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Analysing the Design Criteria of Charging Cordons

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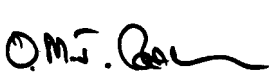
Signature	

The idea of the efficient use of roads, which requires users to pay for the traffic congestion cost that they impose on an urban road network, is long established (Pigou, 1920; Walters, 1961). However, the gap between the constructive theory of road pricing and its real world application is significant due to the issue of public acceptance, technical feasibility, and the cost of implementation (Sharp, 1966; Verhoef et al, 1995; Stenman and Sterner, 1998; and Sumalee, 2000). Different charging regimes have been developed and studied including time or delay based charging, distance based charging, cordon or boundary based charging, and area based charging (Holland and Watson, 1978; May, 1992; Oldridge, 1990; Smith et al, 1994; and Ison, 1998). The cordon charging system is the core of the study in this paper where we are looking for criteria for the judgmental design of cordons. We use the term "judgmental cordon design" to describe the process to identify the best locations to levy the charges and specify the optimal charge levels based on professional judgment.

This paper reviews the literature to identify design criteria in section 2, and then it describes a survey with six UK local authorities in section 3. Section 4 presents the results of the survey and finally section 5 discuss the results and draw the conclusions.

1. Review of the design criteria

The Smeed report (Ministry of Transport, 1964) identified nine criteria of design of congestion charging systems. These criteria can be used to help determine whether the scheme design is likely to perform effectively and to be feasible. The criteria include:

(1) charges should be closely related to the amount of use made of the road;
(2) it should be possible to vary prices for different areas, time of day, week, or year and classes of vehicle;
(3) prices should be stable and readily ascertainable by road users before they embark upon a journey;
(4) payment in advance should be possible although credit facilities may also be permissible;
(5) the incidence of the system upon individual road users should be accepted as fair;
(6) the method should be simple for road users to understand;
(7) any equipment should posses a high degree of reliability;
(8) it should be reasonably free from the possibility of fraud and evasion, both deliberate and unintentional;
(9) it should be capable of being applied, if necessary, to the whole country and to a vehicle population expected to rise to over 30 million.

These criteria have been set for over 40 years, and they still remain valid over time. However, other criteria which have emerged since include:

(10) the system should allow occasional users and visitors to be equipped rapidly and at low cost;

(11) the charge recording system should be designed both to protect individual users' privacy and to enable them to check the balance in their account and the validity of the charges levied;

(12 the system should facilitate integration with other technologies, and particularly those associated with driver information system. (May, 1992)

Criteria 1 and 2 are concerned with the ability to levy an optimal charge; Criteria 3, 4, 6 and 7 concern the ability of drivers to respond in an optimal way to the charge levied; Criteria 8 and 9 and to extent 7 address the efficient operational of charging regime in terms of implementation costs (9), operation (7), and enforcement (8); Criteria 10, 11 and 12 affect the efficiency and success of the operation (May, 1994). Some of these criteria are more related to technological issues which are out of the scope of this research, i.e. Criteria 4, 7, 8, 9, 10, 11, and 12. Most of these criteria (1- 9) aim to ensure that the design meets the three important factors of the congestion charging scheme design including:

- Effectiveness of the scheme
- Public acceptance of the system
- Practicality of the implementation.

In the following sections, the design approach adopted to achieve these three main targets will be discussed.

1.1 Design options

In this research, we particularly concentrate on the design of a cordon charging system. Therefore, the design options can be narrowed down to the three main systems suggested by various literature (Neuenschwander, 2000; Shepherd et al, 2001) These are:

Single Road or Motorway Charging

The idea for charging on the major road infrastructure was first suggested by the French engineer, Depuit (1844). The main advantage of charging on individual roads is to minimise the impact groups and also explicitly relate to the objective of the scheme. There are several examples where urban road pricing scheme is imposed on single roads including Marseille (tunnel) and San Francisco-Oakland Bay Bridge (Neuenschwander, 2000; and Dittmar et al, 1994). Most of the tolls are on the major road facilities, i.e. bridges, tunnels, or motorways. The major barrier of this system is the lack of alternative routes which can lead to public acceptance problems.

Simple Cordon Charging

Only one charging cordon is used, normally where a *'natural position'* for the cordon for example a ring road, river, canal, coast, or rail track already exists (Neuenschwander, 2000). The charge level is usually defined as a single rate to simplify the system.

Complex Cordon Charging

The complex cordon system can be viewed as a development from the simple charging cordon where additional cordons or screenlines will be added to the charging cordon system. There are various reasons to move to this complex system. Shepherd et al (2001) mentioned the possible objectives of using the additional cordons as follows:

- tackling congestion outside the first cordon;
- extending the area of influence of road pricing;
- controlling traffic to the inner city area outside the main centre;
- relating charges more directly to distance travelled;
- reducing the charge at any one crossing point, and hence the boundary effects;

they also mentioned the reasons for adopting screenlines as follows:

- to control orbital traffic generally;
- to control access to particular high traffic generators;
- to protect a specific bottleneck or other source of congestion.

However, Dawson and Brown (1985) and May et al (1996) showed that a more complex cordon system could achieve higher benefits compared to a simpler system.

1.2 Dealing with objectives of the scheme

May (1992) stated that the design of a congestion charging system depends heavily on the objectives of the scheme. This can be confirmed by the differences in the design of the Singapore ALS (Holland and Watson, 1978), Hong Kong ERP pilot scheme (Harrison et al, 1986), London congestion charging scheme (May, 1975), and Oslo toll ring (Larsen and Ramjerdi, 1991). The Oslo toll ring aimed primarily at raising revenue for financing a new road and it was designed to change the traffic pattern as little as possible (Lewis, 1993). The area coverage of the Norwegian cordon is wider than other cases and located on the trunk road system rather than the urban road network. Norwegian toll rings applied a low charge level which will not reduce traffic demand whereas in the other cases the charge level is higher (Menon, 2000; Stoelhorst and Zandbergen, 1990; Ramjerdi, 1995).

The Hong Kong pilot system planned to use a more complicated cordon system where the main objective is to change travel behaviour to more efficient patterns by enhancing the use of public transport and time choice (Harrison, 1986). The structure of the cordon system proposed in the Hong Kong case involved using a number of cordons with different charge level on each cordon, and the charge also varied by time of day. The Singapore ALS and the London congestion charging scheme adopted a simpler cordon, aimed at reducing the congestion in the core area of the city by using a single cordon around the city centre and simple charge structure (GOL, 2000). However, it is noteworthy that the current system in

Singapore is being modified by providing an incomplete second cordon (Shepherd et al, 2001).

1.3 Dealing with public acceptance

1.3.1 Equity and fairness

When we mention equity, we refer to the distribution of the costs and benefits amongst different groups of people resulting from the scheme (Guiliano, 1992; May, 1994). In the interest of equity, charging system should ensure the opportunity for travelling and the access to the activities for each population group, e.g. between the rich and the poor or issues between male and female travellers (Guiliano, 1994). The use of generated revenues from road pricing plays a vital role where the improvement of public transport can offer travel choices to those who are tolled off from their cars which can reduce inequities (Goodwin, 1989). A further equity issue is the discrimination effect caused by the implementation of charging cordon. Holland and Watson (1978) stated strongly that the cordon should not separate the business area that may give the advantages to some business places or shops just outside the cordon.

On the other hand, a fair system can be interpreted as a system charging people as close as possible to their contribution to the congestion or environmental problem (Holland and Watson, 1978; Lewis, 1993; Small and Gomez-Ibañez, 1998, Jones, 1998). Using additional cordons or screenlines can enhance the fairness of the cordon by imposing charges better related to length of a trip (Holland and Watson, 1978; May, 1992; Shepherd et al, 2001). However, Sheldon et al (1993) stated that a more complex cordon system would experience difficulties in implementation due to the opposition of the public. A simple system tends to be more acceptable. Politically, Rom (1994) also suggested that a congestion charging programme which did not rely on complex strategies of implementation would be more politically attractive. Where it is too difficult to adopt a more complex cordon system, it is appropriate to concentrate the charge only on the central area of the city, considered the most congested part of the city. This design can be seen in the aforementioned cases, i.e. the Singapore ALS and ERP, and the London congestion-charging scheme.

