Annex B
Modelling Results and Analysis

Summary

B.1 A number of models have been used to forecast the impact of different pricing schemes on transport outcomes. The models differ in their coverage, as well as in the potential responses that are captured, such as car-sharing and changes in time of travel.

B.2 The scenarios that have been modelled are explicitly not proposals for introduction. In particular, the prices that have been modelled have been selected solely to illustrate the potential impacts and transport outcomes from different types of schemes and charges. In the time of this study it has not been possible to refine all the modelling to produce optimum charges. Some of the results show just how important – and difficult – it is to get the structure and levels of charges right, properly reflecting local circumstances. Charge levels shown by the models are sensitive to the assumptions made.

B.3 There is thus much uncertainty around the results, and it would be misleading to place too much weight on the charges and benefits shown. More confidence can be placed in the relative outcomes of the different schemes modelled than in the absolute numbers. Further work would be needed to assess pricing levels and structures in local areas before robust prices could be put on individual journeys.

B.4 Road users impose a series of external costs on other road users and on the environment. Congestion is estimated to have accounted for around three quarters of marginal social costs in 2000 and this is forecast to increase over time. Environment and safety costs make up the remainder. To capture fully the benefits from road pricing therefore requires a system where charges can be set according to the level of congestion.

B.5 Pricing schemes that try to target marginal social costs could deliver very substantial benefits, largely from reduced congestion. The modelling has identified potential timesaving benefits to society of up to £10 billion per year. Significant benefits accrue to motorists and other road users in the form of time savings.

B.6 The modelling suggests that pricing would lead to only a limited amount of modal shift. The national modelling suggests car drivers are more likely to become car passengers (i.e. car share) than use alternative modes. The local modelling has shown that re-routeing could be a significant response if the scheme was designed without care to avoid unwanted diversion.

B.7 Targeted road pricing could significantly reduce emissions of local pollutants in urban areas as traffic is reduced. It could also significantly reduce CO_2 emissions, but this impact is more dependent on the level rather than the structure of charges and taxes.

B.8 Any well targeted pricing scheme would inevitably involve some journeys costing more, others less. The modelling has not looked at the range of alternative uses of revenue, which could be used to compensate those facing the higher prices, such as investment in public transport or additional road capacity. Unsurprisingly, charges are higher where congestion is heavier, notably for commuting traffic in urban areas, and lower on quiet roads, notably in the countryside.

B.9 A simple revenue neutral version of marginal social cost pricing has been modelled by reducing fuel duty to a point at which the overall revenues from charging and fuel duty would be roughly equal to the amount otherwise raised by fuel duty alone. This delivers significant benefits – congestion could be reduced by around 40 per cent. This shows that it is the structure of charges, rather than the level, which is important in terms of influencing behaviour.

B.10 An increase in fuel duty to produce broadly the same amount of revenue as revenue-raising marginal social cost pricing would reduce congestion by around a fifth of the reduction with marginal social cost pricing. This reinforces the conclusion that the pricing structure is key to reducing congestion.

B.11 The local modelling has shown that more widespread cordon charging would lead to overall benefits, however, these are generally small in relation to the potential benefits from distance charging, because they are not able to target congestion so precisely.

Discussion of modelling approaches

Introduction

B.12 The analysis of the potential impacts of road pricing has drawn on the results from a number of different models. These models differ in their focus and coverage. For example, the Department's National Transport Model (discussed in paragraph B.15 below) is a strategic, multi-modal transport model, which is representative at a national level. The local models focus on one particular area of the country and are based on detailed geographical information.

B.13 The modelling results provide valuable information on the likely responses to different road pricing schemes and the potential impacts. However, it is not possible for any single model to fully capture all of the impacts and the limited empirical evidence on pricing schemes means that there is a range of uncertainty around all of the forecast results presented below. Much more analysis would need to be undertaken prior to introduction of any scheme at either a local or national level. In addition, the study has not assessed the various options for how any revenues raised through pricing could be used (other than through returning it to road users via a fuel duty reduction) which is crucial in determining the overall impacts.

B.14 The range of pricing schemes modelled are explicitly not proposals for introduction. In particular, the prices that have been modelled have been selected solely to illustrate the potential impacts and transport outcomes from different types of schemes and charges.

National Transport Model

B.15 In order to analyse the impacts of different policies at a national level, the study has drawn extensively on the Department for Transport's National Transport Model. This is a multi-modal transport model which covers six modes of transport: car driver, car passenger, rail, bus, walk and cycle. The modelling results all refer to Great Britain unless otherwise stated.

B.16 The National Transport Model (NTM) is able to represent a number of different pricing schemes. Prices can be set by time of day, area type, road type, level of congestion and vehicle type. When prices are input into the road capacity module of the NTM, there are three initial responses related to drivers changing either their route or time of travel. They can switch:

- to a different road of the same type
- to a different road of a lower order, e.g. from a motorway to an A road
- to a different time period – from the peak to one of the adjacent time periods.

B.17 These responses are underpinned by evidence from stated preference research. Once road users have initially changed their route or time of travel, the cost of travelling on different roads is re-estimated, taking account of journey time, fuel costs and other road user charges. These costs are then passed back to the multi-modal Demand Model which is derived from various sources of information, including the National Travel Survey, and is based on the total number of trips made and the costs of travelling by each mode. The Demand Model re-estimates the mode share and any changes to traffic through people choosing to travel to different destinations as a result of the changes in costs (e.g. a distance-based pricing scheme may encourage people to select destinations nearer to home).

B.18 In terms of outputs, the model is able to assess the impact of different pricing schemes on traffic, mode choice, vehicle occupancy, congestion and emissions. An early version of a Welfare Module has also been used to assess the impacts of different schemes on economic welfare.

Key assumptions

B.19 The NTM assumes that the total number of trips by all modes, including walking and cycling, is not affected by road pricing or any other policy. Trip rates for each category of person in the model (e.g. employed female in a two adult, one car household) are assumed to be broadly constant over time. This is in line with evidence from the National Travel Survey, which suggests that the average number of trips made per person per year is around 1,000 and that this has remained stable over time. People respond to policies by changing the length of their trip, destination or mode of travel but the model does not allow them to respond by not making the trip. This reflects that employed people need to get to work each day and households need to go to the shops.

B.20 Unlike the local models, the NTM includes travel as a car passenger as a separate mode. The model makes a number of assumptions about how car passengers respond to changes in cost. In the base year, the number of car passenger journeys matches evidence from the National Travel Survey. In the absence of any hard evidence on how costs are split when car sharing, the modelling assumes that the car driver pays all of the money cost. However, the passenger feels 'guilt' equivalent to 50 per cent of the money cost. In the pricing scenarios, the passenger also perceives 50 per cent of the charge. The results are sensitive to this assumption. Assessing the impact of alternative assumptions relating to cost sharing would require further work.

B.21 The modelling has been based on the set of assumptions which combined to produce the upper end of the range of forecasts (high travel demand) published in the December 2002 Progress Report on the Ten Year Plan.

B.22 The most important of these in the context of pricing is how the value of time changes over time. The upper end of the range assumes that the value people place on travel time savings increases in line with their income. This means that, in 2010, money costs such as fuel and prices form a smaller proportion of the overall costs of travel (which combine time and money costs), so people are therefore less responsive to changes in fuel costs or prices. This is compounded by the assumed 30 per cent fall in fuel costs over the decade, a combination of a 20 per cent improvement in fuel efficiency and a 12 per cent fall in fuel prices.

B.23 All of the charges are expressed in 1998 prices.

B.24 The model assumes people respond to road pricing in line with evidence on how they respond to changes in fuel costs. This means that, in 2000, a 1 per cent increase in fuel costs or charges would lead to a 0.3 per cent reduction in traffic, in line with evidence on behaviour over several decades. The response will be less in 2010 (around 0.17 per cent) due to the reasons outlined in paragraph B.22 above.

B.25 The process of valuing travel time savings and comparing the benefit of travel time savings with construction and other costs has been established for many years as part of the methodology used to appraise transport infrastructure schemes. The value of saving an hour's travel time will depend on the circumstances and on the individual. When appraising road schemes, a value of approximately £5 is used for trips made by car drivers outside the course of work and a value of £18 in the course of work. A value of £8 is used for drivers of vans and other commercial vehicles. These values have also been used in the analysis described in this report to estimate the benefits of the time savings that road user charging will deliver.

B.26 Time spent in travelling as part of the working day is a cost to the employer's business. The value is based on the assumption that savings in travel time convert unproductive travel time to productive use. So the value of an individual's working time to the economy is reflected in the wage rate paid, plus a mark-up to allow for other employment related costs. The value is derived from national data on the earnings of those who travel in the course of work.

B.27 For all other journeys, including commuting trips, the value is based on surveys of people's willingness to pay, supplemented, where possible, with evidence from situations where people trade a cheaper, slower journey against a faster, more expensive one. This measure of willingness to pay to save time will vary according to the circumstances of the trip and of the traveller.

