that all individuals will have positive signs for their coefficient, is more suitable.

Table 7.5 Initial random parameters logit model of voting behaviour as a function of selfish and social perspectives segmented by personal characteristics and perceptions (based on 100 Halton draws)

Variables	Model 1*		Model 2*		Model 3*	
	Coefficient (t-ratio)	Std. (t-ratio)	Coefficient (t-ratio)	Std. (t-ratio)	Coefficient (t-ratio)	Std. (t-ratio)
ASC – Yes	-1.2980 (-9.5)	-	-1.2175 (-10.7)	-	-1.1735 (-10.0)	-
Perception of benefits to self	0.5795 (6.2)	0.3741 (3.2)	0.5664 (7.6)	0.4172 (5.1)	-0.9022 (-5.6)	1.1190 (4.0)
+If bus user	-0.4917 (-4.2)	-	-0.4661 (-5.1)	-	-0.5199 (-4.7)	-
+If female	0.1544 (2.5)	-	0.1492 (2.6)	-	0.1337 (2.6)	-
+If pollution perceived as very serious	-0.2330 (-3.2)	-	-0.2153 (-3.3)	-	-0.1989 (-3.3)	-
Perception of benefits to society	0.2938 (5.1)	0.3678 (2.9)	-1.5613 (-5.1)	0.6973 (1.5)	-1.6393 (-5.6)	0.6435 (1.3)
+If bus user	0.4982 (4.5)	-	0.4544 (5.2)	-	0.5267 (4.9)	-
+If age 55 or over	-0.2085 (-3.2)	-	-0.1932 (-3.4)	-	-0.1716 (-3.2)	-
+If pollution perceived as very serious	0.2847 (4.0)	-	0.2585 (4.2)	-	0.2635 (4.4)	-
No. Observations	2335		2335		2335	
ρ^2 with respect to constants	0.3386		0.3376		0.3305	
Log likelihood at convergence	-962.4052		-963.9066		-968.7055	

* Model 1: both the random coefficients of the perceptions of benefits to self and to society are treated as normally distributed
Model 2: the coefficients of the perceptions of benefit to self and to society are treated as normally and log-normally distributed, respectively
Model 3: both the random coefficients of the perceptions of benefits to self and to society are treated as log-normally distributed.

In Model 2, therefore, the coefficients of the perceptions of benefit to self and to society are assumed to be normally and log-normally distributed, respectively. The standard deviation of the coefficient of the selfish perspective is significant, but it is not significant for the coefficient of the social perspective, indicating that only the selfish perspective parameter varies significantly across individuals. However, Model 2 is not better than Model 1 (the ρ^2 is slightly lower), in explaining the behaviour. When both coefficients were assumed to be log-normally distributed, the results were even worse (the ρ^2 falls), as shown in Model 3.

The results indicate that the variation of the social perspective in the population is not significant. Only the variation of the selfish perspective is significant. This may be the case that individuals' self-interest is related to personal constraints, which are likely to vary from one to another.

Hence, only the coefficient of the selfish perspective is allowed to be normally distributed. This estimation model is shown in Table 7.6. This model is preferred over Models 1 and 2 in Table 7.5, since the ρ^2 is higher than of both Models 1 and 2. By using the likelihood ratio test, the model is significantly better than Model 2 at 95% confidence level. Although the model is not significantly better than Model 1, its ρ^2 is higher and also there is no problem with the large proportion of the negative coefficients.

Table 7.6 Preferred random parameters logit model of voting behaviour as a function of selfish and social perspectives segmented by personal characteristics and perceptions (based on 100 Halton draws)

Variables	Coefficient (t-ratio)	Std. (t-ratio)
ASC – Yes	-1.1981 (-11.5)	-
Perception of benefits to self	0.5730 (7.4)	0.4373 (4.8)
+ *incremental effects*		
If bus user	-0.4504 (-4.6)	-
If female	0.1399 (2.4)	-
If pollution perceived as very serious	-0.2231 (-3.4)	-
Perception of benefits to society	0.2538 (6.0)	-
+ *incremental effects*		
If bus user	0.4300 (5.0)	-
If age 55 or over	-0.1890 (-3.5)	-
If pollution perceived as very serious	0.2533 (4.4)	-
No. Observations	2335	
ρ^2 with respect to constants	0.3393	
Log likelihood at convergence	-961.5086	

Comparing the preferred random parameters logit model to the segmentation model in Table 7.3, the ρ^2 increases from 0.3343 to 0.3393. The likelihood ratio test indicates that it is significantly better at the 99% confidence level.

The model demonstrates that the standard deviation of the distribution for the coefficients of the perceptions of benefits to self is significant. This standard deviation is relatively high, compared to its coefficient. These confirm that there is a taste variation among individuals, whose sources cannot be identified, when they traded off between the benefits to themselves and to society.

On the average of all observations (based on the sample enumeration approach), the weight[3] of the benefits to self is 3.16 times higher than the weight of the benefits to society. In other words, benefits to self are perceived as more than three times as important as benefits to society.

Hudson and Jones (1995) found that, in determining overall attitudes to government spending in public services, attitudes based on the public interest are more than twice as important as attitudes based on self interest. It is likely that weights on the selfish and social perspectives are dependent upon contexts of studies. For the government spending, the public may feel that it

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[3] This weight is the mean of individuals' weights, which is more appropriate than the weight of the mean coefficients from the basic model in Table 7.2.

should mainly benefit society as a whole, as well as they do not pay anything. For the case of road user charging, car users were directly charged, so they would expect benefits to themselves more than benefits to society.

The ratios of the weights on the selfish and social perspectives from the random parameters logit model are slightly changed from the ratios in the segmentation model in Table 7.4. The interpretations of the results are the same as discussed in Section 7.2.2. Nevertheless, the random parameters logit model is improved in providing more precise coefficient of the selfish perspective for each individual. As it varies considerably among individuals, using the individuals' specific coefficients would provide better results than using the fixed coefficients in predicting levels of acceptance (in Chapter 9).

The random parameters logit model also shows that the mean coefficients are consistently higher than the fixed coefficients in the segmentation model in Table 7.3, which is based on the standard logit model. This is because the random parameters logit model treats the variance in parameters explicitly from the error term. The variance of the 'net' error in this model is smaller than in the standard model. This causes the increase of the scale factor[4] of coefficients. This factor is a part of coefficients and cannot be estimated separately from coefficients (Section 3.4.2); thus, magnitudes of coefficients are increased.

Moreover, the ASC was also tested to assess whether its variation was significant. The ASC was treated as random (with normal distribution), while the other parameters were fixed. Its standard deviation was insignificant, indicating that there is no taste variation in the ASC.

In summary, the results of the effects of selfish and social perspectives on acceptability have shown that, on average, benefits to self are perceived as three times more important than benefits to society. However, for some groups such as bus users and those who perceive the pollution problem as very serious, the social benefits are perceived as more important in their decision of voting for a charging scheme. In addition to these known factors (personal characteristics and perceptions), the variation of the weight on the benefits to self among individuals from unknown factors is considerably high. Nevertheless, in general, it can be concluded that the acceptability of road user charging is influenced by both selfish and social perspectives. Before implementing a road user charging scheme, the public should be convinced

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[4] The scale factor (β) is related to the variance of the Gumbel distribution, in which $\beta^2 = \pi^2 / 6\sigma^2$, where σ^2 is variance of the error.

that the scheme will provide benefits to individuals and society as a whole, in order to achieve acceptance.

The result extends a comment in Button (1984) that, "motorists will oppose road pricing unless there are clearly perceived benefits". To achieve this, Button suggested "a longer term education programme prior to any demonstration is necessary and needs to involve a consistent position on the possible merits of road pricing being put forward by policy makers". However, almost two decades later, this is still proving difficult to achieve.

7.3 Factors Influencing Selfish and Social Perspectives

The previous section showed the effects of selfish and social perspectives on acceptability. This section demonstrates how these perspectives are affected by the charging system characteristics and personal characteristics.

7.3.1 Selfish and social perspectives relating to the charging characteristics

Two regression models were estimated for the perceptions of benefits to self and to society. These perceptions were treated as dependent variables in the regression models. The independent variables included the charging benefits and system features.

The regression models were initially estimated by including a constant, fixed for a whole sample (as typical), in both models. The model goodness-of-fit indexes (R^2) were very low (less than 0.06). This is possibly because of high variation among respondents when they rated the perceptions of benefits to self and to society on the scale. People are likely to base the degree of their perceptions on their own evaluation. For example, different individuals evaluated the same scenario quite differently on a scale. This leads to 'noise' in the model and hence the low R^2 measure. The large error could affect the precision of the estimation results obtained.

To overcome this problem, the models reported in Table 7.7 allow a constant for each individual. This represents the effects of unknown factors, which are different among respondents, in addition to the effects of the charging system characteristics offered. The constant for each individual allows for different individuals using different parts of the scale. The models can explain variations within individuals' ratings, and show how the ratings vary according to charging system features from individuals' base points. The R^2 of these models are very high (0.8), indicating that the models explain the behaviour very well. Some coefficients that have very low t-ratios are not excluded from the models. This is because even when they were removed, the models were not improved, in which the magnitudes of the remaining coefficients were the same, and their t-ratios and R^2 slightly increased (less than 0.1 for t-ratios and less than 0.01 for R^2).

Table 7.7 Basic regression models of the perceptions of benefits to self and to society

Variables	Benefits to self	Benefits to society
	Coeff. (t-ratio)	Coeff. (t-ratio)
Constant		
Mean	**-0.6478**	**0.6352**
Standard deviation	**3.11**	**2.95**
Level of charge (p/day)	**-0.0020 (-14.3)**	**-0.0010 (-6.5)**
Car delayed-time reduction (mins./day)	**0.0109 (2.1)**	0.0032 (0.6)
Bus delayed-time reduction (mins./day)	-0.0012 (-0.4)	0.0040 (1.5)
Environment base - as now		
Environment dummy - slight improved	0.1991 (1.2)	**0.5531 (3.4)**
Environment dummy – substantial improved	**0.5852 (3.6)**	**1.5299 (9.4)**
Revenue allocation base - 50%:50%		
Revenue dummy allocated to public transport	-0.0966 (-0.6)	**-0.5127 (-2.9)**
Revenue dummy allocated to tax reduction	0.0682 (0.4)	0.1910 (1.1)
Area of charge base - wide area		
Area of charge dummy - small area	**0.6820 (4.8)**	**0.3980 (2.7)**
Time of charge base - all day		
Time of charge dummy - peak time	0.2060 (1.5)	0.1334 (0.9)
Method of charge base – fixed		
Method of charge dummy – distance-based	0.1007 (0.3)	-0.1290 (-0.4)
Method of charge dummy – time-based	0.2398 (0.9)	-0.4662 (-1.7)
Method of charge dummy – delay-based	0.2121 (0.8)	0.1067 (0.4)
No. Observations	2709	2474
R^2	0.851	0.827

The basic model was estimated for the whole sample, without showing differences among groups of people (as will be reported in Section 7.3.2). The constants in the models are varied among respondents, so their means and standard deviations are shown. For the model of perception of benefits to self, the average constant has a negative sign. This means that even when the charging level is very low (close to zero) in the base charging system with no benefit, this system is overall perceived as detrimental to self-interest. On the other hand, for the model of the perception of benefits to society, the average constant has a positive sign. Overall people tend to believe that there are some benefits to society, even in the base system with no benefit presented.

The level of charge has a significant negative effect for the perception of benefits to self; as expected, the higher the level of charge, the higher the detriment to self. For the perception of benefits to society, the effect of the charge is also significantly negative, but the negative effect is not as high as on the perception of benefits to self. In other words, the perception of benefits to self is more sensitive to the charging level than the perception of benefits to society. This is because charging affects directly individuals' out-of-pocket money.

Car delayed-time reduction is positively significant in increasing the perceptions of benefits to self. When the charge increases by £1, the decrease in the perception of benefits to self can be compensated by approximately 18 minutes per day of car delayed-time reduction ($0.0020 \times 100/0.0109$), equal to 5.5p per minute of delayed-time saving. This value is rather low, compared to the average value of time reviewed from many SP studied by Wardman[5] (2001b). It is because in this analysis respondents are from different trip purposes. The data is also likely to include protest responses to charging schemes. Thus, the value of time is lower than it should be.

Car delayed-time reduction is insignificant in influencing the perception of benefits to society. This indicates that car delayed-time reduction is not perceived as a social benefit. It is seen more as a personal benefit. This is possibly because when journey time falls, it may be perceived as an impact on each individual. In turn, it is likely that when journey time increases, individuals would perceive it more as detriment to themselves than to society.

In both models, the coefficients of bus delayed-time reduction are insignificant. This seems surprisingly to indicate that the perceptions of benefits of road user charging are not influenced by bus delayed-time reduction. This is possibly because of the combined effects from car and non-car users. Nevertheless, the effect of bus delayed-time reduction on the perceptions of benefits to society is almost significant. (This effect is discussed further for the segmentation model in the next section, 7.3.2)

Slight improvement of the environment is not significant in improving the perception of benefits to self, but it is significant in influencing the perception of benefits to society. Substantial environmental improvement has a significant positive effect on both perceptions. This effect, as expected, is higher in the perception of benefits to society than in the perception of benefits to self, when everything else is the same. Respondents consider that environmental improvement is more a social benefit than a personal benefit, as expected. The effect is equal to 293 pence per

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[5] Wardman (2001b) provides a model (formed by a meta-analysis from a large number of previous studies) for estimating UK values of time. Basing on this model, the value of time is 6.8 p/min in year 2000 for commuters travelling 10 miles. The value of delayed-time is about 1.4 times higher than the value of time (Wardman, 1991, 2001a), so the value of delayed-time should be around 9.5 p/min.

day (0.5852/0.0020) for benefits to individuals, and 1530 pence per day for benefits to society (1.5299/0.0010). This value of substantial improvement of the environment is plausible for personal benefits, but it seem to be very high for social benefits. However, it should be noted that these values are purely from selfish and social perspectives. In reality, people are not totally selfish or altruistic. Thus, a proper value should be between the two values. As shown in Section 6.2, the overall value of substantial environmental improvement is 321 pence per day. This is close to the value from the selfish perspective because individuals are concerned with benefits to themselves more than benefits to society, as found in Section 7.2.

For the proportion of revenue allocation, people did not perceive that all revenue allocated to public transport or to tax reduction provided benefits to them significantly different from those with the revenue allocated equally. For benefits to society, they perceived that the revenue should be equally used for public transport and tax reduction or just tax reduction, surprisingly, not just for public transport. This implies that the use of revenue for only public transport is not perceived as a benefit to society as a whole.

A charge in the small area (inside the Inner Ring Road) is perceived as having significantly greater benefits to self than a charge in the wide area. In other words, a charge in the wide area is perceived as having more detrimental than a charge in the small area. This is possibly because some people who can avoid travelling in the small area expect some benefits to themselves without being charged. A charge in the small area is also perceived as having greater benefits to society. However, it is considered more as a benefit to self than a benefit to society. Interestingly, people do not perceive that a charge in the wide area will provide more benefits to society than a charge in the small area. They may consider that the city centre is the main problem area or that there are adverse effects of larger areas.

For the remaining variables, people did not think that the charges during morning peak time are different from the all day charge in providing benefits to them and to society. Nevertheless, the positive effect of a charge during the peak time on the perception of benefits to self is almost significant, indicating that some people may expect some benefits to themselves by avoiding travelling in the peak period, although many people may not be able to do so.

The methods of charge: distance-based, time-based and delay-based were not perceived significantly differently, at 95% confidence level, from the fixed charge. However, the coefficient of the time-based charge is significant at 90% confidence level for the perception of benefits to society. It is of negative sign, indicating that the time-based charging method is not better for society than the fixed daily charge. This may reflect concerns about safety, in which time-based charge tends to influence speeding, in turn increasing risk of accidents, as found by Bonsall and Palmer (1997), and Palmer and Bonsall (1997).

In summary, this section has reported the effects of the system characteristics on the selfish and social perspectives. The regression models demonstrate that individuals do evaluate charging schemes differently between the selfish and social perspectives. These perspectives are influenced by level of charge, area of charge, car delayed-time reduction and environmental improvement. The results confirm, as we expect, that the selfish perspective is more sensitive to charge than the social perspective, car delayed-time reduction is perceived as a benefit to self rather than a benefit to society, and environmental improvement is perceived more as a social benefit than a personal benefit.

7.3.2 Selfish and social perspectives relating to personal characteristics and perceptions

This section explores differences among groups of the public when they rated the perceptions of benefits to self and society. Segmentation analysis (Section 3.4.3) was applied on the basic regression models in Table 7.7.

The results of the incremental effects, which are significant at 95% confidence level, from personal characteristics and perceptions are reported in Table 7.8. The goodness-of-fit (R^2) indexes increase slightly. Although, overall, the interpretations of the effects of the system characteristics are similar to the basic regression models, the segmentation model includes the incremental effects to demonstrate that different groups of people evaluate the charging system characteristics differently. This relates to those who are non-car users, who are aged 55 or over, who live in London, who perceive charging as effective in reducing congestion, who have a strong dislike of charging, who perceive congestion as very serious, who are female, and who perceive the current situation as unacceptable.

There are some aspects of the perception of benefits to self for which car and non-car users are significantly different, as expected. This is because car users are directly affected by charging, but non-car users are not. Interestingly, both car and non-car users perceive the effects of charging systems on benefits to society similarly.

Non-car users are less sensitive to the charging level than car users. However, the impact of charge on non-car users is not zero, though they are not directly charged. A possible reason is because they are concerned about some indirect effects, for example the effects on business and increase of public transport fare (reported in Section 5.6). It may also be because they sometimes use cars or others in the household use cars.

Table 7.8 Segmentation regression models of the perceptions of benefits to self and to society

Variables	Benefits to self	Benefits to society
	Coeff. (t-ratio)	Coeff. (t-ratio)
Constant		
Mean	**-0.4760**	**0.6926**
Standard deviation	**2.95**	**2.80**
Level of charge (p/day)	**-0.0035 (-15.3)**	**-0.0014 (-5.2)**
+ if non-car user	**0.0013 (3.2)**	-
+ if age 55 or over	**0.0012 (3.6)**	-
+ if London	**0.0016 (4.7)**	**0.0008 (2.4)**
+ if perceiving effectiveness in reducing congestion	-	**0.0008 (2.4)**
+ if strong dislike charging	-	**-0.0010 (-2.6)**
Car delayed-time reduction (mins./day)	0.0103 (1.9)	0.0022 (0.4)
Bus delayed-time reduction (mins./day)	-0.0007 (-0.2)	0.0001 (0.0)
+ if non-car user	**0.0144 (2.2)**	-
+ if perceiving congestion as very serious	-	0.0108 (1.9)
Environment base - as now		
Environment dummy - slight improved	0.1814 (1.1)	0.2572 (1.2)
+ if current situation perceived unacceptable	-	**0.9129 (2.4)**
Environment dummy - substantial improved	**0.3801 (2.1)**	**0.9542 (3.7)**
+ if non-car user	**0.8585 (2.4)**	-
+ if female	-	**1.1565 (3.2)**
+ if current situation perceived as unacceptable	-	**0.7753 (2.0)**
Revenue allocation base - 50%:50%		
Revenue dummy allocated to public transport	-0.1282 (-0.7)	**-0.4897 (-2.8)**
Revenue dummy allocated to tax reduction	0.0574 (0.3)	0.1717 (1.0)
Area of charge base - wide area		
Area of charge dummy - small area	**0.8052 (4.9)**	**0.3607 (2.5)**
+ if non-car user	**-0.7703 (-2.4)**	-
Time of charge base - all day		
Time of charge dummy - peak time	0.1929 (1.4)	0.1016 (0.7)
Method of charge base - fixed		
Method of charge dummy - distance-based	-0.0004 (0.0)	-0.1288 (-0.4)
Method of charge dummy - time-based	0.0948 (0.4)	**-0.5659 (-2.1)**
Method of charge dummy - delay-based	0.2038 (0.8)	0.0992 (0.4)
No. Observations	2662	2323
R^2	0.855	0.839

Non-car users perceive bus delayed-time reduction significantly differently from car users for a benefit to self. Bus delayed-time reduction is seen as a personal benefit for non-car users. However, as with car users, non-car users do not perceive bus delayed-time reduction as a benefit to society. They just see it as a benefit to the individual. For car users, bus delayed-time reduction is not perceived as a personal benefit. This supports the reason given in Chapter 6 in that car users do not perceive that reductions of bus delayed-time will make them better off, so acceptability is not significantly influenced by the reduction.

Non-car users also perceive more benefit from substantial improvement of the environment to themselves than car users. This is possibly because they are closer to environmental problems than car users, e.g. waiting for bus, walking and cycling. As reported in Section 5.3, non-car users perceive pollution as more serious than car users. Non-car users also cause fewer environmental problems. They are likely to be more environmentally concerned. In contrast, car users may find it more difficult to be concerned about the environment because it is not easy to reconcile attitudes with behaviour.

For area of charge, non-car users evaluate benefits from a charge in the small area very much differently from car users. Non-car users do not perceive benefits to themselves differently between a charge in the small and wide area. This is reasonable since different areas of charge have no different effect on them. This is contrary to the effect on car users, in which different boundaries of charged area mean the difference in being charged or not.

Moreover, among other groups of the public there are also some differences in the effects of charging system features. Respondents who are 55 or older are less sensitive to the charge than younger respondents in their perceptions of benefits to self. This is possibly because they travel less often (two third of these respondents are non-commuters), so their personal benefits are less affected. However, in Chapter 6, it was found that acceptability of those who are 55 or older is more sensitive to a charge than others. This means that elderly people are more opposed to charging, not because their personal benefits are more affected by the charge than others, but because of something else (which cannot be explained in more detail by this study).

Respondents who live in London are also less sensitive to the charge than those who live in Leeds both for the perception of benefits to self and for the perception of benefits to society. This is unlikely to be because those who live in London are richer. In the sample characteristics (in Table 4.4), the distribution of income groups in London and Leeds are quite similar. The difference may be because road user charging is expected in London more than in Leeds. Congestion and pollution problems are perceived as more serious by people in London than in Leeds (see Chapter 5). Thus, charging would be expected to bring more benefits.

People who believe that charging would be effective in reducing congestion are less sensitive to the charge in their perception of benefits to society than others. Their perception of benefits to society does not fall as much as those who do not believe in the effectiveness, when the charge increases. This implies that they perceive some benefits to society more than others, so there are less protest responses. This helps to explain why charging is more acceptable to those people who perceive charging as effective (the result in Chapter 6).

For the perception of benefits to society those who strongly dislike charging are more highly sensitive to the charge than others, but for the perception of benefits to self, they are similar to others. They are likely to disagree with the principle of charging and tend to be against charging because they see no or little benefit to society, while other people perceive some benefits to society.

Females perceive substantial environmental improvement to be a much larger social benefit than males do. For respondents who find their current travel situation unacceptable, not only the substantial improvement but also the slight improvement in the environment is significantly important on the perception of benefits to society. This is partly because most of these people perceive that pollution in their city is either serious or very serious (reported in Section 5.3).

Finally, those, who perceive the congestion problem in their city as very serious, valued bus delayed-time reduction as relatively different (significant at 90% confidence level) from others for the perception of benefits to society. They may expect bus delayed-time reduction to help to reduce congestion, which would be of benefit society overall. However, for the perception of benefit to self, the effect bus delayed-time reduction is not significant. This is because the effect of bus delayed-time reduction for non-car users is already distinguished from the others who are car users. Thus, those who perceive congestion as very serious are also car users, which do not feel that bus delayed-time reduction benefit them.

7.4 Conclusions

This chapter has tested the hypothesis that acceptability of road user charging is influenced by individuals' selfish and social perspectives. These were reflected by the perceptions of benefits to self and to society. The results from the analyses of the SP data based on the logit models confirmed that the perceptions of benefits to both self and society highly affect acceptability. Overall benefits to self are more important to individuals than benefits to society. In particular, elderly people and females are highly aware of their own benefits from charging schemes when making decisions whether to vote for a charging scheme. In contrast, the results are different for bus users and for those who perceive pollution problem as very serious in their city. They are more concerned for benefits to society as a whole than their own. Nevertheless, it can be concluded that road user charging would not be acceptable if the public are not convinced that charging will provide benefits to them and to society as a whole.

This chapter has also examined the extent to which perceptions of benefits to self and to society are influenced by the system characteristics, as well as, by personal characteristics and perceptions. The regression model showed the effects of some system characteristics on the perspectives. Individuals do evaluate charging schemes differently between the selfish and social perspectives. Increasing the charging level would reduce the perceptions of benefits to self more than to society. Car delayed-time reduction and environmental improvement significantly contribute to the perceptions of benefits. Car delayed-time reduction is perceived more as a benefit to self than to society. In contrast, individuals regard environmental improvement as more of a social benefit than as a personal benefit. A charge within the Inner Ring Road of Leeds and London is perceived as providing more benefits to self than a charge in the wider area. This is possibly because some people who are able to avoid travelling in the area are expecting to benefit from traffic reduction to themselves without being charged.