2.3.2 Freedom of travel

The implementation of a congestion charging scheme will cause infringements on freedom of travelling. The key element to improve public acceptance is the provision of travel alternatives in terms of both alternative routes and modes (Holland and Watson, 1978; May, 1992; Hua, 1994; and Jones, 1998). The combination of public transport improvement and congestion charging can be viewed as a successful element of an integrated transport strategy that can reduce congestion and also enhance public acceptance (May, 1992; Goodwin, 1989). The design of the Singapore ALS boundary provided the ring road as a diversion route for through traffic (Holland and Watson, 1978). In the Hong Kong case, the congested corridors

with good public transport service were considered as good candidates to be tolled (Transpotech, 1986). When the objective is to raise revenues, the provision of diversion routes is not appropriate; instead the use of the lower charge level is adopted to satisfy public opinion (Larsen and Ramjerdi, 1991; Lewis, 1993). Alternative travel periods or days should also be considered. In Bergen, the tolling system is not under operation on Saturday and Sunday providing the opportunity to people wishing to carry out activities in the central area with the free use of the road network. The Singapore ERP also allows free driving period in weekend (Menon, 2000). This has a significant effect on the acceptance level of the scheme (Langmhyr, 1997; and Lewis, 1993).

1.4 Dealing with adverse impacts

1.4.1 Economic and land use impact

The impact on the economy and land use is a serious issue, and it is extremely difficult to isolate the effect of any one element of transport policy on land use (May, 1992). There are several suggestions of approaches to avoid the economic impacts and land use changes as a result of the charging cordon scheme:

- Locating the charging boundary between land use types. In practice it may be appropriate to use existing geographical boundaries such as rivers, railways, canals, or mountains as the boundary of the charged area (Shepherd et al, 2001). However, in some cases where these physical barriers are not appropriate boundaries of land uses, other boundary alternatives should be considered such as ring roads;
- Trying to minimize the interruption on the basic needs trips and residential areas, e.g. trips to school, hospital, or any public services. This means it is better to charge business trips rather than residential trips and other necessary trips (e.g. charging inbound traffic to CBD). By doing this, the land use change can be kept to a minimum and the economy of the area can be maintained (Holland and Watson, 1978).

1.4.2 Dispersion of congestion and environmental impacts

There is a danger that current traffic using the tolled roads could be diverted to other areas causing congestion and pollution problems in those areas. The other dimension is the possibility of dispersion of traffic to untolled periods. Evidence in the Singapore ALS showed dispersion of traffic to the period prior to the charging period and the period after the charging time. There are two facets of this problem:

- the first is that we can view this as a good effect as the concentration of traffic is spread over different parts of the network or different time periods reducing the congestion and the pollution problem in the peak period;
- the other is that the charge spreads the problem over a longer time period and wider city area; the effect is not only an increasing pollution and congestion problem but

also an increasing safety problem particularly when traffic diverts to the residential areas or local streets which are not designed to cope with the high volume of traffic.

Dispersion over space

In the case that the main objective is to reduce pollution over a wide area of the city (not only just the area inside the cordon), the main idea is to suppress trips rather than divert them to other areas. This could be achieved by designing the cordon to capture most of the traffic without providing the diversion routes. On the other hand, if the main objective is to increase efficiency and reduce congestion in a specified area, e.g. city centre, the diversion of through traffic can be allowed (Holland and Watson, 1978). In this case, the cordon location is normally placed just inside the ring road (Shepherd et al, 2001). The capacity of the diversion route also has to be considered with the potential diverted traffic. Another design approach to tackle the dispersion problem is to use a more complex cordon. A number of screenlines and cordons are used with different charge levels on different cordons and screenlines. This finer charging system is expected to smooth traffic at the boundary of the cordon.

Dispersion over time periods

In the Singapore ALS, the initial restriction period was designed to operate from 7.30 am to 9.30 am in order to reduce the congestion in the morning peak. After implementation, congestion developed after 9.30 am and the problem was solved by extending the restriction period to 10.15 am (Holland and Watson, 1978). A different approach was proposed to prevent the same problem in Hong Kong case where the charge structure was designed to vary by time period (Harrison, 1986). The case of the London congestion charging scheme showed an other approach where the flat rate charge is designed to cover the whole day instead of a single time period. The scheme objective distinguishes the case of Norwegian toll rings from the other cases, since the problem of the dispersion of the traffic over the time period seems not to be a problem where a low charge is applied over the whole day.

2. Research questions and survey design

Based on the literature review in the previous section, the hypotheses about the practical design of charging cordon is as follows:

- The issues of public acceptance and adverse impact are the major factors considered in cordon design;
- Appendix A shows the list of the design criteria found from the literature;
- The constraints posed by the acceptability and practicality issues make the objective of the scheme less important in the design process;
- The simplicity of the charging system is considered as the major criterion for cordon design despite producing less benefit from the scheme.

From the hypotheses, we can summarise the research questions to be investigated by using a questionnaire and in-depth interview survey as follows:

i.) What are the objectives of the congestion charging scheme considered by local authority and to what extent do these objectives influence the design of the charging cordon compared to other factors?
ii.) Is the simplicity aspect of the charging system the necessary condition for the practical cordon, and to what extent can the single charging cordon system be modified by introducing additional cordons or screenlines to give the possibility of higher benefit of the scheme?
iii.) Are the design criteria found from the literature consistent with the opinion of the respondents in the survey, and to what extent do these design criteria influence the design of practical cordons?
iv.) Are there any other necessary conditions that the cordon design must follow?

A two stage survey was designed. In the first stage the questionnaires are sent to the respondents and then the answers from the questionnaires are analysed. The second stage of the survey involves using the in-depth interview to probe the points raised from the answers from the questionnaires.

The questionnaire, see Appendix B, is designed to give the researcher the preview of the case regarding to the research questions mentioned earlier. Question one starts the questionnaire by asking the importance of each objective and then question two asks whether there are any differences in the design of the cordon to meet different objectives. The answers to question one and two can reveal the set of objectives considered by local authorities and the way local authorities try to design the scheme to meet these objectives.

Question three asks about the general design of the charging cordon in each city in terms of the cordon and charge structure. Question four asks the respondents about the possibility of using additional cordons or screenlines. These two questions are used to investigate the general design of the cordon and the possible level of complexity of the design, i.e. cordon and charge structure. Question five asks the respondents to express their opinions on whether each design criterion found in the literature review should be considered in the design of the charging cordon. The respondents are also asked to address any other criteria apart from those provided. Question six asks the respondents which conflicts arise between the charging cordon design to meet the objective and the constraints they may have experienced. The answers to this question can be used to find whether each local authority gives more priority to public acceptance and adverse impact issues compared to the objective of the scheme in the design of charging cordon. The last question is designed to ask about the objective of raising revenue which is strictly outside the acceptable views of congestion charging in the

legislation. The answer to this question can show whether raising revenue is one of the objectives of the scheme.

The next stage of the survey is the in-depth interview. The structure of the interview is designed to be a semi-structured interview where there are three main discussion topics including the characteristics of the case, the objectives of the scheme, and the design process of the charging cordon. The interesting points from the questionnaires or from the discussion during the interview are probed into the detail.

3. Questionnaires and in-depth interview analysis

3.1 Background of each case

In this section, the background information for each city is given. This information is based on the results of some parts of the in-depth interview which asked about the characteristics of each city.

3.1.1 Birmingham and West Midlands area

There are seven local authorities in the West Midland area including Birmingham, Coventry, Wolverhampton, Solihull, Dudley, Walsall, and Sandwell. All of these local authorities have a very strong collaboration in terms of transport planning in which there is a West Midlands committee as the political organisation providing an umbrella on the top of these seven local authorities. Each local authority has its own centre, but the whole area is a continuous conurbation.

Of these seven centres, Birmingham, Coventry, and Wolverhampton experience the most severe congestion problem in the city. It is agreed by the seven local authorities to look at the possibility of using congestion charging in the West Midlands area in order to raise revenue for improving public transport services and reducing congestion.

3.1.2 Bristol

Bristol is a city in the southern part of England. The city is surrounded by green-belt where the nearest centre is Cardiff. Therefore, the competition of the economy between the city centres is not so high. There are about 500,000 car movements everyday in and out the city centre alone and the traffic condition in the city centre is very congested and already at capacity. Bristol has two main ring roads, i.e. the inner ring road surrounding the core centre of the city and the outer ring road covering most of the city formed by the motorway network (M4 and M5 in the north and other trunk roads in the south of the city).

The major employment area is in the centre and north of the city. Congestion charging is one approach that the Council of Bristol is actively promoting as part of integrated transport measures to reduce demand for travel by and use of car. The council in conjunction with the

local bus company ran a road user charging trial along the A4 Bath Road during 1998 in which this test aimed to examine both the technicalities of operating as well as how charging might change people's pattern of travel.

