Designing Efficient Local Road Pricing Schemes

TAG Unit 3.12.1

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Transport Analysis Guidance (TAG)

Contents

1 INTRODUCTION

1.1.1 This TAG Unit provides guidance on the design of local road pricing schemes. This covers location, price and periods of operation.

1.1.2 An overview of scheme design issues, including modelling and appraisal issues can be found in *Introduction to Modelling and Appraisal for Road Pricing* (TAG Unit 2.12). Further detailed guidance for analysts may be found in:

- *Modelling for Road Pricing* (TAG Unit 3.12.2), which provides advice on the modelling of road pricing schemes;
- *Appraisal of Road Pricing Schemes* (TAG Unit 3.12.3) which provides guidance on the issues arising when appraising road pricing schemes; and
- *Social and Distributional Impacts of Road Pricing Schemes* (TAG Unit 3.12.4) which provides guidance on how to assess the social and distributional impacts of road pricing schemes.

1.1.3 This unit represents the current state of knowledge. This is a rapidly developing area where we are likely to learn from further development in modelling and design approaches and also from the practical implementation of road pricing schemes. This unit will be revised and updated as further information becomes available or in light of any comments received during consultation and in the application of the unit.

1.1.4 This unit predominantly considers scheme design in terms of the structure and levels of charges, and the location of boundaries and cordons. Scheme design will in practice cover a much broader set of issues around the types of technology, the capital and operating costs, and complementary measures as road pricing will generally be part of a wider transport and economic package. All these elements are fundamental for a successful scheme. The emphasis here on the level and location of charges is that there is strong evidence that these matter. Getting the economic design right is crucial for a scheme to deliver good value for money. In practice this means real world benefits in terms of faster and more reliable journeys, improved economic performance and greater public acceptability and business support.

1.1.5 The analytical requirements in these Sections recognise that modelling resources will vary between promoters and that the development of models capable of modelling road pricing will take time. It is also recognised that in some cases, such as the network of a small town, road pricing may not be the most cost effective option for demand management. The core requirement is that an effective analysis of scheme design is undertaken, so that road pricing delivers good value for money. To make the initial analysis cost effective, allowance is made for option appraisal to be undertaken with a less than full suite of fit for purpose models, with appropriate level of detailed scheme design undertaken once the models have been developed. The initial analysis can be undertaken using standard transport data, such as information about the origins and destinations of trips. Most of the analysis that follows from this – focussing on the demand and supply conditions – can be undertaken using just a highway assignment model with elastic assignment to represent changes in demand backed up by survey information about the incidence of payment and the potential effect on at-risk groups.

1.1.6 For the full business case analysis the models will need to be fit for purpose and consistent with TAG Unit 3.12.2. It is recommended that the scheme design starts with an assessment of the optimal prices, which are adjusted to take account of public acceptability and technology and scheme costs, although analysts are able to use alternative approaches where a strong justification for this can be shown.

1.1.7 In much of the following guidance, design techniques will be more applicable to an area-based charge such as a cordon or area wide user charge. This is not because of a presumption that such a type of scheme will be developed. Rather, it is because a key initial design step is to determine the options for the location of a charge area. Whether the final scheme involves an area-based or a distance-based charge, the area of operation will be significant. It will help to determine scheme costs locating equipment and other infrastructure needed for operation, which trips are likely to be charged, any potential boundary impacts, etc. The results of the initial analysis will then focus on the location of a boundary or boundaries, where design issues are generic across different types of schemes. As the results from more research and evaluation becomes available, including for distance based charging, this will be incorporated into guidance.

1.1.8 Sections 2 and 3 set out the objectives and design options. Sections 4 to 8 set out the requirements for initial option selection covering approaches to scheme design; the relevance and need to measure marginal external congestion costs; the efficient charge level; road user differences; practical issues; and scheme costs. Section 9 covers detailed scheme design, refining options and choosing preferred options.

2 OBJECTIVES AND CONSTRAINTS

2.1 Introduction

2.1.1 Scheme objectives and constraints will determine scheme design and need to be clearly set out.

2.1.2 The main objectives will be a reduction in congestion and in most local road pricing schemes this will be through a significant reduction in traffic levels during the peak time in the central or most congested part of the area. A second objective may be the raising of net revenues over and above the operational costs of the scheme Reducing environmental costs could be a significant objective or a constraint on scheme design, in particular location. Distributional and equity issues will act as a constraint on scheme design as will local objectives or constraints.

2.2 Reduction in congestion

2.2.1 A reduction in congestion will provide time savings and improved journey reliability for road users and these will be the main benefits. Reducing the number of trips into a congested area through road pricing will lead to lower journey times for cars in the area. This impact may extend along entire routes, lessening congestion in areas which may not be covered by road pricing. Further, journey time changes and increased demand for public transport may result in increased frequencies with positive indirect impacts on all users of public transport. However, careful scheme design is needed to ensure that diversion does not increase journey times on non-priced routes that could offset time savings on routes that are priced.

2.3 Environmental objectives

2.3.1 The impact of road pricing on the environment can be complex. Reduced traffic flows at peak times will reduce emissions and other environmental costs. However, trips may be made at other times of the day so that total traffic reduction is less. Additionally, it is likely that schemes will induce re-routeing and this will affect environmental costs. For example, if traffic diverts from less populated areas to more populated areas environmental costs will increase and if traffic is diverted to longer routes environmental costs will increase. The overall impact will depend on the reduction in road traffic.

2.4 Social inclusion

2.4.1 Reducing flows of traffic using a demand management tool such as road pricing is likely to affect different social groups in a different manner. Scheme design will need to identify at-risk groups and consider how any negative impacts on these groups could be minimised or mitigated in line with accessibility objectives. This could be either through the design of the scheme, the use of any net revenues or through complementary transport improvements.