Furthermore, different groups of people evaluate charging schemes differently from both selfish and social perspectives. Car and non-car users are obviously different, particularly in the valuation of personal benefits. The perception of benefits to society is more affected by personal perceptions, including the perception of the current travel situation, the perceptions of congestion and pollution, the perception of charging as effective in reducing the problems and the strong dislike of charging, than by personal characteristics.

In brief, while increasing the charge could reduce the perceptions of both benefits to self and to society, improving the environment and limiting the charge within the Inner Ring Road (a small area) could improve them. Furthermore, the perceptions of benefits to society can be influenced by provision of clear information on the severity of transport problems, and on the effectiveness of road user charging in reducing the problems. These suggestions, which are similar to the findings from the direct voting model in Chapter 6, can increase the perceptions of benefits to self and to society, which in turn will improve acceptability of charging schemes.

The models developed in this chapter will be used later in Chapter 9 to predict acceptance levels for various road user charging schemes, in comparison with the prediction results by the model developed in Chapter 6.

Chapter 8

Effectiveness of Road User Charging

8.1 Introduction

In the previous two chapters, Chapters 6 and 7, the acceptability of road user charging schemes as influenced by system characteristics, personal characteristics and perceptions, and the individuals' selfish and social perspectives were discussed. The objective of this chapter is to examine the charging scheme's effectiveness as affected by the charging system features and the personal characteristics of respondents (the fourth hypothesis in Section 1.2).

In order to evaluate effectiveness of road user charging schemes, this study focuses on a main objective of the policy which aims to reduce congestion by influencing travel mode switching. The SP exercises were designed to examine mode choice response for work trips since individuals are likely to change their behaviour in different ways for different trip purposes. Car commuters' mode choice responses to the charging schemes were measured by their intention to change from using car to other modes (Section 4.5.3).

In this chapter, the results of the mode choice behaviour based on the standard logit model are shown in Section 8.2. The basic model presented was estimated on all respondents from Leeds and London. The effects of personal characteristics on the mode choice are presented in Section 8.3, in order to explore the differences among groups of the public. Section 8.4 examines heterogeneity in the sample. This is achieved through the use of the random parameters logit model. Finally, conclusions on effectiveness are made in Section 8.5.

8.2 Mode Choice Behaviour Influenced by the System Features

This section presents the development of the mode choice behaviour model. This demonstrates the effects of the charging system features, regardless of respondents' characteristics. The model was analysed from 358 respondents who are car commuters from Leeds and London. The initial model, reported in Section 8.2.1, surprisingly found that car delayed-time reduction is not significant in the utility of car use. This is then examined in Section 8.2.2. Section 8.2.3 discusses the reasons why the delayed-time reduction does not significantly affect the mode choice. Instead, this is significantly influenced by car and bus journey times, as demonstrated in Section 8.2.4. In Section 8.2.5, the simulation results of synthetic data are presented to demonstrate what was wrong in the design of SP exercises and how to improve the SP experiment. Then the preferred model, developed for use in the forecast of reduction of car commuting, is presented in Section 8.2.6.

8.2.1 Initial model

Mode choice behaviour affected by the system features was analysed using the standard logit model (Section 3.4.2). Respondents were offered the four responses: car, 'car earlier/later' (travelling by car before and/or after the charged time), bus, and other (specified by respondents). A utility function is initially set for each response, as in Equation 8.1:

$$
\begin{aligned}
U_{car} &= \theta_1 \textit{ (charge)} + \theta_2 \textit{ (car delayed-time reduction)} + \theta_3 \textit{ (area of charge)} + \theta_4 \textit{ (time of charge)} + \theta_5 \textit{ (method of charge)} \\
U_{car\ earlier/later} &= ASC_{car\ earlier/later} \\
U_{bus} &= ASC_{bus} + \theta_6 \textit{ (bus delayed-time reduction)} \\
U_{other} &= ASC_{other}
\end{aligned}
$$

(Equation 8.1)

The utility of car use is a function of charging characteristics. Level of charge is in units of pence per day. Car delayed-time reduction is specified in minutes per day. The remaining car variables are categorical data, whose effects can be shown in dummy variables, relative to a base scenario. If a variable has n categories, n-1 dummy variables would be used. The value given to the dummy variables is one if an observation corresponds with a specific category, otherwise zero. A dummy variable of area of charge is the small area relative to the wide area. A dummy variable of time of charge is the morning peak time (7am-10am), relative to the all day (7am-7pm). For method of charge, there are three dummy variables for distance-based, time-based and delay-based charge, and the base method is the fixed charge per day.

The utilities of using car before and after the charged time and using other mode are represented by constants (ASCs). The utility of bus use is a function of the ASC and bus delayed-time reduction, which is in units of minutes per day. The ASCs of these alternatives represent unmeasured effects, which were not collected from respondents, e.g. petrol cost, flexibility of choosing departure time, bus fare, and quality of bus and other mode services.

Some variables: time and method of charge in the SP exercises are not included in the mode choice model because they do not have significant effects on the behaviour. The parameters for the environmental improvement and revenue allocation are also excluded because they do not influence mode choice behaviour.

For the basic model, without including the effects of personal characteristics, the ASCs, coefficients and their t-ratios are reported in Table 8.1. The results were analysed from the data of the SP exercises (Section 4.3). The sample included 358 car commuters in Leeds (325 respondents) and London (33 respondents). The model discussed below is the average of the sample.

Table 8.1 Initial standard logit model of mode choice behaviour of car commuters

Variables	Coefficient (t-ratio)
Utility of car use	
Charge (p/day)	**-0.0016 (-4.2)**
Car delayed-time reduction (mins./day)	0.0080 (0.7)
Area of charge base – wide area	
Area of charge dummy – small area	0.6165 (1.8)
Utility of car use earlier/later	
ASC-car use earlier/later	**-3.0927 (-13.2)**
Utility of bus use	
ASC-bus	**-2.6570 (-10.5)**
Bus delay time reduction (mins./day)	-0.0115 (-1.3)
Utility of other mode use	
ASC-other	**-3.7258 (-14.1)**
No. of observation	926
ρ^2 with respect to constant	0.0230
Log likelihood at convergence	-592.6981

Each respondent was presented with four charging scenarios. It was found that over half of the respondents (56%) always chose to use car. Some respondents (21%) switched mode when the attributes of the scenarios were changed. Almost a quarter (23%) always chose one of the non-car choices (either car earlier/later, bus or other).

Those who always chose an alternative mode prefer to avoid the charge by changing travel mode even at £1 per day. They were able to access an alternative mode. Most of them (57%) always chose 'car earlier/later'. Some (14%) chose to travel by bus, while the remaining respondents (29%) preferred other modes, e.g. rail, walking and cycling. These commuters were unlikely to trade-off between the charges and time reductions. Therefore, these respondents were excluded from the model analyses.

For the utility function of car use, the estimation results show that car users are significantly affected by the level of charge (at 99% confidence level). Its coefficient is of negative sign, as expected, indicating that the proportion of car users would fall if the level of charge increases. Car delayed-time reduction is not significant in affecting the mode switching. This is contrary to expectations and will be examined and discussed later in this section.

The small area (within the Inner Ring Roads) of charge has a positive sign, indicating that it has less effect in reducing car use than the wider area (within the Leeds Outer Ring Road and London North/South Circular Roads). This effect of the small area charge is significant at 90% confidence level and is equal to the charge at 385p per day. In other words, the charge in the small area needs to be 385p per day higher than the charge in the wide area, in order to have the same effect in reducing car use.

The morning peak-time charge does not influence mode choice differently, compared to its base scenario, the all day charge. This may be because it is difficult for commuters to avoid travelling during the peak time. Thus, there is no significant difference between the peak-time and all day charge.

The effects of the variable charging methods (distance-, time- and delayed-based) also are not significantly different from the effect of fixed charge. For each individual, when the charges are equal, different methods of charges do not influence mode choice behaviour differently. In a charging system, individuals may not be concerned with the basis of the charge in their mode choice decision. They may solely consider how much they would be charged (the amount of charge). Hence, the effects of different charging methods were excluded from the model. However, at the aggregate level, May and Milne (2000) found that different charging regimes have different effects on overall time travelled, distance travelled and route choice.

In the utility function of bus use, the effect of bus delayed-time reduction is not significant, indicating that the bus time reduction cannot encourage car users to travel by bus. This may imply that there is an element of non-compensatory behaviour. Car commuters are satisfied with their cars, so reductions in bus delayed-times have little effect on their mode choice behaviour. However car commuters can be priced out of their car to bus or other modes.

The ASCs in the utility functions of 'car earlier/later', bus use and the other mode use are highly significant. They have negative signs. This indicates that these three choices are not preferable for car commuters. They still want to travel by car. The least preferred choice is the change to use other mode, followed by 'car earlier/later'. Bus use is the most preferred among them. Bus is able to compete (having equal mode split) with car if the charge is 1661p per day, 1933p per day for 'car earlier/later' and 2329p per day for the other modes. These values are very high, in order to reduce the proportion of car use to be equal to the other choices. For example, when using the model to predict the mode choices, at the 1661p per day charge the mode choices for car and bus were equal at 33%, and the remaining mode shares were car earlier/later and other modes.

The model results indicate that car commuters very much prefer car to other modes. They are affected only by the charge in their decision to switch from using the car to other modes. Car delayed-time reduction is not perceived as adequate to compensate the charge. Bus delayed-time reduction also does not help in encouraging the use of bus.

8.2.2 Examining the initial model

Next, these results are investigated in detail using the individual responses in the SP exercises to examine why mode choice is not significantly sensitive to car and bus delayed-time reductions. Table 8.2 demonstrates the proportions of mode choice for each of the hypothetical charging scenarios. The three basic attributes varied in the SP exercises are the charge, and the car and bus delayed-time reductions. The other attributes in the SP exercises are not taken into account in Table 8.2.

There are eight sets of charging scenarios. Each set has four scenarios presented to each individual. The proportions of mode choice are from 262 car commuters who provided mode choices responding to all four scenarios. Respondents who did not respond to all four scenarios were excluded.

In each set of four scenarios there are two scenarios which have the same level of charge. It can be seen that between these the proportions of mode choice do not vary in response to changes in the car and bus delayed-time reductions. For example, between scenarios 2a and 2b, at £1 daily charge car delayed-time reduction increases from 50% to 75%, but the proportion of car use falls from 77.4% to 74.2%. Between scenarios 4c and 4d, at £7 daily charge car delayed-time reduction increases from 25% to 75%, but the proportion of car use remains at 42.5%. These are similar to the cases between scenarios 5c and 5d, 6b and 6c, 7a and 7b, and 8c and 8d. These demonstrate that the levels of charge are the same but the increases of car delayed-time reductions do not influence more car use. This is also similar to the effects of increasing the bus delayed-time reductions, which does not appreciably influence the use of bus. For example, between scenarios 1c and 1d, 2a and 2b, 4c and 4d, and 8c and 8d, bus delayed-time reduction increases but the proportion of mode choice does not change. On the other hand, reductions of the proportions of car use are clearly found when comparing scenarios where the level of charge increases. This demonstrates the significant effect of the charge.

Table 8.2 Proportion of mode choice in response to charging schemes

Charging characteristics				Mode choice				
No.	Charge	Car delayed-time reduction	Bus delayed-time reduction	Car	Car earlier/ later	Bus	Other modes	Number in sample
1a	£1	50%	75%	22 (78.6%)	2 (7.1%)	2 (7.1%)	2 (7.1%)	28
1b	£5	25%	50%	19 (67.9%)	2 (7.1%)	4 (14.3%)	3 (10.7%)	
1c	£7	50%	50%	19 (67.9%)	2 (7.1%)	4 (14.3%)	3 (10.7%)	
1d	£7	50%	75%	19 (67.9%)	2 (7.1%)	4 (14.3%)	3 (10.7%)	
2a	£1	50%	25%	24 (77.4%)	4 (12.9%)	1 (3.2%)	2 (6.5%)	31
2b	£1	75%	50%	23 (74.2%)	4 (12.9%)	1 (3.2%)	3 (9.7%)	
2c	£3	25%	75%	18 (58.1%)	5 (16.1%)	4 (12.9%)	4 (12.9%)	
2d	£5	50%	75%	17 (54.8%)	6 (19.4%)	4 (12.9%)	4 (12.9%)	
3a	£1	25%	75%	24 (75.0%)	6 (18.6%)	2 (6.3%)	0 (0.0%)	32
3b	£3	50%	50%	20 (62.5%)	9 (28.1%)	1 (3.1%)	2 (6.3%)	
3c	£3	50%	75%	20 (62.5%)	8 (25.0%)	2 (6.3%)	2 (6.3%)	
3d	£5	75%	75%	18 (56.3%)	9 (28.1%)	3 (9.4%)	2 (6.3%)	
4a	£3	75%	25%	23 (57.5%)	12 (30.0%)	2 (5.0%)	3 (7.5%)	40
4b	£5	50%	25%	18 (45.0%)	13 (32.5%)	6 (15.0%)	3 (7.5%)	
4c	£7	25%	25%	17 (42.5%)	14 (35.0%)	6 (15.0%)	3 (7.5%)	
4d	£7	75%	75%	17 (42.5%)	14 (35.0%)	6 (15.0%)	3 (7.5%)	
5a	£1	50%	75%	22 (61.1%)	7 (19.4%)	2 (5.6%)	5 (13.9%)	36
5b	£5	25%	50%	18 (50.0%)	9 (25.0%)	4 (11.1%)	5 (13.9%)	
5c	£7	50%	50%	17 (47.2%)	6 (16.7%)	6 (16.7%)	7 (19.4%)	
5d	£7	75%	75%	16 (44.4%)	6 (16.7%)	7 (19.4%)	7 (19.4%)	

Table 8.2 (Cont.)

Charging characteristics				Mode choice				
No.	Charge	Car delayed-time reduction	Bus delayed-time reduction	Car	Car earlier/ later	Bus	Other modes	Number in sample
6a	£1	75%	50%	25 (83.3%)	3 (10.0%)	1 (3.3%)	1 (3.3%)	30
6b	£3	25%	75%	22 (73.3%)	4 (13.3%)	3 (10.0%)	1 (3.3%)	
6c	£3	50%	50%	21 (70.0%)	5 (16.7%)	3 (10.0%)	1 (3.3%)	
6d	£5	25%	75%	19 (63.3%)	5 (16.7%)	4 (13.3%)	2 (6.7%)	
7a	£1	25%	75%	18 (78.3%)	3 (13.0%)	0 (0.0%)	2 (8.7%)	23
7b	£1	50%	25%	18 (78.3%)	3 (13.0%)	0 (0.0%)	2 (8.7%)	
7c	£3	50%	75%	15 (65.2%)	4 (17.4%)	1 (4.3%)	3 (13.0%)	
7d	£5	75%	75%	15 (65.2%)	4 (17.4%)	1 (4.3%)	3 (13.0%)	
8a	£3	75%	25%	31 (73.8%)	6 (14.3%)	1 (2.4%)	4 (9.5%)	42
8b	£5	50%	25%	27 (64.3%)	8 (19.0%)	4 (9.5%)	3 (7.1%)	
8c	£7	25%	25%	26 (61.9%)	7 (16.7%)	6 (14.3%)	3 (7.1%)	
8d	£7	75%	75%	25 (59.5%)	8 (19.0%)	6 (14.3%)	3 (7.1%)	

8.2.3 Reasons of insignificance of the delayed-time reductions

There are some possible reasons why the mode choice is not influenced by car delayed-time reductions. Firstly, car delayed-time reductions offered in the SP exercises are relatively small. When 25%, 50% and 75% reductions are applied to individuals' car delayed-times, overall, average car delayed-time reduction is 8.6 minutes per day (standard deviation = 9.3). A half of observations offered the time reduction of only 5 minutes per day or less. These small time savings tend to be ignored and not to be valued (MVA et al., 1987; Wardman, 1998; Gunn, 2001).

Table 8.3 demonstrates the models when observations, offered small time savings (less than or equal to 1, 3 and 5 minute(s)), were excluded from the data analysis. The coefficient of the car delayed-time reduction and its t-ratio do increase (indicating greater significance). Nonetheless it is still not significant even at 90% confidence level. This is because the number of samples is reduced. It is also because the higher time savings tend to relate to long journeys, in which there was less likely trade-off behaviour (shown later in Table 8.5 and 8.6).

Table 8.3 Standard logit model of mode choice behaviour of car commuters excluding samples which have low car delayed-time reductions (t_c) offered

Variables	Coefficient (t-ratio)			
	All	Rejecting $t_c \le 1$	Rejecting $t_c \le 3$	Rejecting $t_c \le 5$
Utility of car use				
Charge (p/day)	**-0.0016 (-4.2)**	**-0.0015 (-3.8)**	**-0.0012 (-3.0)**	-0.0007 (-1.9)
Car delayed-time reduction (t_c; mins./day)	0.0080 (0.7)	0.0177 (1.4)	0.0144 (1.2)	0.0198 (1.2)
Area of charge base – wide area				
Area of charge dummy – small area	0.6165 (1.8)	**0.6712 (2.0)**	0.4381 (1.3)	0.2999 (0.6)
Utility of car use earlier/later				
ASC-car use earlier/later	**-3.0927 (-13.2)**	**-2.8880 (-12.0)**	**-2.8306 (-11.2)**	**-2.3902 (-7.8)**
Utility of bus use				
ASC-bus	**-2.6570 (-10.5)**	**-2.4754 (-9.6)**	**-2.3554 (-8.6)**	**-2.1951 (-6.4)**
Bus delay time reduction (mins./day)	-0.0115 (-1.3)	-0.0103 (-1.3)	-0.0117 (-1.4)	-0.0069 (-0.8)
Utility of other mode use				
ASC-other	**-3.7258 (-14.1)**	**-3.5166 (-13.1)**	**-3.4253 (-12.1)**	**-3.3218 (-8.8)**
No. of observation	926	877	784	438
ρ^2 with respect to constant	0.0230	0.0227	0.0174	0.0122

Secondly, most of the car time reductions offered in the SP exercises are likely to be too small to compensate for the charge. Therefore, it is understandable that in the experiment there was only a small number of trade-offs between the charge and the delayed-time reductions.

Table 8.4 Proportions of observations offered at least the time reduction needed for compensating the charge by different values of time

Value of time	£1 per day		£3 per day		£5 per day		£7 per day	
	Time reduction needed (mins.)	% of obs. offered at least the time needed	Time reduction needed (mins.)	% of obs. offered at least the time needed	Time reduction needed (mins.)	% of obs. offered at least the time needed	Time reduction needed (mins.)	% of obs. offered at least the time needed
1 p/min	100	0%	300	0%	500	0%	700	0%
5 p/min	20	9.3%	60	0.4%	100	0%	140	0%
10 p/min	10	30.0%	30	4.8%	50	0.5%	70	0.1%
15 p/min	6.7	36.1%	20	9.3%	33.3	3.0%	46.7	0.5%
20 p/min	5	49.0%	15	18.2%	25	5.6%	35	2.7%
25 p/min	4	71.3%	12	20.6%	20	9.3%	28	5.0%

In an SP experiment, if the value of time for a person was known, at each level of charge we would be able to estimate the smallest time reduction he/she needed for compensation. Table 8.4 demonstrates, at each level of charge and value of time, the proportions of observations offered at least the time reduction needed to compensate the charge. For example, if an individual has a value of time equal to 5p per minute, at £1 daily charge he/she needs to be compensated by at least 20 minutes of travel time reduction. The results show that 9.3% of the observations were offered at least the time reduction needed. At £3 daily, only 0.4% of observations were offered at least the time reduction needed, and at £5 and £7 daily charge no one was offered adequate time reduction. In UK, the value of delayed-time is likely to be about

10p per minute (discussed in Section 8.2.3). The results in Table 8.4 indicate that at 10p per minute only a small number of observations were offered travel time reductions sufficiently to trade off the charge over £3 per day.

Thirdly, in addition to the small bus delayed- time reductions offered, it is also possibly because for some people bus delayed-time may be less important, compared to other features of bus services. Some important attributes, for example fare, frequency, reliability and punctuality, were not made better. Other research (e.g. Stokes, 1996; CfIT/MORI, 2001) found that the public consider improving these features of bus services as more important than reducing travel time, in making bus more attractive. In the SP experiment, individuals' responses were based on their own current situations and experiences of bus use.

Fourthly, car commuters may not find that the delayed-time reductions are believable. The small reductions offered in the SP experiment may be close to day-to-day variations of their travel time, for example because of travel in different times of day and on different roads or because of random variations in traffic condition.

Finally, another reason for the insignificance of delayed-time reduction is that some people may not like the presentation method of the reductions, which uses proportionate changes. This is as found by Widlert (1998), in which results may be different between SP experiments with and without customisation of attributes into absolute values[1]. He also mentioned that between the two presentations, price coefficients are not significantly different, but the time coefficient in the customised form is significant higher; hence, this leads to higher value of time.

8.2.4 Effects of car and bus travel times

For the above reasons, the mode choice behaviour was not influenced by the delayed-time reductions offered. Instead, the mode choice behaviour is likely to be influenced by total travel time (current travel time – time reduction) and travel time difference between bus and car (total bus travel time – total car travel time).

The effects of the total car travel time are shown in Table 8.5. (The utility functions are similar to the model in Table 8.1, but the total travel times are included instead of the time reductions.)

[1] In the research the difference between SP experiments with and without customisation of time reduction presented was little known when the SP exercises were designed. Although both forms were tested in the pilot studies, the problem was not found because of the small sample.

The analyses were produced for the all car commuter sample, those whose total travel time is 40 minutes per day or less, and those whose total travel time is higher than 40 minutes per day.

Table 8.5 Logit model of mode choice behaviour showing the effect of total travel time

Variables	Coefficient (t-ratio)		
	All	Total car travel time ≤ 40 mins/day	Total car travel time > 40 mins/day
Utility of car use			
Charge (p/day)	**-0.0017 (-4.7)**	**-0.0027 (-5.9)**	**-0.0014 (-2.2)**
Total car travel time (mins./day)	**0.0122 (2.7)**	**-0.0354 (-3.1)**	**0.0225 (2.3)**
Area of charge base – wide area			
Area of charge dummy – small area	0.6165 (1.8)	**0.7409 (2.0)**	0.5873 (0.5)
Utility of car use earlier/later			
ASC-car use earlier/later	**-2.8061 (-11.8)**	**-4.4528 (-11.1)**	**-1.7753 (-3.3)**
Utility of bus use			
ASC-bus	**-2.5758 (-10.8)**	**-3.8028 (-9.0)**	**-1.9363 (-3.9)**
Total bus travel time (mins./day)	-0.0006 (-0.3)	-0.0088 (-1.2)	0.0016 (0.4)
Utility of other mode use			
ASC-other	**-3.4347 (-12.9)**	**-4.8803 (-11.8)**	-3.7212 (-4.4)
No. of observation	926	708	218
ρ^2 with respect to constant	0.0287	0.0515	0.0419
Log likelihood at convergence	-587.2396	-463.2937	-109.3101

In the overall model, the coefficient of the total car travel time is positive. This is implausible in that long journey times are preferable to shorter journey times. However, the effect is different between the short and long travel times. For the short journey (total travel time less than or equal to 40 minutes), the effect of car travel time is negative. Utility of car use falls when total time increases. For long journeys (total travel time more than 40 minutes), it is likely that bus services may be poor, e.g. less frequency. Car commuters would prefer to use their car, even when car travel time increases.

The coefficient of total bus travel time is not significant, indicating that car commuters are not likely to consider bus travel time in their mode choice. Alternatively, they may already consider bus travel time in comparison to car travel time. As reported in Section 5.2.1, the average bus journey time to work inside the inner areas of Leeds and London is about double the average car journey time. Since the bus time reductions are small, there is still a big difference between car and bus journey time for car commuters. For most respondents, journey to work by bus is still much longer than by car. Only 6% of the observations were offered bus journey time less than car journey time.

Table 8.6 shows the effect of time difference between commuting by bus and by car (Total bus travel time – Total car travel time). On average, for the whole sample, the coefficient of the time difference has a significantly positive sign, as expected; greater the travel time difference between bus and car, the more preference for use of the car.

The different ranges of the travel time difference are considered to have an effect. This is because it is expected that when bus travel time is very much longer than car travel time, bus tends to be less frequent and/or have a long access walk time. Car would be preferable to bus, and car commuters may not be concerned about the time difference. Thus, in addition to the overall model, three separate models are estimated for: (a) bus travel time is less than 1.5 times longer than car travel time, (b) bus travel time is 1.5 times but less than twice as long, and (c) bus travel time is twice as long or more.