B.28 For the welfare analysis in this study an average value of non-working time savings has been used which covers all trips and all travellers[1]. A separate national average value has been

1 The behavioural modelling assumes that people's willingness to pay for travel time savings is related to their income.

used for trips in the course of work. Since time savings make up such a significant part of the benefits of road user charging, there is a strong case for collecting new information on local values so as to measure the expected benefits before any local charging scheme is implemented.

B.29 It is assumed that the road network in 2010 is based on the existing network augmented by Ten Year Plan investment. In general, more road capacity implies that lower charges would be needed for pricing at marginal social cost because the congestion costs element of marginal external costs would be lower.

B.30 Further details of the NTM can be found on the Department's website[2].

Limitations

B.31 The NTM contains a tabular representation of the road network: it is not a geographical model. It is therefore not able to capture route changes at the network level, which the local models have highlighted as an important response.

B.32 The NTM does not show the impact of pricing on the location of activities. It assumes that land-use, and hence the impact this has on the pattern of trips, is unaffected by transport policies.

Other models

B.33 The study has also drawn on some of the models developed for the Multi-Modal Studies, as well as the Belfast Transportation Model and a strategic model of Northern Ireland.

B.34 The multi-modal studies models cover the following areas:

- South and West Yorkshire
- London Orbital
- Cambridge to Huntingdon.

South and West Yorkshire Multi-Modal Study (SWYMMS) area

B.35 Four models have been used in the SWYMMS area:

- a strategic, multi-modal transport model based on START transport model software (SWYSM). SWYSM is a strategic transport model with the following key features: a relatively coarse zoning system; simplified representations of the road and public transport networks; journeys segmented by vehicle type and time of day and for person trips, by trip purpose, car ownership, and mode; the main traveller responses of change in trip frequency, destination, mode, time of travel, route and parking location; a forecasting procedure that takes account of demographic and economic changes; and facilities for representing public transport operators' responses to changes in demand

2 http://www.dft.gov.uk/stellent/groups/dft_control/documents/contentservertemplate/dft_index.hcst?n=8613&l=2.

- a land-use/transport interaction model based on DELTA land-use model software and the START strategic transport model (LUTI SWYSM). LUTI SWYSM has the following key features: the travel demand choice models in SWYSM (frequency, mode, destination, time of day and route) are retained; the exogenously derived demographic inputs to SWYSM are replaced by forecasts from the land-use model; the land-use model represents recognisable processes of change over time, such as demographic change and physical development, and transport changes affect accessibility and environmental quality, which influence some of the processes of land-use change
- a so-called ‘Detailed’ Transport Model based on TRIPS for the demand model and the public transport assignment model and SATURN for the road traffic assignment model (DTM). DTM is a more or less conventional multi-stage, multi-mode transport model. In comparison with SWYSM, DTM is more spatially detailed with about six times as many zones, has conventional assignment models of the road and public transport networks, with networks that are compatible with the more detailed zoning system; treats fewer person types separately; does not model time of day responses to policies; does not represent public transport operators’ responses to changes in demand and takes considerably longer to run
- a SATEASY model based on the DTM SATURN model but with an elasticity demand model in place of the trip frequency, destination, mode, time of travel, route and parking location responses.

London orbital

B.36 Three modelling systems were used in the London Orbital area (ORBIT):

- a road traffic assignment model using an elasticity demand model (NAOMI) based on the SATEASY modelling software. Broadly similar to the SWYMMS SATEASY model, the area covered by NAOMI includes the entire area within the M25 and an area roughly bounded by Luton, Reading, Guilford, Crawley, Maidstone, Chelmsford and Stansted. Inside the simulation area, all motorways, A and B roads, as well as important unclassified roads have been included in the modelled network
- a strategic land-use and multi-modal transport model (LASER) based on the MEPLAN modelling software. LASER is a strategic land-use/transport interaction model which covers three regions of England: East of England, South East England and London. Zoning is coarser than in NAOMI. The modelled highway network is the same as NAOMI, but lacks detailed junction modelling. LASER includes representation of public transport networks and models the following responses to changes in the transport system: change in the location of households and housing-related employment (15 per cent of total employment) in response to changes in accessibility; change in the destination of trips; change in the modes used; and change in the routes taken by trips using both the road and public transport systems
- the NAOMI road traffic assignment model with the demand changes forecast by LASER.

Cambridge to Huntingdon area

B.37 A single model was used in the Cambridge to Huntingdon (CHUMMS) area:

- a MENTOR land-use and distribution model linked to a mode choice model, a SATURN road traffic assignment model and an EMME2 public transport passenger assignment model. The structure of the model is broadly similar to that of the LASER model, discussed above. However, the highways and public transport networks are defined in greater detail, comparable with those used in the NAOMI and SWYMMS DTM models.

B.38 Many of the possible responses to road pricing – change of route, time of travel, destination, mode, frequency of trip and land-use are all captured to varying degrees of sophistication in the different models. Other changes, such as changes in car occupancy, are not included.

Northern Ireland

B.39 The study has also drawn on a strategic model of Northern Ireland (NISTRM), as well as the Belfast Transport Model. The NISTRM model covers a range of responses to charging, including re-routeing, mode shift and change of destination. It does not, however, include a re-timing of journeys.

B.40 The Belfast Transport Model is primarily a model of the Belfast Metropolitan area and is based on TRIPS software. The mode choice model encompasses alternatives of car, bus, rail, taxi, interchange and park and ride. There are additional steps to model choice of parking area and suppression or induction of travel by car in the peak time period.

Results from the National Transport Model

Introduction

B.41 A variety of different pricing schemes has been modelled using DfT's National Transport Model. Unless otherwise stated, results refer to Great Britain. The modelling has focused on the impact of hypothetical pricing schemes in 2010. Although not practicable on this timescale, the aim of the analysis is to provide broad estimates of the potential impacts of different types of national scheme with different degrees of complexity. The schemes modelled are not proposals for introduction and the charges are only intended to be illustrative.

B.42 All the forecasts are presented as central point estimates. As with any forecasts, there is a range or uncertainty around these estimates. More confidence can be placed in the relative outcomes of the different schemes modelled than in the absolute numbers.

Principles of marginal social cost pricing

B.43 In 2001, a DfT-commissioned research report was published[3] containing estimates of the marginal external costs of road use and revenues from road users. The main marginal external costs included in the analysis were congestion, accident costs and environmental costs. The main revenues were fuel duty and VAT on fuel duty, which count as the current charges.

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3 Surface Transport Costs and Charges: Great Britain 1998, Institute for Transport Studies, University of Leeds in association with AEA Technology Environment. DTLR July 2001.

B.44 The research concluded that transport charges would need to rise if charges are to be set on economic efficiency grounds. In particular, a far higher degree of differentiation in charges would be required than existing instruments allow for. Current charges are too low overall, especially on congested roads and at busy times, and sometimes too high, mainly in rural areas.

B.45 Figure B1 is based on similar methodology to the research, updated to 2000 and including forecasts to 2010. In 2000, it is estimated that road users faced only half the costs they imposed on others. This situation is worsening. By 2010 road users will pay less than a third of their external costs. This is because:

- the externalities will increase because of growth in congestion, traffic and in the value travellers place on their time
- improvements in fuel efficiency could reduce the fuel duty per km by 25 per cent in real terms from the 2000 peak.

B.46 Congestion forms the largest proportion of quantifiable external costs – estimated to be around 77 per cent in 2000 increasing to around 88 per cent of external costs in 2010. Accident and emissions costs account for the remainder and, unlike congestion costs, are forecast to fall over time.

B.47 The numbers in Figure B1 are averages, i.e. 7.3p represents the extra cost of the ‘typical’ additional vehicle anywhere on the road network. Marginal external costs will vary widely across the country, with time and place, in line with congestion and other externalities.

Figure B1: Marginal external costs and tax paid by road users

Pence per km	Marginal external cost of congestion (a)	Environment and safety costs (b)	Fuel duty and VAT on duty (c)	Uncovered externality (a+b) -c (d)
Year 2000	7.3	2.2	5.2	4.3
2010	12.3	1.6	3.9	10.1

B.48 We have estimated a set of charges to try and represent the ‘best option’ from an economic perspective. The aim was to reduce the difference between the charges paid and total external costs in Figure B1 to zero. Vehicles would therefore be charged according to the level of congestion, accidents and emissions they impose on the rest of society. The estimated charges would be lower than the ‘uncovered externality’ because people respond to charges by driving less in congested areas which reduces the externality imposed. There is therefore an iterative process to find the best set of charges.

B.49 There are a number of external costs that, due to a lack of information, we have been unable to include in this analysis. These include potential environmental costs such as biodiversity and landscape.

Scenarios modelled

B.50 Our estimates of marginal social cost pricing have been based on a relatively complex pricing structure where prices vary by the level of congestion, area type and road type. This results in 75 different charges.

