Deliverable 9.1 Results from Urban Case Studies

Executive Summary

A key issue in putting differentiated charges into practice is the need for good understanding of user reactions to differentiated prices. Out of all the groups of direct infrastructure users, car drivers constitute the group whose reaction to user charges is most difficult to predict: in contrast to large companies, such as airlines or railway operators, whose reaction is more or less entirely dictated by consideration of costs and benefits, car drivers can be expected to react with a mix of rational and irrational behaviour.

To investigate the effects and the potential for differentiated charges for drivers in urban areas, this deliverable presents four types of evidence under the heading over various “case studies”:

- Real-life case studies,
- Modelling exercises.

Most of this is solely concerned with urban user road charging, but some part of it also addresses the interrelationship between urban and motorway charging. The key findings from each of the case studies are as follows:

- The first case study is **Trondheim**, where a cordon charge, introduced in 1991, led to a reduction of 10% in traffic crossing the cordon during the charging hours. However, this was offset by increases of 8 to 9% in the evening and on weekends, so that, overall there was no notable traffic reduction. The main effect was a shift in departure times with only a 1% traffic increase in the early morning before charging hours and a 3% increase at evenings after charging hours for home to work trips, but a 13% increase for work to home and 19% for home to shopping trips in the evening after the charging hours. Overall, it was very visible how drivers have delayed their cordon crossing in the evening to avoid charge. When the charge was discontinued in 2005, traffic levels increased again at the rate of 3.8% overall and 11.5% during (previous) charging hours.

  The introduction of the charge led to a very small short term-loss in city centre trading, while in the long-term there was still overall growth albeit with some loss in market share. However, the cessation of charge did not, at least not in the short-term, lead to any up-turn in trade.

  Concerning the relationship between charging level and traffic reduction it was found that during the highest charge in the morning peak there was only a 4% reduction for home to work and home to shopping trips, while the main reductions occurred during the low charge period from 10:00 to 17:00 with -13% for work to home and -15% for home to shopping trips.

  The introduction of the spatially more differentiated zonal scheme in 1998 had only minimal impact on overall traffic levels as well as on modal split for those trips that were uncharged before and charged after 1998, while the initial scheme had decreased the car share for trips across cordon by around 6%, and this is the first indication that the initial introduction of a charging scheme has stronger impacts than later modifications.

  The main effect of the introduction of the zonal system was, as in 1992, a time shift. While the general increase in mode share of cars between 1992 and 2001 for non-charged vehicles was 6% and for those charged after, but not before, was 5%, it was only 1% in the highest charged morning peak, 6% during the lower charged mid-day and afternoon, 13% during the evening and night, and 21% during the weekend, which is again a clear indication that higher charged time periods by no means automatically lead to the highest traffic reductions.

- In **London**, there was a dramatic effect at the time of the original introduction of the congestion charge in February 2003 with a reduction of 14% of all traffic and 33% of cars. However, when the level of the charge was increased from £5.00 to £8.00 in 2005, the effect was very small with a

3% reduction of all vehicles and 3% of cars. Similarly, the number of bus passenger increased from 77,000 to 106,000 from 2002 to 2003, while the 2005 price increase had no detectable impact.

Similar to Trondheim, there was shift in departure times from the charged to the non-charged periods: a small shift to earlier starts in the morning and a larger shift to later departures in the evening.

The traffic reduction initially also led to a substantial reduction in congestion, in the range of 30% in 2003 and 2004 compared with 2002, but then congested increased again to nearly old levels, which is attributed by Transport for London to the combined effect of traffic management measures that reduce road space in favour of cyclists and pedestrians and increased levels of roadwork.

The economic impact of the congestion disputed: Transport for London claims a positive impact on jobs, business turnover and profits, while the Chamber of Commerce claims that the charge had a negative impact on retailers.

Effect of exemptions: Substantial shift from chargeable to non-chargeable vehicles with 30% reduction of the former from 2002 to 2006 and 16% increase of the latter. Chargeable are in particular cars, vans and lorries, not chargeable are licensed taxis, buses and coaches, and all two-wheelers.