Table 8.6 Logit model of mode choice behaviour showing the effect of time difference between commuting by bus and car for car commuters

Variables	Coefficient (t-ratio)			
	All	Ratio of bus and car travel time < 1.5	1.5 ≤ Ratio of bus and car travel time < 2	Ratio of bus and car travel time ≥ 2
Utility of car use				
Charge (p/day)	**-0.0017 (-4.4)**	**-0.0028 (-3.9)**	**-0.0017 (-3.5)**	-0.0014 (-1.9)
Time difference between commuting by bus and by car (mins./day)	**0.0137 (3.3)**	0.0235 (1.8)	**0.0267 (3.0)**	0.0014 (0.3)
Area of charge base – wide area				
Area of charge dummy – small area	0.5986 (1.8)	0.2577 (0.4)	1.1085 (1.8)	0.2414 (0.4)
Utility of car use earlier/later				
ASC-car use earlier/later	**-2.8501 (-12.6)**	**-3.5991 (-8.4)**	**-2.4650 (-9.0)**	**-3.0629 (-7.4)**
Utility of bus use				
ASC-bus	**-2.6540 (-12.1)**	**-2.9750 (-7.7)**	**-2.1466 (-8.6)**	**-3.6225 (-8.0)**
Utility of other mode use				
ASC-other	**-3.4787 (-13.9)**	**-3.7422 (-8.5)**	**-3.8513 (-8.6)**	**-3.5425 (-7.9)**
No. of observation	926	268	327	331
ρ^2 with respect to constant	0.0306	0.0528	0.0445	0.0110
Log likelihood at convergence	-588.1252	-185.1926	-209.1267	-180.4326

When the ratio of bus travel time to car travel time is less than 1.5 times, the effect of charge is relatively high. The charge has a high effect on influencing car commuters to change travel mode. The effect of the travel time difference is also relatively high, although it is significant at 90% confidence level (probably because of the small number of samples). This is possibly because for the low ratio, buses are more acceptable than for the higher ratio, and car users are more likely to switch from car to bus.

When the ratio is between 1.5 and 2, the effect of charge is less than for the lower ratios. The effect of time difference is slightly different from the one for the lower ratios. It is significant at 95% confidence level.

When the ratio of bus travel time to car travel time is equal or more than 2, travel by buses is very slow, compared to travel by cars. The effect of charge is relatively low, and significant only at 90% confidence level. Charge has less effect on influencing mode switch. The effect of time difference is very low. As mentioned earlier, this is because there was less likely to be a trade-off between the charge and travel time. Buses are likely to be unacceptable. Car is much more preferable than bus, or other modes.

The overall model demonstrates that when the time difference between bus and car increases, the utility of car use will increase; car use is more preferable. The model provides a reasonable value of time equal to 8.1p per minute, which is close to the value reviewed in Wardman (2001b), (discussed in Section 8.2.3). This model is considerably better in explaining the mode choice behaviour than the models including the delayed-time reduction and total travel time. Nevertheless, the three separate models show that when the ratio of bus travel time to car travel time increases the effect of the time difference and charge tends to fall. This is taken into account later in developing a preferred model in Section 8.2.6.

Moreover, the ASCs for 'car earlier/later', bus and other modes are highly significantly negative, indicating that these alternatives have difficulty in competing with car, unless the charge is high. They represent unmeasured factors, which influence mode choice and cannot be included in the experiment. For example, some car commuters may have restrictions on the alternative choices available. Some cannot change to travel before or after the charge. Some may have no other alternatives e.g. rail. For some commuters destinations may be too far to consider walking and cycling as options. Some may have long walking distance to access bus stops and/or less frequent bus service.

8.2.5 Simulation test

In order to improve the SP experiment to evaluate the value of delayed-time reduction, the experiment should increase the variations of delayed-time reduction. It is not appropriate to do this by directly increasing the reduction to more than 75% of delayed-time. The hypothetical scenarios may be unrealistic to respondents. On the other hand, it can be done by introducing more congestion in the SP experiment (presenting respondents with a congested network when there is no road user charging); increasing the level of the delayed time to be reduced.

Although it was too late for this study to collect new data set, a simulation test (Section 3.3.2) was used to demonstrate that increase of the delayed-time reduction was able to improve the results of the mode choice model. Synthetic data was created from know utility weights. It considered only two choices: car and bus.

$$U_{car} = ASC_{car} + \beta_1 \,.\, charge + \beta_2 \,.\, car\ delayed\text{-}time\ reduction + \varepsilon_1$$
$$U_{bus} = \beta_3 \,.\, bus\ delayed\text{-}time\ reduction + \varepsilon_2$$

The utility of car use is a function of ASC (indicating preference of car over bus), charge, car delayed-time reduction and error. The utility of bus use is a function of bus delayed-time reduction and error. The utilities of car and bus use were generated for each observation, when the ASC and coefficients were given and other parameters were known. The synthetic response was dependent on which choice has higher utility.

The charges offered to respondents in the SP experiment were used. The car and bus delayed-time reduction were based on the data collected from each observation, so sample size of the simulation responses is equal to the actual data. The random errors were estimated from $\varepsilon_i = Ln[-Ln(random\ number)] / \lambda$; where random number is generated between 0 and 1, and λ is known as the scale factor $\lambda = \pi/(\sqrt{6} \cdot \sigma)$; σ is standard deviation of the error ε_i. This is based on the Gumbel distribution of the error (see Chapter 3).

The simulation was tested for the values of car delayed-time reduction 5 and 10 p/min and the values of bus delayed-time reduction 1 and 5 p/min. In the calculation of the utilities, the initial coefficient of the charge was assumed to be equal to -1, and the coefficients of car and bus delayed-time reductions were 10, 5 and 1, when the values of time were assumed to be 10, 5 and 1 p/min. The coefficient of bus time is likely to be lower than the coefficient of car time; the value of bus time is expected to be lower than the value of car time. This is because for car users car is more preferred than bus; they tend to keep using their cars. To them car time reduction is likely to be more important than bus time reduction. (This aspect is different from the case reviewed by Wardman (2001b) in that car users have higher values of bus time than car time, because the disutility of a unit of bus time is higher than for car time.)

For each value of time, two sets of synthetic responses were created. One has proportion of choosing car about 60%, and the other 80% (covering the proportion of car use in the data collected from Leeds and London). These were achieved by varying the ASC-car: the higher the ASC, the higher car use. The standard deviation was varied in the estimation of the random error to obtain the goodness-of-fit index (ρ^2) close to the one in the data analysis in Table 8.1 ($\rho^2 = 0.023$).

The model results analysed from the synthetic responses are shown in Table 8.7. Using the time reductions offered in the SP experiment, at the values of car delayed-time 5 p/min and bus delayed-time 1 p/min, the results are quite close to the model (Table 8.1) analysed from the actual responses. The coefficient of car delayed-time reduction is far from the significance at 95% confidence level. At the value of car delayed-time 10 p/min, the coefficient is about significant. When values of both car and bus delayed-time are 5 p/min, the coefficients of car and bus delayed-time are significant.

When using twice the delayed-time reductions for each individual of these in the SP experiment, the coefficient of car delayed-time reduction becomes more significant, ever at the value of car delayed-time of 5 p/min. The goodness-of-fit indexes also increase. These results demonstrate that the SP experiment would be likely to be improved, if respondents had been offered higher variations of delayed-time reductions.

Table 8.7 Simulation results from the synthetic responses

Assumption for creating synthetic data				Model results from analysing the synthetic data				
Assumed value of delayed-time	Standard deviation	Initial ASC-car	% of car use	ρ^2	ASC-car	Coeff. of charge	Coeff. of car delayed-time reduction	Coeff. of bus delayed-time reduction
Using car and bus delayed-time reductions offered to respondents								
5 p/min for car 1 p/min for bus	800	500	60%	0.0277	**0.6631 (5.3)**	**-0.0016 (-6.5)**	0.0106 (1.4)	-0.0001 (0.0)
		1200	81%	0.0215	**1.716 (10.8)**	**-0.0013 (-4.6)**	0.0085 (0.8)	-0.0037 (-1.0)
10 p/min for car 1 p/min for bus	800	500	61%	0.0393	**1.034 (7.9)**	**-0.0019 (-7.7)**	**0.0178 (2.2)**	0.0038 (1.4)
		1100	80%	0.0446	**2.122 (12.5)**	**-0.0021 (-7.0)**	**0.0219 (2.1)**	0.0041 (1.3)
5 p/min for car 5 p/min for bus	800	700	61%	0.0322	**1.163 (8.8)**	**-0.0015 (-6.1)**	**0.0159 (2.0)**	**0.0113 (3.9)**
		1300	79%	0.0310	**2.013 (12.5)**	**-0.0016 (-5.4)**	**0.0199 (2.0)**	**0.0089 (3.0)**
Using twice car and bus delayed-time reductions offered to respondents								
5 p/min for car 1 p/min for bus	800	500	60%	0.0864	**0.7514 (6.0)**	**-0.0014 (-6.0)**	**0.0094 (2.3)**	0.0014 (1.0)
		1100	79%	0.0597	**1.705 (11.2)**	**-0.0014 (-5.0)**	**0.0098 (2.0)**	0.0017 (1.1)
10 p/min for car 1 p/min for bus	800	500	62%	0.0960	**0.8254 (6.4)**	**-0.0017 (-7.0)**	**0.0148 (3.4)**	0.0008 (0.6)
		1100	79%	0.0730	**1.658 (10.4)**	**-0.0017 (-5.9)**	**0.0130 (2.4)**	0.0014 (0.7)
5 p/min for car 5 p/min for bus	800	800	61%	0.0455	**1.314 (10.4)**	**-0.0017 (-7.3)**	**0.0066 (4.5)**	**0.0084 (4.4)**
		1400	80%	0.0527	**2.382 (14.6)**	**-0.0018 (-6.3)**	**0.0074 (5.1)**	**0.0073 (4.9)**

8.2.6 Preferred model

The objective of this section is to develop the mode choice behaviour model, in order to use it in forecasting reduction of car commuting for different charging systems. The initial models, in Section 8.2.1, demonstrated that car use is much more preferable for car commuters than other modes, though charging would be able to affect mode switch. In the SP experiment, the car and bus delayed-time reductions offered have small variations. Some of the reductions offered were too small to trade-off with the charge. Thus, in the model, car and bus delayed-time reductions were not significant affecting mode choice. However, based on the model in Table 8.6, utility of car use is significantly affected by the travel time difference between bus and car. Furthermore it is also shown that the coefficients of the charge and time difference are also related to the relationship between the amounts of bus and car travel time (the ratio of bus and car travel time).

Therefore, the utility functions for the four responses are set as Equation 8.2. The functional form, $(Time\ ratio)^{\lambda_n}$, is included in the utility function of car use, in order to allow the coefficients of the charge and time difference to vary with the time ratio, which is the ratio of bus to car travel time. Since the magnitudes of the effects of the time ratio are unknown, λ was achieved from trials (to get the best 'fit' model). In the sample, bus travel times of most observations (94%) are higher than car travel times; most time ratios are higher than one. Thus, λ can be expected to be negative because the coefficients of the charge and time difference have been found to decrease when the time ratio increases (as shown in Table 8.6). This means that when the proportion of bus and car travel time is very high, the mode choice is less sensitive to the charge and time difference. Commuters would tend to keep using their car. On the other hand, when the ratio is small, the mode choice is highly sensitive to the charge and time difference. For example, at the same amount of time difference 20 minutes, when bus and car travel times are 120 and 100 minutes (lower time ratio) mode switch would be higher than when the travel time are 40 and 20 minutes (higher time ratio). Therefore, there are likely to be interaction effects between the time difference and the time ratio, and between charge and the time ratio.

It should be noted that the coefficients θ_1 and θ_2 in Equation 8.2 are estimated for the whole function of [Charge.(Time ratio)$^{\lambda 1}$] and [(T_{bus} – T_{car}).(Time ratio)$^{\lambda 2}$.(Distance)$^{\gamma}$], respectively. For each individual, the coefficients of charge and time difference (T_{bus} – T_{car}) are dependent on the individuals' time ratio and travel distance. Hence, individuals' coefficients of the charge and time difference are [θ_1.(Time ratio)$^{\lambda 1}$] and [θ_2.Time ratio)$^{\lambda 2}$.(Distance)$^{\gamma}$], respectively.

$$
\begin{aligned}
U_{car} &= \theta_1 . [\,(Charge) . (Time\ ratio)^{\lambda_1}\,] \\
&\quad + \theta_2 . [\,(Time_{bus} - Time_{car}) . (Time\ ratio)^{\lambda_2} . (Distance)^{\gamma}\,] \\
&\quad + \theta_3 . (Area\ of\ charge) \\
&\quad + \theta_4 . (Time\ of\ charge) \\
&\quad + \theta_5 . (Method\ of\ charge)
\end{aligned}
$$

$$
\text{Where:}\quad Time\ ratio = \frac{Bus\ travel\ time}{Car\ travel\ time}
$$

$$
\begin{aligned}
U_{car\ earlier/later} &= ASC_{car\ earlier/later} \\
U_{bus} &= ASC_{bus} \\
U_{other} &= ASC_{other}
\end{aligned}
$$

(Equation 8.2)

Moreover, in empirical studies reviewed by Wardman (2001a, 2001b), time savings on longer distance journeys are more highly valued. This is because of fatigue, boredom and discomfort of long journeys. It may also be because for longer distance journeys there are higher opportunity cost of time travelled and more pressures on the total time budget than for shorter distance journeys. Hence, in order to allow the value of time to increase with journey distance, the function of distance, $(\text{Distance})^{\gamma}$, is included in the utility of car.

The utility of car use also includes other charging system characteristics: area of charge, time of charge and method of charge. The utilities of alternatives are the alternative specific constants (ASCs), indicating preference of each option compared to preference of car use.

In addition, journey distance may also have an effect on the ASCs, in which a longer journey distance may have higher disutility of alternatives than a shorter distance. However when the ASCs were allowed to vary with the distance, the model was not improved.

The estimation results of the coefficients and their t-ratios are shown in Table 8.8. Four models are presented. Model 1 does not include the effects of the time ratio and distance. Model 2 constrains the effect of the time ratio on charge and time difference to be the same, with no distance effect. This model achieves the best fit when $\lambda_1 = \lambda_2 = -0.5$. Model 3 allows different effects of the time ratio on charge and time difference, with no distance effect. The best-fit model is where λ_1 and λ_2 are equal to -0.2 and -0.7, respectively. This model is slightly better than model 2. The last model, Model 4, includes the effect of distance[2]. The distance elasticity (γ) on the value of time for car taken from Wardman (2001b) is 0.259. This model is superior in explaining the mode choice behaviour. This is indicated by the increase of ρ^2 to 0.0402. It is also pointed out by the increase of t-ratios, showing that the coefficients are more precise. On average, all models indicate reasonable values of time, approximately 8-9p per minute.

Table 8.8 Preferred standard logit model of mode choice behaviour of car commuters

Variables	Coefficient (t-ratio)			
	Model 1 $\lambda_1 = 0$ $\lambda_2 = 0$ $\gamma = 0$	Model 2 $\lambda_1 = -0.5$ $\lambda_2 = -0.5$ $\gamma = 0$	Model 3 $\lambda_1 = -0.2$ $\lambda_2 = -0.7$ $\gamma = 0$	Model 4 $\lambda_1 = -0.2$ $\lambda_2 = -0.7$ $\gamma = 0.259$
Utility of car use				
Charge . (Time ratio)$^{\lambda 1}$	**-0.0017 (-4.4)**	**-0.0020 (-4.6)**	**-0.0019 (-4.7)**	**-0.0021 (-5.9)**
$(T_{bus} - T_{car})$. (Time ratio)$^{\lambda 2}$. (Distance)$^{\gamma}$	**0.0137 (3.3)**	**0.0161 (2.9)**	**0.0222 (3.4)**	**0.0119 (4.5)**
Area of charge base – wide area				
Area of charge dummy – small area	0.5986 (1.8)	0.5639 (1.8)	0.5809 (1.7)	**0.7592 (2.1)**
Utility of car use earlier/later				
ASC-car use earlier/later	**-2.8501 (-12.6)**	**-2.8656 (-12.9)**	**-2.8812 (-13.0)**	**-2.9378 (-15.6)**
Utility of bus use				
ASC-bus	**-2.6540 (-12.1)**	**-2.6695 (-12.4)**	**-2.6851 (-12.5)**	**-2.7355 (-15.3)**
Utility of other mode use				
ASC-other	**-3.4387 (-13.9)**	**-3.4942 (-13.8)**	**-3.5098 (-13.9)**	**-3.5325 (-15.9)**
No. of observation	926	926	926	894
ρ^2 with respect to constant	0.0306	0.0322	0.0329	0.0402
Log likelihood at convergence	-588.1252	-587.1360	-586.6898	-566.8784
Mean of value of time	**8.06**	**8.05**	**8.79***	**8.40***

* Value of time is the average of individuals' values of time (the sample enumeration approach)

The results demonstrate that the utility of car use is influenced by the charge and the difference between bus and car travel time. When the charge increases, car use preference will fall, but when the time difference increases, car use will be more preferred. In addition, mode choice is affected by time ratio of bus travel time to car travel time. The lower the ratio, the more opportunity for bus to compete with car. Car use preference also relates to individuals' travel distance. For long distance journeys, cars are more preferred than for short journeys.

The effects of the remaining factors are similar to the results in Table 8.1. Car is much more preferable than other modes for commuting. This is indicated by the high negative effect of ASCs. The small area of charge is of positive sign, compared to the wide area. Charges in the wide area would generate less car use than in the small area. The other variables: time of charge

[2] The trial and error method was unable to achieve a best-fit model because the ρ^2 did not converge to an optimal value. Thus the distance effect has to be transferred from other studies.

and method of charge are not significant in influencing the use of car (as discussed in Section 8.1).

Table 8.9 reports the values of time for different ranges of journey distance. These values were estimated by using the sample enumeration approach, in which the average value of time was achieved from the mean of individuals' values of time. Each individual value of time was the ratio of the individual's time and charge coefficients, which was dependent on his/her time ratio of bus to car and journey distance. The average value of time for the whole sample is 8.4 p/min.

Table 8.9 Values of time based on the sample enumeration approach for different ranges of journey distance

Distance (miles travelled per day)	Value of time (p/min)	Standard error
0-5	5.5	0.19
5-10	7.4	0.16
10-15	8.1	0.22
15-20	9.1	0.25
20-50	10.6	0.29
50+	13.8	0.54
Average	**8.4**	**0.15**

Table 8.10 reports the values of time for different distances. These values are the ratios of the mean coefficients of time and charge (in Model 4 Table 8.8), when the time ratio is 2. From the whole sample, the average of daily commuting distance is 19.0 miles per day (std. 21.6) and the average time ratio is 1.96 (std. 0.71). When the distance is 20 miles and the time ratio is 2, the value is 8.7 p/min, which is close to the value achieved from the appropriate mean of individuals' values of time (although it is not necessary that the mean of ratios is equal to the ratio of the means).

Table 8.10 Values of time based on the mean coefficients for different distances travelled

Distance (miles travelled per day)	Time ratio of bus to car	Value of time (p/min)	Value of time from Wardman (2001b) (p/min)
2	2.0	4.8	4.6
5	2.0	6.1	5.9
10	2.0	7.3	7.0
15	2.0	8.1	7.8
20	**2.0**	**8.7**	**8.4**
25	2.0	9.2	8.9
50	2.0	11.0	13.8

Although this study does not aim mainly to estimate value of time, the value of time achieved from the mode choice model should be plausible. The value of time can be checked with the review of the UK values of time by Wardman (1998, 2001a, 2001b).

The values for different journey distances are close to the UK values of time, calculated from the model developed by Wardman (2001b), in 2000 for car commuters in non south-east areas. It should be noted that the values from the study in Table 8.10 were averages for Leeds and London sample (with only 10% from London). (In the south-east area, Wardman found that the value of time is 16% higher.) The value of time for 50 miles travelled is rather different from Wardman's value because it is outside the range of the sample (90% of respondents travelled less than 40 miles).

Table 8.11 reports the values of time for different time ratios of bus to car, estimated from the ratios of the coefficients of time to charge (in Model 4 Table 8.8). The lower time ratios have higher values of time than the higher time ratios. For the lower ratios, car commuters are more likely to switch mode. On the other hand, for the higher ratios they tend to keep using car and less consider on the charge and time. When the ratio increases, the effect of charge on mode change falls but the effect of time falls more rapidly (see Table 8.6). Thus the value of time decreases.

Table 8.11 Values of time based on the mean coefficients by different time ratio

Distance (miles travelled per day)	Time ratio of bus to car	Value of time (p/min)
20	1.0	12.3
20	1.2	11.2
20	1.4	10.4
20	1.6	9.7
20	1.8	9.2
20	**2.0**	**8.7**
20	2.5	7.8
20	3.0	7.1

8.3 Mode Choice Behaviour Variation among Groups of the Public

The preferred basic model, in the previous section, demonstrates the average effects of the charging systems from the whole sample. It is likely that different groups of people respond differently to charging systems. For example, some groups may be more sensitive to the charge and time than others. Some may have different preferences for other modes. To examine this effect, the segmentation analysis (Section 3.4.3) was applied on the preferred model, Model 4 in Table 8.8. Respondents were segmented by personal characteristics: household annual income, age, gender and location. They were also categorised by personal perceptions on: current situation, congestion and pollution problem, effectiveness in reducing congestion and pollution, and the strong dislike of charging.

The process of the segmentation analysis was the same as used in chapters 6 and 7 on the voting behaviour models. The analysis began by analysing a separate model for each segment in order to identify the potential sources of the differences between groups. Incremental effects of variables and ASCs in the models were estimated. Then only significant incremental effects were taken forwards to be included in a combined segmentation model.

The model results are reported in Table 8.12. The model identifying some sources of differences across the respondents is substantially better than the preferred basic model in explanation of the mode choice behaviour. This is indicated by the increase of ρ^2 from 0.0402 to 0.0631. A likelihood ratio test (Section 3.4.3) was used to compare the segmentation model and the basic model in Table 8.7. The test is that twice the difference between the log likelihood values of the models (67.2) is higher than a χ^2 critical value of 13.3 for 4 degrees of freedom (the number of parameters imposed on the basic model is restricted to being equal to zero under the null hypothesis), indicating that the segmentation model is statistically superior even at the 99% confidence level.

Table 8.12 Preferred standard logit model of mode choice behaviour segmented by personal characteristics and perceptions

Variables	Coefficient (t-ratio)
Utility of car use	
Charge . (Time ratio)$^{-0.2}$	**-0.0024 (-6.1)**
+ if age is between 35 and 44	**0.0010 (2.0)**
$(T_{bus} - T_{car})$. (Time ratio)$^{-0.7}$. (Distance)$^{0.259}$	**0.0134 (4.6)**
Area of charge base – wide area	
Area of charge dummy – small area	0.7121 (1.9)
Utility of car use earlier/later	
ASC-car use earlier/later	**-2.8550 (-14.6)**
Utility of bus use	
ASC-bus	**-2.5305 (-12.0)**
+ if perceived pollution as very serious	**0.9311 (2.8)**
+ if having strong dislike of charging	**-0.9902 (-3.2)**
Utility of other mode use	
ASC-other	**-3.7491 (-13.4)**
+ if perceived pollution as very serious	**1.1963 (2.9)**
No. of observation	842
ρ^2 with respect to constant	0.0631
Log likelihood at convergence	-533.2544
Mean of value of time	**9.68***

* Value of time is the average of individuals' values of time (the sample enumeration approach)

The results demonstrate that the incremental effects of some segments are significant for the ASCs and the charge. Some groups have different preference of alternatives, compared to cars, and some are differently sensitive to the charge. The incremental effects which were not significant have been excluded from the model.

Some groups of car commuters are differently sensitive to the charge. The incremental factors of the charge show that car commuters whose age is between 35 and 44 are less sensitive to charges than other age groups (implying higher value of time). In this group, there is a higher proportion of high income people than other groups. Over a half have annual household income over £40,000. They are also in a middle age of working; they may need their car for work and/or view the car as a status symbol. Between income groups, the effects of the charge and time are not significantly different. Between respondents in Leeds and in London, there is also no significant difference, possibly because of the small number of car commuter respondents from London (only 10%).

Furthermore, the value of time is estimated using the sample enumeration approach, in which overall value of time is the average of individuals' values. The average value of time is 9.68 p/min, which is slightly higher than the values reported in the previous section.

The ASCs of alternatives are highly negatively significant, as expected, indicating that in general car is much more preferable than other modes or changing travel time. Interestingly, those who perceive the pollution problem as very serious have more preference for bus and other non-car modes than the other people. This result is similar to the study by van Vugt et al. (1996a) who found that people who perceive a large impact of cars on environmental pollution have less preference for car. Golob and Hensher (1998) also noted that those who are concerned with pollution have an intention to reduce car use, and the attitudinal survey by LEX (1999) found that the public perceive public transport as environmentally friendly but car as environmental damaging. These results support Gärling et al. (2000) who claim that pro-environmental behaviour intention is related to awareness of consequences.

For those who have a strong dislike of charging, car use is much more preferred than bus use. They are likely to perceive very poor services of bus or unavailability for them. This is possibly a reason for their lower acceptance of charging systems than other people (see Chapters 6 and 7).

8.4 Mode Choice Behaviour Variation among Individuals

In the previous section, the segmentation model (Table 8.12) addressed some differences in the effects of the system features between the groups of car commuters. However, for the segmentation model based on the standard logit model, the coefficients of variables were assumed to be the same for all individuals in specific groups. This section examines whether there is a taste variation among individuals from unknown sources, in addition to the personal characteristics and perceptions. This is explored through the use of the random parameters logit model (Section 3.4.3), which is applied to the segmentation model.