3.1.3 Durham

Durham has a fairly unique character compared to other cases. It is the country tows of a large county but has no strong commercial centre. There is a river running through the centre of the city forming a peninsula. The peninsula is considered as the historical area where there are the cathedral and castle, which are famous tourist places. The peninsula can only be accessed by a road which run through the market place. Beyond the market place there is no commercial activity.

The historical area on the peninsula has suffered from unnecessary traffic where a lot of traffic just drops people off at the market place area to go to banks or shops and then drives up to the peninsula area to wait and turn around to pick up people. The city council has decided to use road user charging in order to reduce the unnecessary trips in the historical area. The technological trial is on the progress and the system will be implemented in 2002.

3.1.4 Edinburgh

Edinburgh is the capital city of Scotland situated in the east of Scotland. The north of the city is bordered by the coast. There is a trunk road system generally surrounding the whole area of Edinburgh forming a very good outer ring road; there is also a tight inner ring road system surrounding the core of the city known as the Old and new towns which is considered as the historical area of the city. The city has two controlled parking zones including the inner parking zone which concentrates on the central area of the city and the outer parking zone which extends beyond the core of the city. The city has been considering the plan to implement road user charging scheme in order to reduce congestion in the city and raise the revenue to be used to improve public transport service.

3.1.5 Leeds

Leeds is one of the major cities situated in the north of England. Geographically, the city is quite separated from its neighbours, especially the city centre which is the major business and shopping area of the region. The inner ring road formed by a motorway system is regarded as the boundary of the central area. However, this ring road is still not completed yet; the completion of the ring road to the east of the city is on the plan. Similarly to the other big cities, Leeds faces the problem of increasing traffic and congestion in the city.

There are two types of congestion including the congestion on all radial routes, particularly on motorways, coming to the city centre in the peak period and the area inside the inner ring road which is congested almost all day. The University of Leeds is located just outside the inner ring but it is considered as a major trip attraction for inbound traffic in the peak period.

The current problem is the lack of control in parking space in the city centre which causes failure to control the traffic demand in the city centre. The city has considered implementing a congestion charging scheme around the city centre in order to control the traffic demand and also reduce congestion in the city.

3.1.6 Manchester

There are nine districts in Greater Manchester district for which the geography of the area is considered as a polycentric conurbation area. Around Manchester, there are major important towns with their own shopping centres including Stockport and Bolton. This causes a very competitive situation for the city centre of Manchester with other centres and also the retail shopping area outside the city centre. Manchester city is a strange shape, long thin and rectangular. The city centre is only about two miles from the neighbouring local authority which is Salford. The worst congestion area is around the outer ring road whereas there are also some particular congestion areas in the cit centre. Manchester has joined the DTLR Congestion Charging Partnership but has not got a firm plan to implement a congestion charging scheme.

4.2 Response to the questionnaires

The summary of the responses to some of the questions is shown in Appendix C. In this section, we will analyse the answers in order to answer the research questions set earlier.

4.2.1 Objective of the scheme and hierarchy of objectives

Table C.1 in Appendix C shows the answers to this question from the survey. Despite the absence of the explicit option of an objective of revenue generation in the questionnaire, some local authorities raised this objective in the responses as well as the objective of economic regeneration. The answers show the wide range of objectives of using congestion charging, with most of the schemes being expected to serve more than one objective. Nevertheless, the main objective of most of the local authorities in this survey is to reduce congestion and increase efficiency.

4.2.2 Conflict between the different objectives

The responses to this question tend not to show great concern that different designs are needed to meet different objectives.

4.2.3 General design of charging cordon

It is politically sensitive to give the detail of the design of each case here. Instead, the general response will be given and discussed. Four out of the five local authorities in the survey have some idea about the design of the actual cordon. From these four local authorities, the general responses to question three asking about the cordon location and charge structure are as follows:

- the cordon will cover the core or city centre area of the city;

- the cordon will use a ring road as the reference boundary (normally the cordon will be situated inside the inner ring road);
- the size of the scheme will be a relatively small compared to the whole area of the city;
- three out of four cases only consider a single cordon application; the other case considers different options including a city centre cordon, double cordon (inner and outer ring road), and a wide area cordon (outer cordon with area licensing scheme instead);
- the charge structure will be very simple, with a uniform charge for the whole day or two charge levels for peak and off-peak;
- three out of four cases expressed that the charge would be operated only in the peak period and for inbound traffic only;
- the charge level would be a uniform rate for all toll points on the cordon;
- three out of four cases are considering the application of area licensing scheme or charge only once a day regardless of the number of crossings.

4.2.4 Additional cordons and screenlines

Question four particularly asked further about the extent to which the complexity of the cordon structure could be reconsidered. Only one out of four local authorities accepted the possibility of introducing the additional cordons and screenlines in the future. It is fair to conclude that the simple cordon and charge structure is an important element of the design of practical cordon.

4.2.5 Design criteria

Table C.2 in Appendix C shows the responses to this question in the survey. It shows that most of the design issues, found during the literature review, are consistent with the views of the respondents in the survey. Eight design issues out of 22 receive a unanimous positive answers from all respondents. The design issues related to practicality receive the most negative responses. It is noteworthy that the understanding of the respondents to this issue is still at an early stage, since most of the schemes are still in the early design stage. Two issues in the group of public acceptance receive strong negative responses including:

- the issue of whether the design should avoid the low-income areas and
- whether the design should avoid a charge on the residents (only Bristol agrees with this issue).

Also two issues receive a vary of responses (there are both groups of agree and disagree response) which are:

- whether the cordon should be placed between land-use types(Bristol and Leeds disagree, others agree); and
- whether the design should aim at charging the traffic which is of least benefit to the area (Edinburgh and Manchester agree, others disagree).

The response from Edinburgh is significantly different from others especially when compared with the group of Bristol, Birmingham, and Leeds. The design issues of provision of bypass

route from the charging area and public transport quality in the charging area received a negative response from Edinburgh whereas other local authorities agreed with these issues.

4.2.6 Conflict between objectives and design criteria

Similarly to the response to question three, there are no very interesting answers to this question from the respondents. Most of the answers tend to say that there is no conflict between the design to meet the objectives and other constraints in their cases. It is decided to investigate this point further in the in-depth interviews.

4.2.7 Spending revenues

The local authorities have a very clear idea about the way to spend the revenues from the scheme. Most of the generated revenues will be used to invest in public transport.

4.3 In-depth interview analysis

The detail analysis of the interview can be found in Appendix D. A brief summary of the finding in each case is presented in this section.

4.3.1 Birmingham and West Midland area

The process of cordon design starts by looking at a possible single cordon around the centre of each city. Only the inner ring roads are considered as the potential boundaries of charging cordons. Birmingham, Walsall, and Solihull have feasible cordon boundaries based on the characteristics of the inner ring roads of these cities whereas the other cities have problems with their ring roads. From the interviews, the reasons why the ring roads in other cities are not feasible or satisfactory to be used as the cordon boundary are as follows:

- The ring road is too small in terms of the surrounded area, a too small cordon may not be able to reduce the congestion sufficiently and generated revenues from the scheme could be too low;
- The ring road is not completed or in some cases there is not a clear ring road at all;
- Ring road does not provide a clear boundary between business area and residential area.

It is also less politically feasible to implement the scheme in Solihull or Walsall, which have a feasible cordon boundary, when the more congested cities like Coventry or Wolverhampton will not implement a charging scheme due to the lack of the feasible cordon.

Considering only Birmingham city, the potential cordon will be situated just inside the middle ring road. The walking distance from the boundary of the cordon to city centre is about ten to fifteen minutes. There is a plan to increase the yellow line parking control around the cordon in order to prevent the dispersion of parking demand at the fringe of the cordon. The design also plans to allow free lanes on the main motorway passing through the city, since the ring road is predicted not to be able to cope with diverted traffic from this main

through route. The charge level will be low in order to maintain support from the public and the charge will be a uniform rate all day.

4.3.2 Bristol

Bristol considers a small cordon covering the city centre, and the cordon will be located just inside the inner ring road covering most of the inner parking zones of the city. The underlying reason for the small scheme is the political and public acceptability, since the group affected by the scheme can be kept to a minimum and this small scheme seems to be able to express the objective of the scheme clearly to public. The design of the cordon location is also trying to minimise the number of crossing points or toll points by using the river on the south of the city to form the boundary.

The recommended scheme has 14 entry points and includes the city's main Broadmead shopping area, the Centre, West End, and Harbourside but excludes the main inner city residential area. The bus station is also deliberately left just outside the cordon. There are a number of car parks outside the charging boundary. It was indicated that for Bristol there is a potential extension of the scheme toward a more complex system but this possibility really depends on the success of the forthcoming scheme whereas in this stage it is only possible to implement the single cordon with a simple charge structure. The charge will be in the morning peak and for inbound traffic only and the level of charge will be at an acceptable level. It is accepted that this low charge level may not be able to reduce congestion significantly but can be more politically acceptable.