B.51 In theory the structure could be complicated further by differentiating by vehicle type. For modelling purposes, the network is divided into links (on average 3 miles long). The charge is allowed to vary by:

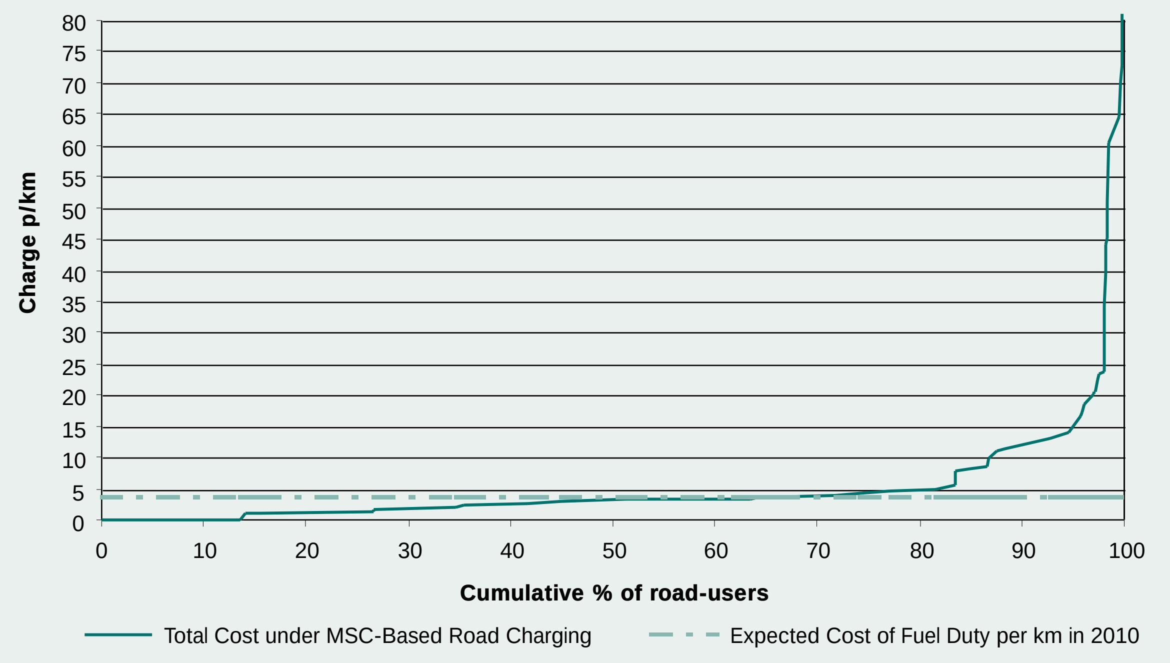
- location (rural, large urban area etc)
- type of road (Motorway, A road etc)
- whether or not the travel is in the busy direction of a road (especially an issue for peak driving)
- time of day
- how busy that link usually is at that time, as measured by the relationship between the volume of traffic and capacity of each stretch of road. So charges vary by time of day but it is not strictly a separate consideration – we have taken time of day and charge according to the average busy-ness over that time period. Time period is defined as an hour (around peak time) or longer period (e.g. Mon-Fri 10-4).

B.52 The following scenarios have been modelled:

- (i) marginal social cost pricing with 75 charges
- (ii) using the same methodology, we have looked at the impacts of much fewer charges, by grouping the 75 charges into 10 with a maximum charge of 80p/km (which would be paid by only 0.5 per cent of traffic). Many of the 75 charges were very similar and grouping the most similar and roughly taking the mid-point led to 10 charges. The 10 charges mean that motorists would pay the following charges per km, including fuel duty: 1.5p, 2.5p, 3.5p, 4.5p, 5.5p, 8.5p, 14.5p, 23.5p, 53.5p and 83.5p/km. As fuel duty is forecast to cost around 3.5p/km in 2010, a significant amount of traffic would be paying pence/km charges that are lower than they otherwise would pay in fuel duty
- (iii) a revenue neutral version of Scheme (ii), where for the purposes of the modelling it has been assumed that fuel duty is reduced to compensate for the pence per km road charges
- (iv) scheme (ii) but with maximum prices (excluding fuel duty of 3.5p/km in 2010) of 60p/km, 50p/km, 40p/km, 30p/km and 20p/km
- (v) applying the charges in scheme (i) but only in London and the conurbations or in all urban areas with a population of over 10,000
- (vi) much simpler schemes where charges vary only by area type, road type or by time of day.

B.53 As mentioned above, very little traffic would actually pay the highest charges. Figure B2, overleaf, shows the proportion of traffic paying each charge level under scheme (i), which has the highest modelled charges, along with a line to show, for comparative purposes, what car traffic would be likely to pay, on average, in fuel duty in 2010. Just over half of traffic would be paying less than it would in fuel duty, but a typical trip could include both lower and higher cost segments. The proportion of traffic paying above 15p per km would be very small – and such levels would only account for part of a journey.

Figure B2: Proportion of traffic paying each charge



Impact on traffic and congestion

B.54 Figure B3 shows the relative impacts of the schemes on traffic and congestion. The numbers relate to the impact in 2010 on top of policies in the Ten Year Plan.

Marginal social cost pricing (scenarios 1-9)

B.55 Charging by marginal social cost is forecast to reduce congestion significantly. The level of congestion in urban areas in 2010 could be halved. According to economic theory, this is the ideal level of congestion – the benefits of reducing it further would be outweighed by the costs. This result is maintained as the number of charges is reduced from 75 to 10 with a maximum of 80p/km. This is because many of the 75 charges are very similar (within a penny) or identical.

B.56 The modelling has assessed the importance of the maximum charge rate. The results suggest that each successive reduction in the maximum charge has a relatively small impact on the overall congestion benefits. However, with each reduction the benefits fall by an ever increasing amount. When the maximum charge is reduced to 20p/km (or thereabouts) the congestion benefits are considerably lower but even then a reduction of around 28 per cent on 2010 levels is forecast.

Figure B3: Impact on traffic and congestion relative to the Ten Year Plan

England, 2010		Change in traffic			Change in congestion		
Change on Ten Year Plan		All roads	Urban roads	Inter-urban roads	All roads	Urban roads	Inter-urban roads
1	Charging by marginal social cost: 75 charges	-3%	-9%	0%	-48%	-52%	-34%
2	Charging by marginal social cost: 10 charges capped at 80p/km	-4%	-9%	-2%	-46%	-52%	-34%
3	Revenue neutral version of (2)	2%	-4%	6%	-41%	-48%	-17%
4	Increasing fuel duty to raise same revenue as (2)	-5%	-5%	-7%	-7%	-7%	-15%
5	10 charges capped at 60p/km	-4%	-9%	-2%	-44%	-49%	-34%
6	9 charges capped at 50p/km	-4%	-9%	-2%	-42%	-46%	-34%
7	9 charges capped at 40p/km	-3%	-8%	-1%	-39%	-42%	-33%
8	9 charges capped at 30p/km	-3%	-7%	-1%	-35%	-36%	-31%
9	8 charges capped at 20p/km	-2%	-6%	0%	-28%	-29%	-29%
10	Charging in London & conurbations only	-3%	-8%	-2%	-27%	-44%	-10%
11	Charging in all urban areas	-6%	-10%	-5%	-43%	-53%	-18%
12	Very simple charging by road type	-5%	-5%	-4%	-3%	-3%	-14%
13	Very simple charging by area type	-5%	-12%	-3%	-10%	-13%	-9%
14	Very simple charging by time of day	-6%	-5%	-9%	-5%	-4%	-20%

B.57 Marginal social cost (MSC) pricing has a limited impact on total traffic, which falls by 3-4 per cent. This reflects that such a scheme would have a relatively small impact on the overall cost of travel.

B.58 When forecasting the decisions made by travellers, the model includes both time costs, such as travel time and time spent waiting and accessing public transport, and money costs such as fuel costs, parking costs and any road user charges. Because congestion is halved, the time costs associated with travel have fallen – because journey times will be quicker.

B.59 In addition, with MSC pricing, around half of traffic would pay less than they would in fuel duty alone so, for some drivers, particularly those in uncongested rural areas, there is an incentive to travel further.

B.60 Some drivers would be shifting onto different road types (changing route) and, to a limited extent, to different time periods in response to the charges.

B.61 These factors combine to produce a relatively small reduction in total traffic.

B.62 There would be significant gains from marginal social cost pricing even if fuel duty was reduced so that overall road users as a group paid no more under marginal social cost charging – see scenario 3 in Figure B3. This is because the charges are better targeted than is possible with fuel duty, with prices better reflecting the levels of external cost. This shows that the pricing structure, rather than the total amount paid, is key.

B.63 The revenue neutral version of marginal social cost pricing is forecast to increase traffic by around 2 per cent. This is because the combined time plus money costs of road travel have fallen. The money costs are neutral because it has been assumed, for modelling purposes, that fuel duty is reduced to offset the charges. However, because the charges lead to a significant reduction in congestion the time costs of travel have fallen which mean that overall it costs less to travel by car.

B.64 For comparison, we have looked at the impacts of an increase in fuel duty to raise broadly the same amount of revenue as from MSC pricing. This would have a more significant impact on traffic – around a 5 per cent reduction – but less than a fifth of the impact on congestion. This reinforces the conclusion that the structure of charges is more important than the level. An across the board increase in fuel duty would result in higher charges for some traffic than under MSC pricing.