Furthermore, in the case of different types of alternatives, the mode choice model includes the constants (ASCs) to represent unmeasured attributes. Bates and Terzis (1997) pointed out that bias in coefficients (also in the value of time) may occur when some characteristics of choice are omitted and represented by a single constant, particularly if there are substantial variations of the constant among individuals. This can be examined by the random parameters logit model.

The model allows the coefficients to vary across individuals within the sample. To avoid an unstable model (when all parameters are allowed to vary), at least one variable should be fixed (Ruud, 1996). In the analysis based on Equation 8.2, the coefficient of the charge function (θ_1) is not allowed to vary across individuals (the value of time would be distributed as the coefficient of time). The coefficient of the charged area was also fixed because the initial analysis found that it was insignificant. The remaining coefficients: time difference function and ASCs are allowed to vary. Mean coefficients and standard deviations of the random parameters were estimated by LIMDEP programme. The standard deviation is for indicating whether a parameter significantly varies among respondents.

Two random parameters logit models are presented in Table 8.13. In Model 1, the random coefficients are assumed to be normally distributed. This found that the coefficients of the time difference function (θ_2) for some observations (9.7%) have negative sign. This is not plausible, it should be positive because when travel time of bus gets worse than for car (the time difference increases) car will be more preferred, as discussed in Section 8.2.3. The negative sign arises because of the nature of the normal distribution. In Model 2, the θ_2 is assumed to be log-normally distributed, for which the coefficient is always positive, while the others are still normally distributed.

Table 8.13 Random parameters logit model of mode choice behaviour segmented by personal characteristics and perceptions (based on 100 Halton draws)

Variables	Model 1		Model 2	
	Coeff. (t-ratio)	Std. (t-ratio)	Coeff. (t-ratio)	Std. (t-ratio)
Utility of car use				
Charge . (Time ratio)$^{-0.2}$	**-0.0054 (-3.3)**	-	**-0.0049 (-3.6)**	-
+ if age is between 35 and 44	**0.0015 (2.0)**	-	**0.0015 (2.0)**	-
$(T_{bus} - T_{car})$. (Time ratio)$^{-0.7}$. (Distance)$^{0.259}$	**0.0213 (2.6)**	0.0164 (1.9)	**-4.3767 (-6.8)**	1.1470 (1.4)
Area of charge base – wide area				
Area of charge dummy – small area	0.7784 (1.3)	-	0.7548 (1.6)	-
Utility of car use earlier/later				
ASC-car use earlier/later	-12.8340 (-1.8)	7.8687 (1.6)	**-9.0691 (-2.4)**	**5.2980 (2.0)**
Utility of bus use				
ASC-bus	**-4.2908 (-3.4)**	1.4236 (1.4)	**-3.7923 (-3.5)**	0.9763 (0.8)
+ if perceived pollution as very serious	**1.2729 (2.3)**	-	**1.1805 (2.0)**	-
+ if having strong dislike of charging	**-1.3726 (-2.6)**	-	**-1.230 (-2.5)**	-
Utility of other mode use				
ASC-other	-8.4808 (-1.6)	3.4288 (1.1)	**-6.6831 (-2.7)**	2.3212 (1.5)
+ if perceived pollution as very serious	2.2743 (1.5)	-	**1.7508 (2.1)**	-
No. of observation	842		842	
ρ^2 with respect to constant	0.0803		0.0777	
Log likelihood at convergence	-523.4506		-524.9307	
Mean of value of time	**6.49***		**8.12***	

* Value of time is the average of individuals' values of time (the sample enumeration approach)

The goodness-of-fit indexes (ρ^2) for Models 1 and 2 are 0.0803 and 0.0777, respectively. These increase from 0.0631 in the segmentation model in Table 8.12. A likelihood ratio test (Section 3.4.3) was used to compare the random parameters logit models and the segmentation model. The test found that both random parameters logit models are statistically improved from the segmentation model at the 99% confidence level, in turn they are better than the basic model in Table 8.8.

Between these two models, the goodness-of-fit indexes are slightly different. Nevertheless, the model 2 is more preferred because the t-ratios are higher than in Model 1 (providing more precise coefficients), particularly for the coefficient of the time difference function. This indicates that the log-normal distribution is more appropriate than the normal distribution.

It should be noted that in Model 2, for the log-normal distribution[3], the mean coefficient (-4.3767) and standard deviation (1.1470) of the time function represent the mean and standard

[3] When the parameter is assumed as log-normal distributed, the coefficient is expressed as $\theta = \exp(b+s\mu)$, where b and s represent the mean and standard deviation of lnθ. The mean of $\theta = \exp[b+(s_i^2/2)]$. The standard deviation = (the mean of θ) × $\sqrt{[\exp(s^2)-1]}$.

deviation of $\ln\theta_2$. Thus the θ_2 is 0.0243 and its standard deviation is 0.0401, (see also Section 3.4.3, Equation 3.11 and 3.12).

The results show that only the standard deviation of the constant of car earlier/later is significant. The standard deviations of the other random parameter distributions are not significant at the usual 95% confidence level, indicating that the parameters' coefficients do not significantly vary across individuals. However, the standard deviations are relatively high, compared to their coefficients, and the t-ratios are not very small (potentially increased with higher sample size). In order to achieve more precise predictions of mode choice, the individuals' coefficients should be used. (The specific coefficients for each individual can be achieved from LIMDEP.)

Furthermore, the values of time were also estimated from using the individuals' coefficients based on the sample enumeration approach. In Model 1 the value of time overall is 6.49 p/min, which is slightly lower than the review by Wardman (discussed in Section 8.2.3). In Model 2, the value of time is 8.12 p/min, which is close to the UK value of time. This is another reason for suggesting that Model 2, in which the coefficient θ_2 is log-normally distributed, is better than Model 1, and is the most suitable to be used further for the prediction of mode choice in Chapter 9.

8.5 Conclusions

This chapter has tested the hypothesis that the effectiveness of road user charging, focusing on the reduction of car commuting, depends on the benefits and system features of the charging schemes, as well as personal characteristics and perceptions. The SP experiment presented the designed hypothetical charging scenarios to respondents in Leeds and London. The results of mode choice behaviour were from the analyses of the SP data based on the logit model.

In the initial analysis, it was found that car and bus delayed-time reductions up to 75% of current delayed-time presented in the experiment were too small to compensate the charge. Only a small proportion of the observations provided appropriate trade-offs between the charge and time reduction. The time reductions seemed to be ignored by respondents in their choice mode for journeys to work.

The further development of the model found that the mode choice behaviour is better to be explained by travel time difference and time ratio of bus travel time to car travel time, and travel distance. The higher time difference, the more preferred is car use. In addition to the absolute time difference, the time ratio allows the model to represent the amounts of bus and car travel time. The higher the ratio, the fewer respondents considered bus as a choice. The model estimated the plausible value of time around 8-9 p/min, which is close to the review of UK value of time. The model also allows the value of time to increase with increase of travel distance, and to decrease with increase of time ratio of bus to car travel time.

The results demonstrated that car use is very much preferable to car commuters than other modes. Increasing level of charge would reduce travel to work by car. The effect of charges in the small area (Inner Ring Road) in reducing car use are less than in the wide area. The effects of other system characteristics: charged time and the variable methods of charge are not significant in reducing car use.

Moreover, car use is also influenced by some personal characteristics and perceptions. Those whose age is between 35 and 44 (high proportion of high income people) are less sensitive to the charge. They have a higher value of time than others. Those who perceived the pollution problem as very serious are more likely to switch to bus or other non-car mode than others. In contrast, those who having a strong dislike of charging perceive that bus is very poor, compared to car.

In brief, as expected, effectiveness of road user charging schemes in reducing travel to work by car can be increased by increasing level of charge. Interestingly, those car commuters who perceive the pollution problem as very serious in their city are less dependent on their car than the others. They tend to reduce their car use for travelling to work before the others. The results of predicted car commuting reductions and mode choice elasticities with regard to charging, derived from the use of the model developed in this chapter, are presented in Chapter 9.

Chapter 9

Acceptability and Effectiveness

9.1 Introduction

The previous three chapters presented the modelling development from the SP data. In Chapters 6 and 7, the results of acceptability influenced by the charging system characteristics, personal perceptions and characteristics, and the individuals' selfish and social perspectives, were discussed. The voting behaviour models were developed to predict acceptance levels of charging schemes. For the first voting model, in Chapter 6, acceptability is affected directly by the system characteristics and personal perceptions and characteristics. For the alternative voting model, in Chapter 7, these factors were assumed to influence the acceptability through the selfish and social perspectives. Chapter 8 reported the results of mode choice for car commuters influenced by the charging systems. The mode choice behaviour model was developed to predict proportions of car commuting reduction in charging schemes.

The objective of this chapter is to demonstrate the use of the developed models to forecast behaviour. In Section 9.2, the voting models are used to predict acceptance levels of road user charging schemes. In Section 9.3, the mode choice behaviour model was used to predict car commuting reductions. Then in Section 9.4, the relationships between acceptability and effectiveness of the road user charging schemes are discussed. In Section 9.5, suggestions for how to design acceptable and effective schemes are presented. Finally, Section 9.6 provides conclusions.

9.2 Acceptability of Road User Charging Schemes

In the study, acceptability of road user charging is reflected by the voting behaviour, that is whether individuals vote for the charging schemes presented in the SP experiment (Chapter 4). The aim of this section is to report the results for the predicted acceptance levels of different road user charging schemes and for different groups of the public. This is based on the assumption that the schemes would be acceptable, when they were supported by at least 50% of voters.

The voting behaviour models developed in Chapters 6 and 7 are used to forecast the acceptance levels. The direct voting model from Chapter 6 is based on the logit model, in which the utility is a function of the charging system characteristics. The indirect voting model in Chapter 7 is also based on the logit model, but the utility is a function of the selfish and social perspectives. These perspectives are based on regression models of the charging system characteristics.

In this section, both direct and indirect models are used to forecast levels of charging schemes. Differences in the predicted results are discussed. The direct model is preferred and then used for the prediction of acceptance levels for different groups of the public.

9.2.1 Procedure for prediction of acceptance levels

The forecasting procedure is based on the sample enumeration approach. This is suitable for forecasting the effects of policies that impact differently on various groups of the public (Ben-Akiva and Lerman, 1985; Bradley and Kroes, 1992). Choice probabilities (Equation 3.7) of acceptance are obtained from the preferred voting behaviour model for each respondent. These probabilities are influenced by the system characteristics, as well as the personal characteristics and perceptions. The predicted acceptance level for the whole sample is an average of the probabilities of the 830 respondents. The predicted acceptance level for each group of the public is an average of the probabilities of the people in the group.

For the direct voting model, the individuals' choice probabilities can be estimated by using the preferred utility function of 'yes' vote. This is a function of the system characteristics and personal characteristics and perceptions (the model in Table 6.4), while the utility of 'no' vote is zero. It was found that acceptability is highly sensitive to the level of charge. However, it can be improved by increasing the levels of environmental improvement and car delayed-time reduction. A charge within the city centre is more acceptable than in the wide area. A fixed charge also is significantly more acceptable than the variable: distance-based, time-based, and delayed-based charges.

For the indirect voting model, the individuals' choice probabilities can be estimated by using the utility function of 'yes' vote, which is the function of the perceptions of benefits to self and to society, reflecting the selfish and social perspectives (the model in Table 7.6), and the utility of 'no' vote is zero. The results confirm that acceptability is influenced by both selfish and social perspectives. Furthermore, these perspectives are related to the system characteristics, and personal characteristics and perceptions (the regression models in Table 7.8).

In order to demonstrate different levels of acceptance in different groups of the public, a base charging scenario is set as follows.

- Fixed charge per day;
- Within the Outer Ring Road for Leeds and the North/South Circular Roads for London (the wide area in the model);
- Between 7am – 7pm;
- No car and bus delayed-time reduction;
- No environmental improvement (as now).

Various scenarios of charging systems are set as shown in Table 9.1, to demonstrate variation of acceptance levels across the systems. The other system features: times of charge and revenue allocations, which are not significant in affecting acceptability, are not varied across the schemes.

Table 9.1 Various road user charging systems

Scenario	Effects of	Car delayed-time reduction	Environmental improvement	Area of charge	Method of charge
1	Base	0	As now	Wide	Fixed charge
2	Area of charge	0	As now	Small	Fixed charge
3	Environmental improvement	0	Substantial	Small	Fixed charge
4	Car delayed-time reduction	10	Substantial	Small	Fixed charge
5		20	Substantial	Small	Fixed charge
6		30	Substantial	Small	Fixed charge
7	Method of charge	30	Substantial	Small	Distance-based
8		30	Substantial	Small	Time-based
9		30	Substantial	Small	Delay-based

The different systems are presented as scenarios 1-9 showing the cumulative effects of the system features. Scenario 1 is the base charging system, in which charging is within the Outer Ring Road of Leeds and the North/South Circular Roads of London (the wide charged area) between 7am and 7pm, but with no car and bus delayed-time reduction or environmental improvement. Scenarios 2 and 3 show the effects of the charge in the small areas and of the environmental improvement, respectively. Scenarios 4 – 6 show the impacts of different car delayed-time reductions. Scenarios 7 – 9 demonstrate the effects of different methods of charging. The prediction results (from the direct and indirect voting model) of these scenarios for a range of levels of charge are presented in the next two sections, Sections 9.2.2 and 9.2.3.

These illustrate a wide range of acceptance levels across the charging scenarios, rather than a single general acceptance as presented in many attitudinal studies.

9.2.2 Predicted acceptance levels using the voting model of the charging system features

In Chapter 6, Sections 6.2 – 6.4 examined the acceptability of road user charging as influenced by the system characteristics, and personal characteristics and perceptions, using the standard logit model, segmentation model and random parameters logit model. The standard logit model showed the effects of the charging system characteristics. The segmentation presented greater details in the differences between groups of people, categorised by their personal characteristics and perceptions. The random parameters logit model identified whether taste variation across individuals is significant.

It was found that the segmentation model (Table 6.4) is very much better than the standard model (Table 6.1) in explaining the voting behaviour. It showed that different groups of the public are different in evaluating charging systems. The random parameters logit model (Table 6.5) demonstrated that there is no significant taste variation across individuals. The random parameters logit models were not significantly better than the segmentation model. This means the segmentation model is suitable to predict acceptance levels of charging systems.

By using the segmentation model, the prediction results of each charging scenario in Table 9.1 for a range of levels of charge are presented in Table 9.2 for people in Leeds and in Table 9.3 for people in London.

In every scenario, not surprisingly, the higher the charging level, the lower the acceptability. Voting for scenario 2 shows that the system will be dramatically more acceptable when it covers the area inside the Inner Ring Road (small charged area), compared to the charge within the Leeds Outer Ring Road and London North/South Circular Roads (wide charged area) in scenario 1. Voting for scenario 3 shows a further substantial increase of acceptance when the environment is substantially improved. Scenarios 4 – 6 show a small effect of an increase in car delayed-time reduction in improving the acceptance levels, compared to scenario 3. By comparing scenarios 7 - 9 to scenario 6, the results demonstrate that fixed charges are significantly more acceptable than distance-based, time-based and delay-based charges. There are slightly different acceptance levels for these variable charges. Very low acceptance can be expected when these methods of charge are applied in a wide area and with no environmental improvement. Overall, the results demonstrate that acceptability varies considerably across the charging system characteristics.

Table 9.2 Predicted acceptance levels of road user charging systems in Leeds by using the voting model of the system characteristics

Level of charge (per day)	1	2	3	4	5	6	7	8	9
	Base	Area of charge	Environmental improvement	Car delayed-time reduction			Method of charge		
				10 mins	20 mins	30 mins	Dis.	Time	Delay
£1	30.6%	46.1%	60.8%	63.4%	65.8%	68.2%	43.5%	42.5%	45.5%
£2	25.7%	39.9%	54.4%	57.0%	59.6%	62.1%	37.4%	36.5%	39.3%
£3	21.4%	34.2%	48.0%	50.6%	53.2%	55.7%	31.9%	31.1%	33.6%
£5	14.9%	24.6%	36.2%	38.5%	40.9%	43.3%	22.8%	22.2%	24.2%
£7	10.5%	17.7%	26.8%	28.6%	30.6%	32.6%	16.4%	15.9%	17.4%

Note: shadings are made on the schemes which are voted for by more than 50% of the public

Table 9.3 Predicted acceptance levels of road user charging systems in London by using the voting model of the system characteristics

Level of charge (per day)	1	2	3	4	5	6	7	8	9
	Base	Area of charge	Environmental improvement	Car delayed-time reduction			Method of charge		
				10 mins	20 mins	30 mins	Dis.	Time	Delay
£1	53.8%	69.2%	80.4%	82.0%	83.6%	85.0%	67.0%	66.1%	68.7%
£2	49.7%	65.4%	77.2%	79.0%	80.7%	82.3%	63.0%	62.1%	64.8%
£3	45.8%	61.4%	73.8%	75.7%	77.5%	79.3%	59.0%	58.1%	60.8%
£5	38.8%	53.6%	66.4%	68.5%	70.5%	72.5%	51.3%	50.4%	53.1%
£7	33.1%	46.6%	59.0%	61.1%	63.2%	65.3%	44.4%	43.6%	46.1%

Note: shadings are made on the schemes which are voted for by more than 50% of the public

In Leeds, options for designing acceptable schemes are limited. The only scheme that would achieve over 50% acceptance would be a fixed charge of less than £3 per day, within the Inner Ring Road with substantial environmental improvement. In London, many more options are available, even variable charging methods based on distance, time and delay could be used. Level of charge can be set at up to £5 per day, even for the variable charging methods. It can be £7 per day if the public believe that the environment will be substantially improved. However, the systems need to be within the Inner Ring Road.

The results indicate that any charging is more acceptable in London than in Leeds, though the segmentation analysis (in Chapter 6) found that there is no significant difference in evaluating the charging system characteristics between people who live in Leeds and in London. The difference of the acceptance levels is because they are different in the distributions of sample characteristics and perceptions (shown in Section 4.6), which evaluate the charging schemes differently. For example, in Leeds the proportion of car users is higher, but the proportions of those who perceive the transport problems as very serious and perceive the effectiveness are lower than in London. The acceptance levels for these different groups of people are presented in Section 9.3.

9.2.3 Predicted acceptance levels using the voting model of the selfish and social perspectives

In Chapter 7, Section 7.2 examined the effects of the selfish and social perspectives on acceptability. These perspectives were reflected by the perceptions of benefits to self and to society. Three models were developed. The standard logit model was estimated with the utility of voting behaviour as the function of the selfish and social perspectives (Table 7.2). The results showed that both perspectives highly influence acceptability. People would vote for charging schemes if they perceived benefits to themselves and to society. In general, benefits to self were perceived as of more importance than benefits to society. The segmentation model (Table 7.3) explored the differences among groups of the public. Different groups had different weights for the benefits to self and to society. The random parameters logit model (Table 7.6) examined the differences across individuals. This showed that the taste variation in the population is significant. Among these models, the random parameters logit model was the most superior in explaining the behaviour, so it was preferred for use to predict levels of acceptance through the perceptions of benefits to self and society.

Section 7.3 examined how much the charging system characteristics affect the perceptions of benefits to self and to society. The regression model (Table 7.8) was estimated in order to demonstrate the effects of the charging systems characteristics, and personal characteristics and perceptions on the perceptions of benefits to self and society. It was found that different groups of people value the charging benefits and features differently. This model can be used to predict the degree of perceptions of benefits to self and to society for each individual, responding to charging systems.

Therefore, by using the regression models of the perceptions of benefits (Table 7.8) and the logit model of voting behaviour (Table 7.6), forecasts of acceptance levels for different road user charging systems can be achieved. The forecasting procedure is based on the sample enumeration approach (Section 9.2.1). To each charging system, degrees of perceptions of benefits to self and society for each individual are produced by the regression models. Then, choice probabilities of acceptance are obtained for each respondent by the logit model, in which its utility is a function of the perceptions of benefits to self and society. The predicted acceptance level of the system for the whole sample is an average of the probabilities of the 830 respondents. The prediction results of the charging scenarios set in Table 9.1 for a range of levels of charge are presented in Table 9.4 for people in Leeds and in Table 9.5 for people in London.

Table 9.4 Predicted acceptance levels of road user charging systems in Leeds by using the voting model of the selfish and social perspectives

Level of charge (per day)	1	2	3	4	5	6	7	8	9
	Base	Area of charge	Environmental improvement	Car delayed-time reduction			Method of charge		
				10 mins	20 mins	30 mins	Dis.	Time	Delay
£1	27.4%	33.0%	42.0%	42.8%	43.6%	44.4%	43.9%	42.8%	46.1%
£2	25.4%	30.8%	39.6%	40.3%	41.1%	41.8%	41.3%	40.3%	43.6%
£3	23.6%	28.6%	37.2%	37.9%	38.6%	39.4%	38.9%	37.8%	41.0%
£5	20.3%	24.7%	32.7%	33.4%	34.1%	34.7%	34.3%	33.2%	36.3%
£7	17.4%	21.3%	28.7%	29.3%	29.9%	30.5%	30.1%	29.0%	31.9%

Table 9.5 Predicted acceptance levels of road user charging systems in London by using the voting model of the selfish and social perspectives

Level of charge (per day)	1	2	3	4	5	6	7	8	9
	Base	Area of charge	Environmental improvement	Car delayed-time reduction			Method of charge		
				10 mins	20 mins	30 mins	Dis.	Time	Delay
£1	47.3%	52.8%	70.5%	71.1%	71.7%	72.3%	71.6%	69.5%	73.8%
£2	46.6%	52.0%	69.8%	70.4%	71.0%	71.6%	70.9%	68.8%	73.1%
£3	45.8%	51.2%	69.1%	69.7%	70.3%	70.9%	70.2%	68.0%	72.4%
£5	44.3%	49.5%	67.7%	68.3%	68.9%	69.5%	68.8%	66.6%	71.0%
£7	42.8%	47.9%	66.2%	66.8%	67.4%	68.0%	67.3%	65.1%	69.6%

Note: shadings are made on the schemes which are voted for by more than 50% of the public

The charging schemes in London are more acceptable than in Leeds (because they are different in the distribution of sample). In Leeds, the acceptance level would be close to 50%, if charging were at £1 per day, within the Inner Ring Road with substantial environmental improvement. In London, with this system feature the acceptance level is over 70%. Even when level of charge is increased up to £7 per day, the acceptance level is still over 60%.

Overall, the figures demonstrate that acceptability varies across the charging system characteristics. The effects of these factors are the same as shown in Tables 9.2 and 9.3, in which the results are predicted from the direct voting model. Increasing charge would reduce acceptance levels. On the other hand, these would be increased by limiting charges to the city centre and improving the environment substantially. Variable charges are less acceptable than fixed charges. However, the effects of these system characteristics predicted from the indirect voting model are relatively smaller than the effects predicted from the direct voting model. This is discussed in the following section, 9.2.4.

9.2.4 Discussions on the results of the predicted acceptance levels of charging systems

In Sections 9.2.2 and 9.2.3, the levels of acceptance for Leeds and London were predicted from different models. One was from the direct voting model, in which the system characteristics influenced acceptability directly. The other one was from the indirect voting model, in which the system characteristics affected acceptability through the selfish and social perspectives. The prediction results were different. The effects in the indirect model were smaller compared to the direct model:

- Acceptance is less sensitive to the level of charge, particularly in London;
- The effects of the small area charge and substantial environmental improvement increase acceptance significantly, but these effects are smaller;
- The effect of the variable charging methods is very small. Acceptance of these methods are not significant different from the fixed charges in the indirect model, but the results from the direct model show that they are much less acceptable.

These are firstly because of errors of model prediction. The indirect voting model forecasted the acceptability through the perceptions of benefits to self and to society. The regression models were used to estimate the degrees of the perceptions of the benefits for each individual. Then the logit model with utility as the function of the perceptions was used to estimate the acceptance levels. The error in the indirect voting model was likely to be more than in the direct model, which only involved one step in the prediction. In the indirect mode, error of the forecast could have occurred in the regression model. In a logit model, if there is more error, its coefficients (in terms of absolute values) will be lower. Hence, the effects of variables would be less than they should be.

Moreover, the difference is likely to be because in the indirect voting model the effects of system characteristics on voting are less likely to transfer totally through the perceptions of benefits to self and to society, when respondents were asked to express their degrees of the perceptions of the benefits. For example, (a) the effect of disagreement with the principle of charging may be taken into account less in the expression of the perceptions of benefits than in the voting. (b) For some people who cannot avoid the charge in the small area, their perceptions of benefits to self from charging in the small and in the wide area may not be different. Nevertheless they may vote for a charge in the small area because they support the charge only within the congested area. Hence the effects of the small area on voting in the direct model would be higher than in the indirect model. (c) With the same amount of charging, different charging methods are unlikely to generate different perceptions of benefits. On the other hand, in the voting people may prefer fixed charges to variable charges.