4.3.3 Durham

The design of the charging system in Durham is different from other cases. Only one toll point will be located at the access point to the market place which is the only access point to the peninsula area. The geographic of the peninsula area forms a natural closed cordon. The charge level will be at £2 operated from Monday to Saturday from 10 am – 4 pm. The design of the scheme tries to avoid the effect on necessary trips, such as school trips, by providing an exemption to the parents of the students under 6 years old studying at the schools in the peninsula area. The scheme should not affect the employees in the area since normally most of them do not use a car for working trips due to the lack of parking space.

4.3.4 Edinburgh

The inner ring road and outer ring road are considered the possible boundaries for charging cordons. The implementation of two cordons, i.e. inner and outer cordon, may cause problems in the doughnut area in between these two cordons in which there may be problems of increased traffic, and the public transport services in the orbital direction around the city centre are not at a good level. One of the points mentioned about the design of this outer cordon is that the cordon must be wholly inside the city bypass and it has to be purely inside the City of Edinburgh Council's area. The location of the inner cordon should cover the inner

parking zone, but not as far as the boundary of the outer parking zone which in this design aims to reduce the parking dispersion problem around the cordon boundary.

It was mentioned that it becomes inevitable to include one of the residential areas, which is just outside the boundary of the initial cordon, inside the cordon in order to avoid worsening the congestion problem in that already congested area. The inner cordon also uses some of the physical boundaries such as parks, railway line, and river to form the closed charging boundary to help minimise the number of toll points and make the cordon easily recognised. At each toll point, there will be an escape route for those who want to avoid the charge by diverting to other routes, but the diversion route from one side to the other side of the cordon will not be advised to the drivers in order to discourage rat-running traffic.

In the case the twin cordon system is implemented, the charge will be higher on crossing the inner cordon and lower on crossing the outer cordon whereas the single uniform charge will be used if only the inner cordon is implemented. The level of charge is not definitely decided but it would be at an acceptable level to the public and politicians.

4.3.5 Leeds

The system considered in Leeds is an area licensing scheme (ALS). Similarly to other cases, Leeds considers the inner ring road and outer ring as good candidates for the location of charging cordons. However, the outer ring road cordon is considered to cause a major political acceptance problem because many people living inside the cordon would be charged. Therefore, the inner ring is chosen as the reference boundary of the charging cordon subject to the completion of the inner ring road.

The city council has conducted several modelling tests on whether the capacity of the inner ring road can cope with the diverted traffic, and it is concluded that the capacity of the inner ring road is sufficient. It is accepted that the inner cordon does cover the whole congested area in the city centre but it does not address the congestion problem of the whole city. The detailed design of the cordon is trying to minimise the number of toll points, trying to include the University area inside the cordon, and to exclude the major hospital outside the cordon.

Politically, the hospital inside the central area must be outside the cordon although it is located just inside the inner ring road. This political requirement causes a conflict with the requirement to include the university area inside the cordon where this area is actually just outside the cordon. The charge level has been decided based on the requirement that it should reduce the congestion in the city centre, generate significant amount of revenue, and receive support from public and politicians. According to the concept of ALS, the charge structure will be a uniform charge throughout the day. Similarly to the Bristol case, there is a

possibility to introduce additional cordons in the future in which the second and third cordon may be located just inside the outer ring road and the middle ring road respectively in which the charging system would change ALS to a more complex cordon charging structure.

4.3.6 Manchester

Manchester is still in a very early stage of the plan to implement a congestion-charging scheme. From the geography of Manchester city, it is too difficult to find an appropriate cordon that is wholly inside the Manchester City Council's area, ,and it may cause the problem to the economical development of Manchester city if the charging scheme will be introduced in the Manchester city alone. It is thus necessary that all of the local authorities in Greater Manchester must come to an agreement in introducing a congestion charging scheme together. It is affirmed that a simple charging system that is just good enough to make the scheme work would be preferable to a more complicated system that has to rely on the high technology.

4.4 The finding

The questions about differences in design to meet different objectives and about the conflict of the design to meet objectives and constraints are not well answers, since most of the answers do not express concern over these issues. The discussion with local authorities in the in-depth interviews shows that the issues of public acceptance and adverse impact are more important to the design compared to the objectives of the scheme. During the discussion, the design of the cordon is regularly associated with public acceptance and adverse impact issues whereas the objective of the scheme is only mentioned when it is to be decided whether the scheme is worthwhile to be introduced. It was regularly mentioned that the objectives of the scheme, particularly the objective to reduce congestion, cannot be met by only using congestion charging (and in fact it is expected that charging cordon alone will not be able to reduce the congestion significantly) but the revenues generated from the scheme are the key to success where this money will be invested in public transport to attract more people to use public transport.

The other point found in the responses to the question about the cordon design is that the design of cordon location and structure is a separate process from the decision on the charge level. The charge level may be even defined in advance at an acceptable level before the location of the cordon is decided. It is found from the questionnaire and in-depth interview that the design criteria found in the literature review are not all necessary. Some of these criteria are "hard constraints" which the cordon design must follow, but some are not. We refer to the other type of constraints as "soft constraints". Some criteria are not even agreed by most of the respondents, such as the issue to avoid charging residents of poor income areas. It seems to be that the design tries to find the cordon that strictly meets the set of the hard constraints which could be considered as a "acceptable design" which can be acceptable

and will not cause the new problems. The common features or hard constraints of the "good enough cordon" are as follows:

- Use ring road as the skeleton design of the cordon and as the diversion route;
- Cordon and diversion route must be wholly inside the authorised area of local authority;
- However, in the case that there is no obvious ring road, try to find the road network that can form the escape routes from the toll points instead;
- The capacity of diversion or escape route should be able to cope with the diverted traffic;
- Ensure that the problem of the dispersion of congestion to the surrounding area around the cordon is kept to a minimum;
- Cordons should concentrate on the central area of the city, even though congestion also exists elsewhere in the city;
- Include major trip attractions but exclude sensitive locations if possible, i.e. hospitals or bus or train stations;
- Associate the cordon boundary with the controlled parking zone which can give a buffer area to protect the dispersion of parking demand around the fringe of cordon;
- Minimize the crossing points by using a natural boundary, such as park, river, or railway line;
- Keep the boundary as simple and clear as possible and try to use key landmarks or natural boundaries;
- Use a simple charge structure that is easy to understand and remember;
- Charge level should be defined at the acceptable level to the public;
- Finally, the scheme must be worthwhile to be implemented in terms of the benefit of the scheme given the possible cordon design and charge level.

Several issues are discarded from this list, e.g. separation between land use type, fairness and equity issues, residential or poor income areas. These are the supplementary criteria which it would be ideal to include in the design, but are not necessary to do so (referred as the set of "soft constraints").

A simple charging cordon is clearly more preferable to a complex one. However, the interviews show that local authorities are also aware of the greater benefit that they could achieve by using a more complex charging system. Most of the comments on this issue is that *"at this stage, we are trying to find the system that is just good enough to make this scheme work and start rather than trying to find the optimal design that may not be possible to implement, but of course there is a possibility to extend the system toward the more complex system subject to the success of this starting scheme"*. From this statement, it is clear that the practical design of the cordon is trying to find the scheme that could be implemented now (an "acceptable scheme") and leave the space for further development or evolution of the scheme in the future towards a more effective and optimal system.

5. Summary

Following the objective of the research, an extensive review of the literature regarding the design of charging cordon systems has been carried out (Ministry of Transport, 1964; Goodwin, 1989; Guiliano, 1992; Sheldon et al, 1993; May, 1994; Rom, 1994; Hua, 1994; Langmhyr, 1997; Small and Gomez-Ibañez, 1998; Jones, 1998; and Neuenschwander, 2000). The cordon design in different studies including Singapore, Hong Kong, London, and Norwegian toll ring reveals the design process of charging cordons and issues that should be considered (Holland and Watson, 1978; Harrison et al, 1986; Transpotech, 1986; Larsen and Ramjerdi, 1991; May, 1992; Lewis, 1993; Ramjerdi, 1995; Menon, 2000; GOL, 2000; Shepherd et al, 2001). The main conclusion from the review is the set of design issues found and three factors that the design tries to achieve including effectiveness, acceptability, and feasibility. The research investigated these issues further in the context of the UK for which six local authorities in the DTLR Congestion Charging Partnership including Birmingham, Bristol, Durham, Edinburgh, Leeds, and Manchester participated in the survey of this research. They were asked to complete questionnaires and participate in the in-depth interview.