- Although the congestion tax has been introduced in **Stockholm** as a permanent feature in August 2007, only little data is available from this and the case study had to be based on the trial carried out in the first half of 2006.

  The introduction of the trial scheme led to traffic reductions of up to 35% on some arterials and the average reduction of traffic crossing all cordons was 22% during the charging period, and by 19% for the 24-hour day. Overall, and for all modes, it is estimated that 110,000 trips per day ‘disappear’, i.e. are diverted from the city centre or no longer take place at all. It is possible, however, that not all of these reductions are due to the congestion charge, since one study found a general trend of decrease in travel between 2004 and 2006. In contrast to Trondheim and London, there was very little, if any, shift in traffic to non-charging hours; some of the data even indicates a decrease in traffic for all hours of the day.

  The traffic reduction also reduced congestion significantly. During the morning peak, for traffic travelling into the city, congestion was reduced by around 30% and the respective travel times by around 20%. For outbound traffic, congestion was much smaller in the first place, but the tax could reduce this further by 40% and the travel times by around 20%, which means in effect that traffic was flowing quite freely.

  Within the charging period, the lowest traffic reductions are found in the morning during the main peak and the post-peak shoulder. The general assumption for explaining this phenomenon is that commuters as well as business travellers, who may be on the way to their first appointment during this time, have the lowest elasticities.

  However, both in the morning and in the afternoon, the traffic reduction is larger in the pre-peak shoulder with the € 1.50 charge than in the main peak with the € 2.00 charge and, furthermore, the biggest reductions overall occur during the first charging period in the morning and the last in the afternoon, when the charge is only € 1.00. Neither the Swedish reports nor any of the work carried out within the DIFFERENT project can shed any light on this surprising finding, and this is therefore an area that deserves further research and investigations.

  The figures available so far from the permanent scheme show that the results from the trial, as far as traffic reductions and other headline figures are concerned, were very close indeed to those figures that so far emerged from the permanent scheme. Therefore the trial has to be considered a resounding success both in terms of predicting the effect of the congestion tax as well as in terms of persuading the Stockholm residents to vote for it in the public referendum.

- In **Milan**, where the 'Ecopass', a pollution charge has only been introduced as recently as 2 January 2008 for vehicles entering the city centre, only very preliminary results are available. In the first month, the traffic reduction during charging hours was 26% in the charging zone and 12.5% outside; and, as in the Trondheim and London, there is a very small increase in traffic in the morning before charging starts, but a clear peak in the evening after the end of charging. In

February and March traffic reduction was significantly lower (14% in the charging zone and 8% outside).

What was very noticeable is the strong shift from higher to lower emitting cars as a result of the charge. The share of passenger cars with for emission class 3 (€2/d) among all cars went in February down from 14% to 9% and for class 4 (€5/d) from 25% to 11%. For Light Duty Vehicles numbers the share of class 4 went down from 51% to 38% and for class 5 (€10/d) from 20% to 15%. At the same time, the share of low emitting cars increased accordingly.

Air quality improved initially as well, but weather conditions could explain the largest part of the reduction of pollution, since in March the improvement in the charging area was not better than outside.

Public transport benefited as well with an increase of 9% in underground passengers and an increase in surface commercial speed, initially as high as 11% but soon reduced to a 4% gain.

- The road pricing scheme in Singapore has developed over time from a simple paper-permit area charge to a highly differentiated electronic charge, where different charges are used for different groups of road users. A key feature of the current scheme is that charges vary from place to place and during the day depending on congestion levels – making it difficult for drivers to predict the charges they will incur when they start their journey.

  The electronic scheme has reduced traffic levels in the Central Business District by 15% for the whole day and by 16% in the morning peak when it was initially introduced. Unfortunately, there is no data available concerning the effects of the current differentiated scheme - which is the most interesting scheme from the DIFFERENT perspective. Although the current scheme appears to be widely accepted in Singapore, It is not clear whether European drivers would so readily accept such a detailed attempt by state authorities to influence driver behaviour.