From these reasons, therefore, the predicted acceptance levels from the direct voting model are likely to be more reliable than the indirect model. Unfortunately, the results cannot be compared with the reviewed acceptability from previous studies in Section 2.5.1. This is because the previous studies presented little or no information about charging system characteristics to respondents. However, the study here presented the various schemes and the results show that different charging schemes are considerably different in their acceptability.

9.2.5 Predicted acceptance levels for different groups of the public

To demonstrate different levels of acceptance among different groups of the public, the base charging scenario is used. This system is based on the fixed daily charge within the wide areas (Leeds Outer Ring Road and London North/South Circular Roads) between 7am-7pm, with no car and bus delayed-time reduction and no environmental improvement. The sample enumeration approach is used in the prediction procedure (Section 9.2.1). The predicted acceptance level in each group is an average of individuals' choice probabilities of 'yes' vote in the group. These are predicted from the direct voting model.

Table 9.6 demonstrates the effect of charges on the acceptance levels of the base scenario for different groups of people. These involve the different attitudes between mode users and between age groups, which are significantly different in the voting model. It can be seen that levels of charges have a very large impact on acceptability for every group. When the level of charge is increased, the level of acceptance is dramatically decreased.

Table 9.6 Predicted acceptance levels of the base scenario for different personal characteristics by charging level (and % change from base)

Charging level (per day)	All	Car users	Non-car users	Age < 55	Age ≥ 55
£1 (base)	35.0%	27.2%	56.2%	36.8%	31.5%
£2	30.2% (-13.7%)	22.5% (-17.3%)	51.0% (-9.3%)	32.7% (-10.9%)	25.3% (-19.9%)
£3	26.0% (-25.6%)	18.6% (-31.6%)	46.0% (-18.1%)	29.0% (-21.2%)	20.1% (-36.2%)
£5	19.4% (-44.6%)	12.8% (-52.9%)	37.2% (-33.8%)	22.9% (-37.8%)	12.5% (-60.3%)
£7	14.7% (-58.0%)	9.0% (-66.9%)	30.4% (-45.9%)	18.3% (-50.3%)	7.9% (-74.9%)

Acceptability of the base scenario with £1 per day charge among car users is much lower than for non-car users. Only just over a quarter of car users vote for it, while more than a half of non-car users accept the scheme. When the charge increases, the proportion of acceptance decreases in car users more than non-car users. Between the age groups, acceptance is slightly different at the £1 daily charge. The difference increases when the charge increases because elderly people are significantly more sensitive to the charge than younger people.

Table 9.7 demonstrates the impact of charge on the acceptance levels of the base scenario for those who have different personal perceptions.

Table 9.7 Predicted acceptance levels of the base scenario for different personal perceptions by charging level (and % change from base)

Charging level (per day)	Perceiving current situation acceptable	Perceiving current situation unacceptable	Congestion perceived as very serious	Congestion perceived as not very serious	Pollution perceived as very serious	Pollution perceived as not very serious
£1 (base)	27.4%	47.8%	53.8%	27.1%	52.6%	29.2%
£2	22.6% (-17.5%)	43.0% (-10.0%)	49.5% (-8.0%)	22.1% (-18.5%)	50.0% (-4.9%)	23.6% (-19.2%)
£3	18.6% (-32.1%)	38.4% (-19.7%)	45.4% (-15.6%)	17.9% (-33.9%)	47.4% (-9.9%)	18.9% (-35.3%)
£5	12.7% (-53.6%)	30.7% (-35.8%)	37.9% (-29.6%)	11.6% (-57.2%)	42.4% (-19.4%)	11.7% (-60.0%)
£7	8.8% (-67.9%)	24.7% (-48.3%)	31.8% (-40.9%)	7.6% (-72.0%)	37.8% (-28.1%)	7.1% (-75.7%)

Table 9.7 (cont.)

Charging level (per day)	Perceiving effective in reducing congestion	Not perceiving effective in reducing congestion	Perceiving effective in reducing pollution	Not perceiving effective in reducing pollution	Having strong dislike of charging	Not having strong dislike of charging
£1 (base)	46.4%	27.4%	46.2%	28.2%	21.4%	40.6%
£2	41.1% (-11.4%)	22.9% (-16.4%)	40.8% (-11.7%)	23.7% (-16.0%)	17.5% (-18.2%)	35.4% (-12.8%)
£3	36.3% (-27.8%)	19.2% (-29.9%)	35.9% (-22.3%)	19.9% (-29.4%)	14.4% (-32.7%)	30.8% (-24.1%)
£5	28.2% (-39.2%)	13.5% (-50.7%)	27.8% (-39.8%)	14.2% (-49.6%)	10.9% (-49.1%)	23.2% (-42.9%)
£7	22.3% (-51.9%)	9.7% (-64.6%)	21.9% (-52.6%)	10.3% (-63.5%)	7.2% (-66.4%)	17.8% (-56.2%)

The acceptance levels of £1 per day charge are relatively high (about a half) in those who perceive their current travel situation unacceptable, those who perceive congestion and pollution problems as very serious, and those who perceive charging as effective in reducing congestion and pollution. These people would expect some benefits from the charging schemes. For those who do not have these perceptions, the acceptance levels are lower (about a quarter for a £1 charge and lower for higher charges). In other words, road user charging would be more acceptable if it is proposed in a place where the current travel situation is not acceptable to the public, people perceive congestion and pollution as very serious, and people perceive charging as effective in reducing the problems. On the contrary, it would be difficult to gain support, if people strongly dislike charging (e.g. those who object to being made pay more for car use, who are concerned with the indirect effects of charging, and who have a high preference for car use).

These differences of acceptance between the characteristics and perceptions lead to the different levels of acceptance in Leeds and London (presented in Section 9.2.2). Between respondents from Leeds and London, though the results from the model analysis (Section 6.3) found that there is no significant difference in evaluating the charging schemes, they are different in their distribution of sample characteristics (Section 4.6) and perceptions (Chapter 5). For example, in Leeds the proportion of car users is higher, but the proportions of those who perceive the transport problems as very serious and perceive the charging system as effective are lower than in London. These cause the results of lower level of acceptance in Leeds.

9.2.6 Predicted acceptance levels for car commuters

This section focuses on only acceptance of car commuters. These results are used later in Section 9.4.2 to examine the relationship between acceptability and effectiveness in reducing car commuting, to see whether acceptable schemes for car commuters are effective.

Tables 9.8 and 9.9 present the predicted acceptance levels of the charging schemes (set in Table 9.1) for car commuters in Leeds and London. These results were estimated from the direct voting model.

Table 9.8 Predicted acceptance levels of road user charging systems in car commuters in Leeds

Level of charge (per day)	1	2	3	4	5	6	7	8	9
	Base	Area of charge	Environmental improvement	Car delayed-time reduction			Method of charge		
				10 mins	20 mins	30 mins	Dis.	Time	Delay
£1	25.7%	40.9%	**56.3%**	**59.0%**	**61.7%**	**64.3%**	38.3%	37.3%	40.3%
£2	21.4%	35.2%	**50.1%**	**52.9%**	**55.6%**	**58.3%**	32.7%	31.8%	34.6%
£3	17.7%	29.9%	44.0%	46.7%	49.5%	**52.2%**	27.7%	26.9%	29.4%
£5	12.0%	21.2%	32.9%	35.5%	37.7%	40.3%	19.5%	18.8%	20.7%
£7	8.2%	14.8%	23.8%	25.8%	27.8%	29.9%	13.6%	13.1%	14.5%

Note: shadings are made on the schemes which are voted for by more than 50% of the public

Table 9.9 Predicted acceptance levels of road user charging systems in car commuters in London

Level of charge (per day)	1	2	3	4	5	6	7	8	9
	Base	Area of charge	Environmental improvement	Car delayed-time reduction			Method of charge		
				10 mins	20 mins	30 mins	Dis.	Time	Delay
£1	38.1%	55.1%	69.4%	71.7%	73.9%	76.0%	52.4%	51.4%	54.4%
£2	33.6%	50.0%	64.7%	67.1%	69.4%	71.7%	47.3%	46.3%	49.3%
£3	29.6%	45.1%	59.7%	62.2%	64.6%	67.0%	42.5%	41.5%	44.4%
£5	22.9%	36.2%	49.9%	52.4%	54.9%	57.3%	34.0%	33.1%	35.7%
£7	18.1%	29.2%	41.2%	43.5%	45.8%	48.1%	27.2%	26.5%	28.7%

Note: shadings are made on the schemes which are voted for by more than 50% of the public

As expected, in car commuters the acceptance levels for every charging scheme are lower than for the public overall, shown in Tables 9.2 and 9.3. The results demonstrate that the effects of the system features on acceptability in car commuters are similar to the effects overall. Acceptance falls when the charge increases and when variable methods of charge are used instead of the fixed charge, but it increases significantly when the area of charge is limited to the small area and the system provides substantial environmental improvement. Car delayed-time reduction helps slightly in increasing the acceptance.

9.3 Effectiveness of Road User Charging Schemes

This section illustrates the results of the assessment of effectiveness of different road user charging schemes and the effectiveness for different groups of car commuters. This is shown by the proportions of car commuting reduction that are estimated from the mode choice behaviour model developed in Chapter 8.

9.3.1 Procedure for prediction of car commuting reduction

In Chapter 8, Sections 8.2 – 8.4 developed the mode choice behaviour models. The random parameters logit model in Table 8.13, Model 2, was the most superior and appropriate to use to predict car use for journey to work, and in turn to predict car-commuting reduction. In the prediction, the model was based on individuals' specific coefficients of the random parameters. Bus and car travel time (in terms of the time difference and ratio) and travel distance were based on each individual's current travel circumstances. Bus and car delayed-time reductions were considered not to influence mode choice (see Section 8.2).

The model was developed from respondents who were car commuters. The choice probabilities of car, car earlier/later, bus and other were estimated from the mode choice model for each respondent. The sample, which was used to develop the model, excluded the respondents who always chose a 'non-car' mode: either car earlier/later, bus or other. (Car earlier/later was considered as 'non-car' because commuters change their travel time to use car in uncharged periods.) Those who always chose a non-car mode were not likely to trade-off among attributes of the options. They were able to access an alternative and did not change, regardless of the charging characteristics. However in the prediction of mode choice, they were included. Their choice probabilities of the mode they chose were equal to one, while the choice probabilities of car and other mode use were zero.

Similar to the prediction of acceptance level, the forecasting procedure of mode choice was based on the sample enumeration approach. The choice probabilities (Equation 3.7) of car and other options were obtained from the mode choice behaviour model for each respondent. The predicted proportion of each option for the whole sample was an average of the probabilities of every car commuter, and the prediction for each group of car commuters was an average of the probabilities of the people in the group (categorised by personal perceptions and characteristics).

In the prediction process, with zero charge the model predicted the proportion of car use as slightly less than 100%, 96.4% in Leeds and 98.4% in London. Clearly, these figures should be 100% because all respondents travelled to work by car. Thus the predicted proportions of car use for other levels of charge needed to be adjusted by multiplying the results by 1.037 (100/96.4) for Leeds and by 1.016 (100/98.4) for London.

9.3.2 Predicted car commuting reduction for different schemes

The base charging scenario, charging scenario 1 in Table 9.1, is used to demonstrate the levels of car commuting reduction. This system is based on the fixed daily charge within the wide areas (Leeds Outer Ring Road and London North/South Circular Roads) between 7am-7pm, with no car and bus delayed-time reduction. The analysis (in Chapter 8) found that only the level of charge and area of charge affect the mode choice significantly. Other changes of the system characteristics would not help in increasing effectiveness. Thus, car commuting reduction is predicted for another charging system, which is within the small area. This scenario is charging scenario 2 in Table 9.1.

The predicted results of car commuting reduction in Leeds and London for different levels of charge are shown in Table 9.10.

Table 9.10 Predicted car commuting reduction for charging schemes in Leeds and London (and % change from £1 charge)

Level of charge (per day)	Leeds		London	
	Base*	Base + the small area	Base*	Base + the small area
£1	23.8%	22.2%	31.3%	30.4%
£2	25.0% (5.0%)	22.9% (3.2%)	31.9% (1.9%)	30.8% (1.3%)
£3	26.6% (11.8%)	24.0% (8.1%)	32.9% (5.1%)	31.3% (3.0%)
£5	30.9% (29.8%)	26.9% (21.1%)	36.1% (15.3%)	33.0% (8.6%)
£7	37.3% (56.7%)	31.4% (41.4%)	41.1% (31.3%)	36.3% (19.4%)

* Base scheme is a fixed charge within the wide area between 7am-7pm with no delayed-time reduction

Not surprisingly, the results demonstrate that the car use reduction increases when the charge increases. The car use reduction for charges in the small area is slightly lower than in the wide area. Overall, any charging system is relatively effective in reducing car commuting. Even for the daily £1 charge within the city centres, almost 22% of car commuters in Leeds and 30% in London will switch to non-car modes or without-charged time. When the charge increases to £7 per day, the car use reduction increases further to 31% in Leeds and 36% in London.

The reductions are relatively high at £1 charge because they are included those car commuters who always chose a non-car option in response to charging in the SP experiment (as mentioned in Section 9.3.1). In responding to charging systems, they preferred to avoid the charge by changing to travel in un-charged times or use alternative modes. There were 21% and 24% of respondents from Leeds and London, respectively. About a half of them were able to change to use car before and after the charged time.

Between Leeds and London, although the model in Chapter 8 has shown that there is no difference, charging systems in London are more effective in reducing car commuting than in Leeds. This is because in London there are more people perceiving pollution and congestion problems as very serious (who are more likely to reduce car use) and fewer people having the strong dislike of charging (who are less likely to reduce car use) (see Section 9.3.3). However the additional reduction from an increase of charges in Leeds is more than in London. This is because the reductions of car commuting in London are higher at £1 (base charging level) and also include higher proportion of the samples who always chose a 'non-car' mode. (This is also reflected in the charge elasticities, presented later in this section).

Figures 9.1 and 9.2 illustrate the predicted mode choices for different levels of charges within the Inner Ring Roads of Leeds and London (which are considerably more acceptable than within the wider area, as demonstrated in Section 9.2.6; but slightly less effective then the wider areas). The proportions of the car commuting reductions are presented in greater detail. They include those who change to use car in the un-charged period, to use bus, or to use other means e.g. rail, walking and cycling.

In Leeds, the scheme can reduce car commuting by 22% with the charge of £1 per day, and by up to 31% with the charge of £7 per day. Over half of the reductions are because commuters change to use car before and/or after the charged period. The others switch to bus or others means of travel. The proportions of car earlier/later and other (non-bus) change slightly, when the charges increase. This is likely to be because of personal constraints; for example whether they have flexible travel time, whether they have alternatives (non-bus) available and whether their destinations are within walking distance. Those who have these options would choose them, even at the low charge. On the other hand, those who do not have the options would be most likely to switch to use bus, which usually service widely, when the charge increases.

In London, the car use reduction rises from 30% to 36%, when the charge varies from £1 to £7 per day. The proportions of car commuters switching to other modes (non-bus) are high (15%), compared to the total reductions of car use; most of them use the underground. As in Leeds, the proportions changing travel time (15%) are about a half of the car use reductions. The further reductions, when the charges increase, are from switching to use buses.

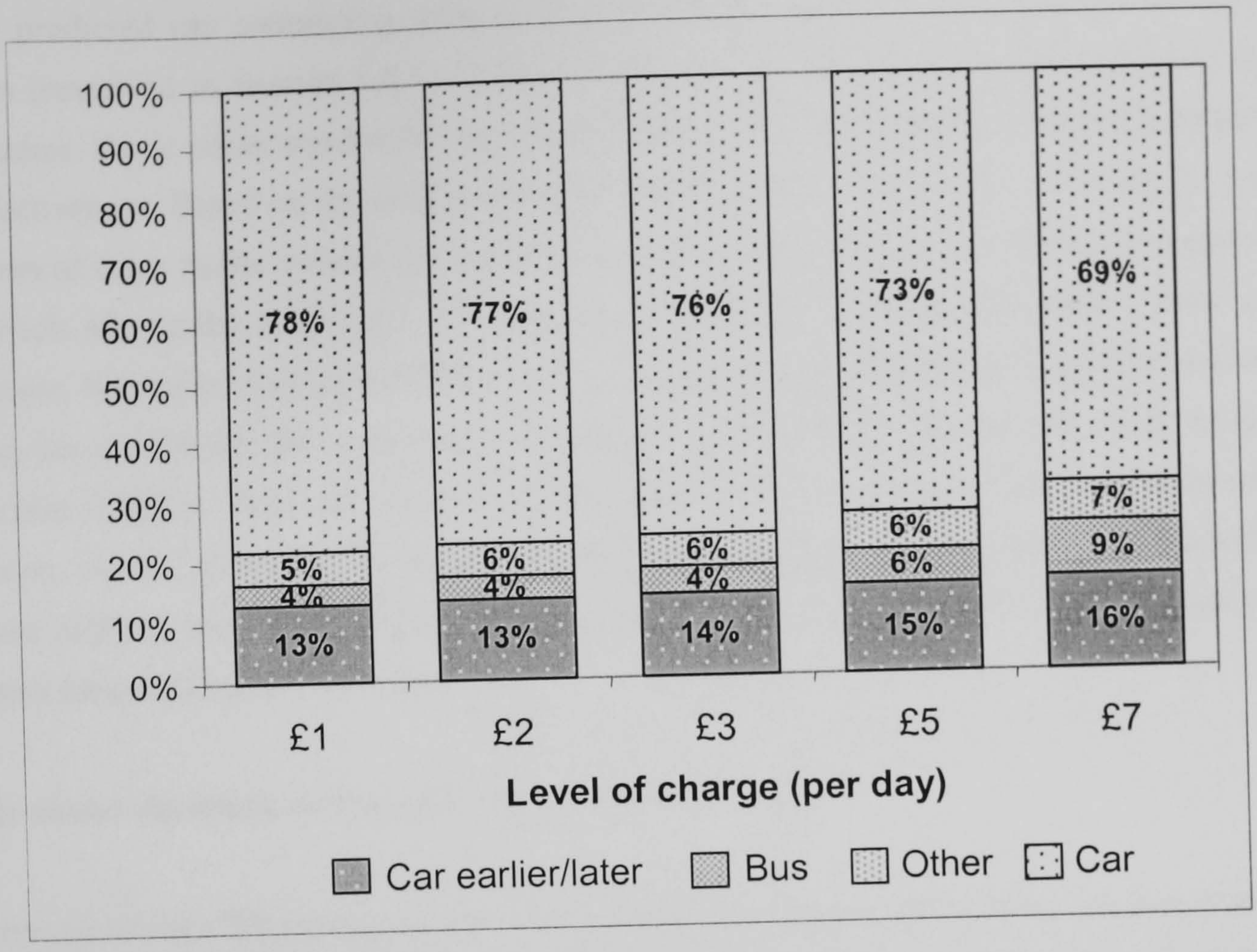

Figure 9.1 Predicted mode choices for charging within the Inner Ring Road of Leeds

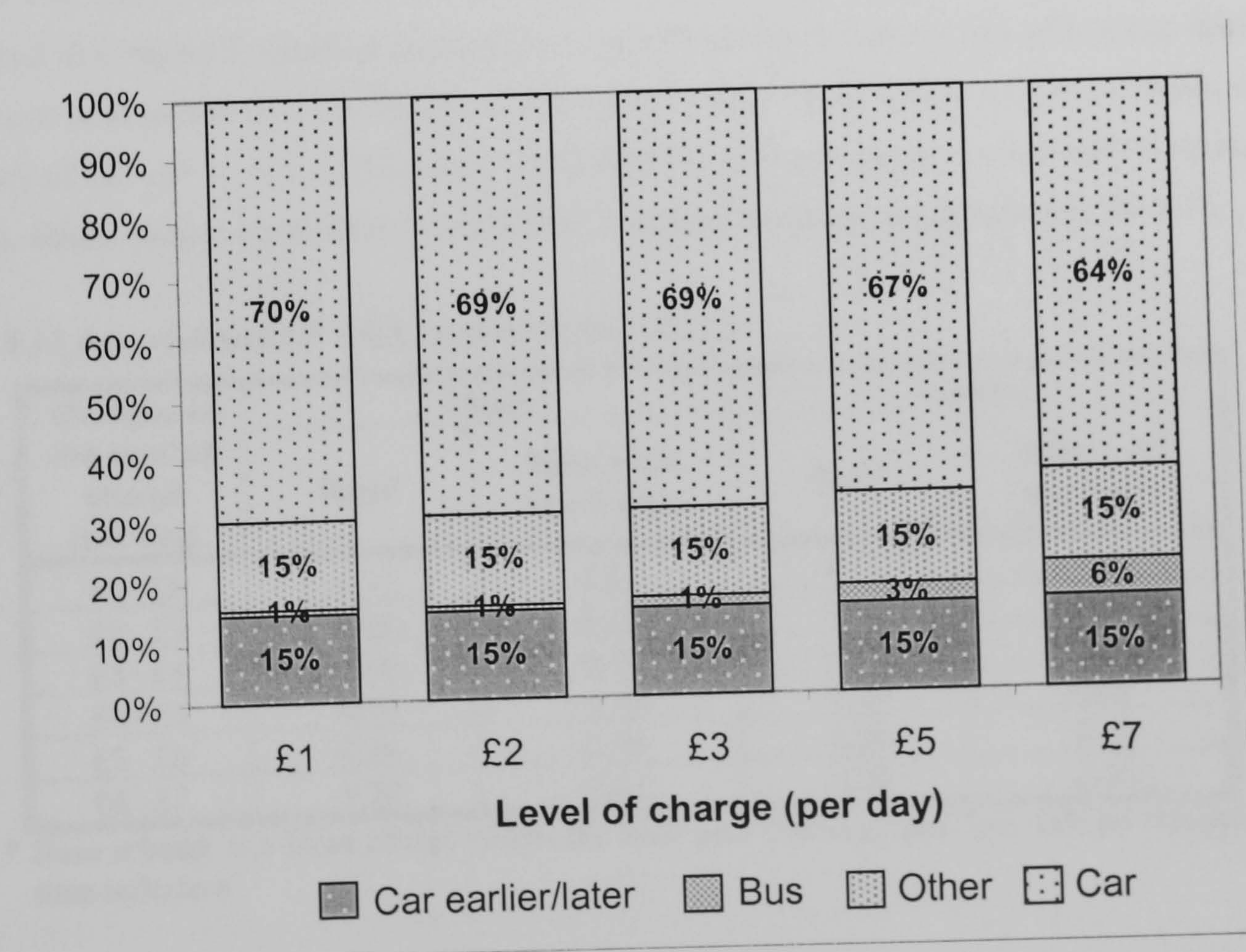

Figure 9.2 Predicted mode choices for charging within the Inner Ring Road of London

These predicted car commuting reductions are broadly similar to the results from previous studies (reviewed in Section 2.6.1). However, the results cannot be directly compared among the studies. Some issues need to be considered. Firstly there are different units of measurement of effectiveness. Based on the modelling results, reductions of car use are presented in terms of numbers of trips, traffic volume and vehicle kilometres. The results from attitudinal surveys and field trials are similar to the ones from stated preference surveys, which measure mode choice responses. Secondly, there are different system features. Nevertheless it is possible to compare among the studies for the same levels of charge, because other features are likely to be less important. Finally, there are different trip purposes. The previous studies involve all trip purposes, but the study here is focused on only commuting trips. Reductions of commuting by cars are likely to be slightly higher than overall reductions, because work trips are usually more frequent (more charged) than other trips.

Mode choice elasticity with respect to increasing charges

The results of the effectiveness of charging can also be compared to previous studies in terms of demand elasticities with respect to increasing costs of car use (e.g. road pricing, tolling, parking charges and fuel price). From the predictions of car use, using the mode choice model developed in Chapter 8, demand elasticity can be calculated to indicate the percentage change in the car use in response to a 1% change in the charge, other factors constant (for example, charge elasticity of car use is -0.1, indicating a 0.1% reduction of car use as a result of 1% increase of charge). Mode choice elasticities for different charging levels are reported in Table 9.11.

Table 9.11 Arc elasticities[1] with respect to the charge

Changes of the level of charge (per day)	Leeds		London	
	Base*	Base + the small area	Base*	Base + the small area
£1 - £2	-0.02	-0.01	-0.01	-0.01
£2 - £3	-0.05	-0.03	-0.04	-0.02
£3 - £4	-0.09	-0.06	-0.07	-0.04
£4 - £5	-0.16	-0.10	-0.13	-0.07
£5 - £6	-0.24	-0.16	-0.20	-0.12
£6 - £7	-0.36	-0.23	-0.30	-0.18

* Base scheme is a fixed charge within the wide area between 7am-7pm with no delayed-time reduction

[1] The arc elasticity is defined as $\eta^{arc} = \dfrac{ln(demand_2 / demand_1)}{ln(charge_2 / charge_1)}$ (TRRL, 1980).