Charging in urban areas only (scenarios 10 & 11)

B.65 Marginal social cost pricing in London and the conurbations would have a significant impact on traffic and congestion on urban roads – reductions of 8 per cent and 44 per cent respectively. Overall, congestion would be around a quarter lower in 2010 than without pricing.

B.66 Extending this pricing scheme to all urban areas (with a population over 10,000), has an even greater impact and the congestion results are very similar to the runs in Figure B3 showing marginal social cost pricing in all area types. This is to be expected given that only rural areas (which account for less than 20 per cent of total congestion) would be excluded from the scheme.

B.67 There is a larger reduction in traffic than with MSC pricing on all roads (both urban and rural). This is partly because with MSC pricing some traffic, particularly in uncongested rural areas, would pay less which would lead to increases in some areas.

Very simple pricing schemes (scenarios 12-14)

B.68 We have also modelled some very simple pricing schemes where charges were allowed to vary only by road type or area type or time of day, with a maximum of four charges.

B.69 The results are based on early estimates of the best prices (from an economic perspective) for these simple schemes. Further work would be needed to assess whether different prices would produce better outcomes. These results should, therefore, be treated with caution.

B.70 Area types, road types and time periods have been grouped into four categories. For example, the area type groups are (i) central and inner London; (ii) outer London and conurbations; (iii) urban areas and (iv) rural areas. This means that each km driven in central and inner London is modelled as paying the same charge, regardless of the time of day or type of road. Road types and time periods have been similarly grouped together into bands containing similar types (e.g. motorways and dual carriageways).

B.71 At this stage, because we have yet to try out alternative prices, we are unable to draw conclusions about the relative merits of charging either by road type, area type or by time period. However, the results do suggest that such simple schemes could deliver less than a quarter of the congestion reduction achieved by targeting congestion more directly.

B.72 This result is not surprising given how much variation there is in congestion within each area type, road type or time period. For example, the amount of congestion experienced on a busy urban motorway is very different to that experienced on a largely rural motorway, yet such simple schemes would charge the same rate on both roads. Similarly, congestion in urban areas can vary greatly at different times of day and by the direction of traffic flow. By setting an average price for each group of area types/road types etc, many people will be overpaying and many underpaying relative to the external costs imposed.

B.73 There is a significant reduction in traffic under all schemes, of around 5 per cent. However, although the reduction in traffic is larger than the marginal social cost-based schemes examined above, the reduction in congestion is considerably less – overall reductions of 3 per cent-10 per cent. This is several times lower than the reduction achieved by schemes based on marginal social costs.

B.74 As mentioned above, more work would be needed to fine tune the charges before conclusions could be drawn regarding the relative merits of charging e.g. by area type rather than time period. A different set of charges could reverse the pattern but would be unlikely to change the orders of magnitude of overall congestion reduction.

Impact on other modes and the environment

B.75 Figure B4 shows the impact on other modes and the environment. With all the schemes there is a modest shift to other modes of travel, up to a 5 per cent increase in bus trips and rail passenger km. This reflects the limited reductions in road traffic.

B.76 The revenue raising schemes have a similar impact on CO_2 emissions, a reduction of 3-6 per cent. This equates to a reduction in carbon of up to 1.5 MtC.

B.77 There are also significant impacts on emissions of local pollutants, with falls of between 2 per cent and 8 per cent in London and large urban areas (population over 250,000). These findings generally mirror the falls in traffic in urban areas. The impact of more simple schemes is generally less, reflecting the reduced impact of these schemes on urban traffic and congestion.

B.78 The reduction in rail patronage from revenue neutral pricing is a result of the increased traffic, particularly on inter-urban roads. At this stage, the analysis has not considered the potential impacts on car choice if (as modelled) revenue neutrality is achieved through a reduction in fuel duty.

Figure B4: Impact on other modes and on the environment, relative to the Ten Year Plan

England, 2010		Impact on other modes				Impact on environment		
Change on Ten Year Plan		Bus	Rail (GB)	Walk	Cycle	CO_2[1]	London and large urban areas NO_x	PM_{10}
1	Charging by marginal social cost: 75 charges	3%	2%	0%	2%	-4%	-7%	-7%
2	Charging by marginal social cost: 10 charges capped at 80p/km	3%	2%	0%	2%	-5%	-7%	-6%
3	Revenue neutral version of	1%	-1%	0%	0%	-1%	-4%	-5%
4	Increase in fuel duty to raise same revenue as	2%	3%	0%	1%	-4%	-3%	-2%
5	10 charges capped at 60p/km	3%	3%	0%	2%	-5%	-7%	-6%
6	9 charges capped at 50p/km	3%	2%	0%	2%	-4%	-7%	-6%
7	9 charges capped at 40p/km	2%	3%	0%	2%	-4%	-6%	-5%
8	9 charges capped at 30p/km	2%	2%	0%	1%	-3%	-5%	-4%
9	8 charges capped at 20p/km	2%	2%	0%	1%	-3%	-4%	-3%
10	Charging in London & conurbations only	3%	4%	0%	2%	-3%	-6%	-5%
11	Charging in all urban areas	3%	5%	0%	2%	-6%	-8%	-7%
12	Very simple charging by road type	3%	3%	1%	3%	-3%	-3%	-2%
13	Very simple charging by area type	5%	4%	1%	4%	-4%	-7%	-6%
14	Very simple charging by time of day	2%	4%	1%	2%	-4%	-3%	-2%

Notes:

1. Tailpipe emissions. The impact on CO_2 from the revenue neutral scenario does not include potential impacts on vehicle choice and driving style as a result of the modelled reduction in fuel duty.

Impact on economic welfare

B.79 DfT has developed a Welfare Module to use with the NTM. An early version has been used to produce estimates of the economic welfare benefits of the different national schemes.

B.80 The Welfare Module takes the full range of outputs from the NTM, attaches a monetary value to each output and summarises to produce an overall estimate of welfare, i.e. the total benefits of each scheme.

B.81 At this stage, no assumptions have been made about how any revenues from the different road pricing schemes would be spent. The use of revenues would have important implications for the 'final' welfare impacts on different groups: the estimates presented below should therefore be treated as 'first round' welfare effects.

B.82 For a full cost benefit analysis, the estimated benefits would be compared with the costs of setting up and maintaining the different pricing schemes. These costs have been excluded from this analysis due to a lack of clarity of the future costs.

B.83 Our estimate of economic welfare includes the change in:

- time savings to car users and freight arising from reduced congestion. These are valued at two different rates: one rate per mode for trips in the course of work (£18 per hour for car drivers, £14 for car passengers, £8 for commercial vehicles, £12 for bus passengers and £26 for rail passengers) and one rate for all non-work trips (£5)
- welfare costs to road users of paying charges. The amount paid in charges is a cost to those who pay but a benefit to society. Road users will value their time savings differently and while for some the value of their time savings will exceed the charge paid, for others it will not
- vehicle operating costs (both fuel and non-fuel) for road users
- revenue from charges plus changes in indirect taxation. This includes fuel duty, VAT on fuel duty, as well as wider impacts, for example, from people spending money on road charges rather than on other goods in the economy on which taxes are levied. No assumptions have been made on how the revenue might be spent
- environmental costs and benefits based on emissions of CO_2, NO_x, PM_{10} and noise. Values of the costs per tonne of different local emissions and noise are an update of estimates used in the DfT-commissioned research on Surface Transport Costs and Charges[4]. The impact on noise emissions is estimated from the change in traffic by area type and vehicle type. For CO_2, a value of £70 per tonne has been assumed, which falls within the range set out in DEFRA guidance
- safety implications based on estimates of accident costs
- road maintenance costs. An estimate of the change in maintaining the road infrastructure is calculated using the same method used for noise impacts.

B.84 As with any modelling results, the estimates presented below have a range of uncertainty attached. More confidence can be placed in the relative welfare benefits of different schemes than in the absolute values. Estimates are all in 1998 prices. Unlike the results in Figures B2 and B3 above, which mainly related to England, these estimates of changes in economic welfare are for Great Britain (because they are based on the NTM's Demand Model which is based on GB level National Travel Survey data).

B.85 There are a number of wider impacts not included in the Welfare Module. The module omits reliability impacts, which we would expect to increase the estimates of the benefits of the time savings, perhaps by around a fifth in urban areas. Various environmental impacts are excluded, such as landscape if pricing involved gantries or other tolling structures.

Marginal social cost-based pricing schemes

B.86 Figure B5 presents a summary of the estimated welfare benefits and revenue from the schemes presented in Figures B3 and B4. These schemes are explicitly not proposals for introduction. The prices modelled are purely illustrative and have been estimated solely for the purposes of this theoretical analytical exercise. All estimates take the Ten Year Plan in 2010 as the base case. The main results are:

4 Surface Transport Costs and Charges: Great Britain 1998, Institute for Transport Studies, University of Leeds in association with AEA Technology Environment. DTLR July 2001.