2.5 Local objectives

2.5.1 Local objectives need to be identified. Road pricing could affect accessibility to hospitals, schools, etc. and economically sensitive areas such as regeneration areas

2.6 Scheme efficiency

2.6.1 An overriding objective is scheme efficiency given objectives and constraints. Schemes with a positive net present value (NPV) will generally be high value for money and the level of NPV will depend on the other scheme objectives and constraints. Clearly there will be trade-offs between objectives. For instance, reductions in the level of road traffic will impact on revenues; inducing longer routes will impact on environmental costs.

2.6.2 It is recommended that objectives should not be set out in terms of specific targets for reduction in congestion or the raising of net revenues at the beginning of the process. The reason for this is that the extent of reduction in congestion and the amount of revenue should be established in the process of careful scheme design.

3 DESIGN OPTIONS

3.1 Introduction

3.1.1 There are many elements to scheme design. These are:

- Type of scheme - cordon, area or distance based;
- Location of boundaries;
- Level of price;
- Other elements including pricing by class of vehicle and time of day; exemptions and discounts; and enforcement and penalties.

3.1.2 The combinations of the various elements can give numerous possible schemes. Initial scheme design will necessarily focus on the first two elements of a scheme, identifying the type of scheme and the location of the area. This will help to determine scheme capital and operating costs, locating and quantifying the need for equipment and other infrastructure needed for operation, which trips are likely to be charged, any potential boundary impacts, etc. The pricing schedule in a scheme will be a third important component.

3.2 Types of scheme

3.2.1 There are various types of schemes that could be implemented. Cordons can be single or multiple, e.g. an inner and an outer cordon, with prices for entry and exit or entry only. With multiple cordons there could be differentiated prices or a single price irrespective of the number of cordon crossings. Area wide license schemes could also be single or multiple. Distance based schemes could be based on the type of road or the varying demand for routes or zones around central locations.

3.2.2 It may not be possible to model all of the different types of road pricing schemes. The level of complexity will be an issue ranging from a flat price single cordon to a multiple price distance based scheme and the ability to design each type will depend on modelling capability (see *Modelling for Road Pricing* (TAG Unit 3.12.2)).

3.2.3 It should also be noted that complex schemes are likely to be more expensive to implement and run and harder for travellers to use. There are trade-offs to be made and these will need to be considered at an early stage. For example, cordon based schemes may be easier for the public to understand and a flat price may be more acceptable to the public. However, targeting prices to take account of the location and time of congestion will improve the efficiency and benefits of scheme. Some flexibility may also be desirable as travel patterns will change over time and, consequently, the demand for road space will vary. A relatively fixed system may become inefficient over time.

3.2.4 Whilst it is expected that the type or types of scheme – cordon, area or distance based – is identified at an early stage, the scheme design options in terms of locations, prices, etc. should be formed from an analysis of demand and supply conditions.

3.3 Location of boundaries

3.3.1 The location of boundaries is an important component of scheme design, possibly the most important for cordon and area wide license schemes. An early indication of the options for boundaries would be needed because the significant equipment and other infrastructural costs will largely be determined by the location and operating costs are to some extent dependent on traffic flows. It is may be less of an issue for distance based schemes, where the boundary issues are less of a factor as the price is incurred along a greater part of a route. However, even in these circumstances, it is likely that an initial indication of where the distance-based charge will operate would greatly facilitate scheme design. The issue of location is developed further below.

3.4 Level of price

3.4.1 The level of price is clearly important in determining the efficiency of a scheme both because it acts to change road user behaviour and in terms of value for money. Careful scheme design will allow more informed decisions to be made about this trade-off. More details are given below.

3.5 Other components of the scheme design

3.5.1 The class of vehicle will determine, in part, the impact on congestion and the environment. This would suggest that, in an idealised road pricing scheme, prices should vary between classes of vehicle with those causing more congestion or environmental costs paying more. However, it could also have an impact on the cost and complexity of a scheme. If scheme promoters are proposing to vary prices according to vehicle class this should be based on evidence that this would improve the overall efficiency of a scheme. For example, discriminating between commuter traffic using cars and motorcycles may be justified by the lower congestion impact of motorcycles. Setting a lower price on environmentally friendly vehicles would be a response to an environmental objective but might lessen the impact on congestion.

3.5.2 When to price will depend on the level of congestion and the variability of the price will depend on the functionality and costs of the available technology. For instance, in most urban settings, congestion generally peaks in the morning commute period where arrival times are a constraint for many users. In addition there is likely to be an evening peak that is more spread out as arrival times are less important. On inter-urban roads traffic could be fairly constant throughout the working day.

3.5.3 Exemptions to road pricing schemes may be desirable to meet certain objectives or requirements. For instance exemptions might be given to certain classes of users such as emergency vehicles, the registered disabled or motorcycles, taxis and buses. Here there is a trade-off between efficiency and public acceptability. For motorcycles there may be also a recognition issue with some technologies or the difficulty of mounting on-board detection units. National guidance may be issued on exemptions. Whatever level of exemption is deemed reasonable the impact of exemptions should be included in any analysis when it proves significant. The number of exempted users and their patterns of road use will help in any analysis of the impact of exemption on the value for money of the scheme. For example, if exemptions mean that 10% of traffic is not priced the impact of this on scheme efficiency needs to be analysed. With area based license schemes there is the issue of residents within the zone and whether or not they would be eligible for any discount.

3.5.4 Each type of scheme will involve enforcement issues largely concerned with non payment of the charge. The local costs of enforcement need to be added to scheme implementation and running costs in the assessment of value for money.