- In **Rome** extensive modelling has been carried out over the years to investigate the effects of a day-time scheme and a summer and winter variant for a night-time scheme for the city centre. For the day-time scheme seven different scenarios have been modelled, five scenarios for the night summer scheme and 4 for the night winter scheme. The main differences between these scenarios are the charging level and the level of public transport supply. The modelling distinguishes further between regular and occasional users, cars, mopeds and PT users, and between work, recreational and shopping trips.

  For the day-time scheme it was found that none of scenarios has a substantial impact on modal split but, instead the main impact comes from the reduction of through-trips. In contrast, for the summer night scheme there is a reduction in car use by one third for work trips at a charge of € 6 per trip and by three quarters for shopping trips, while – somewhat surprisingly – the effect on recreational trips is very low; the highest impact by far comes also here from the reduction in crossing trips. Aggregate figures for the winter night scheme also show an overall reduction in car use by two thirds for the most expensive scheme; crossing trips by car are reduced by 85% already at a charge of € 3 per trip, and nearly disappear altogether at the € 6 charge.

  Overall it appears that a per trip car pricing scheme (time based or not) during the daytime would not be as effective in reducing car use consistently as the current mix between permits and flat-fare pricing scheme is. This result matches ex-ante surveys where both residents and shopkeepers in the charging zone consider a mix of measures, such as improvement of PT and reducing the number of entrance permits, to be more effective in reducing historic centre traffic and pollution problems than a per trip time based pricing scheme. In contrast, for the night-time schemes with different characteristics of travellers, a charge per trip would probably be most effective.

- The **Edinburgh** charging scheme was aborted following a resounding rejection by the public in a referendum, but extensive modelling had been carried out over the years with two different models.

  From the first set of model runs, it was found that one of the key effects of any of the investigated charging schemes was the shift from car travel to public transport use. The reductions in flows across the cordons for the 24-hour day were up to a maximum of 24% for a £ 4.00 charge at the cordon across the inner suburbs, with charges of £ 2.00, £ 1.00 and £ 0.50 leading to reductions of 16%, 8% and 5 % respectively.

The gain in PT passenger trips was considerably higher than the loss in car trips. This was in part due to the fact that the average car carries more than one passenger, and in part due to the reduction in bus travel times due to reduced congestion, which attracts additional passengers. The modal shift increased with the level of charges, but the relationship between the charging level and the modal shift was not linear and the marginal effect of charge increases on modal shift decreased more and more the higher the charge became.

Overall, and at least in this modelling exercise, there is no impact from any temporal differentiation of charges on traffic reductions, neither by number of cordons nor by differentiation over the day. All differences in impact can be simply explained by the overall charging level.

The analysis of the economic impact also confirms the non-linearity of the impact of higher charges: a “spatial differentiation” of charges is overall more effective than a mere increase in the level of charges at one particular cordon, i.e. ‘catching’ more people in the cordons has a stronger effect than charging fewer drivers more money.

From the second modelling exercise it is unfortunately not possible to draw any general conclusions. Differences in traffic reductions between different schemes are largely due to the simple question of whether the charging is operating at any cordon during the time period considered, without any obvious further effects of differentiation by time of day.

- Furthermore, loosely based on the Edinburgh network, a **conceptual model** has been used to investigate the comparative benefits of various charging schemes with different degrees of differentiation as well as to explore the importance of correct estimates of elasticities for the outcome of these comparisons.

Two of the schemes modelled were primarily for benchmarking purposes: a system of MSC tolls applied across the whole network, and a Uniform scheme (at a common rate per km across the whole network) intended to act as a proxy for a fuel duty increase. Other schemes modelled were cordon-based, distance-based and area-based, plus some motorway-based schemes that were largely for use in the co-introduction study in chapter 10. The positions of the two cordons were fixed, and corresponded with those proposed for actual implementation in Edinburgh. This gave a set of eleven schemes in the main body of tests, each of which was modelled at a number of different charging levels.