- the overall welfare benefits of each scheme broadly follow the reductions in congestion. The most detailed MSC pricing scheme with 75 charges would deliver the largest increase in benefits, worth around £10.2 billion. Reducing the number of charges to 10, with a maximum charge of 80p/km, would not reduce the benefits significantly (£9.9 billion), but lowering the maximum charge to 50p/km would lose a further £0.9 billion worth of benefits (total £9.0 billion)
- for both the MSC-based scheme with 75 charges and the scheme with 10 charges and a maximum of 80p/km, the benefits to road users in terms of time savings are estimated to outweigh the increased costs from paying the charges. There would also be a large revenue gain (from £8.2 billion to £8.6 billion) and estimated environmental benefits of around £0.5 billion. The results of the scheme with 10 charges are analysed in more detail in B.100 onwards
- however, once the maximum charge is reduced to 50p/km or lower, the time savings to road users as a whole are no longer large enough to outweigh the increased costs they face. This is because the lower maximum charge fails to effectively target the times and places where congestion is worst. This shows that charging a very small proportion of traffic to more fully reflect marginal social costs could yield substantial benefits (only 0.5 per cent of traffic is forecast to pay 80p/km). The overall welfare benefits would depend on whether the revenues were spent in favour of society generally or road users specifically
- the revenue neutral version of the MSC-based scheme with 10 charges involves a relatively small reduction in overall welfare, relative to the revenue raising schemes. But the pattern of benefits is very different. Road users would gain both from the substantial time savings (worth around £10.1 billion), as well as through the reduction in fuel duty and other vehicle operating costs
- when modelling this scheme, revenue neutrality has been achieved by reducing fuel duty so that the savings to road users from fuel duty and VAT paid on fuel duty are roughly equal to the charges paid, i.e. the scheme is revenue neutral to road users. Figure B5 shows the charges we have assumed have not succeeded in hitting the target exactly – the scheme modelled results in the charges paid by road users being lower than the amount saved in fuel duty plus VAT on fuel duty.

Figure B5: Estimated welfare benefits of marginal social cost-based pricing schemes

£ billion (GB) 2010, 1998 prices Negative numbers represent a loss of social welfare	MSC pricing: 75 charges	MSC pricing: 10 charges capped at 80p/km	MSC pricing: 9 charges capped at 50p/km	Revenue neutral version of 10 charges	Increase in fuel duty to raise the same amount of revenue as (2)
Road users' benefits from time savings	+11.8	+11.3	+10.2	+10.1	+2.1
Road users' change in costs (road charges, fuel duty and vehicle operating costs)	-10.2	-10.4	-10.5	-0.1	-10.2
Revenue	+8.2	+8.6	+8.8	-2.2	+10.5
Environment and safety benefits	+0.5	+0.5	+0.5	+0.1	+0.5
Public Transport	-0.2	-0.2	-0.1	-0.2	-0.1
Total benefits	+10.2	+9.9	+9.0	+7.8	+2.8

Increasing fuel duty to raise the same amount of revenue as from MSC pricing

B.87 Increasing fuel duty to raise a similar amount of revenue as from marginal social cost pricing schemes is estimated to yield benefits of around £2.8 billion. This largely reflects the much lower time savings achieved relative to marginal social cost pricing schemes.

Very simple pricing structures

B.88 Figure B6, below, presents the estimated welfare benefits of more simple pricing structures, based on grouping area types, road types and time periods into four categories as described in paragraph B.70.

B.89 The main results are:

- the overall welfare benefits are not closely aligned with the reductions in congestion, as they were in the previous section. Area type charging was forecast to reduce congestion by around 10 per cent, time of day charging by 4 per cent and road type by 3 per cent. However, the economic welfare benefits are estimated to be around £0.5 billion, £1.2 billion and £0 billion respectively
- The main differences occur in the estimated time savings from each scheme. Although the forecast reduction in congestion from charging by time period is considerably less than charging by area type, the estimated value of time savings to road users is very similar. This is because the impacts fall on different groups – the time savings from charging by time period (more in the peak than off-peak) fall mainly to work-related travel that is valued more highly than non-work travel

- it is estimated that setting an average charge for each road type[5] would have a negligible impact on overall welfare. This is likely to reflect how poorly targeted the charges are, with the result that some traffic in very congested conditions would be paying less and some uncongested rural traffic would be paying more (e.g. because the M25 would be charged the same rate as traffic on uncongested motorways)
- the environmental benefits reflect the reduction in traffic from these schemes (of between 5-6 per cent).

Figure B6: Estimated welfare benefits from very simple pricing schemes

£ billion (GB) 2010, 1998 prices Negative numbers represent a loss of social welfare	Area type	Time period	Road type
Road users' benefits from time savings	+1.7	+1.5	+0.6
Road users' change in costs (road charges, fuel duty and vehicle operating costs)	-10.2	-9.2	-9.3
Revenue	+8.5	+8.5	+8.2
Environment and safety benefits	+0.7	+0.5	+0.5
Public Transport	-0.3	-0.2	-0.2
Total benefits	+0.5	+1.2	+0.0

B.90 As highlighted in paragraph B.69, it is unlikely that the charges input reflect marginal social costs as closely as possible so the precise estimates need to be treated with caution. However, it is clear from the results that such simple schemes offer relatively little in the way of economic benefits.

Charging in urban areas only

B.91 Figure B7 shows the estimated welfare benefits from charging in urban areas only.

B.92 It is estimated that charging in all urban areas with a population over 10,000 would result in welfare benefits of around £6.4 billion. This is around £3.8 billion less than if the same charges were applied nationally. The main difference is that the overall time savings are lower because rural traffic (including strategic inter-urban roads) accounts for around 20 per cent of total congestion.

B.93 Road users pay more in charges because most traffic in urban areas would pay more (unlike in the national scheme where many people in rural areas would pay less because their marginal social costs are estimated to be below what they pay in fuel duty and VAT on fuel duty).

B.94 Reducing the scope of a charging scheme further, to London and conurbations only, reduces the benefits by around £1 billion relative to charging in all urban areas. Nevertheless, very significant economic welfare benefits of over £5 billion are forecast.

5 These are: (i) motorways and dual carriageways, (ii) trunk and principal single roads, (iii) urban B and C roads, rural B roads, and (iv) rural C roads and all unclassified roads.

Figure B7: Estimated welfare benefits from MSC-based charging in urban areas only

£ billion (GB) 2010, 1998 prices Negative numbers represent a loss of social welfare	London and conurbations only	All urban areas (>10,000)
Road users' benefits from time savings	+6.5	+8.6
Road users' change in costs (road charges, fuel duty and vehicle operating costs)	-7.9	-11.5
Revenue	+6.4	+9.2
Environment and safety benefits	+0.4	+0.2
Public Transport	-0.2	-0.2
Total benefits	+5.4	+6.4

More detailed analysis of marginal social cost pricing

B.95 To illustrate the potential impacts of pricing in more depth, we have looked in more detail at the impacts on traffic and trips by journey purpose and the distributional impacts of marginal social cost pricing. The marginal social cost-based scenario with 10 prices and a maximum charge of 80p/km, has been chosen, purely for illustrative purposes as it is representative of the many MSC-based scenarios modelled.

Distributional analysis

B.96 This section presents first round impacts on groups of travellers who use different modes, who have different journey purposes, and who reside in different types of area.

B.97 The analysis does not consider options for spending the revenues from the scheme or their distributional impacts. The impacts measured are the initial effects of a charging scheme – the time savings less the charges paid by road users and the associated external benefits.

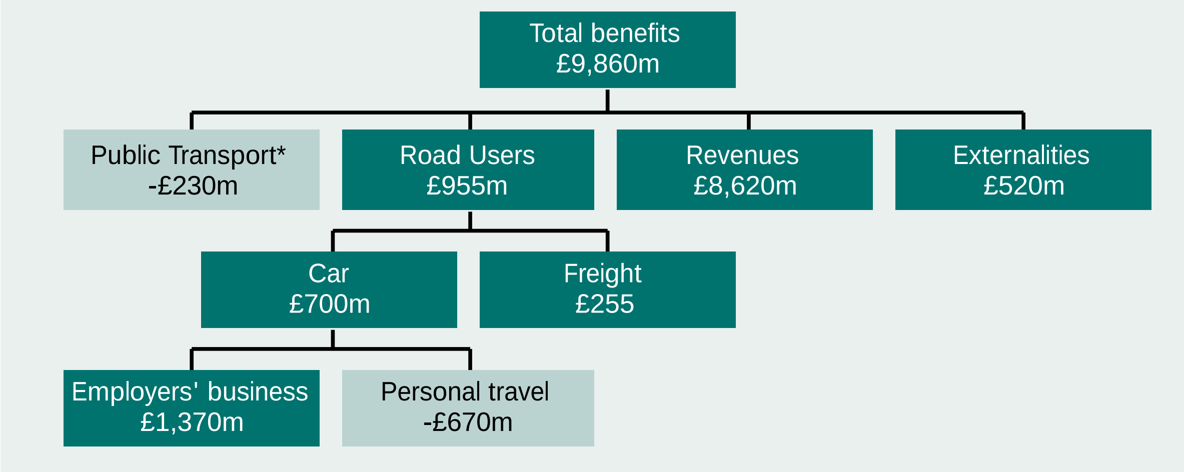
B.98 No account is taken of the benefits that would accrue either from spending the revenues or from complementary measures separately funded. The analysis can help to provide information on where the revenues might be spent to offset the initial effects modelled using the NTM. It should not be interpreted as indicating the final impact of any charging option.