The results from the survey show that the design of practical cordons concentrates much more on the issues of public acceptance and adverse impacts. The effectiveness of the scheme can be achieved by using the revenues generated from the scheme instead of using the charging cordon directly to tackle the problem. Some of the design issues found in the literature are not necessary criteria for the cordon design. Local authorities in the survey consider a smaller set of design criteria that will ensure the scheme would be able to be implemented. We refer to these criteria as the hard constraints of the cordon design (see section 4.4). Most of the designs will start with a simple scheme despite probably less benefit, with the possibility of extension of the scheme subject to the success of the starting scheme.

The design of practical cordons put more emphasises on the issues of public acceptance and adverse impacts considered as sensitive issues to public and politicians. It is clearly that this practical design is not an optimal design to meet the objective of the scheme. The purpose of the next stage of this research is to combine these practical design constraints with a mathematical model that can produce an optimal design in which the scheme is still able to be implemented in the practical point of view. The possibility of using the modelling approach to help the design of cordon has to be investigated to determine the extent to which the model can represent the problems. For instance, the issue of dispersion traffic to untolled periods needs a model that can represent the time choices and departure time choices in the model. This issue will be investigated further in the subsequent paper.

Appendix A: Design criteria found in literature review

Avoid the adverse impacts
▪ The design should ensure the provision of sufficient alternative routes for drivers who want to bypass the charge area.
▪ The design should avoid the dispersion of environmental or congestion problem to other areas.
▪ The cordon should cover only the area having good public transport service.
▪ The design should leave the facilities for interchange outside the cordon (e.g. park and ride or parking facility).
▪ The design should ensure that all entry points to the charge area are charged or closed.
▪ The design of the entry points should not be visually unattractive.
▪ The design should place cordons at boundaries between land use types.

Gain public acceptance
▪ The cordon structure should be simple and easy to understand.
▪ The charge structure should also be simple and easy to understand.
▪ The charge should be at a level which is acceptable to the public.
▪ The charge should be perceived as fair by the public.
▪ The design should avoid the problem of local inequities (e.g. people just outside the cordon needing to access places just inside)
▪ The design should avoid the problem of commercial inequities (e.g. with the same type of business, one is just inside the cordon and the other is just outside the cordon)
▪ The design should aim at charging the traffic which contributes most to congestion and pollution.
▪ The design should aim at charging the traffic which is of least benefit to the area.
▪ The design should avoid charging the city's residents.
▪ The design should avoid charging people from the low income area of the city.

Practicality
▪ The number of charging points should be minimized to reduce capital costs.
▪ The system should be designed to limit the schemes operating costs.
▪ The design should avoid the types of road that cannot be tolled.
▪ The design should avoid areas or locations that may cause technological or communication problems the system.
▪ The cordon should be located wholly inside the city authority area.

Appendix B: Questionnaire

SECTION I

1. What are the objectives of using charging cordons in Leeds and what is the level of importance of each selected objective?

	High	Medium	Low	Not an objective
Reducing congestion	❑	❑	❑	❑
Environmental protection	❑	❑	❑	❑
City centre management	❑	❑	❑	❑
Increase efficiency	❑	❑	❑	❑
Redressing inequity in transport system	❑	❑	❑	❑
Other, please state	❑	❑	❑	❑

Answer the next question if you choose more than one objective in question 1. If not, go to question 3.

2. Are there any differences in the charging cordon to meet the different objectives of the scheme at the same time?

Yes ❑ No ❑

If the answer is yes, please explain the differences:

3. What is the general design of the proposed cordon of Leeds?
Please give the detail in terms of:

Location of the cordon

Charge structure

4. Would you consider using the additional cordons or screenlines?

Yes ❑ No ❑

If yes, please explain the reasons, and define the additional cordons or screenlines. If no, please explain the reasons.

SECTION II

5. For each of the design aspects, do you agree that that design aspect should be included into the design of the charging cordon? If there is the other design aspects that should be considered, please state in the blank box.

Avoid the adverse impacts	**Strongly Agree**	**Agree**	**Not consider**	**Disagree**	**Strongly Disagree**
▪ The design should ensure the provision of sufficient alternative routes for drivers who want to bypass the charge area.	❑	❑	❑	❑	❑
▪ The design should avoid the dispersion of environmental or congestion problem to other areas.	❑	❑	❑	❑	❑
▪ The cordon should cover only the area having good public transport service.	❑	❑	❑	❑	❑
▪ The design should leave the facilities for interchange outside the cordon (e.g. park and ride or parking facility).	❑	❑	❑	❑	❑
▪ The design should ensure that all entry points to the charge area are charged or closed.	❑	❑	❑	❑	❑
▪ The design of the entry points should not be visually unattractive.	❑	❑	❑	❑	❑
▪ The design should place cordons at boundaries between land use types.	❑	❑	❑	❑	❑

Gain public acceptance	**Strongly Agree**	**Agree**	**Not consider**	**Disagree**	**Strongly Disagree**
▪ The cordon structure should be simple and easy to understand.	❑	❑	❑	❑	❑
▪ The charge structure should also be simple and easy to understand.	❑	❑	❑	❑	❑
▪ The charge should be at a level which is acceptable to the public.	❑	❑	❑	❑	❑
▪ The charge should be perceived as fair by the public.	❑	❑	❑	❑	❑
▪ The design should avoid the problem of local inequities (e.g. people just outside the cordon needing to access places just inside)	❑	❑	❑	❑	❑
▪ The design should avoid the problem of commercial inequities (e.g. with the same type of business, one is just inside the cordon and the other is just outside the cordon)	❑	❑	❑	❑	❑
▪ The design should aim at charging the traffic which contributes most to congestion and pollution.	❑	❑	❑	❑	❑
▪ The design should aim at charging the traffic which is of least benefit to the area.	❑	❑	❑	❑	❑
▪ The design should avoid charging the city's residents.	❑	❑	❑	❑	❑
▪ The design should avoid charging people from the low income area of the city.	❑	❑	❑	❑	❑

Practicality	Strongly Agree	Agree	Not consider	Disagree	Strongly Disagree
▪ The number of charging points should be minimized to reduce capital costs.	❑	❑	❑	❑	❑
▪ The system should be designed to limit the schemes operating costs.	❑	❑	❑	❑	❑

5. Based on the case of Leeds, are there any difficulties in the design to meet the required objectives and to satisfy the design issues mentioned above?

Yes ❑ No ❑

If the answer is Yes, please explain some difficulties in your city case.

SECTION III

6. How would your Local Authority spend the revenue generated from the congestion-charging scheme and why will you spend the revenues this way?

Appendix C: Response to questionnaire

Table C.1: Response to question regarding the objective of the scheme

Objective	Bristol	Birmingham	Edinburgh	Leeds	Manchester
Reducing congestion	H[1]	M	H	H	M
Environmental protection	N	L	M	M	M
City centre management	H	N	M	M	M
Increase efficiency	H	L	H	M	M
Redressing inequity in transport system	N/A	L	N/A	M	M
Raising revenue (LAs added this objective by themselves)	N/A	H	N/A	L	N/A
Economic regeneration	N/A	N/A	R	N/A	H

Table C.2: Response to question regarding the design issues

Avoid the adverse impacts	Bristol	Birmingham	Edinburgh	Leeds	Manchester
▪ The design should ensure the provision of sufficient alternative routes for drivers who want to bypass the charge area.	A[2]	SA	D	SA	SA
▪ The design should avoid the dispersion of environmental or congestion problem to other areas.	A	SA	SA	A	A
▪ The cordon should cover only the area having good public transport service.	A	A	D	A	SA
▪ The design should leave the facilities for interchange outside the cordon (e.g. park and ride or parking facility).	A	A	SA	SA	A
▪ The design should ensure that all entry points to the charge area are charged or closed.	SA	SA	SA	SA	A
▪ The design of the entry points should not be visually unattractive.	A	A	SA	A	SA
▪ The design should place cordons at boundaries between land use types.	D	SA	A	NC	A

[1] H = high, M = medium, L = low, N = not an objective, R = raised but not specify level, N/A = no response

[2] SA = Strongly agree, A = Agree, NC = Not consider, D = Disagree, and SD = Strongly disagree (N/A = no response to the question)