4 INITIAL OPTION SELECTION

4.1 Introduction

4.1.1 A lot of research has been undertaken about efficient scheme designs and the methods used have been broadly categorised into judgmental, benefit maximising (‘first best’) and second best. Judgmental and second best are tools to help in the scheme design. As part of this process, the benefit maximising design gives some initial benchmark against which schemes can be compared and is a useful tool for analysis, as well as being a good starting point for scheme design.

4.2 Judgmental design

4.2.1 Scheme design will be an iterative process, combining data analysis and modelling work, with expertise from those involved in implementing the road pricing scheme. It is likely that some early analysis, using readily available quantitative and qualitative information, will help to identify possible areas to be covered by road pricing. Such judgemental design may be based on assumptions about acceptable locations, such as a natural boundary or recognisable boundaries like a ring road. Identifying initial options for the area to be covered by a scheme would provide important information for costing the infrastructure for a road pricing schemes. Experience has shown that designing schemes on the basis of judgment and natural boundaries is only likely to provide positive change in social surplus by chance. This section suggests some straightforward analyses that can be used to sift proposed charge areas.

4.2.2 Initial analysis will follow the same structure as general scheme appraisal, starting by identifying the congestion problem faced by the area to be charged. This will involve estimating the peak flow of traffic into the area and the associated congestion. Most scheme designers would have ‘congestion maps’ available to them, highlighting which roads are close to capacity. They may also have marginal external cost maps (described later). In some circumstances, it will be possible to model the benefits maximising prices (see later) which will estimate the level of traffic flows along links when an efficient road pricing scheme is in operation. It is useful for scheme designers to use evidence to identify what level of flow may be associated with successful lowering of congestion. As noted earlier, it is unlikely that a precise estimate for a particular area is possible without modelling.

4.2.3 The judgemental approach in scheme design would focus on analysing charge areas. For a suitable range of options the pattern of trip origin/destinations, focussing primarily on the most congested times of day, should be analysed. As this analysis will primarily identify an area for charging, it would be easiest to assume a cordon or area wide user charge will circle an area of congestion, most likely the business centre. A selection of potential areas may be identified varying the size covered by the charge. Where an option involves multiple areas, analysis should be undertaken on individual areas and on the areas combined.

4.2.4 It is often suggested that there is a good case for allowing alternative routes, such as locating cordons within ring roads. Such an alternative route will allow journeys which do not start or end in the congested areas to avoid being charged. This would only be of benefit if the ring road is less congested than the area within. Alternatively administrative or natural boundaries may provide a boundary for a possible option. At this stage, it would be best to provide a selection of diverse options to ensure that the data analysis can be generalised to a range of schemes.

4.2.5 Origin-destination datasets covering an area sufficiently large to include a high proportion of trips into the charge area are ordinarily available to scheme designers. Such data, combined with information on the modal split of journeys, would provide some high-level indications of the flows of traffic that would be affected by a proposed charge area. Given the charge area to be analysed, origin-destination information can be used to identify the number of trips according to a range of disaggregations, such as journey purpose and time of day.

4.2.6 However, a second set of analyses should be undertaken taking into account the proposed charge area. A useful disaggregation is whether none, one or both trip ends are in the proposed area. A further analysis would focus on trips that do enter the charge area, identifying how far into the charge area their routes go, because trips that end close to the boundary would be more likely to avoid the charge area by stopping short of the charge area. Analysis of the other end of these trips will indicate which radial routes or corridors into the congested area are used by these trips.

4.2.7 The second category of analysis should provide a particularly useful set of breakdowns quantifying the extent to which traffic would pass through a charge area screen-line. In the busiest times, such as the AM peak, those trips where only the destination end is in the area would be affected by the charge. The behaviour of these travellers would reflect the charge of the road pricing scheme. For trips where both ends are in the proposed charge area, this incentive would be more blunted. If the scheme is a cordon, such a trip would be unaffected by road pricing as no charge would be incurred. In an area wide congestion charge, the scheme designer might also consider whether such a trip would be allowed some resident discount. For a trip with no trip end in the charge area, the effect of road pricing can be to deter the journey crossing through the area, with it re-routed around the charge area, if such a route is available. Using this breakdown, the scheme designer will provide an early analysis of the level of traffic that may or may not be affected by the charge area. It would then be possible to combine this information with some assumptions about likely behaviour to give an indication of whether the area option under consideration could reduce traffic sufficiently to reduce congestion.

4.2.8 The origin-destination information may be improved by other commonly available datasets. In the busiest times, it would be possible to analyse information on trip destinations. For example, in the AM peak, the location of employment is likely to be the determinant of a significant proportion of destinations predicting the number of journeys into congested areas. Other information may be available for likely destinations, such as places of education possibly from work on accessibility planning, to provide the density of trip destinations in the scheme area.

4.2.9 The important result from such a high level analysis is that the number of trips likely to be deterred by a charge will be identified for a range of charge areas. In an area-based charge, the boundary of the area is the determinant of whether a trip will be charged.

Some general results can be given. A charge area that is small is likely to have trips ending short of the charge area. This would mean the decision to travel would be unaffected by the charge for a large number of trips and the effect on congestion of the road pricing may be low. Similarly, an area that is very large may not affect enough trips that are destined for a central congested area. The effect may be to reduce trips, but find that these trips did not contribute significantly to the congestion problem in the area.

4.2.10 It should be noted that a careful initial analysis replicates some of the steps in the 'select link analysis' that is described below. That approach automates the processes that are described here and so offers a faster and more robust means to undertake this initial option sifting and provide designs that better meet the efficiency objective. The main advantage of the judgemental approach is that it allows an intuitive analysis of the most commonly used transport dataset, namely the origin-destination patterns. While the analysis will not be as robust, it will highlight the geography of congestion in a local area, possibly involving a wider range of the scheme design team. It may also indicate any data shortcomings or other analytical issues which may be corrected at this early stage in scheme design. However, it needs to be recognised that this approach alone, will have efficiency, in terms of value for money, as a by-product rather than an objective and could not guarantee the design of a successful scheme. The following sections set out how initial judgemental designs can be significantly improved on with the aim of meeting the objective set out above.