B.99 As in the previous section, welfare changes are expressed in pounds per annum in 1998 prices.

Structure of benefits

B.100 Figure B8 illustrates how the benefits arising from the scheme can be categorised according to their source. As shown in Figure B5, the total benefits from the introduction of such a charging scheme would be around £9.9 billion.

Figure B8. First round benefits arising from a hypothetical charging scheme (£m p.a.)



* paragraph B.104 explains the limitations of these estimates

B.101 The vast majority of this sum (£8.6 billion) is in the form of revenues paid by road users to the charging authority. Over £10 billion is raised in charging revenues, offset in part by a fall in fuel tax revenue of £2.4 billion because there is less traffic and it travels at more fuel-efficient speeds.

B.102 Society as a whole also benefits from reductions in externalities. Reductions in traffic levels and the redistribution of remaining traffic to more suitable roads result in over £0.5 billion of benefits in the form of reductions in accident costs, noise, pollution and climate change.

B.103 The final contribution to the total is from benefits to car users, which account for £0.7 billion per year[6]. The next section of this paper examines how the charging scheme impacts on transport users, by breaking these user benefits down into impacts on:

- travellers who use different modes
- travellers who are travelling for different reasons
- travellers who reside in different types of area.

Benefits by mode of transport

B.104 The initial net impact of charging on the welfare of transport users as a whole would be positive, but not all groups of traveller would benefit from its introduction. Charging reduces congestion by increasing the cost of car travel in congested conditions:

- some car users, who place great value on savings in travel time, would welcome charging because the value of their car travel time savings would outweigh the charges that they would pay
- other car users would find that their time-savings are worth less than the charge but would choose to continue using their car because, for them, it is better than the alternatives. The initial impact on this group would be a loss in welfare

6 Excluding reliability benefits.

- some car users would switch to other modes of transport. Although they would avoid paying the charge, initially they would be worse off than before
- the NTM only shows the first round effect of charging on public transport patronage. On this basis, existing public transport users, who would not be attracted to car travel by the time savings resulting from the charge, would experience the effects of increased patronage of their chosen modes of transport e.g. discomfort from increased rail overcrowding. The NTM does not show the benefits either of the reduction in the scheduled journey times for buses that we would expect as a consequence of charging or of the increase in frequency that higher public transport demand would justify. So the effects on public transport are a very incomplete measure
- finally, some public transport users would, on balance, find car use more attractive than their current mode of transport and they would therefore switch to car in order to increase their welfare.

B.105 In line with the Department's guidance, a value of travel time-savings of over £9 per hour has been adopted for the valuation of light goods vehicle time-savings, and a value of over £7 per hour for heavy goods vehicle time-savings. Accounting for improvements in journey time reliability resulting from reductions in congestion, freight operators would realise a net increase in economic welfare of around £0.25 billion per annum.

Car benefits by journey purpose

B.106 As a group, car users would experience a £0.7 billion increase in economic welfare. However, individual car users would only benefit from the introduction of charging if the value that they place on the time-savings exceeds the charge. There is strong evidence to suggest that the value people place on time-savings varies by the purpose of their journey, and if they are travelling on behalf of their employer they (or their employer) value their time at a much higher rate. This distinction is incorporated in the NTM – business time-savings are valued at over three times the rate of personal travel time savings.

B.107 Breaking the £0.7 billion gain for car users down according to whether a traveller is on business or travelling in their own time reveals that the total comprises a welfare gain for business travellers of £1.4 billion and a welfare loss for other car users of £0.7 billion (before any assessment of how the revenues might be spent).

B.108 Figure B9 breaks this total down even further by presenting changes in welfare for different personal travel purposes. The time-savings for all of the personal travel purposes are valued at the same rate, and therefore differences in the totals reflect the geographic distribution and frequency of different types of trips.

Figure B9: Car benefits by journey purpose before accounting for spending the revenues

Journey purposes	Change in welfare (£m p.a.)		
	Time savings	Money savings	Net savings
Employers' business	2500	-1130	**1,370**
Commuting	1645	-2640	**-994**
Education	294	-287	**7**
Personal business	1669	-1686	**-17**
Recreation	2300	-2223	**77**
Holiday/day trip	408	-172	**236**
Other	615	-589	**26**

B.109 Commuters, who have to travel frequently into congested urban areas, would suffer an initial welfare loss of almost £1 billion per year. People who are travelling to conduct their personal business, e.g. banking, visiting their doctor, also suffer some of the welfare losses associated with travelling into urban areas, but because they do so less frequently, the sum loss is considerably smaller. These losses reflect the high level of demand for limited road capacity in urban areas.

B.110 People travelling on day-trips and for recreational purposes would pay less than they currently pay in fuel duty when travelling to/through rural areas. This reduction in cost would offset some of the charges paid on the more congested parts of their trip and consequently, once the time-savings have been accounted for, there would be a net benefit. Note that the data on traffic flows and the charges assumed represent the average weekday or weekend. They do not reflect seasonal peaks.

B.111 Travellers making education-related trips would also experience a net increase in welfare. With relatively high vehicle occupancy rates, the sum of the time savings for a car's occupants would often exceed the charge.

Car benefits by area type

B.112 Figure B10 presents initial welfare changes for car-users that reside in different area types.

Figure B10: Car benefits by area type before accounting for spending the revenues

Area type	Change in welfare* (£m p.a.)		
	Employer business	Personal travel	Total
London	**278** (758 -480)	**-599** (2145 -2744)	**-321** (2904 -3224)
Metropolitan	**202** (425 -223)	**-646** (1363 -2009)	**-444** (1788 –2232)
Large urban (pop > 100k)	**204** (336 -132)	**-133** (920 -1053)	**71** (1256 -1185)
Small	**242** (474 -232)	**-305** (1134 -1439)	**-63** (1608 -1671)
Rural	**445** (506 -61)	**1017** (1367 -350)	**1462** (1873 -411)

*Change in welfare as **Net benefits** (Time savings + Money savings)

B.113 The NTM shows that, before any account is taken of how the revenues would be spent, the largest welfare losses would be in large congested cities e.g. London and metropolitan areas such as Birmingham, Manchester, Leeds and Liverpool. Although not shown in the table above, the majority of the revenues would also accrue in these locations, and so provide the opportunity to more than offset this loss. Business travellers would gain more in terms of time-savings than they would pay in charges and therefore gain in welfare, but there would be a larger initial off setting fall in welfare for other car users.

B.114 Travellers who reside in rural areas or small settlements (population less than 25,000) are likely to gain from the introduction of the scheme regardless of whether they were travelling on business or not. This gain in welfare would result from a fall in the cost of motoring in rural areas.

B.115 On this basis one might expect travellers from small urban areas to fare better than those who reside in large urban areas. However many of the towns in the ‘small urban’ category are in the congested South East of England (42 per cent in the South East regions, 25 per cent within 20 miles of Greater London) where the charges (and revenues) would be correspondingly higher.

More detailed analysis of the impact on traffic by area type and journey purpose

B.116 Results from the same scheme (marginal social cost-based with 10 charges and a maximum charge of 80p/km) have been analysed in more depth to assess the potential impact on traffic by area type and journey purpose.

B.117 Figure B11, below, shows the change in traffic, congestion and average charge paid by area type.

Figure B11: Change in traffic and congestion and average charge paid by area type (England)

Change on Ten Year Plan in 2010 Area type	Change in traffic	Change in congestion	Average charge paid, p/km
London	-21%	-51%	14p/km[1]
Inner conurbations	-11%	-51%	13p/km
Outer conurbations	-5%	-46%	3p/km
Urban areas >250,000	-4%	-43%	5p/km
Urban areas >100,000	-3%	-41%	5p/km
Urban areas >25,000	-4%	-32%	4p/km
Urban areas >10,000	-1%	-33%	2p/km
Rural highways agency roads	-1%	-32%	0p/km
Rural other roads	-1%	-41%	-1p/km
Total	-4%	-46%	1.9p/km

1. This is in addition to the congestion charge.

B.118 In total, traffic is forecast to fall by around 4 per cent, but this masks a wide variation across the country. The table shows a fall in traffic in London of around 21 per cent. Traffic in inner conurbations is forecast to fall by 11 per cent. Other urban areas with a population of more than 25,000 fall by 3-5 per cent. In small urban and rural areas, traffic would fall by around 1 per cent.

B.119 This general pattern is consistent with the charges input to the model which are closely related to the size of the area type. Rural areas see a slight fall in traffic despite the average negative charge because of the reduction in trips starting and/or finishing in urban areas which would have passed through rural areas.

Putting these numbers in context: the London experience

B.120 The London congestion charging scheme where vehicles pay a daily charge of £5[7] is obviously very different from the comprehensive per km schemes being modelled in NTM. However, monitoring of the London scheme provides some evidence on the broad magnitudes of change that might be expected.