The results demonstrate that the elasticities vary between -0.01 and -0.36. These are different among different charging ranges, between charged areas and between Leeds and London. For different charging ranges, it is clear that the higher the levels of charge, the higher effect of charge increases.

Between the charged areas, the elasticities of charges in the small area are lower than in the wide area. This is because the smaller area affects fewer car commuters. The elasticity of charge increases in London are slightly lower than in Leeds (as discussed earlier in this section).

It can be recognised that the charge elasticities are sensitive to the initial level of charge. The elasticities, presented in Table 9.12, are derived from the demands of car use at different levels of charge, compared to no charge (the arc elasticity cannot be calculated for an initial of charge of zero), in order to make them comparable to the previous studies (reviewed in Section 2.6.4).

Table 9.12 Linear elasticities[2] with respect to the charge

Changes of the level of charge (per day)	Leeds		London	
	Base*	Base + the small area	Base*	Base + the small area
£0 - £1	-0.14	-0.13	-0.19	-0.18
£0 - £2	-0.14	-0.13	-0.19	-0.19
£0 - £3	-0.15	-0.14	-0.20	-0.19
£0 - £5	-0.18	-0.16	-0.22	-0.20
£0 - £7	-0.23	-0.19	-0.26	-0.23

* Base scheme is a fixed charge within the wide area between 7am-7pm with no delayed-time reduction

Overall, charging schemes in London are more effective in reducing car use than in Leeds, because in London there are a higher proportion of car users switch to other travel means at £1 charges. The wider area has a larger effect on car use than the smaller area. The higher the levels of charge, the higher impacts on car use.

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2 The linear elasticity is defined as $\eta^{linear} = \dfrac{(demand_2 - demand_1)/\frac{1}{2}(demand_2 + demand_1)}{(chargeg_2 - charge_1)/\frac{1}{2}(charge_2 + charge_1)}$,

which is generally close to the arc elasticity (TRRL, 1980). The linear elasticity is sometimes also called arc elasticity (e.g. in Halcrow Fox and Associates, 1992; Fowkes et al., 1993a; Luk and Hepburn, 1993).

The estimated elasticities are reasonable, compared to previous studies of road user charging. Particularly, the values for London appear to match relatively well with the results of the ROCOL study (GOL, 2000); elasticities for work trips with respect to £2.50 and £10 charge are -0.17 and -0.27, respectively. They also broadly similar to the values transferred from the evidences of increases of fuel price, parking charges and tolls, which the elasticities are between -0.1 and -0.2 (reviewed in Section 2.6.4).

It should be noted that some elasticities, reviewed in Section 2.6.4, involve aggregate demand elasticities, while the values in Tables 9.11 and 9.12 are derived from the disaggregate mode choice model. Oum and Waters II (2000) argued that mode choice elasticities tend to be lower than ordinary demand elasticities in terms of absolute values because they do not take into account of the effect of price change on aggregate volume of traffic, but only the split between modes. They suggested that in order to produce regular demand elasticities, the discrete choice study must include non-travellers in the dataset, as the choice of not making a trip is one of the options facing users. This recommendation was taken into account in the study here, in which the proportions of car commuting reductions included those who always chose not to travel by cars, and in the SP experiment respondents were able to state not making trip (e.g. by work at home, etc.), if they wished.

The plausible elasticities are another confirmation that the developed mode choice model is appropriate for use in the predictions of the car use reductions (in addition to the confirmation by the similar values of time achieved by this study and from the review of the UK values of time, as presented in Section 8.2.3).

9.3.3 Predicted car commuting reduction in different groups of commuters

This section demonstrates the levels of car use reduction for different groups of commuters for the base charging scenario. The predicted car commuting reduction in each group is the average of individuals' choice probabilities of non-car in the group. This prediction procedure is explained in Section 9.3.1.

Table 9.13 demonstrates the effects of charges on the mode choice behaviour for car commuters who have different perceptions of the transport problems and a strong dislike of charging, as well as the difference between age groups, which are the factors that show significant effects in the mode choice model in chapter 8.

Table 9.13 Predicted car commuting reduction of the base scenario for different personal perceptions by charging level (and % change from base)

Charging level (per day)	All	Pollution perceived as very serious	Pollution perceived as not very serious	Perceiving effective in reducing congestion	Not perceiving effective in reducing congestion
£1 (base)	24.4%	28.7%	23.0%	32.0%	22.3%
£2	25.4% (4.7%)	30.6% (6.7%)	24.0% (4.5%)	33.3% (3.9%)	23.5% (5.1%)
£3	26.9% (10.6%)	33.0% (14.8%)	25.4% (10.3%)	34.8% (8.9%)	24.9% (11.5%)
£5	31.3% (28.5%)	39.5% (37.4%)	29.4% (27.8%)	39.4% (23.0%)	29.1% (30.4%)
£7	37.6% (54.5%)	48.1% (67.4%)	35.4% (53.8%)	46.4% (45.1%)	35.3% (58.1%)

Table 9.13 (cont.)

Charging level (per day)	Having strong dislike of charging	Not having strong dislike of charging	Age 35 - 44	Other ages
£1 (base)	22.6%	25.2%	25.8%	23.5%
£2	23.7% (4.6%)	26.6% (5.3%)	26.4% (2.4%)	24.8% (5.8%)
£3	24.8% (9.6%)	28.2% (11.9%)	27.2% (5.6%)	26.6% (13.3%)
£5	27.8% (22.8%)	31.1% (23.5%)	29.4% (13.9%)	31.7% (35.0%)
£7	32.4% (42.9%)	40.6% (60.9%)	32.5% (26.3%)	39.3% (67.3%)

The results show that for car commuters who perceive pollution as very serious, car use is reduced more than for the other groups. (This result can be expected to be similar for the effects of the perceptions of congestion problems, due to the high correlation.) For those who have the strong dislike of charge, charging is less effective in reducing car use. (The differences between the perceptions were discussed in Section 8.3).

At £1 daily charge, the effect of charging on those whose age is between 34 and 44 is slightly higher than those in the other age groups. However, when the charge increases, car commuting in the other age groups decreases faster. Car commuters aged between 34 and 44 are likely to be more dependent on their car than the others (discussed in Section 8.3).

The differences of the effectiveness of charging between the perceptions lead to the higher level of effectiveness in London than in Leeds (presented in Section 9.3.2), in which in London there are higher proportions of people perceiving pollution and congestion as very serious and lower proportion of people who have a strong dislike of charging.

In brief, Section 9.3 has demonstrated the effectiveness of different charging schemes, which is mainly dependent on levels of charge and areas of charge. It has also illustrated the effectiveness on different groups of car commuters.

9.4 Acceptability and Effectiveness

Sections 9.2 and 9.3 presented the prediction results of acceptability and effectiveness of road user charging schemes separately. The objective of this section is to draw conclusions about the relationship between the acceptability and effectiveness. It examines the arguments by many researchers that road user charging is effective but less acceptable (see Section 2.7). This led to the fifth hypothesis in Section 1.2 that those who do not accept charging may be forced to change from using their car to other modes (low acceptance, high effectiveness), and on the other hand those who are able to continue use a car in charging systems may support the systems (high acceptance, low effectiveness).

This section examines the relationship at disaggregate (individual) and aggregate levels. At the disaggregate level, individuals are analysed to see whether those who vote for charging schemes tend to keep travelling by cars, and those who vote against the schemes are forced to switch travel means. At the aggregate level, charging schemes are assessed to see whether acceptable schemes are less effective, and unacceptable ones are more effective.

9.4.1 Acceptability and effectiveness among individuals

In the SP experiment (Chapter 4), the commuters were asked whether they would vote for the presented charging schemes and what mode they would use for travelling to work. The overall results of the voting and mode choice, regardless of the system characteristics, are demonstrated in Table 9.14, in order to show the weak relationship between voting and mode choice at the individual level.

Table 9.14 Voting and mode choice behaviour by different modes of commuting

Mode choice	Car commuters (1314 observations)		Bus commuters (404 observations)		Other mode commuters (376 observations)	
	'Yes' vote 235 (17.9%)	'No' vote 1079 (82.1%)	'Yes' vote 214 (53.0%)	'No' vote 190 (47.0%)	'Yes' vote 170 (45.2%)	'No' vote 206 (54.8%)
Car	**155 (66.0%)**	**680 (63.0%)**	2 (0.9%)	5 (2.6%)	12 (7.1%)	10 (4.9%)
Car earlier/later	33 (14.0%)	206 (19.1%)	4 (1.9%)	8 (4.2%)	3 (1.8%)	12 (5.8%)
Bus	22 (9.4%)	98 (9.1%)	**203 (94.9%)**	**170 (89.5%)**	37 (21.8%)	27 (13.1%)
Others	25 (10.6%)	95 (8.8%)	5 (2.3%)	7 (3.7%)	**118 (69.4%)**	**157 (76.2%)**

For car commuters who have direct effects from charging, less than one fifth of the observations (17.9%) voted for the charging schemes, while the majority voted against them. The mode choices between those who vote for and against are relatively similar. About two thirds preferred to pay the charges to keep using their cars. The remaining responses chose to travel to work by car in the un-charged times, by bus or by other alternatives.

For bus commuters, charging systems are relatively highly acceptable; over half voted for the schemes. Most of them, either voting 'yes' or 'no', preferred not to change mode of travel. A small number switched to other means.

For other mode commuters, although acceptance of charging systems is not as high as for bus commuters, it is considerably higher than for car commuters. Between those voting 'yes' and 'no', mode choices are relatively similar, as found for car and bus commuters. About three quarters of responses did not change mode of travel to work. Some switched to use buses, possibly as a result of bus delayed-time reductions. A small number changed to use cars. This would help charging systems to remain being effective in reducing car use. Many car users switch to non car modes, but small numbers of non car users will switch to using cars.

Moreover, Table 9.15 reports the strength of the relationship between voting and mode choice, based on the Cramer's V coefficients[3]. These are reported separately for different modes used. The results are also divided for all samples and samples from Leeds and London.

Table 9.15 Cramer's coefficients showing strength of the relationship between acceptability and effectiveness

Sample	Commuters		
	Car user	Bus user	Other mode user
All	0.05	0.11	0.16
Leeds	0.06	0.11	0.26
London	0.16	0.26	0.16

The results demonstrate that the relationship overall is very low in both Leeds and London, and for all mode users, particularly for car users, indicating the weak relationship between

[3] Cramer's V coefficient varies between 0 and 1 to indicate the strength of relationship between two nominal variables that have more than two categories (Bryman and Cramer, 1997).

acceptability and effectiveness in commuters. This rejects the hypothesis that those who accept charging would still use their car.

9.4.2 Acceptability and effectiveness among different charging schemes

At the aggregate level, the relationships between acceptability and effectiveness for different charging systems in Leeds and London are illustrated in Figures 9.3-9.6. In Figures 9.3 and 9.4, the acceptability is for only car commuters, while in Figures 9.5 and 9.6 acceptability is for the public in general, including commuters and non commuters for all modes (whose opinions would also be taken into account, if there was a referendum). (Note that in the figures the origin for the levels of effectiveness is not zero.)

The acceptability is presented in terms of the proportions of people who vote for the schemes (predicted from the voting model developed in Chapter 6 and presented in Tables 9.2 and 9.3 for the general public and Tables 9.8 and 9.9 for car commuters). The effectiveness is presented in terms of the proportions of car commuting reductions (predicted from the mode choice model developed in Chapter 8 and presented in Tables 9.10). The results show the acceptability and effectiveness of four charging scenarios:

- *Base*: the base scenario, a fixed charge within the wide area (the Leeds Outer Ring Road and London North/South Circular Roads) between 7am-7pm with no delayed-time reduction;
- *Base + Small area*: the base scenario but within the small area (the Inner Ring Roads of Leeds and London);
- *Base + Small area + Subst. Env. Imp.*: the base scenario but within the small area with substantial environmental improvement;
- *Base + Variable charge*: the base scenario but the charge based on a variable charge[4] (either distance-based, time-based or delay-based).

The results demonstrate that effectiveness of charging is mainly affected by levels of charges: the car use reductions increase when charges increase. Nevertheless, the effectiveness varies moderately between 22% and 37% reductions in Leeds and between 30% and 40% reductions in

[4] The different effects of different charging methods are small (see Chapters 6, 7 and 8), thus the results presented in this section are average effects of the three methods.

London. The different areas of charge also have a small effect on the reductions, which in the small area are slightly lower than in the wider area.

On the other hand, acceptability of the schemes is highly affected by the levels of charge, areas of charge, substantial environmental improvement and methods of charge. The acceptability for the public in general varies substantially between 4% and 60% in Leeds, and between 16% and 80% in London. The acceptability for car commuters in Leeds (Figure 9.3) is slightly lower than for the public in general (Figure 9.5) because there are a small proportion of non car users. On the contrary, in London the acceptability for car commuters (Figure 9.4) is moderately lower than for the overall proportion (Figure 9.6) because there are a high proportion of non-car users.

For each charging scheme, there is some relationship between acceptability and effectiveness with regard to charging levels; the higher the effectiveness, the less the acceptance. However, among the schemes, when the charging levels are equal, effectiveness is slightly different but acceptability is considerably different.

The figures in both Leeds and London do not support the belief in the relationship between acceptability and effectiveness by many researchers (reviewed in Section 2.7), in which highly effective charging schemes are less acceptable, and less effective schemes are highly acceptable. In fact, overall, every charging system is relatively effective, but they can be highly or less acceptable depending on charging system characteristics. Even with a charge at £1 per day, for example, over 20% of car commuters in Leeds would switch to un-charged times or other modes (see Figure 9.5). If the charge was based on a variable charge within the Outer Ring Road, it would be acceptable to only 14% of the public. If the charge was fixed per day within the Inner Ring Road and the environment was substantially improved, the system would be supported by 60% of the public.

In London, the road user charging scheme, proposed by the Review of Charging Options for London (ROCOL) Working Group to the Mayor of London, is based on the £5 daily charge operated between 7am and 7pm within Central London (GOL, 2000). The results from the study here demonstrate that the scheme would be acceptable to the majority of the public and effective in reduce car commuting. Figure 9.6 shows that it could reduce car travel to work by 33%, and could be acceptable to 54% of the public. This result is very similar to ROCOL's findings; that the scheme can reduce car use by 30%, and that 53% of the public agreed that it was a 'good thing' (reviewed in Chapter 2). If the environment was substantially improved, the acceptance would increase to 66%.

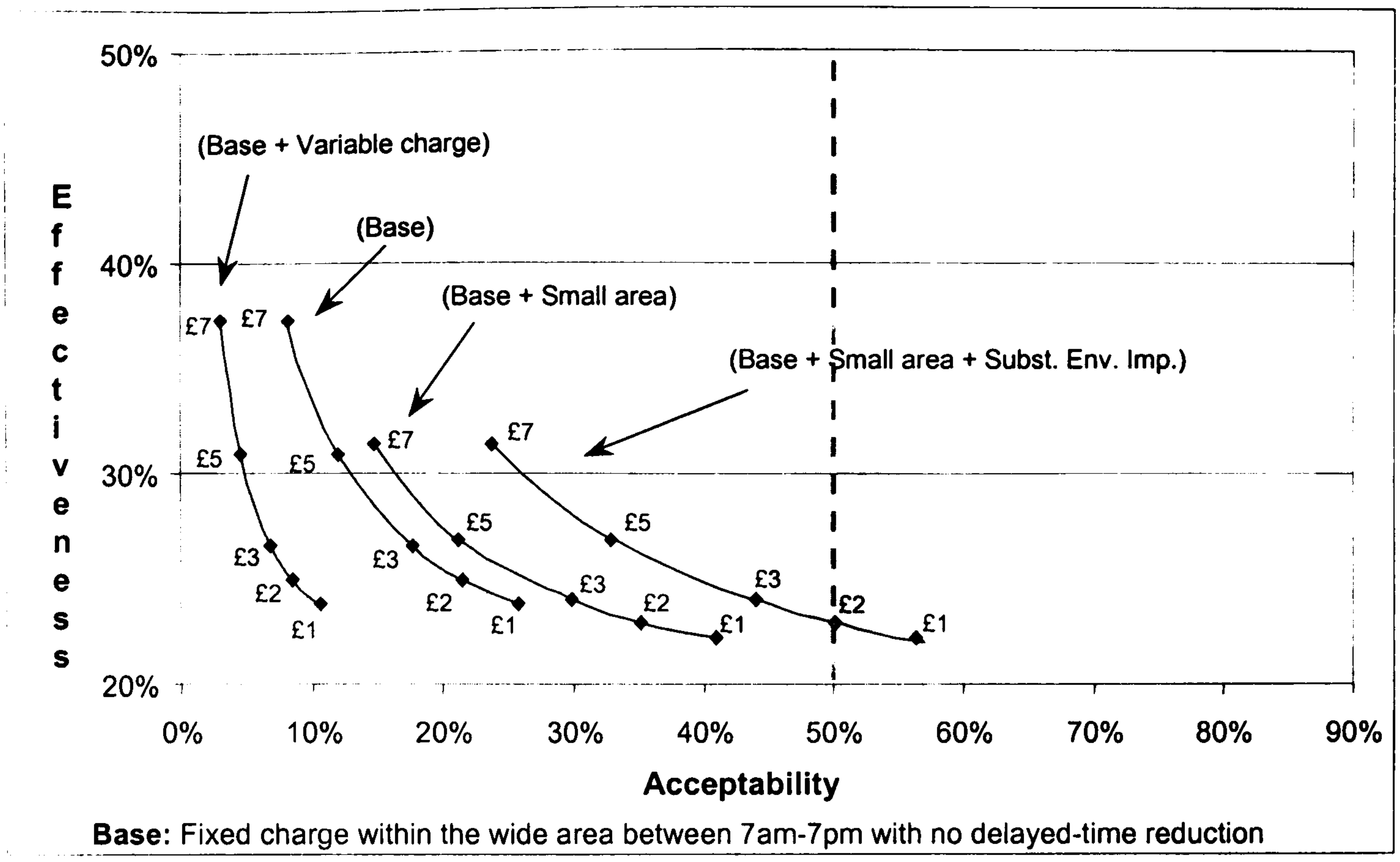

Figure 9.3 Comparing acceptability and effectiveness[5] among charging schemes for car commuters in Leeds

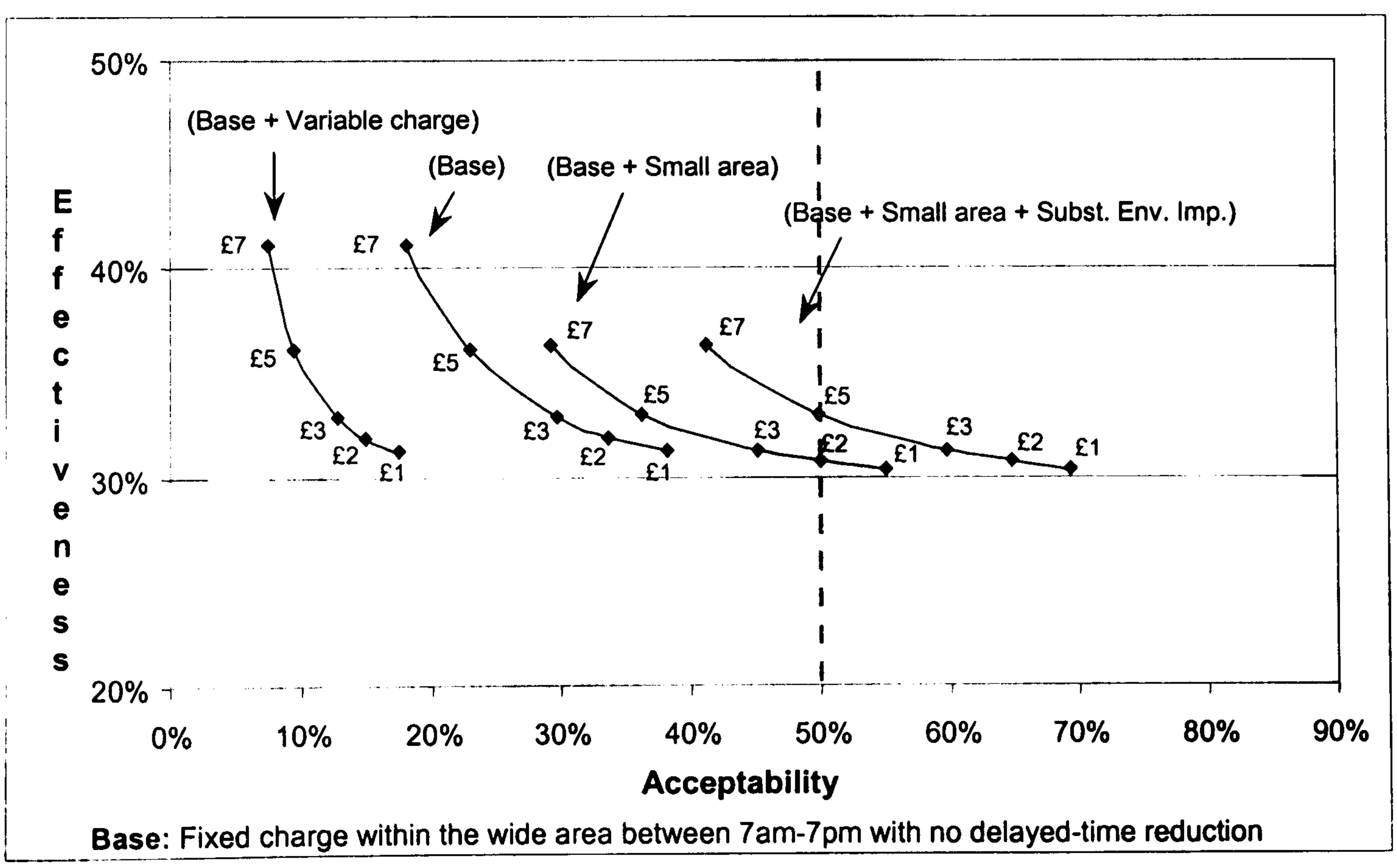

Figure 9.4 Comparing acceptability and effectiveness[5] among charging schemes for car commutes in London

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5 The acceptability is presented in terms of the proportions of people who vote for the schemes. The effectiveness is presented in terms of the proportions of car commuting reductions.