4.3 Gross benefit maximising prices

4.3.1 The economic term 'first best' is the application of prices that equilibrate the marginal benefits or willingness to pay to travel (in terms of time and money) with the marginal social costs. The marginal social costs of a trip include the marginal private resource costs incurred by a road user and those that the user imposes on others by slowing down traffic (marginal external congestion costs) or increasing noise and pollution levels (marginal external environmental costs). When the marginal benefits equal only the private costs there will be a loss of gross benefits as a result of excess demand. For example, at uncongested periods with free flow speeds marginal external congestion costs would be zero. In congested periods the external costs that an additional vehicle travelling one kilometre at the candidate time of day on the candidate network imposes on all users would not be zero – the marginal external congestion costs is then additive to the private costs. However, road users do not take account of the external costs when making a decision to drive or not. As a result, in times of peak road use, there would be excess demand for road space as decisions are made with regard to the level of private or generalised cost only.

4.3.2 Road pricing provides a means to internalise these external costs to enable road users to make more efficient decisions. To maximise benefits, prices can be applied that exactly match these external costs at the point where demand equals marginal external costs plus generalised costs. It is important to note the external costs with road pricing in place will be lower than the external costs before road pricing is introduced.

4.3.3 Full efficiency would require prices to vary by each link, by class of vehicle, and by any other variable that had an impact on the travel time of all other users (and that all congested roads have road pricing).

4.3.4 Clearly this would be complex to impose and, though it maximises the benefits of the road pricing scheme for society, it could conflict with other objectives. For example, the scheme costs could be much higher than alternatives, which do no not have as high user benefits. Nevertheless, in modelling this scenario, it does provide a useful benchmark against which to gauge schemes options that by necessity will result in lower gross benefits (the sum of changes in time savings, user charges, scheme revenues, tax revenues and any other monetised costs except scheme costs). It will be explained below why this is an important part of the analysis in scheme design.

4.3.5 A ‘first best’ analysis provides the backdrop against which to design scheme options that take account the objectives and constraints.

4.4 Second best

4.4.1 Second best takes account of scheme objectives and constraints and attempts to maximise benefits given these. To some extent, scheme designers may be able to start from the optimal, benefit maximising scenario. However, the location of the scheme, times of operation and prices will differ from this recognising that other objectives in scheme design will also have to be taken into account.

4.4.2 The location of a second best scheme will diverge from the benefit maximising scenario because the charging area covers only part of the network. There will be some roads that are priced and some that are not. In the case of first best all links would be priced and any re-routeing would maximise the benefits of using road space (this is a system optimum). If benefit maximising prices were applied only to a subset of links, excessive re-routeing to non-priced roads could reduce the benefits. The second best price factors down the first best price to optimise the net benefits of differently priced routes. In other words it is a first best price less an amount to minimise the impact of distortions elsewhere.

4.4.3 In summary, this section has considered the role of first stage analysis and benefit maximising ('first best') analysis in developing a practical 'second best' road pricing scheme design. The first stage sift of information may give a good steer on where to locate the charging area. The optimal, 'first best' analysis will help to refine the location of the charging area. The 'first best' prices estimated will enable the analyst to select appropriate practical 'second best' prices. The practical constraints incorporated in the 'second best' analysis will result in 'second best' prices that are lower than 'first best'.

5 ANALYSING THE MARGINAL COSTS OF CONGESTION

5.1 Introduction

5.1.1 Marginal external costs are the costs that an additional vehicle travelling one kilometre at the candidate time of day on the candidate network imposes on all users. Such costs could be calculated using the marginal external congestion costs (MECC) which are based only on the time delays imposed on all other users; or the Marginal Social Costs (MSC) which include a wider range of the external costs, such as environmental externalities. The annex to this unit provides more detail about the definition of the first, which has the advantage of being relatively straightforward to calculate. In the annex to the WebTAG unit 3.12.2, *Modelling for Road Pricing*, there is a detailed description of the marginal social cost pricing method, where road pricing reflects the full marginal external costs of an additional vehicle, including environmental and other non-congestion external costs.

5.1.2 The calculated marginal external costs – whether the marginal external congestion costs (MECCs) or using prices based on marginal social costs – will depend significantly on whether or not road pricing has been modelled on the network. Where there is no road pricing, the levels of traffic and associated external costs would, at the margin, be higher. As road pricing is applied, the traffic flows should decrease lowering the marginal external costs, reflecting the reduced congestion. In the following discussion it is assumed that some optimisation has been applied to deliver marginal external costs which reflect the operation of a road pricing scheme. It is recognised that this may be impractical for some models and a first analysis may use marginal external costs without any road pricing assumed. Scheme designers are encouraged to discuss with the Department results from such analysis and possible further steps towards an optimal marginal external cost analysis.

5.1.3 A first stage of the modelling is the estimation of the marginal external costs by link and by time of day after taking account of network effects. Estimation of marginal external costs is important for several reasons. Firstly, they serve as status indicators that describe the current state and trends of congestion. Secondly, changes in marginal external costs provide the basis for cost-benefit analysis that assesses whether individual projects and programs are worthwhile investments. Finally, and possibly most importantly, obtaining accurate marginal external costs is crucial for designing efficient pricing schemes.