B.121 The London scheme is estimated to have reduced congestion in the charging zone by around 30 per cent. This compares with forecast reductions from a per km MSC-based charge of around 51 per cent in London as a whole (42 per cent for central London).

B.122 TfL estimates that traffic within the charging zone has reduced by 10 per cent to 15 per cent. The number of cars, vans, lorries, buses and coaches entering the charging zone during charging hours has fallen by 16 per cent. However, the reduction in potentially chargeable vehicle movements (i.e. cars, vans and lorries) is 26 per cent. The NTM forecasts reductions in car trips in London of 16-33 per cent (for different trip purposes).

Impact on mode choice by journey purpose

B.123 Figures B12 to B13 look in more detail at the impact on mode choice for different journey purposes, in terms of the change in the number of trips made. Trip purposes have been grouped into 3 categories:

- trips made in the course of employer's business
- commuting, education related and personal business trips (e.g. going to the bank)
- leisure trips e.g. shopping, visiting friends and holiday trips.

B.124 Three area types are shown:

- Great Britain
- trips starting or ending in London
- trips starting or ending in towns the size of Leicester in the East and North of England or Scotland[8].

Impact on business trips

B.125 Figure B12 shows that, for trips made in the course of business (around 5 per cent of all trips), there is little response from car drivers. This is because they are more willing to pay the road charges and benefit from the quicker journey times resulting from reduced congestion.

7 Between 7am and 6.30pm, Monday to Friday excluding public holidays.
8 Leicester, Nottingham, Hull, Middlesbrough, Edinburgh.

These factors result in a small move away from public transport and walking and cycling to car.

Figure B12: Impact on business trips

Mode	Great Britain	London	Leicester-sized towns
Walk	-1%	-4%	-1%
Cycle	-2%	-5%	-2%
Car driver	0%	1%	0%
Car passenger	3%	12%	2%
Bus	-3%	-7%	-2%
Rail	-5%	-8%	-2%

Impact on commuting, educational and personal business trips

B.126 Figure B13 shows the impact on commuting, educational and personal business trips (‘essential’ trips). These trips represent around 50 per cent of all trips. The table shows a fall in car driver trips of 4 per cent across the country, increasing to 16 per cent in London.

B.127 Pricing is forecast to have a greater impact on single occupancy trips than it does on higher occupancy (2 or more people). Pricing encourages more car sharing. The reduction in car driver trips is accompanied by a large increase in car passenger trips – 8 per cent across the country and 28 per cent in London. There are also increases in trips by other modes: public transport trips increase by 5 per cent to 11 per cent; walking and cycling trips by 1 per cent to 5 per cent.

Figure B13: Impact on commuting, educational and personal business trips

Mode	Great Britain	London	Leicester-sized towns
Walk	0%	1%	0%
Cycle	1%	4%	2%
Car driver	-4%	-16%	-4%
Car passenger	8%	28%	7%
Bus	2%	5%	2%
Rail	5%	6%	3%

Impact on recreational trips

B.128 Figure B14 shows the impact on recreational trips such as shopping, visiting friends or holidays. These represent around 45 per cent of all trips. The table shows a larger reduction in car driver trips, of between 6 per cent and 31 per cent, which would be expected given the greater flexibility to change destination, car share or use public transport.

B.129 Our estimates show similar increases in car passenger trips and use of public transport: car passengers increase by between 8 per cent and 34 per cent and public transport trips by between 6 per cent and 37 per cent. Walking and cycling also increase by 1 per cent to 11 per cent.

Figure B14: Impact on recreational trips

Mode	Great Britain	London	Leicester-sized towns
Walk	0%	2%	0%
Cycle	2%	9%	1%
Car driver	-7%	-31%	-6%
Car passenger	10%	34%	8%
Bus	5%	14%	3%
Rail	14%	23%	3%

Proportion of car driver trips switching to each mode

B.130 This section looks at, of those people who move out of their car, what proportion switch to each mode. These figures are in Figure B15 below for essential (commuting, education and personal business) and recreational trips (shopping, visiting friends, holidays).

B.131 This shows that, for both trip purposes, the vast majority of people who have stopped driving (around 79 per cent), switch to being car passengers, i.e. car sharing. As discussed in paragraph B.20, this result is sensitive to what is assumed about the costs of car sharing and further work would be needed to assess the impact of alternative assumptions.

B.132 Across Great Britain, the increase in car passengers represents an increase in average car occupancy of around 5 per cent. In London, an increase of around 20 per cent is forecast.

B.133 Around 10 per cent of car drivers switch to bus and a further 7 per cent switch to rail. 4-7 per cent switch to walking or cycling.

Figure B15: per cent of trips previously made as a car driver that are now made by another mode

	Essential	Recreational
Walk	2%	5%
Cycle	2%	2%
Car passenger	79%	78%
Bus	10%	9%
Rail	7%	7%

Impact on 'typical trips'

B.134 This section outlines the impacts of a marginal social cost pricing scheme with 10 charges and a maximum of 80p/km on various 'typical' trips. These trips have been selected to try and represent a varied sample of the population of road users.

B.135 The NTM does not contain a 'map' of the road network. Instead, it contains a tabular representation of the network with individual road links categorised by 20 sub-regions, 10 area types and up to 7 road types. The trips have therefore been constructed by using the various categories of the road network contained in the model so as to mimic the real trip as closely as possible.

B.136 It is not possible, however, to represent local conditions using the NTM, therefore the results should be taken as indicative only.

B.137 The main results are:

- in the majority of cases, road pricing leads to quicker journey times than in 2010 with the Ten Year Plan, and in no instances does it lead to slower times. Savings are as high as 22 per cent of journey time. As expected, the highest time savings tend to occur on trips made in congested conditions. For example, after charging, the commute into London from Flitwick in Bedfordshire is estimated to be eighteen minutes quicker. The time spent travelling is estimated to be one hour six minutes representing the 22 per cent saving highlighted above
- similarly, a plumber making a business trip in Birmingham now only takes 34 minutes as opposed to 40 minutes. This is a time saving of some 15 per cent
- trips which tend to be made in less congested conditions, such as shopping and leisure trips, tend to see smaller reductions in their journey time.

Changes in trip length

B.138 Figure B16, below, shows the impact on average car trip lengths by journey purpose for the pricing scheme with 10 charges and a maximum charge of 80p/km. Overall, average car trip length is forecast to increase slightly. This is particularly so for holiday trips, employers business trips as well as recreational trips. Reductions in average trip length are forecast for journey purposes that are largely made in peak hours – commuting trips, education trips and personal business trips.

Figure B16: Change in average trip length by journey purpose

Sensitivities

B.139 A number of sensitivity tests have been carried out on the results from the National Transport Model.

Impact of assuming the value of time increases over time

B.140 As discussed in paragraph B.21 above, the NTM modelling results have been based on a set of assumptions that were used to produce forecasts for the Progress Report on the Ten Year Plan, published in December 2002. In particular, the results were based on the assumptions which combined to produce the upper end of the range of forecasts (high travel demand).

B.141 As highlighted in paragraph B.22, the most important of these in the context of pricing is how the value of time changes over time. The results so far have been based on the assumption that the value people place on their time increases as incomes increase over time[9]. This means that, in 2010, money costs such as fuel and prices form a smaller proportion of the overall costs of travel (which combine time and money costs), so people are therefore less responsive to changes in fuel costs or prices.

B.142 The rationale for this is that as incomes rise, individuals attach a decreasing value to the additional money they receive. Since they value money by less, they are likely to pay increasing amounts of it to save a given amount of time. As a result, the monetary value of time increases.

B.143 However, if the value of time were to increase in line with income, then it would be expected that as incomes rise, transport users would be less sensitive to the monetary cost of travel. This would show up in the form of falling fuel cost elasticities over time. However several studies looking at the last thirty years have found no evidence of this occurring. Given this uncertainty, we have tested the impact of assuming that the value of time is assumed to be constant over time.

B.144 Assuming a constant value of time over time has 2 main impacts on the modelling results:

- it implies lower marginal social costs in 2010 because a lower value of time means that congestion, which is measured in terms of lost time, has a lower cost associated with it
- it implies people will be more responsive to money costs (i.e. pricing) because time represents a smaller proportion of overall costs.

B.145 These factors combine to produce a set of marginal social cost prices that are around 40 per cent lower than the schemes presented above.

B.146 The reduction in total congestion and congestion in urban areas from such prices is estimated to be around 1-2 per cent points less than schemes which assume the value of time increases over time. There is more of a difference on inter-urban roads (around 7 per cent points less), where a constant value of time leads to charges that are around 50 per cent lower.

B.147 Although the congestion impacts are very similar, the welfare benefits of schemes assuming a constant value of time are less, reflecting the reduced value attached to the time savings.

9 For business trips, the value of time is assumed to grow in line with income. For all other trips, it is assumed to grow at 75 per cent the rate of income growth.