Gain public acceptance	Bristol	Birmingham	Edinburgh	Leeds	Manchester
▪ The cordon structure should be simple and easy to understand.	SA	A	SA	SA	SA
▪ The charge structure should also be simple and easy to understand.	A	A	SA	SA	SA
▪ The charge should be at a level which is acceptable to the public.	A	A	A	A	SA
▪ The charge should be perceived as fair by the public.	A	A	A	A	SA
▪ The design should avoid the problem of local inequities (e.g. people just outside the cordon needing to access places just inside)	A	A	NC	A	SA
▪ The design should avoid the problem of commercial inequities (e.g. with the same type of business, one is just inside the cordon and the other is just outside the cordon)	A	A	NC	A	SA
▪ The design should aim at charging the traffic which contributes most to congestion and pollution.	SA	A	SA	A	A
▪ The design should aim at charging the traffic which is of least benefit to the area.	N/A	D	SA	NC	SA
▪ The design should avoid charging the city's residents.	A	SD	D	NC	NC
▪ The design should avoid charging people from the low income area of the city.	N/A	D	NC	NC	D

Practicality	Bristol	Birmingham	Edinburgh	Leeds	Manchester
▪ The number of charging points should be minimized to reduce capital costs.	N/A	A	D	A	D
▪ The system should be designed to limit the schemes operating costs.	N/A	A	D	A	A
▪ The design should avoid the types of road that cannot be tolled.	N/A	N/A	N/A	A	N/A
▪ The design should avoid areas or locations that may cause technological or communication problems the system.	N/A	NC	N/A	A	NC
▪ The cordon should be located wholly inside the city authority area.	N/A	NC	SA	SA	SD

Appendix D: Detail analysis of in-depth interview

BRISTOL

Characteristics

- Bristol is surrounded by green-belt. The nearest centre is Cardiff. [3]**The competition of the economy between the city centre is not significant**.
- There are 500,000 car movements everyday in and out of the city centre alone. The **traffic condition in city centre is very congested and already at the capacity**.
- The south and east of the city have been affected by decline in the docks, railways, mining, and tobacco industries, only partially offset by new employment while north Bristol has seen employment, retail and housing growth stimulated by the accessibility of the M4 and M5 motorways.
- **The major employment area is in centre and North of the city**. There is a **problem of north/south split**; the barrier presented by the River Avon also exacerbates the separation resulting in increase in the travel length,
- At present, a **controlled parking zone covers the central area of the city centre** and the parking zone is **extended beyond the inner ring road in the north of the centre**.
- Bristol has **two main ring roads**, i.e. the **inner ring road surrounding the core centre of the city** and the **outer ring road covering most of the city** formed by the motorway network (M4 and M5 in the north and other trunk roads in the south of the city).

Objective of the scheme

- Road user charging is **one of the elements of Local Transport Plan**.
- **Reducing congestion and pollution** is the target. Particularly, it is aimed to progressively **reduce through traffic** within the city centre.
- **Generated revenues** will be invested in the transport system, particularly in improving the quality of public transport service.

Cordon design

- The design principle of the charging cordon in Bristol is that [4]the cordon must be small and tight cordon in the city centre, avoid major public service centres like major hospitals, avoid educational places like schools, and avoid residential areas.
- The reason behind the idea of the tight city centre cordon is that it can **address and express the objective of the scheme clearly to the people** regarding the objective of reducing congestion and improving

[3] Bold letter refers to the latent variables of the design including the city characteristics, objectives of the scheme, and other design constraints.

[4] Underlined letter refers to the solution to the design problem in which this can be a design of the cordon or charging system.

environment.[5] "*We are trying to charge the area where the perception of congestion is clear and try to choose a location so that this clear to people where the cordon would be and what we are aiming at*".

- This small scheme is also preferred by the **political decision where the affected group is limited** and it seems to be a scheme that **receives the support from public**.
- The recommended scheme has 14 entry points and includes the city's main Broadmead shopping area, the Centre, West End, and Harbourside but excludes the main inner city residential area. It is also deliberate to leave the bus station just outside the cordon. The cordon is just inside the inner ring road, which is claimed as **the natural boundary of the charging cordon**.
- The river on the south of the city centre is used as the boundary **reducing the toll point** into only one point on the bridge crossing the river. "The b*oundary is normally close to something physically divides quite easily, such as river, road, railway line, or bridge."*
- The cordon is delineated following the parking zone and car parks around the inner ring road.
- A wider cordon inside the outer ring road with different screenlines was also considered but it was rejected due to public acceptance and political acceptance.
- The charge will be in morning peak and inbound traffic only and the level of charge would be at an acceptable level. "Politically, the low charge is **easier to introduce and could gain public acceptance**, but actually this charge cannot reduce congestion significantly".
- The complexity of charging structure could be possible with a larger scale scheme, but with this small scheme it is not worth using the different charge levels on the different locations.
- The extension of the charging cordon system is possible but really **depends on the success of the forthcoming scheme**. If the current scheme receives positive feedback and prove to be successful, **the politicians could be more open** with the larger and more complex scheme.

BIRMINGHAM AND WEST-MIDLAND AREA

Characteristics

- There are **seven local authorities in West Midland area** including Birmingham, Coventry, Wolverhampton, Solihull, Dudley, Walsall, and Sandwell. All of these local authorities **have a very strong collaboration in terms of transport planning** in which there is West Midland committee as the political organisation providing an umbrella on the top of these seven local authorities.
- Each **seven local authority has its own centre, but the whole area is a continuous conurbation**.
- Of these seven centres, **Birmingham, Coventry, and Wolverhampton experience the most severe congestion** problem in the city.
- It is agreed by the **seven local authorities to look at the possibility of using road pricing in West Midland area together**.

Objective of the scheme

[5] The italic letter refers to the sentence directly quoted from the interview context whereas the normal letter refers to the summary of the discussion regarding each issue.

- It is clearly stated that the **main objective of using road pricing is to raise revenues** that can be used in transport investment, especially in public transport improvement.
- However, it is also **necessary that the scheme must reduce congestion** following the legislation.

Cordon design

- According to the **conurbation aspect** of the area, it is decided to look at three possible cordon systems covering the whole region.
- The first option is a cordon around each centre. After consideration, it was found that **a number of centres did not suit a cordon approach** because there is no **obvious distinction between one area and another** or one land-use and another (Walsall has an appropriate route that can become a cordon but there is no such clear cut between business area and residential area). More importantly, in some cases there is no **clear or complete ring road around the centre** (Dudley's road network does not give any satisfactory boundary or ring road around the centre) or **the ring road is too small (in term of coverage area)** in which the are that will be encompassed by cordon is not really worth doing (too small and too tight).
- Of the seven centres, four or five centres have a reasonable cordon. But, two of these cordons are not really worth using (Coventry and Wolverhampton have too tight and too small ring road). This leaves Birmingham, Walsall, and Solihull as the three potential centres that can use cordon system. However, **it is politically unacceptable if the scheme cannot be implemented in Coventry and Wolverhampton which are much more congested than other centres**. This will raise the public acceptability problem.
- For the Wolverhampton case, **the radius of the inner ring road is too small**, so the controlled parking zone is a very important measure to support the cordon charging scheme in order to **avoid the traffic dispersion at the fringe of the cordon** and to **achieve the objective of the scheme**.
- For Birmingham alone, it is possible to implement the city centre cordon because of **the level of congestion in the centre and the existence of the natural cordon**. The more complicated cordon is not considered since it is expected that **people will not like the more complicated cordon**.
- The ring road in Birmingham is appropriate because **the capacity can cope with the potential diverted traffic** and the **ring road cover the whole area of city centre**. Also, the ring road is a **physical boundary between land uses**. Therefore, the cordon in Birmingham would be immediately inside the inner ring road, i.e. once you turn off from ring road you will face charge.
- The other consideration is the radius of cordon gives the average of the walking distance about 20-30 minutes to centre, so there should not be a problem with the **dispersion of parking demand at the fringe of the boundary**. However, there is a plan to add more yellow line parking control around the cordon boundary.
- This design **makes it very clear that you will not be charged as long as you are on or outside the ring road**.
- Despite the confidence of the capacity of ring road, it is expected that the **ring road cannot cope with the diversion of the traffic from the major route (motorway route) that passes through the centre of the city**. This route is 4-lane carriageway having a very high volume of through traffic. *"We are planning to paint 2 lanes green all the way through and as long as you stick on the green lanes you are not charged."*

- The second cordon option considered is the cordon around the whole West-Midland using ALS system. *"However, it is **non sense that about 2.6 million people have to pay** in which it **will become a supplementary registration tax instead of a congestion charging scheme**."*
- Therefore, the last option is considered using the motorway box, which is the **well-defined cordon**, as the boundary of the crossing charge cordon. It is identified that **there is a small number of toll points required**, but the problem is then the **traffic movement inside the cordon would not be charged** since **the cordon is too wide**. This is rather considered the development of the complete scheme in the future.
- For the charge structure, it is indicated that the scheme will start with a low charge level. The charge will be associated with a parking charge where people who already pay the toll will get the discount for parking inside city centre.