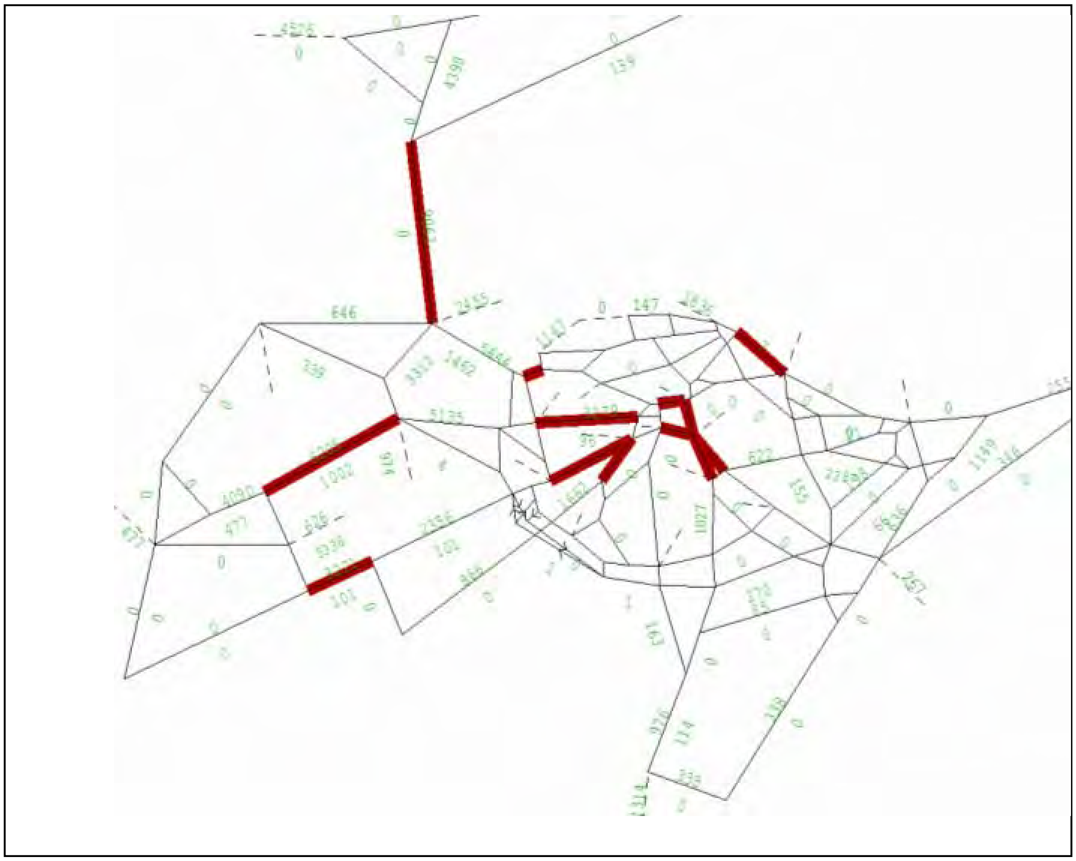
5.1.4 Marginal external costs will depend on route choices, feasible alternatives, flexibility in arrival times, perceived costs of all of the choices, journey purpose and willingness to pay or demand for the trip. The perceived costs (or disutility of travel) will depend on values of time and other personal attributes of users of the route. This means that good quality data is needed, not just on the network and levels of service but on the personal attributes of road users.

5.1.5 To get good estimates of marginal external costs a high level of demand segmentation is desirable but there is a trade-off between segmentation and run times and available resources. Even if there is limited segmentation it is essential that a range of willingness to pay by income is represented. Further information on minimum requirements is given in *Modelling Road Pricing* (TAG Unit 3.12.2).

5.1.6 If modelling capacity is limited at the outset of a study, the estimation of marginal external costs can be undertaken using a highway assignment model. A method for calculating marginal external costs which focuses on the congestions costs over the network is set out in Annex A of this TAG Unit.

5.1.7 A useful way of presenting marginal external costs is via maps that show the marginal external costs for each link. In the first place this could be done at a strategic level by concentrating on the most congested routes/links.

5.1.8 Figure 1 below shows an example of an analysis of a simplified network. This was undertaken using the SATURN facility for identifying system optimal charges and shows in bold the top fifteen links with the highest marginal external congestion costs (MECC). Whilst these are MECCs equal to first best charges similar analysis can be applied using MECCs in the absence of pricing. The diagram shows that the main congestion is on the radial approaches to the centre except for one orbital route to the east and one river crossing to the north.



5.1.9 If it is the case that initial modelling capability rules out this type of analysis it should be possible to do a common link analysis. On many routes road users may not be able to avoid certain links if they are to make the trip at minimum cost. These common links are likely to be the most congested and identification of these common links and the level of congestion throughout the day would a useful starting point in any analysis. This could be done by simply comparing demand with capacity on major links and selecting those with the highest ratios.

5.2 Using select link analysis in cordon design

5.2.1 The marginal external costs analysis will show which links are highly congested. For cordons and area based license schemes the analysis described in this section will provide a perimeter for the charge area. The method has been developed by the Institute of Transport Studies, University of Leeds that combines this with flows to aid the design of efficient cordon locations using select link analysis.

5.2.2 Select link analysis is an aid to designing an efficient closed pricing cordon by looking at the proportion of flows on "high cost" links which are potentially caught by a charge area. The technique currently assumes that the charge area will be managed as a cordon scheme. However, with the technique locating a charge area, it should offer significant insights for an area-based license scheme.

5.2.3 The approach addresses the problem that, whilst congestion *tends* to get heavier as you approach urban centres, network topology also exerts an influence on the location of congestion. Consequently, trying to draw cordons that connect or contain the top X most congested links (regardless of whether they are the top 10, 20 or 100), is often not possible - the congestion may be heaviest at 2 or 3 non-contiguous places across the network. The select link analysis approach allows you to design the cordon to capture a large proportion of the traffic that uses these links with a single scheme without necessarily having to price these trips *on* the most congested links. Think of it as 'remote pricing'. The rationale is that it is not necessary to include the top links in a cordon but it is important to cover as much as possible of the path flows from those links by the cordon. The hypothesis is that the higher the proportion included is, the greater the gross benefit from the cordon will be.