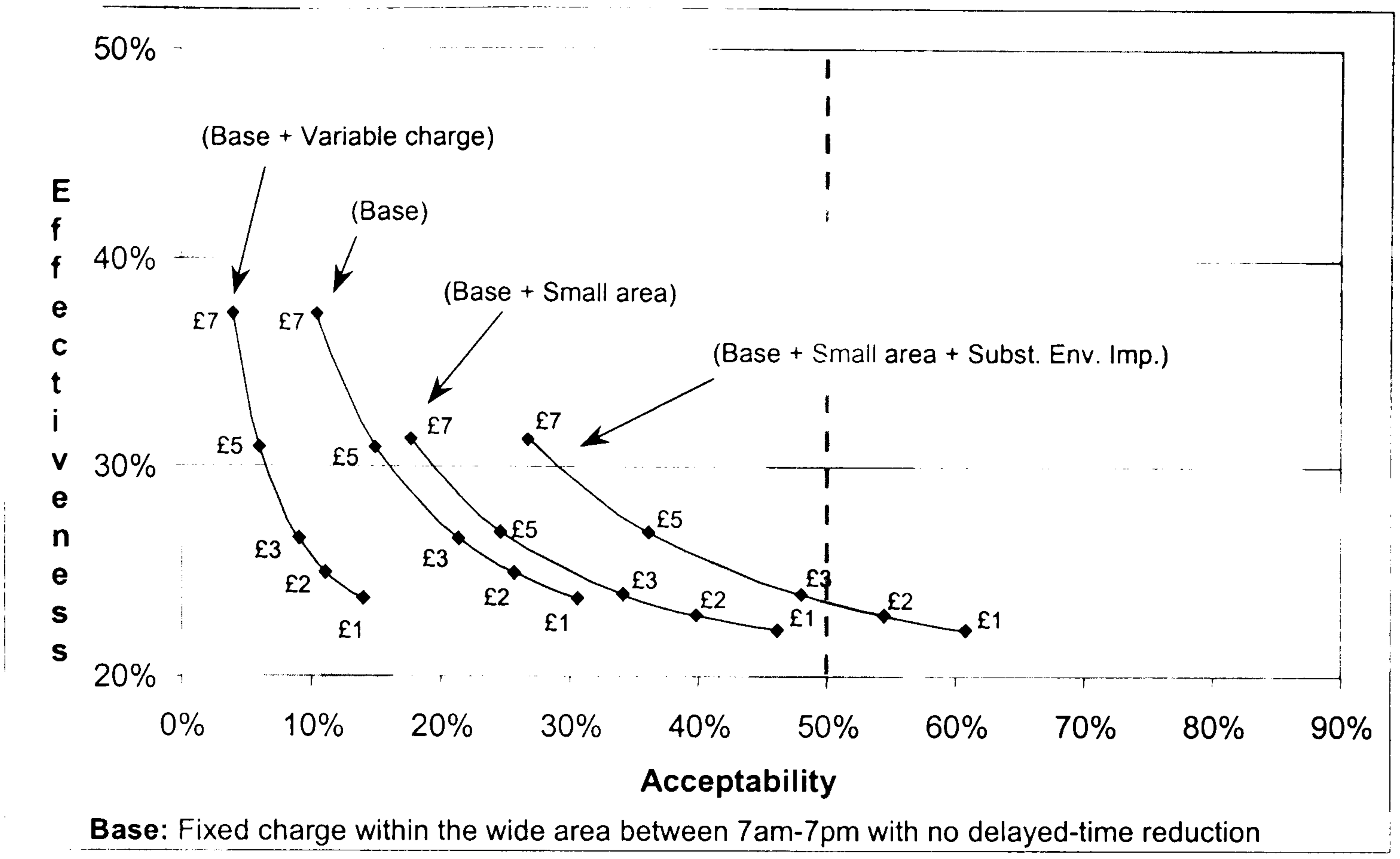

Figure 9.5 Comparing acceptability and effectiveness among charging schemes for the general public in Leeds

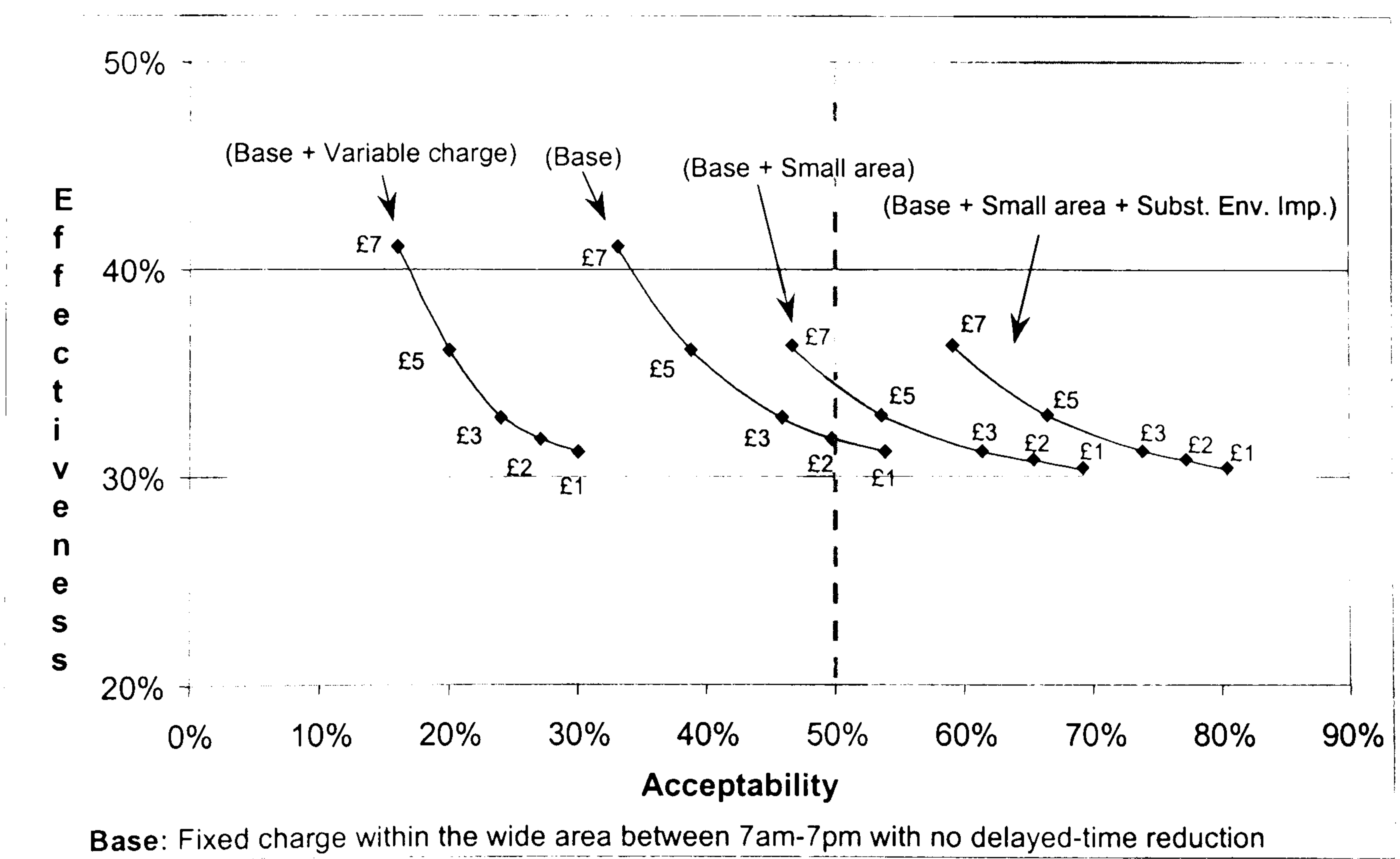

Figure 9.6 Comparing acceptability and effectiveness among charging schemes for the general public in London

9.5 Design of Acceptable and Effective Charging Schemes

This final section provides some suggestions on the design of acceptable and effective charging schemes. These are drawn together from the findings in Chapters 6, 7, 8 and the previous section in this chapter. The effects of the system characteristics and personal characteristics and perceptions on acceptability and effectiveness are summarised in Table 9.16.

Table 9.16 Summary of the effects on acceptability and effectiveness

System characteristics	Effects on		Personal characteristics and perception	Effects on	
	Acceptability	Effectiveness		Acceptability	Effectiveness
Level of charge (↑)	– – –	++	Mode used (non-car)	++	N/A
Environmental improvement (subst.)	++	O	People in London (compared to in Leeds)	O	O
Proportion of revenue used to PT and Tax reduction	O	O	Perceiving current situation as unacceptable	++	O
Car delayed-time reduction (↑)	+	O	Perceiving congestion and pollution as very serious	++	+
Bus delayed-time reduction (↑)	O	O	Perceiving charging as effective in reducing the problems	++	O
Area of charge (small)	++	–	Strong dislike of charging	– –	–
Time of charge	O	O	Age 55 or over	–	O
			Age 34-44	O	–
Method of charge (fixed charge compared to variable charges)	++	O	Gender	O	O
			Income	O	O

Note: O → insignificant effect, – and + → small effect,
–– and ++ → high effect, ––– and +++ → very high effect.

Level of charge has a conflicting effect on acceptability and effectiveness. When it is increased, acceptance of charging schemes falls substantially, but their effectiveness in reducing car use increases. For area of charge, acceptance increases when charges are limited within city centre, compared to area-wide, but the effectiveness falls slightly.

Although other system characteristics also influence acceptability, they do not significantly affect effectiveness. Fixed daily charge is very much more acceptable than variable charges based on distance, time and delayed-time. But these methods are not significantly better in influencing car commuting reduction. Different times of charge, peak-time only and all day, do not have different effects on either acceptability or effectiveness.

Interestingly, there is no conflicting effect of the personal perceptions on acceptability and effectiveness. Those people who perceive very serious transport problems tend to willingness to accept charging and also to reduce car use. On the other hand, those who have a strong dislike of charging are less supportive of charging schemes and less likely to reduce car use.

Between those who live in Leeds and London, the results from the model analysis found that they are not significantly different in evaluating charging characteristics in their decision of voting and mode choice. However, the predicted results demonstrated that charging systems are more acceptable and effective in London than in Leeds. This is because in London there are higher proportions of people perceiving pollution and congestion as very serious, perceiving effectiveness of charging and perceiving the current situation as unacceptable.

To achieve success in implementation of road user charging, the design is concerned with its acceptability and effectiveness, as stated in the main research question: how can road user charging schemes be designed to be simultaneously acceptable to the public and effective in achieving their objective?

Over 50% of the public would vote for a scheme and at least 20% in Leeds and 30% in London of those commuting by car would expect their car use to be reduced (see Figures 9.5 and 9.6), if

- the environment was improved substantially;
- the scheme was based on a fixed daily charge;
- the area of charge was within the city centre;
- the level of daily charge was less than £3 in Leeds, and less than £7 in London.

Acceptability varies substantially across different charging characteristics, but effectiveness as measured by reduction of car use has small variations. The design should be mainly focused on achieving acceptability because any charging scheme is relatively effective in reducing car use (Section 9.4.2). This allows some flexibility in the design to achieve another objective of road user charging which is for generating revenue. The level of charge can by selected by trading-off between acceptance and revenue.

Moreover, acceptability and effectiveness can be improved by influencing the individuals' perceptions of transport problems and effectiveness of the scheme. The public should be encouraged to understand how serious transport problems are in damaging the society. Direct influences on the perceptions of benefits to self and to society (the selfish and social perspectives) would also help (Chapter 7).

9.6 Conclusions

This chapter has demonstrated the predictions of acceptance and car commuting reduction, responding to different charging systems, and for different groups of the public. The results illustrated that acceptability varies substantially across individuals and system characteristics, while effectiveness in reducing car use has a small variation across the factors.

This chapter has also investigated the relationship between acceptability and effectiveness. It is interestingly found that in the groups of those who perceive transport problems (congestion and pollution) as very serious, for which acceptance is high, car use reduction is also high.

At the aggregate level, although more highly effective charging schemes (with higher levels of charge) are less acceptable, more highly acceptable schemes (with lower levels of charge) are not substantially less effective. Even at a £1 per day charge, over 20% of car commuters in Leeds and 30% in London would be expected to switch to non-car modes or not to use a car at the charged time.

The design of road user charging schemes should be mainly concerned with their acceptability, because any charging scheme is likely to be effective in reducing car use. Acceptable road user charging schemes can be designed by limiting the area of charge to within the city centre and basing it on a fixed daily charge. Support would be significantly increased if the scheme was perceived to bring substantial environmental improvement. Over 50% of people would vote for such a scheme, if the charging level is less than £3 per day in Leeds, and £7 per day in London.

The public are highly concerned with improvement of the environment. This suggests that road user charging would be more acceptable, if its revenue was used in improving the environment. As found by Stokes (1996), support for using the revenue in environmental improvement is as high as in public transport. Thorpe et al. (2000) found that the revenue spent in improving the environment is a second preference, following improving public transport.

Moreover, increasing acceptance of road user charging schemes can be influenced not only by the design of charging system characteristics, but also by provision of clear information on the severity of congestion and pollution, and on the effectiveness of road user charging in reducing the problems. In addition, they need to be convinced that road user charging will provide benefits to both themselves and society as a whole.

Chapter 10

Conclusions

10.1 Summary of Research

This final chapter aims to provide a summary and conclusion for the research, which has been reported in the previous nine chapters. Chapter 1 presented the objectives of the research and the framework of the study. Chapter 2 reviewed road user charging and previous studies, which led to the requirements for the study. Chapter 3 provided background about the stated preference (SP) technique, which was used as a tool to achieve the objectives. In Chapter 4, the development of the SP questionnaire was presented.

In Chapters 5 – 9, the results of the data analyses were reported. Chapter 5 demonstrated the general public attitudes to the transport problem and road user charging. In Chapters 6 and 7, acceptability influenced by the system characteristics and the individuals' perspectives (selfish and social perspectives) was presented in the voting behaviour models. In Chapter 8, the impacts of the charging characteristics, as well as the personal characteristics and perceptions, on car commuters' mode choice behaviour were presented in the mode choice models. In Chapter 9, the predicted results of acceptability and effectiveness of charging schemes from the voting and mode choice models were illustrated. It also presented the relationship between acceptability and effectiveness and suggested how to design acceptable and effective schemes.

The remainder of this section provides a summary of the research objectives and methodology. Section 10.2 summarises the findings[1] from the research and their implications. Finally, Section 10.3 suggests ideas for further research.

10.1.1 Research objectives

The review of previous studies (in Chapter 2) clearly showed that road user charging can be designed to manage travel demand effectively in urban areas, in order to reduce congestion and

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[1] Some findings from the research were presented in conferences (listed in Appendix C).

pollution, and raise revenue to finance transport and public services. This is also confirmed by the long experiences from the systems in Singapore and Norway.

Many countries have been interested in the implementation of urban road user charging. Apart from Singapore and Norway, nowhere else has succeeded in introducing urban charging schemes. The major obstruction is whether road user charging can be acceptable and effective (Jones, 1998). Many researchers concluded that in general road user charging is highly effective, but less acceptable to the public.

The aim of this research was to examine the impact on acceptability and effectiveness, in order to help in the design process of road user charging schemes. The main research question was (Chapter 1):

> *How can road user charging schemes be designed to be simultaneously acceptable to the public and effective in achieving their objective?*

In order to answer the question, the study examined the effects of various factors on acceptability and effectiveness (reviewed in Chapter 2). This involved investigating the effects of road user charging characteristics, which included the benefits (delayed-time reduction, environmental improvement and revenue allocation) and the charging features (charging levels, charging methods, charged area and charged time). This allowed the research to arrive at measures of different degrees of acceptability and effectiveness for various charging schemes.

The research also investigated the impacts of personal characteristics and perceptions. The personal characteristics related to transport mode used, income, age, gender, perception of current travel situation, perception of transport problems (congestion and pollution), perception of effectiveness of charging in reducing the problems and the level of dislike of charging. It then demonstrated different levels of acceptance and effectiveness among different groups of the public.

Furthermore, it examined the influence of individuals' selfish perspective (primarily concerned with their own well-being) and social perspective (primarily concerned with well-being of society) on acceptability. This was based on a hypothesis that people are not concerned only with benefits to themselves, but also benefits to society as a whole.

Finally, it examined the argument by many researchers that road user charging is effective but less acceptable, and also investigated how to design acceptable and effective road user charging schemes.

10.1.2 Methodology

The stated preference (SP) method was used to examine the impacts of charging system characteristics on acceptability and effectiveness. The reasons for choosing the method (discussed in Section 3.2) were mainly that it can explain the effects of relevant factors on preference and behaviour in quantitative terms, and provide results which can be used for predictions.

The design and development of the paper-based SP questionnaire (presented in Chapter 4) was carried out through four pilot surveys between August 1999 and July 2000. The main survey was conducted between November 2000 and March 2001 in Leeds and London by household and employee surveys. There were 830 respondents in the sample, of whom 660 were from Leeds and 170 from London. The SP exercises presented a set of hypothetical charging scenarios to respondents. For each scenario, questions were asked to measure the studied issues, including acceptability, effectiveness, and the selfish and social perspectives.

Acceptability was reflected by voting behaviour, in which individuals were asked whether they were willing to vote for charging schemes. Selfish and social perspectives were reflected by the perceptions of benefits to self and to society. Effectiveness in reducing congestion was evaluated by mode switching of commuters responding to the scenarios. This was concentrated only on work trips because mode choice is very much likely to depend on trip purpose, and the work trip is seen as the most important for the majority of the public.

The analysis technique was based on random utility theory, in which individuals were assumed to maximise their utility by choosing the option with the highest preference or utility to them. This was used to formulate the multinomial-logit based model of voting and mode choice. The model involved three different forms of model analyses. The standard logit model was used to demonstrate the overall effects of variables for the whole sample. The segmentation model, based on the incremental factors, was used to identify different effects for different groups of people. The random parameters logit model was used to examine the taste variation among individuals (heterogeneity), which was from unobserved sources and unable to be captured by the segmentation of respondents. These three models were estimated for both the voting behaviour and mode choice behaviour. Then, the preferred models were used to predict the levels of acceptance and the levels of effectiveness for different charging schemes.

10.2 Main Findings and Policy Implications

The main findings of the research relate to the effects on acceptability and effectiveness, and the suggestions on how to design acceptable and effective road user charging schemes. These involve both the charging system characteristics and the intrinsic influences on individuals. The effects of these factors are summarised in the previous chapter (in Table 9.16).

10.2.1 General public attitudes

Overall, most respondents perceived that congestion and pollution problems in their cities are serious or very serious, particularly in London. However, many people still perceived their current travel situations as acceptable. This perception is also likely to be influenced by other factors, not only the perceptions of congestion and pollution. Furthermore, the majority of car users did not perceive that charging is an effective solution in reducing congestion and pollution, but it was perceived as such by a majority of non-car users.

From the general comments provided by respondents in a free space, it was found that one main concern was about public transport and alternatives. Many respondents felt that the provision of alternative means of travel is currently not sufficient and needs to be improved. The other frequent comments were about scepticisms of road user charging. Many respondents did not think that charging is a solution for transport problems or that they should pay more for using their cars.

10.2.2 Acceptability

Effects of the system characteristics on acceptability

The study found that acceptability of road user charging is influenced by the benefits and system features of the charging scheme. It is highly sensitive to the level of charge: the higher the level of charge, the lower acceptance, as expected. However, the levels of acceptance can be considerably increased, when the environment is substantially improved through road pricing. Car delayed-time reduction also has some effects in increasing acceptance. Bus delayed-time reduction was found to have no significant influence on acceptability. Other attributes of bus services, such as reliability, punctuality, convenience and availability, are likely to be more important than just the delayed-time reduction. Charges within the city centre are much more acceptable than in a wider area. Fixed daily charges are significantly more acceptable than variable charges: distance-based, time-based, and delayed-based charges. People prefer a simple system in which the charge is known before travelling. For time of charge, there is no difference in acceptability between the charge during the morning peak-time and all day. For the use of revenue, there is no significantly different effect among revenue allocation to public transport improvement only, to tax reduction only, and to public transport improvement and tax reduction equally. Although, previous studies (reviewed in Section 2.5) found that spending on public transport improvement and tax reduction can increase acceptability, it is likely that there is no consensus among people about the proportions of spending.

Effects of the personal characteristics and perceptions on acceptability

For personal characteristics, mode used has a significant effect on acceptability; acceptance among car users is much less than among non-car users. Elderly people are more sensitive to increases of charging levels than others. However, other personal characteristics: gender, location and income, surprisingly, do not influence acceptability. Moreover, acceptability is highly affected by personal perceptions. Individuals tend to accept a charging scheme, if they perceive their current travel situation as unacceptable, perceive congestion and pollution problems as very serious, or perceive charging schemes as effective in reducing the problems. On the contrary, charging schemes attract less support from those who have a strong dislike of charging (e.g. those who complained that they should not pay more for using cars, those who were concerned about indirect effects of charging and those who highly preferred to use cars; discussed in Section 5.6).

Moreover, it was found that every charging system in London is more acceptable than in Leeds. This is because in London there is a higher proportion of non-car users, and higher proportions of people perceive their travel situation as unacceptable, perceive very serious transport problems, and perceive charging schemes to be effective.

Effects of the selfish and social perspectives on acceptability

It was found that acceptability is highly sensitive to the individuals' perceptions of the overall benefits of charging schemes to themselves (from a selfish perspective) and to society as a whole (from a social perspective). In other words, individuals are not concerned only about the benefits to themselves, but also partly about the benefits to their community. Each individual has his/her own weight for trading-off between these perspectives when they vote for a scheme.

Furthermore, it was found that individuals evaluate charging schemes differently between the selfish and social perspectives. These perspectives are affected by the system characteristics. The selfish perspective is mainly influenced by the level of charge, while the social perspective is mainly affected by the environmental improvement. The perspectives are also influenced by personal characteristics and perceptions. Different groups of people evaluate charging schemes differently. The selfish perspective is clearly different between car and non-car users. The perceptions of benefits to society are more affected by personal perceptions, including perception of current travel situation, perception of congestion, perception of charging as effective in reducing congestion and the level of dislike of charging, rather than personal characteristics.

Design of acceptable schemes

Acceptable road user charging schemes can be designed by limiting the area of charge to within the city centre and having a fixed charge per day. Support would be increased significantly if the scheme was promised to bring substantial environmental improvement. Over 50% of people would vote for this scheme, if the charging level is less than £3 per day in Leeds, and up to £7 per day in London. Moreover, acceptability could be influenced by providing clear information on the severity of congestion and pollution, and on the effectiveness of road user charging in reducing the problems, and by emphasising both personal and social benefits.

The study results illustrated that acceptability varies substantially across different systems. This implies that acceptance levels of any transport policy could be changed from very low to very high, depending on its system features (particularly its level of charge). One cannot say that the policy is acceptable to, for example, a third of the public without mentioning the system characteristics. In studies of acceptability, respondents should not be simply asked whether they support or oppose a policy without being provided with some information of main characteristics of system.

10.2.3 Effectiveness

Effects of the system characteristics on effectiveness

In order to evaluate effectiveness of road user charging schemes, this study focused on a main objective of the policy which is to reduce congestion by influencing travel mode switching. This was evaluated by mode choice of commuters responding to the charging schemes.

It was found that the car and bus delayed-time reductions of up to 75% of individuals' current delayed-time presented in the experiment were too small to compensate for the charge and hence to influence the mode choice behaviour of car commuters. The time reductions were ignored by respondents in their decisions on choosing mode for journeys to work. Instead, the mode choice behaviour was influenced by the travel time difference and ratio between bus and car, and travel distance. When the charge increases, car use preference will fall, but when the time difference and ratio increase, car use will be more preferred. Car use preference also relates to individuals' travel distance. For long distance journeys, cars are more preferred than for short journeys. The model estimated a plausible average value of time at 8.12 p/min, which is close to the review of UK value of time, and the demand elasticities for work trips are around -0.15 and -0.20 for a charge within the Inner Ring Road of Leeds and London, respectively.

Although car use is very much more preferable to car commuters than other modes, increasing the level of charge would reduce travel to work by car. The effect of charges in the small area (Inner Ring Road) on reducing car use are less than in the wider area. The other system characteristics: different charged times and different methods of charge are not significantly different in reducing car use for the journey to work.

Furthermore, the study found that most commuters who do not use a car do not change their travel modes in responding to charging schemes. This would help to keep road user charging schemes effective, in that while car users switch to non-car modes, non-car users do not change to using cars.

Effects of the personal characteristics and perceptions on effectiveness

In addition to the charging characteristics, some personal characteristics and perceptions also influence car use. Those aged between 35-44 (including a high proportion of high income people) are less sensitive to the charge. They have a higher value of time than others. On the other hand, those who perceived pollution problems as very serious are more likely to switch to bus or other non-car modes than others. They tend to have pro-environmental behaviour. In contrast, those, who have a strong dislike of charging or perceive that bus is very poor compared to the car, are more dependent on their cars. In turn, this may be a reason for having a strong dislike of charging.

These differences among individuals' perceptions lead to a higher level of effectiveness in London than in Leeds. This is because in London there are more people perceiving pollution and congestion problems as very serious and fewer people having a strong dislike of charging.

Design of effective schemes

Not surprisingly, the research found that the car use reduction increases when the charge increases. The car use reduction for charges in the small area is slightly lower than in the wide area. However overall any charging system is relatively effective in reducing car commuting. Even at £1 per day, over 20% of car commuters in Leeds and about 30% in London would switch to non-car modes or uncharged times. When the charge rises to £7 per day, the reductions would increase to around 40%. About half of the reductions are through car use change to travel in uncharged times. Others would switch to alternative modes. Small number of non-car users would change to using cars because of car delayed-time reductions. Furthermore, road user charging would be more effective in reducing car use, if people perceived that pollution problems are very serious.

10.2.4 Design of acceptable and effective road user charging schemes

To achieve success in implementation of road user charging, the design is concerned with its acceptability and effectiveness, as stated in the main research question: how can road user charging schemes be designed to be simultaneously acceptable to the public and effective in achieving their objective?

The research examined the relationship between acceptability and effectiveness in reducing car use. This was based on the sample who were car commuters. Many researchers believe that road user charging is effective, but less acceptable. This may imply that highly acceptable charging schemes are less effective, while less acceptable schemes are highly effective. However, this is not totally correct. Although more highly effective charging schemes (with higher levels of charge) are less acceptable, more highly acceptable schemes (with lower levels of charge) are not substantially less effective. In other words, effective charging schemes are not always unacceptable. Even at a £1 per day charge, over 20% of car commuters in Leeds and 30% in London would be expected to switch to non-car modes or not to use cars during the charged period. This charge can be designed to achieve support from the majority of the public.

The study found that acceptability varies substantially across system characteristics, while effectiveness in reducing car use has a small variation across the factors (see Figures 9.5 and 9.6). The acceptance levels of charging schemes would be considerably increased if the area of charge was limited to the city centre and if the environment was substantially improved. The effectiveness drops just a little with the small area of charge and has no effect from the environmental improvement. For example, for car commuters in Leeds, at a £1 daily charge within the Inner Ring Road and with substantially environmental improvement, the acceptance level is relatively high (56%), but it falls dramatically when the charge increases. At a £7 daily charge, acceptance level is rather low (24%). On the other hand, the effectiveness at a £1 daily charge is relatively high (22% reduction of car commuting), and it rises slightly when the charge increases.

Therefore, the design of road user charging schemes should be mainly concerned with their acceptability, because any charging scheme is likely to be effective in reducing car use. In other words, charging schemes that are acceptable are also effective. Over 50% of the public would vote for a scheme and at least a quarter of those commuting by car would expect to reduce their car use, if:

- the environment was improved substantially;
- the scheme was based on a fixed daily charge;
- the area of charge was within the city centre;
- the level of daily charge was less than £3 in Leeds, and less than £7 in London.