The value assumed for CO_2

B.148 The estimates of marginal social costs are dependent on evidence on the value people attach to their time, as well as the costs of environmental damage. The latter are particularly uncertain so sensitivity analysis has looked at the impact of assuming higher values for environmental damage caused by CO_2 emissions. The main NTM results are based on a value of £70/tonne, which is the mid-point of the range outlined by DEFRA (£35-£70-£140). Because CO_2 accounts for a relatively small proportion of estimated external costs, doubling it to the top of the DEFRA range has a relatively small impact on the average charge paid by road users (as shown in Figure B17 below). If the value of CO_2 were considerably higher, then there would be a much greater impact on traffic and also on the CO_2 savings from road pricing.

Figure B17: Impact on traffic and CO_2 relative to the Ten Year Plan

England, 2010		Change in traffic				
Change on Ten Year Plan		All roads	Urban roads	Inter-urban roads	Average pence/km (incl fuel duty)	CO_2 emissions[1]
1	Value of carbon £70/tonne	-3%	-9%	0%	5.4p/km	-1.5Mtc
2	Value of carbon £140/tonne	-5%	-11%	-2%	5.7p/km	-1.7MtC

1. UK, end user.

Charging HGVs and cars separately

B.149 The main NTM results have charged all vehicles the same pence per km charge. However, external costs vary considerably between vehicle types so the analysis has looked at the impacts of also charging by vehicle type.

B.150 The main result is that the average charges paid increase considerably for heavy goods vehicles, particularly articulated vehicles where the average charge would be around 20p/km. Despite this increase just under half of articulated goods vehicles traffic would still pay less than 5p/km. By comparison, the charges car users face would fall.

B.151 The impacts of charging on traffic and congestion are almost unchanged from the same pricing run without the additional differentiation. However, underlying the results there is an increase in car traffic and a fall in goods vehicle traffic (particularly articulated vehicles).

B.152 Local pollutants would be reduced by a greater amount with the differentiated pricing, due to the reduction in HGV traffic, which is relatively polluting.

Local modelling

B.153 The following types of pricing scheme were modelled on the multi-modal studies models:

- charges to cross cordons around the central business districts and outer fringes of urban areas but with no charging in the rural areas

- distance-based charges across the whole of the fully modelled areas, both rural and urban.

B.154 We have only had preliminary results from runs on the MMS models, which are still being worked on, and have not therefore been able to reflect them adequately in this report. As the following summary shows, some of these results were inconclusive, demonstrating the need for further work to determine the level and mix of charges in the area covered by the model that would deliver the greatest benefits.

Cordon charging

B.155 The level of geographic detail in the local models enables them to capture the potential impacts of cordon charging in each local area. The results suggested overall benefits in each area, with small reductions in traffic and higher reductions in journey times. In South West Yorkshire, the modelling showed that there would be a low migration away from the area of both employment and households. However, if charges were to be applied in areas surrounding South and West Yorkshire, it is to be expected that the outward migration impacts would be more muted.

B.156 The cordon charges in the London orbital area suggested that while cordon charging can reduce congestion and yield net economic benefits, these are significantly more modest than those obtained from distance-based charging. The LASER model showed there would be a small relocation of car owning households from Inner London to the peripheral parts of the region. Cordon charging would have only a limited impact on education and shopping/personal business car travel, because many of these trips are short enough to not need to cross the cordons. The higher socio-economic groups would experience much larger absolute commuting cost increases on average, than would the lower socio-economic groups, and employers of low income workers in those lower density areas outside London that do not have good public transport services would face particularly high cost pressures.

B.157 A similar picture emerged from the Cambridge to Huntingdon model which showed a large reduction in lost time per trip, along with moderate reductions in employment, retail rents and dwelling costs, and small reductions in commercial rents, households and employed residents.

Distance-based charging

B.158 As a starting point, the initial distance-based charges were specified by DfT's NTM modellers, in line with the charges used for the NTM-modelled marginal social cost-based scheme with 10 charges and a maximum of 80p/km. The intention was for the charges to vary by link according to area type, road type and the level of congestion (measured using volume to capacity ratio).

B.159 The results from the local modelling have highlighted some important issues. For example, the results suggest that drivers, when faced with an increase in travel cost on a specific link, are most likely to change route. The highly variable indicative set of charges tested has suggested that drivers would respond to highly variable charges, link by link, by taking more circuitous routes. Due to the road network in the National Transport Model being a tabular representation rather than a geographic network as with the local models, this response will not have been fully captured in the national modelling.

B.160 In South West Yorkshire, the results showed a large reduction in the number and average length of vehicle trips. The lost time per trip also showed a large reduction. However, the net welfare[10] was negative. This arises principally because travellers experience a net time disbenefit, largely as a result of the charge levels being generally too high for the congestion levels in the modelled area and probably also because of the circuitous routeing. A much simpler charge varied to reflect congestion levels (higher than average charges for high volume to capacity ratios and lower than average charges for low volume to capacity ratios) showed strongly positive welfare benefits.

B.161 In the London area, the NAOMI model showed that the initial set of charges would yield a large reduction in the number of vehicle trips but a small increase in the average vehicle trip length. There was a large reduction in the lost time per trip. As with South Yorkshire, however, the welfare benefits were negative. Taken together, these results indicated that drivers would respond to the highly variable charges, link by link, by taking more circuitous routes but that, nevertheless, congestion would be reduced.

B.162 Compressing the range of charge rates resulted in a modest reduction in the number of vehicle trips but also a small reduction in the average vehicle trip length. As a result, a large reduction in the lost time per trip was shown and the welfare benefits were positive. This test shows that congestion can be reduced by variable distance-based charges without causing circuitous routes to the extent that negative economic benefits result. Surprisingly, and contrary to the NTM results, a flat rate distance charge was shown to yield higher economic benefits. Further work is needed to identify the optimal level and structure of charges, as discussed in more detail below.

B.163 The LASER modelling showed that a small relocation of car owning households would occur from Inner London to the peripheral parts of the region. There would be a greater proportional reduction in car trips for education and shopping/personal business than in commuting or business travel. Employers in Outer West London, which is rich in jobs, would experience greater cost pressures than employees residing there. In contrast, areas in Essex and Kent, which are net exporters of car commuters, would experience greater cost pressures on residents than on employers. The higher socio-economic groups would experience much larger absolute commuting cost increases on average, than would the lower socio-economic groups; their greater trip lengths and greater proportional use of the car mode cause this effect. Employers of low income workers in those lower density areas outside London that do not have good public transport services would face particularly high cost pressures.

B.164 The results for the Cambridge to Huntingdon area showed a small reduction in car trips, a small increase in the average car trip length, a small increase in the lost time per trip and large negative benefits. These results occurred because with generally low congestion levels, much of the traffic would be charged less than they would be paying in fuel duty alone. This means that, at a daily level, user time and money benefits and disbenefits net out at a small disbenefit, and there is a large reduction in overall taxation revenue. In the peak periods, however, the time and vehicle operating cost benefits substantially outweigh the user charges so that overall users show a large gain. In the periods outside the peaks, the reverse is the case, yielding the small user disbenefit over the day as a whole.

10 The sum of all time and money (operating costs and charges) benefits and disbenefits to users, the revenues accruing to the charging authority and the changes in indirect taxes.

B.165 The results from the Belfast Transportation Model suggested that distance-based charging would lead to a reduction in the number of car trips in the am peak period by 1 per cent. It would also lead to a re-routeing of travel by car, leading to increases of 5 per cent in the total distance travelled and 2 per cent in the time spent travelling, with an accompanying increase in average speed of 4 per cent. Further work is needed to assess the overall benefits.

B.166 The result from the strategic model of Northern Ireland suggested that the introduction of charging would lead to a decrease in average speed, although this was lessened with further iterations of the charges to produce a set more suitable for the local conditions. There was also an increase in vehicle kilometres as trips re-routed to avoid the charging, an increase in emissions and a negligible impact on mode split.

Bringing the local modelling together

B.167 The issue of re-routeing and diversion is an important one. As mentioned above, due to its tabular representation of the road network, the NTM is unable to capture detailed route changes in response to pricing. The local modelling has shown the importance of taking account of re-routeing in the design of road pricing schemes. There is no real world evidence, however, of how drivers would react to a high degree of variability of charge rates. The re-routeing impacts predicted by the local models are likely to be exaggerated as the indicative set of prices estimated by the NTM are clearly not welfare maximising once set in the context of the local models.

B.168 As would be expected, the modelling has shown that no single level or structure of charges fits all places. Much more work would be needed to identify the appropriate structure and level of charges prior to the introduction of any road pricing scheme. To increase economic efficiency, the principle for charging should be to reduce the external impacts of road transport, however, the charges themselves would need to reflect local circumstances. These include the availability of other modes/routes, the mix of trips and their purposes and the amount of congestion at different times of the day. Ideally such models would take account of responses at present omitted, most notably changes in vehicle occupancy.

B.169 Local charges would need to be set to avoid such unwanted effects as diversion to unsuitable and circuitous routes. The analysis of the local modelling has shown such effects can happen, but charging is a flexible policy that can be designed to minimise such impacts; and other measures, such as traffic management, can also play a role.

B.170 The modelling work has identified a wide range of potential responses to pricing and demonstrated very substantial benefits from well designed pricing schemes. Further development of transport modelling would be needed to determine the correct level and structure of charges for individual local areas.