5.2.4 This method can be used with all assignment models. For the location of boundaries and level of charge for cordons and area license schemes the important issue is the relative levels of marginal costs on each link. Excepting for scale, these relative differences should be the same however marginal costs are estimated. Thus the most congested links can be identified using MECCs in the absence of pricing as in Annex A to this TAG Unit, or MECC based prices if the model has a system optimisation facility or using the more comprehensive marginal social cost approach set out in the annex to *Modelling Road Pricing* (TAG Unit 3.12.2). Cordon or area license prices will, by necessity, be averages of the link based prices and the estimation of optimal average prices will determined by the location of the boundaries (see Section 6). However, where various options are to be tested covering distance based charges it is recommended that the MECC approach detailed in Annex A is used (see Section 5.3 below).

5.2.5 The approach is to carry out a select link analysis for a limited number of links with the highest marginal costs or marginal cost based prices. The select link analysis shows where flows using the selected links come from and go to through the rest of the network. These flows may be used to help locate cordons. A calculation of the proportion of flow on the selected links that is "caught" by the cordon provides a measure of the effectiveness of the cordon.

5.2.6 The steps in the process can be summarised as follows-

1. Either estimate marginal external congestion costs or estimate marginal social cost based prices .
2. Select the top X links by price or congestion cost level.
3. Perform a select link analysis on these links to show the paths through the network used by the traffic on the selected links.
4. Draw a cordon (or set of cordons) that "catches" a high proportion of the flows from the selected links.
5. Optimise the uniform charge level for the selected cordons (see Section 6 below).
6. Calculate the proportion of flows on the selected links that are captured by the cordon.
7. Adjust the cordon(s) identified in step 4 to maximise the proportion of flows on the selected links that are captured by the cordon.
8. Re-optimise the uniform charge level for the selected cordons (see Section 6 below) and compare gross benefits.

5.2.7 This approach combines analysis with the judgement required to take account of the objectives and constraints.

5.3 Application to distance based charges

5.3.1 The above analysis is generally applicable to whatever type of scheme is proposed. For example, for distance based charging it will provide information about marginal external costs that would be vital in considering the appropriate average distance based charges. The level of averaging will depend on public acceptability, the type of distance based scheme in consideration and modelling capability.

5.3.2 When local distance based charges are being considered it is recommended that the MECC approach detailed in Annex A is used. This is because the network effects arising from route and mode choice need to be taken into account to ensure that the appropriate costs are estimated (estimating link costs in isolation may over or underestimate true costs where only a sub-set of links are priced). Also, the use of the MECC approach means that the main external costs will be estimated without the need to take account of fuel duty and other differences between resource costs and perceived costs. Whilst these are important in estimating the optimal link based charge the MECC approach should result in similar prices that would provide a good basis for choosing average prices. The efficiency of the average prices can be examined by calculating the change in gross benefits.

5.4 Additional analyses

5.4.1 It should be possible to use the same approach to address environmental problems. This would entail capturing flows that added most to environmental costs.

5.4.1 For cordons where there is a significant amount of through traffic and there are alternative unpriced routes that are close substitutes, demand within the cordon will fall as a result of less terminating traffic and through traffic re-routing. If some of these alternative routes have similar or higher levels of congestion than the levels of congestion within the cordon before pricing, then there could be a significant fall in overall time savings.

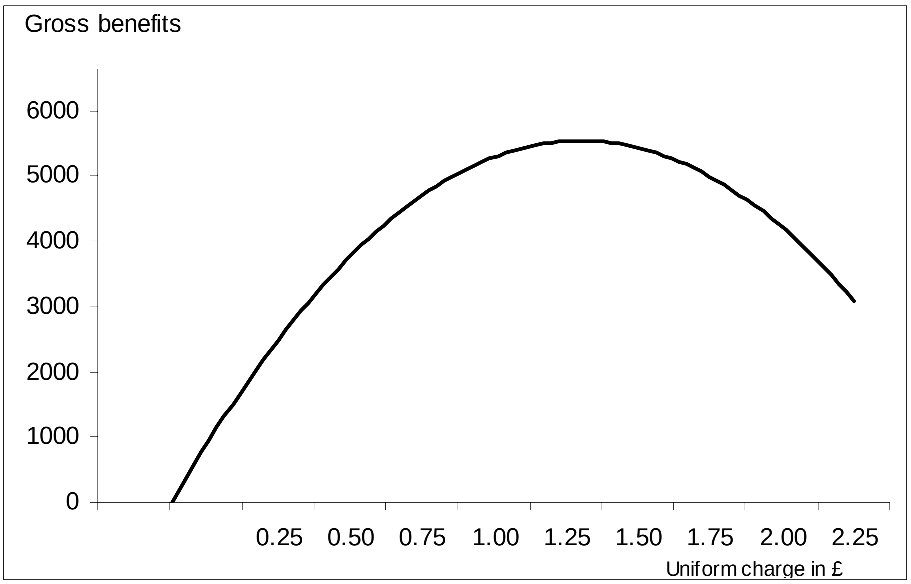
5.4.2 The potential for rerouting could be analysed by using the methods above or by setting a price on links with high marginal external costs equal to the ex-post MECC. This could be assumed to be two thirds of the ex-ante MECC and would give a good indication of the likely levels of rerouting.

5.4.3 It could be that for some routes where there is a high proportion of users with high values of time there is less rerouting and for other routes where there is a high proportion of users with low values of time there is more rerouting.