Other issues

- Based on the first option with the cordon around Birmingham, there are two sensitive locations, including a service station and a retail shopping centre. These **two places are just immediately inside the inner ring road and have no frontage access through the inner ring road**. Therefore, as the effect of inner cordon, **these two places will have a problem of decrease of trade**.
- It is being considered whether to include these two places inside the cordon.

Durham

Characteristics

- Durham is **a large county, but there is no strong commercial centre**. The **centre of Durham a small area in which there is no serious problem of congestion**.
- There is a **river running through the centre of the city** and the river **forms a natural peninsula**. Within this area, **there are the cathedral and the castle**, which are famous tourist places. There are about **25-30 residents in this area together with some university colleges and schools**.
- This peninsula area is considered as the **important historical area** of the city.
- This **peninsula is accessed by a road which runs through the market place**. There is **no other form of vehicle access to this area** apart from this access road. Beyond the market place area, there is no commercial activity.
- From the limited access point, there is **no through traffic in this area**, but **the problem is the conflict between the traffic and pedestrians** in this area.
- There is **no parking area inside the peninsula** at all. Around this central area, there is a controlled parking zone.
- **Most of the traffic in the peninsula area is not essential**. A lot of traffic quite often **just drops people off at the market place area** to go to bank and then drive up to the peninsular area to **wait and turn round to pick up their people**.
- Normally, **the employees in the peninsula area and the market place area do not use car** for the journey to work **since there is no parking area** at all in this area.

Objective of the scheme

- The objective of using congestion charging in Durham is very clear where it aims to **reduce the traffic in the historical area** of the city (peninsula) and try to preserve area.
- The main target is to **reduce the non-essential traffic just dropping people** at the market place.
- *"If the scheme makes a lot of money, the scheme will not be considered successful at all, because **the idea is to remove the traffic**."*

Cordon design

- A toll will be charged at the access point to the market place area which is the **only access point to the peninsula area**.
- The charge will be at £2 operated from Monday-Saturday from 10am-4pm.
- The toll actually will be collected on the outbound direction from the peninsula in order to **avoid a queue of traffic at the toll point blocking the main street**.
- An exemption will be given to the parents of the students under 6 years old of the school inside the peninsula. However, it is expected that **the charging period would not cause the problem to school trips**. This design tries to **raise the public acceptance** of the scheme.
- The scheme will **not affect the employees in the area** since normally **they do not use car for working trip** (no parking space). The revenues generated from the scheme would be used to improve bus services into the area, which will help the employees in the area.

EDINBURGH

Characteristics

- The north of the city is bordered by the coast.
- The city of Edinburgh is considered as **the main business and shopping centre of the region**.
- There is **a trunk road system generally surrounding the whole area of Edinburgh forming a very good outer ring road**. Also, there is **a tight inner ring road system** surrounding the core of the city known as the old town area which is considered as the historical area of the city.
- There are **two controlled parking zones in the city**, i.e. the inner parking zone (concentrating on the central area of the city) and the outer parking zone (extending beyond the core of the city).
- Travellers coming to Edinburgh are not only their residents but also **the people from other districts** surrounding Edinburgh.

Objective of the scheme

- The main objective is to **reduce congestion** in the city, but inevitably the **money generated** would be invested in improving public transport to compete with car.

Cordon design

- The possible cordon boundaries are the inner ring road and outer ring road. However, **the inner ring road cordon is too tight**. Also, using the outer ring road as the boundary of the cordon causes **the problem of the fairness between the resident of Edinburgh and of other surrounding districts**.
- Therefore, Edinburgh starts to consider the twin cordon. However, the major concern of the twin cordon is **the doughnut area in between the inner and outer cordon which may encounter problems of**

increased traffic and also because **public transport is actually only in the radial direction** to the city rather than the orbital direction around the city centre.

- *"In Scotland, road user charging **is not allowed to be imposed on trunk roads**. But, in Edinburgh we are fortunate that **the only trunk road in our area is the city bypass (outer ring road)**. Although, the majority of radial route coming to city centre are trunk roads but they have been reclassified as non-trunk roads."*
- *"It is necessary that the cordon must be wholly inside the city bypass and it has to be purely inside Edinburgh according to **political decision**, and **the revenue generated would totally be ours**".*
- The principle to define the cordon location is that the cordon boundary should cover the inner parking zone, but not as far as the boundary of the outer parking zone. This design aims to reduce the **parking dispersion problem around the fringe area of the cordon, and also enhance the use of public transport from origin of the journeys**.
- Initially, the inner cordon boundary did not cover a particular residential area which also has a congestion problem. Politically, it is necessary to include this area inside the cordon in order to **avoid worsening the congestion problem in that already congested area**.
- Also, some of the physical boundaries have been used to form the inner cordon, e.g. park, railway line, and the river running through the city (use bridges as the charging points). This will enhance the attempt to **minimise the charging points** and also **make the cordon simple and easily recognised**. It is noteworthy that all of **these existing physical boundaries cover the target area of the cordon and congestion area**.
- *"**We also have to consider the vehicles that may divert**, and we consider we should not direct the car how to get from one side to the other side of the cordon, but what we have done is that at each point we provide an escape route so that the driver can divert if they want to avoid the charge. The underlying reason is that **we do not want to encourage rat-running traffic**."*
- Two level of charges on different cordon, i.e. higher charge on crossing inner cordon. The charging structure would be something easy and simple to understand. It is going to be very **difficult to manage and explain to the public if more complicated charging is used**. The driver passing the cordon only has to pay once/day.

LEEDS

Characteristics

- **There are two types of congestion in Leeds, i.e. on all radial routes, especially on motorways, coming to the centre of Leeds in the peak period and** congestion inside the inner ring road **which is congested almost all day.**
- The congestion also exists around the outer ring road area **outside the city centre.**
- **There is** a significant proportion of through traffic **coming to the central part of the city.**
- **Geographically,** Leeds is quite separate from its neighbours**, especially the city centre which is mentioned as the major business and shopping area of the region.**

- **The** inner ring road which is formed by a motorway system is regarded as the boundary of the central area of the city**. However, the inner ring road system is still not completed yet; the completion of the ring road on the south east of the area is on the plan.**
- **However,** the university area is situated just outside the inner ring road**. This area is regarded as one of** the major trip attractions **of inbound traffic in the peak period.**

Objective of the scheme

- Leeds aims to use road pricing as the demand management measure in order to **reduce the travel demand in city centre. The current problem is the lack of control in parking space in city centre (about 50% of parking spaces are private).**
- The environmental problem **is also addressed and defined as one of the objective of using road pricing.**
- Inevitably, the **revenue generated from the scheme is also one of the main reasons of the scheme.**

Cordon design

- The system in Leeds is actually an area-licensing scheme (ALS) where the people would be charged once a day when they travel either inside or across the cordon.
- The issue that the cordon should **provide the alternative route** is mentioned as the most significant issue of cordon location.
- *"There is not much concern about **the economic impact in the city centre**, since the scheme has received a lot of support from the business community, but the main concerns are **the impact on the fringe of the cordon.** The effect of the previous action when we extended the controlled parking zone shows **the great response of people trying to avoid the parking charge** by parking outside the controlled area and walk into city centre despite 15 minutes walking length."*
- In the city network, firstly there are two clear candidates for the cordon boundary which are the outer ring road and inner road.
- The outer ring road cordon is considered to cause a **major political acceptance problem** because many people living inside the cordon would be affected by the cordon.
- Therefore, the location of the cordon inside the inner ring road has been chosen subject to the completion of the inner ring road system.
- The **capacity of the inner ring road has been tested** by using traffic modelling in order to ensure the issue of diverted traffic.
- *"The cordon does cover the whole of the congested area in the central of the city. However, the **cordon does not address the congestion problem of the whole city**. But if we think of practicality of road user charging in Leeds that is what we cannot get at this stage."*
- From the previous statement, it is mentioned that there is a possibility of introducing an additional cordon in the future in which the second cordon could be located just inside the outer ring road and the potential third cordon could be located just inside the middle ring road of the city. It is also indicated that there is the possibility of moving up from this simple ALS system to a more complicated cordon charging system in the future.