It was found that the system of MSC tolls gives the greatest reduction in total network delay, and the greatest “benefit” as measured by the sum of the reductions in the cost of total delay and externalities, from the base, “no tolls”, case, but that no one scheme could be said to be best under all aggregate measures.

The simple Uniform scheme was perhaps surprisingly similar to the first-best MSC tolls scheme. This shows that it is the spatial nature of the charging scheme that is more dominant than the precise link-by-link level of charge once the total toll revenue is kept fixed. The next most effective schemes are those involving charging both within the inner city and within the city bypass.

Direct comparisons of area-based and distance-based schemes indicate that, whilst they give similar reductions in demand, the area-based scheme gives a much greater reduction in total delay, whilst the distance-based scheme gives a much greater reduction in veh*kms in the relevant regions. In each case, the pure cordon scheme gives a rough compromise between the distance-based and area-based equivalent, but with a somewhat smaller reduction in demand. An important distinction between the area-based and distance-based schemes is that, in the latter, drivers will seek to re-route to minimise the charge they incur, which can induce a considerable increase in veh*kms.

The results for the specific network modelled show that the size of the area covered by the scheme, and therefore the overall number of drivers who would have to pay the charge is more important in terms of overall effect of the scheme than the type of scheme used or the degree of differentiation within it; and it seems safe to say that this is not specific to the network modelled here, but would be found in other networks as well.

Whilst the results described here were obtained assuming a value for elasticity of $e = 0.3$, a further series of tests were conducted assuming different values for e. The sample results from these further tests confirm that, whilst the numerical value of measures such as total delay obviously depend on the value of *e*, the broad nature of the results, and the relative ranking of schemes, is not significantly affected by this. Therefore, it appears safe to say that generally the precise estimate of elasticities is much less crucial for the comparison between different schemes than for the estimate of their effects in absolute terms.

- In order to put urban road user charging into a wider context, the impacts of the **combined** introduction **of urban and motorway charges** were examined. Different scenarios of such a co-introduction were explored, using the aforementioned conceptual model and other external evidence.

  The investigation concluded that considerable problems are likely to occur if charges on urban roads are designed without regard to their potential impact on any adjacent motorways or if charges on motorways passing through metropolitan areas are designed without regard to their potential impact on the roads in those areas or on the local economy. Some diversion of traffic from one network to the other is an inevitable consequence of introducing charges. Although some diversion may be desirable in order to achieve a better match of demand to capacity or to prioritise particular types of traffic, excessive diversion can cause serious problems. Diversion of traffic from motorways to other roads can be particularly serious because it leads to increased accident risk and environmental externalities.

  Co-operation on technical and procedural issues, and over detailed definitional points such as start and finish times, vehicle classifications and exemptions, is desirable and can be effective even if the two road authorities have different objectives. In the absence of such co-operation the resulting complexity will increase costs for system operators and end users and cause particular resentment among the latter. Although it has not been proven by detailed modelling, it appears unlikely that a scheme designed to maintain free-flow on the motorways or maximise revenue for the motorway manager would simultaneously minimise congestion and other externalities within the urban area. It follows that, in order to maximise overall benefits, a degree of prioritisation or compromise is required, which also involves the introduction of different charges on the different road types.

  It seems likely that overall benefits (defined as minimisation of delay, accidents and other externalities while maximising the benefits to society and the economy) will be maximised by combining a charge on the urban roads with charges designed to give a degree of protection to traffic using motorways and other strategic links. The urban charge might be levied on traffic crossing specified cordons or using roads within a specified area, while the strategic-link-protection charge might involve specific charges for using motorway access or egress links or dynamic charges just sufficient to preserve free flow conditions.

- Furthermore, the main findings from a UK study with a view to the potential introduction of a **UK wide road user charging scheme** are analysed. The basis of the charging was marginal social cost (MSC) pricing, with the charge reflecting the average cost of marginal externalities (comprising congestion, infrastructure, accidents and pollution). The study found that a highly differentiated MSC-based pricing scheme with 75 different levels of charges (ranging from zero to 80 pence per km) should deliver substantial benefits - largely due to time saving reductions - of the order of £10 billion per year. However, simplified MSC schemes (for example, with just 10 separate levels of charge per km, rather than the full 75) can produce a very large proportion of the potential congestion reduction.