5.4.4 The analysis above gives a lot of information about the demand for and supply of the network. It is critically dependent on the behaviour of road users and, as such, the level of segmentation that accurately portrays road user characteristics. It will show the level of rerouting that is possible and the consequences of pricing on some routes while leaving alternative routes non-priced.

6 LEVEL OF CHARGE

6.1.1 For all schemes the level of charge will be critical in delivering benefits and revenues. For cordons the charge that delivers the highest gross benefits ((the sum of changes in time savings, user charges, scheme revenues, tax revenues and any other monetised benefits except scheme costs) can be identified by looking at different charging levels and the resulting gross benefits For example, nine different levels of cordon charge could be used. Illustrative results for such an exercise are shown below.



6.1.2 It can be seen the gross benefits rise as the charges are increased, reach a peak at £1.25 in this hypothetical example then tail off as the charge is increased further. At the optimal level of charge, time savings and the difference between user charges and revenues are maximised. Either side of the optimal charge, the time savings will fall faster than the difference between user charges and revenues. At the extreme if charges are high enough to bring traffic levels down to free flow speeds any increase in charges would make gross benefits negative as there would be no offsetting time savings.

6.1.3 This analysis will show how much benefit is foregone by adopting charges that are lower than or higher than the optimum. There may be trade-off between economic efficiency and public acceptability and any incentive to maximise revenues.

6.1.4 For distance based charges a similar approach can be adopted except that the comparison will be between options with different levels of charges. Similar analysis might consider the trade-offs between overall benefits and the variability of charges for different times and locations.

7 PRACTICAL ISSUES AND OTHER CONSIDERATIONS

7.1.1 There are a number of practical issues that will affect scheme design. These include: impact on different users; scheme design where road pricing is part of a package, local authority boundary issues; economically sensitive areas; and Highway Agency Roads

7.2 Different user groups

7.2.1 The impact on different groups of users will affect scheme design and public acceptability. Details on the importance of income and the need for segmentation by this and journey purpose are given in *Modelling for Road Pricing* (TAG Unit 3.12.2). The geographical location of any pricing scheme and the type of traffic could have different effects on different wards or location within and without boundaries, and there will be distributional and equity analyses that need to be made. Details of how to analyse these impacts are given in *Appraisal of Road Pricing Options* (TAG Unit 3.12.3) and in *Social and Distributional Impacts of Road Pricing Schemes* (TAG Unit 3.12.4).

7.3 Road pricing as part of a package

7.3.1 Road pricing will generally be part of a wider package of transport and economic measures, and many of these complementary measures may be designed to provide better transport opportunities for groups affected by road pricing. The use of net revenues may also be an important factor in improving the public acceptability and economic impact of pricing schemes.

7.3.2 All these factors will need to be taken into account in the scheme design, and will be highly dependent upon the local circumstances of the scheme. In order to do this the starting point is having the required information on the optimal pricing structures and the distributional implications of the scheme. There will then need to be process of require testing the performance of the overall package with a range of complementary measures, combined with judgements on public acceptability and scenarios on how revenues may be used to maximise the impact and support for the scheme.

7.4 Local authority boundaries

7.4.1 Scheme design will cover the core network and the hinterland. In many cases the area to be charged could be covered by more than one local authority or different tiers of local government.

7.5 Economically sensitive areas

7.5.1 The objectives of efficient scheme design and the development of economically sensitive areas could well conflict. Regeneration areas are closely tied to accessibility that could be affected by a road pricing scheme.

7.6 Highway Agency Roads

7.6.1 It is likely that in some schemes the pricing area will cover or impact upon the strategic road network. The close involvement of the Highways Agency in the development of any proposals will be important to avoid conflicts of objectives.

8 SCHEME COSTS

8.1 Introduction

8.1.2 Scheme design should reflect congestion costs and distributional concerns but financial viability will be an issue and this is clearly linked to value for money. The choice of scheme technology and the costs (capital and operating) will have an impact on scheme design in two ways. The technology will determine how variable the prices can be and, thus, the efficiency of the scheme, while the costs will affect the size of the scheme and the level of net benefits. The most efficient scheme may not be the one with the highest benefits or the best value for money, as cheaper schemes may offer greater net benefits. This would indicate that there should be some flexibility in scheme design and it will be important to estimate the costs of alternative designs. Separate advice on the costs of alternative scheme technologies is also being prepared by the Department and scheme developers should talk to the Department about this issue.

8.2 Period of operation

8.2.1 Financial viability or cost recovery will depend on the period of operation and traffic volumes. Schemes could operate all day or for part of the day. In some situations the operating costs might outweigh the revenues. If the period of operation is short, for example the am peak only, the operating costs could be significant and, with small schemes, outweigh the revenues. Consequently, the technology costs are a determinant of the size of the scheme. Scheme developers should talk to the Department about this issue.

8.3 Contingent benefits

8.3.1 It is recognised that there could be contingent benefits from the adoption of technologies that accelerate the take-up of road pricing, though this will be an issue for the Department to judge.

9 DETAILED SCHEME DESIGN

9.1.1 The initial analysis described above will be useful for clarifying the problem, where and when congestion is highest, the potential for rerouting and the transfer of congestion, and the location of at-risk groups. Options for location, charges and time of operation for the type of scheme chosen can be identified but the modelling tools used for the initial option selection may not allow for a sufficiently detailed analysis of demand responses or for sufficient heterogeneity in response. Analysis of demand responses is critical for the selection of options and to help in deciding where complementary measures would best perform either to mitigate adverse affects on some groups or enhance the benefits overall.

9.1.2 Therefore a further level of detailed scheme design will need to be undertaken. In order to move towards a firmer consideration of the options a minimum requirement will be a properly constructed, fully developed and fit for purpose four of five stage transport model that is sufficiently segmented.