The suggested scheme is likely to achieve both acceptability and effectiveness. Nevertheless, if a charging scheme was designed for charging within the city centre with a low level of charge, it may be difficult to achieve substantial environmental improvement. It should be clear to the public how the environment will be enhanced (this leads to further research; see Section 10.3). A programme for the environmental improvement may need to be proposed with charging schemes.

Since acceptability can be improved considerably by improving the environment substantially, this implies that the public awareness of the environment is relative high. This suggests that if some revenue from charging schemes was promised for use in the environment programme, acceptability is likely to be increased. This extends a typical suggestion that revenue from road user charging should be used to finance public transport improvement and to lower taxes.

Acceptance of road user charging schemes and its effectiveness in reducing car use can be influenced not only by the design of charging system characteristics, but also by provision of clear information on the severity of congestion and pollution, and on the effectiveness of road user charging in reducing the problems. In addition, individuals need to be convinced that road user charging will provide benefits both to themselves and to society as a whole.

To induce these perceptions, intrinsic instruments (e.g. education programmes and awareness campaigns) are useful. They are likely to be able to improve acceptability of charging schemes. They may also motivate car users to be aware about the negative effects of car use on themselves and society, which in turn lead them to reduce their car use.

In brief, this research suggests that road user charging schemes can be designed to achieve acceptability and effectiveness in reduce car use by choosing appropriate charging features and offering sufficient benefits. This design can be seen as involving extrinsic incentives, based on pricing mechanism and compensation, which are successful at some levels. Furthermore, the acceptability and effectiveness can be enhanced by intrinsic motivations on individuals' perceptions. People should feel themselves involved as parts of the problems and solutions. They should understand why they should support the schemes and why they should reduce their car use.

10.2.5 Summary of the main findings

- The relationship between acceptability and effectiveness of road user charging schemes is not high. It is not simply the case that highly effective schemes are less acceptable. Acceptance levels of effective schemes can vary from low to high. It is possible to design road user charging schemes to achieve acceptability and effectiveness simultaneously.
- The charging system characteristics have high effects on acceptability, but small effects on effectiveness. Although acceptability falls substantially when the charge increases, it improves considerably where the charged area is limited within city centre and the environment is substantially amended. Effectiveness in reducing car use increases moderately when the charged increases. It is slightly different between charges in a city centre and a wider area. Nevertheless, from any charging scheme, some car use reduction can be expected, even a £1 daily charge.
- Acceptability and effectiveness is also influenced by some personal characteristics (mode used and age). More interestingly and importantly, acceptability and effectiveness are motivated by personal perceptions (perceptions of current travel situations, congestion and pollution, effectiveness of charging in reducing the problems and strong dislike of charging). Acceptability and effectiveness can be improved by provision of clear information on the principles and objectives of charging, on the severity of congestion and pollution, on the adverse effects of car use, and on the effectiveness of road user charging.
- Each individual has different perspectives in evaluating charging schemes on whether or not to support them. One is concerned primarily with benefits to self (called selfish perspective). The other is concerned mainly with benefits to society (called social perspective). Each individual has his/her own weights for these two perspectives. Overall, benefits to self are considered as more important than benefits to society, in contrast to bus users and individuals who are highly aware of the pollution problem. Hence, to improve the acceptability, the public need to be convinced that road user charging will provide both personal and social benefits. In general, this indicates that utility of an individual (particularly from a public policy), is not only maximised based upon what a person gain personally, but also upon whether society as a whole will be better off.
- Acceptance levels vary substantially across different system characteristics. They could be changed from very low to very high. Attitudinal studies (for any policy) should not ask individuals' attitudes without providing some information on the main features of systems.

10.3 Suggestions of Further Research

This research has examined the impacts of charging system characteristics and individuals' characteristics and perceptions on acceptability and effectiveness. It has also suggested how to design charging schemes which are simultaneously acceptable and effective. Nevertheless, some further research would be useful for the design.

Firstly, it is interesting to study in greater detail the acceptability and behavioural responses. Using the SP method, the study cannot get into deep details of the effects of each factor and the reasons behind those effects. For example, it has not been possible to determine why bus delayed-time reduction has no significant effect on acceptability, why there are no significantly different effects between different proportions of revenue used for public transport improvement and tax reduction and between different charged times, how to achieve substantial environmental improvement, how the environment is desired by the public, and whether the revenue used in improving the environment is important in increasing acceptance. These studies will require qualitative research.

By using the activity-based approaches (Jones, 1990; Ettema and Timmermans, 1997), further details of behavioural responses to charging schemes can also be examined, for example how departure time and route choice change, how individuals' schedules change, how interactions between activities of individuals and other members in their households are, and what the constraints of each individual and his/her family on behavioural responses are.

Further research should also examine one of the findings from this research in that effectiveness of a £1 daily charge in reducing car commuting is relatively high, but when the charge increases the reduction only increases slights, compared to the initial reduction. This implies that the small charging level filters out some car users who are not willing to pay for any charge and have alternative options available, while the remainder who want to keep using their cars are much less price sensitive. To some extent, this is similar to the evidence from Singapore, in which the elasticity for the first implemented congestion tolls in 1975 is much higher than the elasticities for the toll changes in following years (see Luk, 1999).

Secondly, it would be useful to examine the effects of combinations of road user charging with other policies on acceptability and effectiveness. When road user charging is combined with other transport policies, acceptability and effectiveness is likely to be different from those for road user charging alone. This needs further research to examine how acceptability and effectiveness of packages of policies changes; for example, when road user charging is combined with improving public transport, raising or reducing parking charges, and raising or reducing petrol taxes. The study should be able to identify the package of policies which is the most acceptable and effective.

Thirdly, in addition to uses of transport policies (extrinsic instruments) as solutions to transport problems, we should investigate intrinsic instruments to motivate individuals to support policies which are effective, and to cooperate in reducing causes of problems (e.g. car use). Although some approaches have been used to reduce car use and address environmental concerns, such as travel awareness campaigns and travel blending programme (see Curtis and Headicar, 1997; Stradling et al., 2000; Rose and Ampt, 2001), for the case of road user charging some programmes are also needed to help in improving acceptability and effectiveness. This should involve programmes that are able to help the public to understand the principle and need of charging.

Finally, we may also need to study in deeper detail the political problems. It is not clear why politicians in both central and local governments make decisions not to introduce road user charging. It is unlikely to be just simply related to public acceptability. In the case of cordon pricing in Norway, public acceptance was relatively low (less than a third of people) before the scheme was in place (Odeck and Brathen, 1997), but the government was able to implement it. In the case of London, the current mayor has planned to implement a congestion charging scheme in 2003 (GAL, 2001). Results of the attitude surveys found that the scheme is supported by over half of people in London; even more (about two thirds) support it if revenue is used for improving public transport (GOL, 2000). Nevertheless, it is still in doubt whether the scheme will be introduced. Though these are not strong evidences, they imply that in addition to public acceptability something else obstructs the implementation of road user charging.

A political problem was mentioned by Robinson (2000) who studied the politics of transport. He argued that in the UK transport policy change and the formation of policy proposals have been constrained by policy imperatives of the state which attempt to maintain its commitment to high levels of freedom, mobility and economic activity. This has created considerable instability in the agenda setting process. The government tries to solve transport problems, but does not want to challenge the structural imperatives. The problem of road user charging is that it is incompatible with the imperatives.

Further research should investigate whether there are different perspectives between government (who decide which policies should be implemented) and transport planners (who suggest which policies are able to solve transport problems). This may help to understand why road pricing recommended by transport planners is not easily implemented.

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Appendix A

An Example of the SP Questionnaires

ITS Institute for Transport Studies University of Leeds

Survey of Transport Problems and Solutions

This is an opportunity to put your views forward about transport problems and solutions in Leeds, whatever transport you use. Please answer the following questions and return the questionnaire in the freepost envelope provided. If you have any queries please contact me, Sittha Jaensirisak, (0113) 233-6613, e-mail: sjaensir@its.leeds.ac.uk.

◈ **Part 1:** In your opinion,

- how serious a problem is traffic congestion in Leeds?

  ☐ No problem ☐ Slight ☐ Serious ☐ Very Serious

- how serious a problem is traffic pollution (air and noise) in Leeds?

  ☐ No problem ☐ Slight ☐ Serious ☐ Very Serious

- Do you think charging a fee for using a car would be effective in reducing congestion?

  ☐Yes ☐ No

- Do you think charging a fee for using a car would be effective in reducing traffic pollution?

  ☐Yes ☐ No

- How do you normally travel for non-work journeys (mode most frequently used)?

  ☐ Car ☐ Bus ☐ Rail ☐ Walking ☐ Cycling ☐ Other _________ (please specify)

If you currently do not work, please go to ***Part 2 Section 2*** *on the next page*

If you currently work, please continue...

- How do you normally travel to work (mode most frequently used)?

  ☐ Car ☐ Bus ☐ Rail ☐ Walking ☐ Cycling ☐ Other _________ (please specify)

- How many days a week do you normally travel to work in this way? _________ days a week

Please estimate your travel time and cost of your daily return journey to work

- How long do you normally take to travel to and from work **each day**? _____ hours___ minutes
- How many miles do you travel to and from work **per day**? ________ miles
- How much do your work journeys cost **per day**? £_______._______ p
- For car journeys, how much of the total daily cost is parking? £_______._______ p

Part 2: Please estimate your daily travel time **inside the Outer Ring Road** (see attached map) **between 7am-7pm** on weekdays

It does not matter if you are unsure about some of the times, please give us your best estimate.

Section 1: Journeys between home and work	**Section 2:** Journeys other than between home and work
For **work journeys**, if you do, or were to, travel to work by CAR or BUS,	For **non work journeys**, if you do, or were to, make your current journeys by CAR or BUS,
*Please give us your best estimate for **both car and bus**, whatever transport you use*	
• how long do/would you spend **per day** on roads inside (but not including) the Outer Ring Road between 7am-7pm? (daily return journey to work) if by car: _______ hours _______ minutes if by bus: _______ hours _______ minutes	• how much time do/would you spend on roads inside (but not including) the Outer Ring Road on an average weekday between 7am-7pm? if by car: _______ hours _______ minutes if by bus: _______ hours _______ minutes
Please note that **delayed time** is the time spent moving slowly or stopped in congested traffic, at traffic lights, or bus stops	
• how long on average would the delayed time be in these trips **each day**? if by car: _______ hours _______ minutes if by bus: _______ hours _______ minutes	• how long on average would the delayed time be in these trips **each day**? if by car: _______ hours _______ minutes if by bus: _______ hours _______ minutes
Do you find your current situation for your journeys acceptable? ☐Yes ☐ No	

◆ **Part 3**

ROAD USER CHARGING involves drivers being charged a fee for using their vehicles within specific areas (e.g. within the city centre), or on specific roads (e.g. on motorways), in order to reduce congestion, improve the environment, and/or generate revenue to be spent on transport projects and/or social service projects.

Please imagine that a road user charging scheme has been introduced for using vehicles on roads inside (but not including) **the Outer Ring Road** between **7am and 7pm** during Monday to Friday only. Weekend travel would not be charged.

Please consider the four situations (A-D) inside the Outer Ring Road presented below and answer the following questions.

Situation	A	B	C	D
Charge for using car	£5 per day	£7 per day	£7 per day	£1 per day
Environmental improvement	Substantial	Slight	None	None
Car delayed time reduced by	A quarter	A half	A half	A half
Bus delayed time reduced by	A half	A half	Three quarters	Three quarters

- **How much would each situation benefit yourself and society?**

(Please circle numbers where: -5 = very detrimental, 0 = no impact, +5 = very beneficial)

Situation	To yourself? Very detrimental					no impact					Very beneficial	To society? Very detrimental					no impact					Very beneficial
A	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
B	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
C	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
D	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5

- **Would you vote for each situation?**
(If there was a local referendum)

Situation	Vote?	
A	☐ Yes	☐ No
B	☐ Yes	☐ No
C	☐ Yes	☐ No
D	☐ Yes	☐ No

- **In each situation, how would you travel to work?**
(If you currently do not work, please answer about non work journeys)

Situation	Travel by?				
A	☐ Car	☐ Car earlier/later*	☐ Bus	☐ Other	(please specify)
B	☐ Car	☐ Car earlier/later*	☐ Bus	☐ Other	(please specify)
C	☐ Car	☐ Car earlier/later*	☐ Bus	☐ Other	(please specify)
D	☐ Car	☐ Car earlier/later*	☐ Bus	☐ Other	(please specify)

* Car **earlier/later** means travelling by car before and/or after the charged time

Leeds SP 1-1

◈ Part 4: Please give the following details about yourself

Gender: ☐ Female ☐ Male

Age: ☐ under 24 ☐ 25 to 34 ☐ 35 to 44 ☐ 45 to 54 ☐ 55 or over

Total household annual income (before deduction of tax and National Insurance):

☐ Less than £10,000 per annum
☐ £10,000 to £19,999 per annum
☐ £20,000 to £29,999 per annum
☐ £30,000 to £39,999 per annum
☐ £40,000 to £49,999 per annum
☐ £50,000 to £59,999 per annum
☐ £60,000 or more per annum
☐ I do not wish to answer

Number of cars in your household:

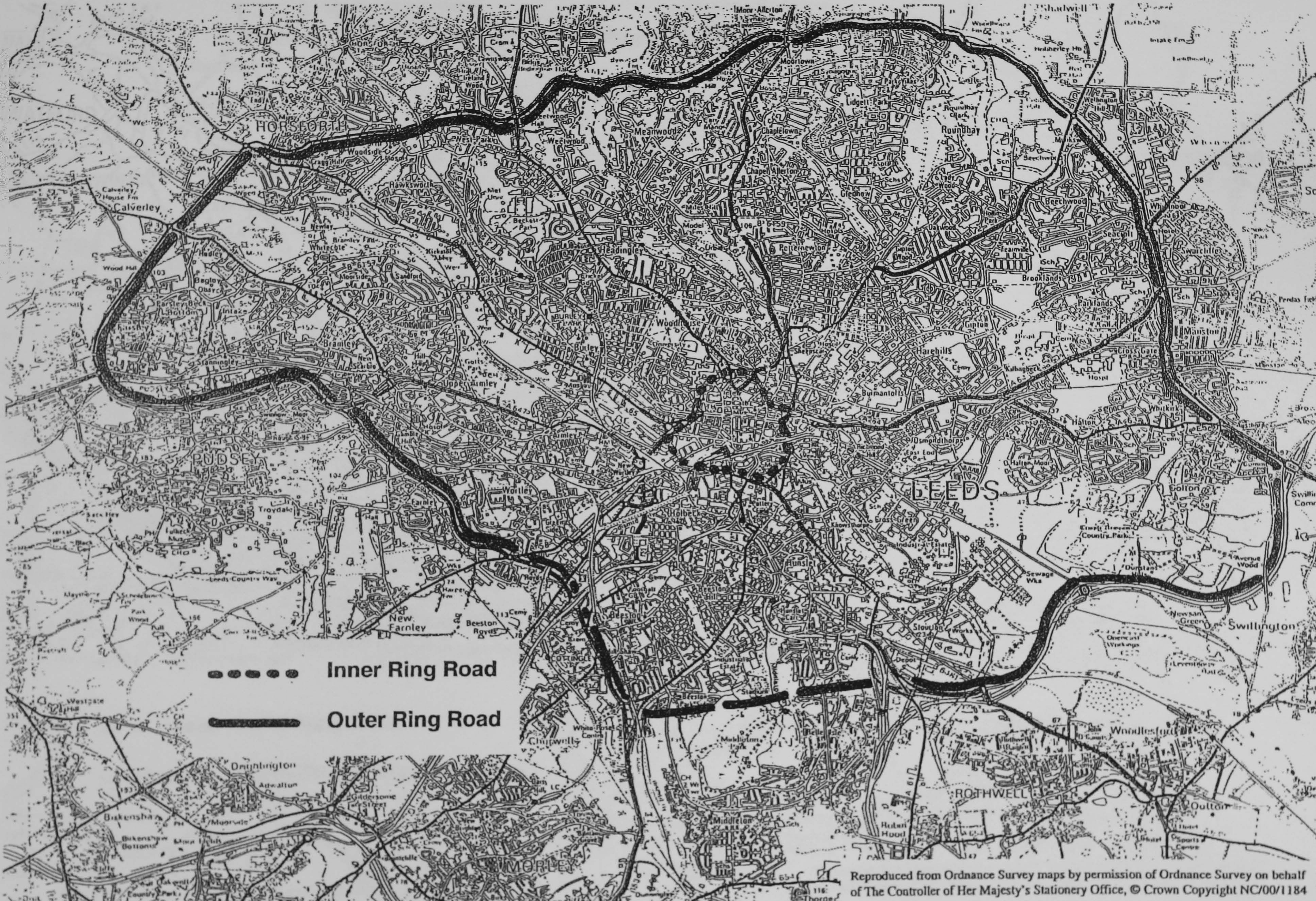
☐ No car ☐ 1 car ☐ 2 cars ☐ 3 or more cars

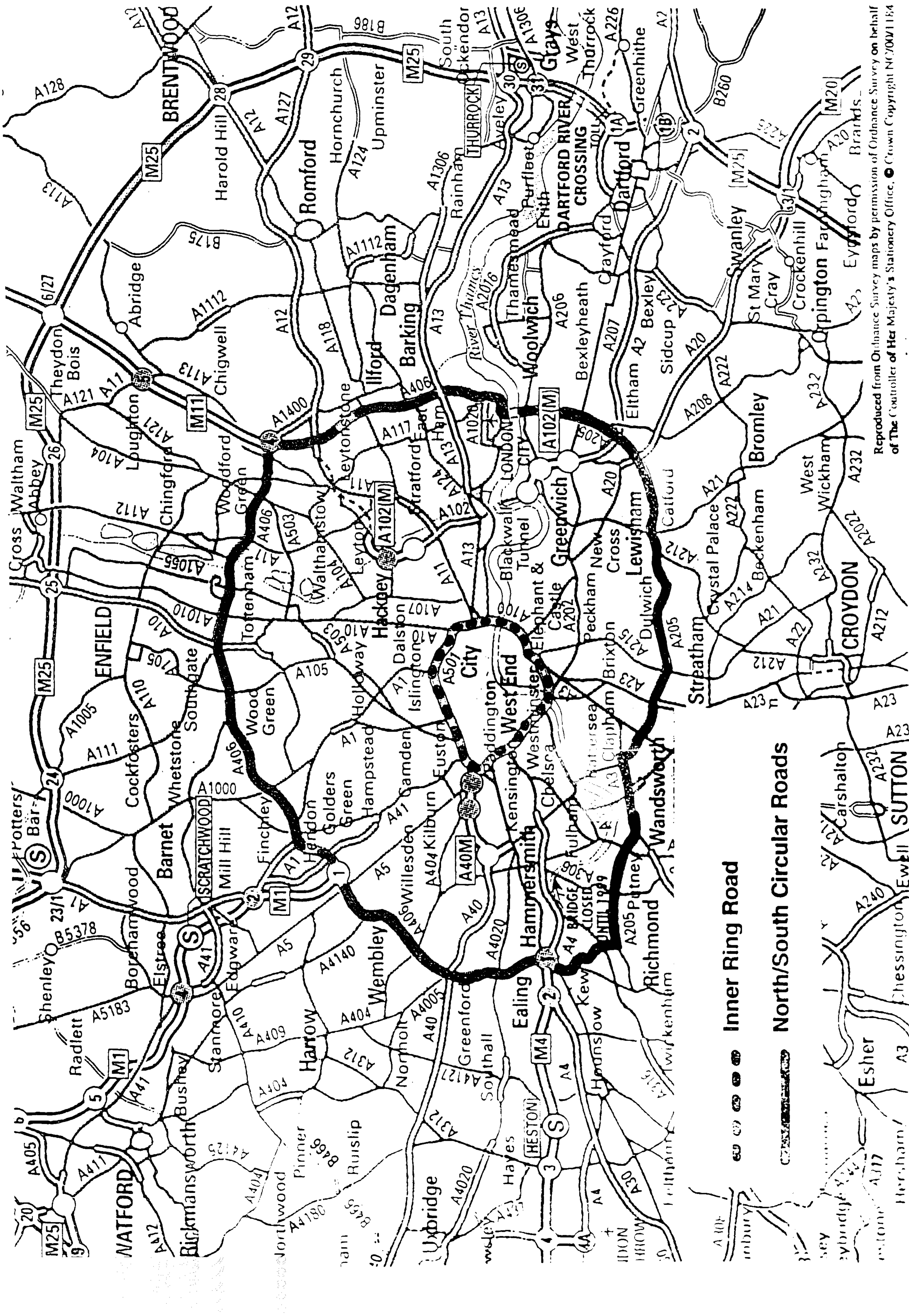
If you have any comments, please write them in them space below

Thank you very much for your help
Please return the questionnaire in the freepost envelope provided

Appendix B

Maps of Leeds and London Provided to Respondents


Inner Ring Road
Outer Ring Road
LEEDS
HORSFORTH
PUDSEY
ROTHWELL
MORLEY
Headingley
Chapel Allerton
Roundhay
Swillington
Woodlesford
Oulton
Calverley
New Farnley


Inner Ring Road
North/South Circular Roads
Reproduced from Ordnance Survey maps by permission of Ordnance Survey on behalf of The Controller of Her Majesty's Stationery Office, © Crown Copyright NC/00/1184
WATFORD
Rickmansworth
Uxbridge
Harrow
Wembley
Ealing
Hammersmith
Richmond
Wandsworth
Streatham
CROYDON
SUTTON
Barnet
ENFIELD
Cockfosters
Wood Green
Tottenham
Hackney
West End
City
Greenwich
Lewisham
Woolwich
Barking
Dagenham
Ilford
Romford
Hornchurch
Upminster
BRENTWOOD
Harold Hill
Chigwell
Loughton
Theydon Bois
Abridge
Dartford
DARTFORD RIVER CROSSING
Swanley
Bromley
Bexleyheath
Sidcup
Eltham
Orpington
Esher
Twickenham
Hounslow
Hayes
Ruislip
Pinner
Northwood
Bushey
Stanmore
Edgware
Mill Hill
Finchley
Hendon
Golders Green
Hampstead
Camden
Islington
Euston
Kilburn
Willesden
Paddington
Westminster
Kensington
Chelsea
Fulham
Putney
Clapham
Battersea
Brixton
Peckham
Dulwich
Elephant & Castle
Blackwall Tunnel
Stratford
Leyton
Leytonstone
Walthamstow
Woodford Green
Chingford
Southgate
Whetstone
Borehamwood
Elstree
Radlett
Shenley
Potters Bar
Waltham Abbey
Northolt
Greenford
Southall
Kew
Carshalton
Beckenham
Crystal Palace
West Wickham
Catford
New Cross
Thamesmead
Erith
Purfleet
Rainham
Grays
West Thurrock
Greenhithe
Crockenhill
St Mary Cray
Bexley
Crayford
Aveley
South Ockendon
THURROCK
SCRATCHWOOD
HESTON
River Thames
M25
M1
M11
M4
M40
M20
A102(M)
A40(M)
BRIDGE CLOSED UNTIL 1999

Appendix C

List of Papers Presented in Conferences

Jaensirisak, S. (2001a), "Public valuation of road user charging: selfish and social perspective", presented at the 33rd UTSG Annual Conference, 3-5 January 2001, Transport Studies Unit, University of Oxford, UK.

Jaensirisak, S. (2001b), "Public valuation of road user charging: selfish and social perspective", Traffic Engineering and Control, 42(7), 221-225.

Jaensirisak, S. (2002), "Public acceptability of road user charging schemes based on voting behaviour model", paper presented at the 34th UTSG Annual Conference, 3-5 January 2002, Transport Research Institute, Napier University, Edinburgh, UK.

Jaensirisak, S., A.D. May and M. Wardman (2001a), "Acceptability of road user charging: sensitivity to system characteristics and individuals' perspectives", paper presented at the THINK-UP Workshop Series, on 'Policy Factors and Mobility Prediction: Transport Planning & Modelling', 21-22 May 2001, ICCR, Vienna, Austria.

Jaensirisak, S., A.D. May and M. Wardman (2001b), "Effects of road pricing systems on acceptability", paper presented at the EASTS'01 Conference, 24-27 October 2001, Hanoi, Vietnam.

Jaensirisak, S., A.D. May and M. Wardman (2002a), "Acceptability of road user charging influenced by system characteristics and individuals' perspectives", paper prepared to present at the MC ICAM Conference on 'Acceptability of Transport Pricing Strategies', 23-24 May 2002, Dresden, Germany.

Jaensirisak, S., A.D. May and M. Wardman (2002b), "Designing acceptable and effective road user charging schemes", Traffic Engineering and Control, July 2002 (forthcoming).

Jaensirisak, S., A.D. May and M. Wardman (2002c), "Acceptability and effectiveness of road user charging", paper prepared to present at the European Transport Conference, 9-11 September 2002, PTRC, Cambridge, UK.

Jaensirisak, S., A.D. May and M. Wardman (2002d), "Designing acceptable and effective road user charging schemes", paper prepared to present at the international conference on 'Seamless & Sustainable Transport', 25-27 November 2002, Singapore.