  Also a simple revenue neutral version of MSC pricing (in which fuel duty would be reduced by such an amount as to offset the revenue raised from road pricing) would deliver benefits that are not significantly less than a full MSC scheme. This demonstrates clearly that it is the structure of charges that is important and not the overall level. On the other hand, an increase in fuel duty to raise the same revenue as an MSC pricing scheme would reduce congestion by only one-fifth of that given by MSC pricing..

  If charging were imposed only in urban areas (for example, in all cities with population in excess of 10,000), this would produce benefits that were not far short of those from a full MSC scheme. Simple charging systems by road type, area type or time of day reduce overall traffic volumes more than the full MSC scheme, and for the charge based on area type even in urban areas, but they all have only a fraction of the MSC scheme’s impact on congestion. However, it should be noted that the report contains a series of caveats, so the results should be taken with a degree of caution.

The local modelling carried out was quite limited in scope, but indicated that cordon-based schemes could produce overall benefits, even if these are likely to be smaller than distance-based schemes. It also suggested that, with highly differentiated charges, distance-based charging could lead to a significant amount of re-routeing, with drivers seeking circuitous routes to avoid or minimise the charge.

The local modelling also found that a simple, flat-rate charge imposed in urban areas could produce significant benefits. This was somewhat at odds with the findings from the national modelling in the main part of the report. However, it is important to appreciate that the national modelling covered the whole of the country with a sample of links rather than a network representation, whereas the local modelling covered predominantly congested urban areas, and used a network structure capable of modelling re-routeing. The findings about the flat-rate distance charge are consistent with the findings from the conceptual model for the Uniform scheme.

- Finally, the findings from a study, named '**Spitsmijden**' and carried out in The Netherlands are presented. Spitsmijden was an experiment in which is examined whether car drivers can be persuaded to avoid the rush hour on a congested motorway corridor by providing them with positive stimuli through a reward scheme.

  The data collected in the experiment was used to estimate a number of discrete choice models that describe commuter's behaviour with respect to departure time choice as well as transport mode choice. The estimated behavioural parameters were all significant, with the expected signs, and give a clear indication that a reward can be used as an effective policy instrument.

  The analysis of the participant's behaviour revealed that the shadow prices of schedule delay in the experiment are close to constant, a finding in line with the classic assumptions in literature, but departing from other recent findings. The correlation in preferences for different departure times for car trips within the rush hour matches expectations and indicates that shifting departure time is likely to be a more important behavioural response to policies for congestion relief, compared to a modal shift or teleworking, albeit with the caveat that quality of the other modes in the specific setting of the experiment was limited.

  Comparing the relative size of the different valuations of schedule delay early, schedule delay late and travel time as well as the absolute size of travel time valuation under a reward stimulus, results are similar to past findings in literature.

Overall Findings for the Effects of Differentiation for Car Drivers in Urban Areas

Concerning the findings with regard to the specific effect of the differentiation of charges, which is, from the overall perspective of the project, the key issue in this deliverable, unexpected conclusions have emerged. In the most important ones of the real-life case studies, namelyTrondheim and Stockholm, it is not only that surprisingly little recognisable effects of differentiation by time-of-day could be shown, but moreover in the case of Stockholm some truly astonishing effects were be observed that are very counterintuitive.

Furthermore, the modelling exercises with the conceptual model also show less impact of a charge differentiation that reflects Marginal Social Costs than could have been reasonably expected.

The analysis of the effect of differentiation by type of vehicle class shows, however, very different results: both in Milan and in London, clear effects could be observed and, moreover, these point into the direction that would have been expected and predicted in the first place.

Very clearly, more research is needed in this area to explain these results and to allow accurate forecasts of the likely effect of the introduction of a new differentiated charging scheme elsewhere, most notably if the differentiation is done by time of day. What could be most revealing would be further research into the breakdown of the actual travel behaviour in Stockholm by different groups of travellers.