9.1.3 The use of fit for purpose models is the only way that scheme options be appraised. robustly. This will identify which of the initial options are worth pursuing and which options could be improved or adjusted to increase gross benefits or to minimise conflicting objectives that may not be apparent using less well defined models. For example, the use of a highway assignment model with elastic demand will not be able to identify the various different demand responses that will depend on the availability of choices and personal preferences, except in a very aggregate sense, and these will impact on scheme design.

9.1.4 For cordons, methods are being developed for selecting and combining links that will provide efficient locations and charges that take account of objectives and constraints. This is done by maximising net benefits depending on the objective function using a combination of links. These combinations are based on the concept of genetic algorithms that have been tested on coarse networks with single user classes. These should enable efficient cordon designs to be made that incorporate objectives and constraints and allow for more efficient judgments to be made. This methodology has yet to be applied to networks with finer zones and multiple user classes.

9.1.5 In the meantime best practice in scheme design should incorporate the analysis identified above, using fit for purpose models, but recognising that an element of judgement will be necessary in designing second best schemes.

9.1.6 As discussed above, a first best solution provides a useful benchmark against which to judge the benefits of second best schemes. *Modelling for Road Pricing* (TAG Unit 3.12.2) outlines how existing modelling tools may be modified to enable the identification of first best prices. For some modelling packages, the model user may be able to make these modifications, but for others it may be necessary to seek the assistance of the package owner.

9.1.7 A second best solution may be obtained by using the initial analysis of flows and congestion costs to identify areas that capture a number of highly congested links and most of the terminating flows of the congested links that are outside any priced area. Modelling and appraisal will show how travellers will respond to the options, enabling the selection of preferred options that fit best with the scheme objectives and refinements to be made to these options to reduce undesirable responses.

9.1.8 The analysis of marginal external costs and flows should enable a range of locations and prices to be identified for testing. Whether a distance based, cordon, or link based scheme is being considered, the principle of setting a price based on the MECC at the outset should be preserved. Where system optimisation is not available choosing a price that is around two thirds of the estimated ex ante MECC based on income segmented demand can be used to direct analyses of welfare benefits in the search of the best location and price. The subsequent averaging of link prices will depend on public acceptability and modelling capability in terms of testing for value for money. For cordons and area wide pricing this would not be a problem as, unless there are multiple cordons, it is likely that a flat price or stepped price would be appropriate. For distance based prices, testable variations may depend on how much variation in marginal congestion cost there is.

9.1.9 The preferred options should be developed from the initial options that can be developed using assignment models for a first sift, where more complex models are not available. If this analysis shows that road pricing is an efficient means of traffic management, and this will depend heavily on the size of the scheme and the levels of congestion, this would provide the incentive to develop fit for purpose models. Where close to fit for purpose models are available, noting the requirements in *Modelling for Road Pricing* (TAG Unit 3.12.2), the initial analysis can be undertaken at a more detailed level though for initial sifting some of the stages such as trip generation and destination (and time of day choice) can be switched off to improve run times allowing more options to be tested.

9.1.10 One of the main benefits of going through the above procedures is that efficient schemes will be designed that have the appraisal process explicitly incorporated in the design stages. If followed, the result of the value for money appraisal that follows the guidance in *Appraisal of Road Pricing Schemes* (TAG Unit 3.12.3) should not be a surprise.

10 FURTHER INFORMATION

Technical queries and comments on this TAG Unit should be referred to:

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11 REFERENCES

12 DOCUMENT PROVENANCE

TAG Unit 3.12.1 is a new Unit

ANNEX A ESTIMATING MARGINAL EXTERNAL CONGESTION COSTS

A.1.1 In order to account for the interaction between traffic congestion on different links on the network, one has to perform a new traffic assignment and compute marginal external congestion costs on links resulting from changes in speeds on the entire network. This is done by decreasing or increasing the demand for travel between all origin-destination pairs by the same small percentage, one that will not be lost in the assignment process e.g. 5 per cent and run the highway assignment model with the new initial demand. Then, the marginal congestion costs on link k can be computed as follows:

$$MECC_k = \sum_s \frac{(t_{ks1} - t_{ks0})VOT_s(q_{ks0} + q_{ks1})}{2(q_{ks1} - q_{ks0})}$$

where t_{ks} is the travel time for demand segment s on link k, q_{ks} is the flow in demand segment s on link k, VOT_s is the value of time for demand segment s, and subscripts 0 and 1 denote initial and resulting traffic assignments. To convert into marginal external costs per kilometre these costs will need to be divided by link length.

A.1.2 This formula provides values for the aggregate marginal congestion cost, built up from the marginal congestion cost for each segment of demand. In principle, separate marginal congestion costs could be determined for each segment of demand. However, practical road prices can only be segmented very coarsely – by vehicle type, for example – so there is little to be gained from having marginal congestion costs for each segment in the model.

A.1.3 An important advantage of this method is that it accounts for the interaction of the speeds and traffic flows on the network. It also ensures that the estimated marginal congestion costs reflect variations by location according to income levels and the mix of journey purposes. In fact, it accounts for all the network effects and is very cost-effective since obtaining a full set of marginal congestion costs using this method requires only two model runs.

A.1.4 It is important to note that this method will provide the marginal external congestion cost *in the absence of pricing.* If pricing is introduced, the traffic flows should decease, leading to a reduction in marginal external congestion costs. If prices equal to marginal external congestion costs are required, an iterative procedure will be required to estimate the traffic levels and prices that represent an equilibrium. Annex B in

Modelling Road Pricing (TAG Unit 3.12.2) presents two techniques that have been applied in the Department's National Transport Model to address this problem.