- Apart from the issue of alternative routes, it is also necessary to **give people alternative travel modes**. There is a proposal for park and ride (P&R) which should concentrate on the inbound traffic from outside the cordon in which the improvement of the bus or rail service on major radial routes is considered.
- However, the idea of using P&R is not only considered for the area inside Leeds. The idea of improving park and ride is considered and discussed with other districts in the wider area looking at P&R in their areas that can be used and may be affected by the charging cordon.
- Different charging levels have been tested using a traffic model; the most appropriate level should **provide a significant reduction of traffic in centre area, significant revenues, and political acceptance.**
- It is strongly advised that the charging level would be a uniform charge throughout the day which is consistent with the idea of ALS.
- The detailed design of the cordon has to **minimise the crossing points**.
- The university area would be covered by the charging boundary despite **its location outside the inner ring road**. This is due **to the main concern about the dispersion of the parking problem at the boundary of the charging cordon**, and also the university area is considered as **the major trip attraction**.
- **Politically**, the hospital inside the central area must be outside the charging boundary. The location of the hospital is just inside the inner ring road. This political requirement causes the conflict with the location of the university area.

MANCHESTER

Characteristics

- There are nine districts in Greater Manchester district in which the geography of the area is considered as **a polycentric conurbation area**. Within the area there are ten local authorities. Around Manchester, there are major important towns with their own shopping centres including Stockport and Bolton. This causes a very **competitive situation for the city centre** of Manchester with other centres and also the retail shopping area outside the city centre.
- **Regional centre is Manchester city in which there are roughly 120,000 jobs in this area**. There are about **300,000 journeys/day to and from this area**. It is also considered as **the largest commercial centre outside London**.
- Manchester city is in **strange shape, long thin and rectangular**. The city is only about 2 miles from the neighbour local authority which is Salford.
- The rail and bus network for commuting traffic are under-used at the moment.
- The worst congestion area would be around he outer ring road whereas there are also some particular congestion areas in city centre.

Objective of the scheme

- The main objective is **regenerating the city**. Road user charging is considered as the traffic demand management measure that will be used to reduce and control travel demand in city centre.
- **Improving air-quality** is also considered as an objective of the scheme.

- Using **generated revenues** from road user charging is considered as the approach to **address the equity problem** ì¥Á 7 ø ¿ rI

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ôS ôS ôS 8 ,T „ scheme. However, it is accepted that **the effect on business development is very sensitive**.

- From the geography of Manchester city, **it is too difficult to find an appropriate cordon that is wholly inside Manchester city local authority**.
- From this fact, it is necessary that Greater Manchester have to come to an agreement in using congestion charging together. It would be very difficult if Manchester city tries to implement the road user-charging scheme alone.
- It is necessary to check the capacity of the alternative routes for the **potential diversion traffic**.
- It is indicated that a simple system that is just good enough to make this scheme work would be preferable than the more complicated system that needs to **rely on the high technology**.
- Similarly to the case in Edinburgh, **the trunk road network cannot be tolled**.

References

Dawson, J.A.L and Brown, F.N (1985) Electronic road pricing in Hong Kong 1: a fair way to go?. *Traffic Engineering and Control* **26(12)**.

Depuit, J. (1844), 'On the measurability of the utility of public works' in D.Murphy (ed.) *Transport* (1968), Penguin, London.

Dittmar H., Frick K. and Tannehill D. (1994) 'Institutional and Political Challenges in Implementing Congestion Pricing: Case Study of the San Francisco Bay Area' *Transport Research Board Special Report*, **242 volume 2**

Goodwin P.B. (1989). 'The rule of three – a possible solution to the political problem of competing objectives for road pricing', *Traffic Engineering and Control*, **30(10).**

GOL (2000) ' Road Charging Options for London, A technical Assessment (ROCOL)'.

Guiliano, G. (1992) 'An assessment of the political acceptability of congestion pricing, *Transportation*, **19 (4)**.

Holland, E.P. and Watson, P.L (1978) Traffic restraint in Singapore. 1. Measuring the effects of the Area License Scheme; and 2. Some design factors in traffic pricing schemes. *Traffic Engineering and Control* **19(1)**.

Hua, T.D. (1992). An evaluation of current practices in congestion pricing. *71st Annual Meeting of Transport Research Board*, Washington.

Harrison, B., et al. (1986) 'Electronic Road Pricing in Hong Kong: 3. Estimating and Evaluating the Effects' *Traffic Engineering and Control*, **27(1)**.

Ison, S. (1998) A concept in the right place at the wrong time: congestion metering in the city of Cambridge. *Transport Policy* **5**.

Jones, P.M. (1998) 'Urban road pricing: public acceptability and barriers to implementation' in Button K,J and Verhoef E.T (eds.) *Road Pricing, Traffic Congestion and the Environment*, Edward Elgar Publishing Limited, Glos

Langmyhr T (1997). 'Managing equity: the case of road pricing', *Transport Policy*, **4(1)**

Larsen O. and Ramjerdi F. (1991). *'Road pricing as a means of financing investment in transport infrastructure – the case of Oslo*', Institute of Transport Economics, Oslo.

Lewis, N.C. (1993). *Road Pricing: Theory and Practice*. Thomas Telford, London.

Luk, J.Y.K. (1999). Electronic road pricing in Singapore. *Road & Transport Research* **8(4)**.

May, A.D. (1975) 'Supplementary Licensing: An evaluation'. *Traffic Engineering and Control*, **16(4)**.

May, A.D. (1992) Road pricing: an international perspective. *Transportation* **19(4)**.

May A.D. (1994). 'Potential of Next-Generation Technology' *Transport Research Board Special Report*, **242 volume 2**

May, A.D., Coombe, D. and Travers, T. (1996) The London Congestion Charging Research Programme: 5 Assessment of the impacts. *Traffic Engineering and Control* **37(6)**.

Menon, A.P. (2000). ERP in Singapore – a perspective one year on. *Traffic Engineering and Control* **41(2)**.

Ministry of Transport (1964). *Road pricing – the technical and economic possibilities*. London, HMSO.

MVA consultant (1995) The London Congestion Charging Research Program Final Report Volume 1.

Neuenschwander R (2000) 'Optimal Design of Road Pricing Scheme', *Prima project, the European Union 4th framework programme*, http://www.certu.fr/internat/peuro/prima/prima.htm

Oldrige, B. (1990). Electronic road pricing: an answer to traffic congestion? *Proc. Information Technology and Traffic Management. London, NEDO.*

Pigou, A.C. (1920). *Wealth and Welfare*, Macmillan (London).

Ramjerdi, F. (1995) An evaluation of the impact of the Oslo toll scheme on travel behaviour, in *Road pricing and toll financing: with examples from Oslo and Stockholm*. Royal Institute of Technology, Department of Infrastructure and Planning, Stockholm.

Rom M. (1994). 'The Politics of Congestion Pricing' *Transport Research Board Special Report*, **242 volume 2**

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

Sheldon, R., M. Scott, and P. Jones (1993). 'London congestion charging: exploratory social research among London residents'. *Proc. of seminar F of the PTRC 21st Summer Annual Meeting*.

Shepherd, S.P., May, A.D. and Milne, D.S. (2001) The design of optimal road pricing cordons. *Proc. of the ninth world conference on transport research, Seoul, Korea.*

Small K.A. and Gomez-Ibañez J.A. (1998). 'Road pricing for congestion management: the transition from theory to policy'. in Button K,J and Verhoef E.T (eds.) *Road Pricing, Traffic Congestion and the Environment*, Edward Elgar Publishing Limited, Glos

Smith, M.J., May, A.D., Wisten, M.B., Van Vliet, D. and Ghali, M.O. (1994). A comparison of the network effects of four road-user charging systems. *Traffic Engineering and Control* **35(5)**.

Stenman, O.J. and Sterner, T. (1998). *Road pricing, traffic congestion and the environment*: chapter 7, What is the scope for environmental road pricing?. Edward Elgar (Cheltenham, UK).

Stoelhort, H.J. and Zandbergen, A.J. (1990). The development of a road pricing system in the Netherlands. *Traffic Engineering and Control* **31(2)**.

Sumalee A (2000). **"***Effect of demand variation on the location of optimal road pricing cordons"***,** MSc(Eng) Transportation and Engineering dissertation, Institute for Transport Studies, University of Leeds.

Sumalee A (2001). "*The review of practical design criteria for charging cordon"*, ITS working paper No. 4XX. Institute for Transport Studies, University of Leeds.

Transpotech (1985) Electronics Road Pricing Pilot Scheme prepared for the Hong Kong Government.

Verhoef, E.T., Nijkamp, P. and Rietveld, P. (1995). Second-Best Congestion Pricing: The Case of an Untolled Alternative. *Journal of Urban Economics* **40**.

Walters, A.A. (1961). 'The theory and measurement of private and social cost of highway congestion'. *Econometrica* **29(4)**.