

6 PREDICTION

6.1 INTRODUCTION

The focus of this chapter is on the topic of prediction. It considers the contribution of work carried out in advance of implementing a road pricing scheme in order to judge its expected impacts, including levels of success in achieving desired objectives and potential negative effects that may need to be addressed.

6.2 WHAT IS THE IMPORTANCE OF THE TOPIC?

6.2.1 What is prediction?

Prediction may be defined to include the full range of activities carried out in advance of implementation in order to aid understanding of the impacts of road pricing. In particular, it incorporates both empirical survey work and model-based studies designed to test the performance of scheme options.

A broad definition of prediction may also be taken to include the appraisal of road pricing schemes, such as the calculation of economic benefits and the assessment of wider impacts via multi-criteria approaches, through which the outputs of other empirical and model-based work are interpreted for policy-making.

We make a purely artificial distinction between prediction on one hand and appraisal on the other by separating them out. Prediction is discussed here while appraisal is covered in the next chapter. These two are, however, inextricably linked.

A further related area is evaluation, which involves measuring the actual outcomes of road pricing schemes after implementation. This is dealt with in Work Package 3 of CURACAO, so is not addressed in any detail in this report. However, the issue of how successful prediction is in reflecting observed outcomes will be discussed in Section 6.3.

6.2.2 How does it link to the objectives of road pricing?

Prediction has a tangential link to the objectives of road pricing, because it exists to aid understanding of how proposed schemes will perform against the objectives set. Figure 1-1 has shown how prediction fits into the issues considered within CURACAO, demonstrating that *objectives*, in conjunction with specifications of schemes (represented through the themes of *design*, *technology* and *Business Systems*), represent the two key inputs to the prediction process.

While it would be desirable to be able to predict the performance of road pricing schemes with equal reliability for all possible objectives, in practice prevailing levels of knowledge and expertise tend to be skewed towards certain areas. Most modelling approaches currently used in transport planning are based on economic principles of behaviour, so are better equipped to predict performance against economic objectives such as efficiency and raising revenue than they are to shed light on human perspectives such as liveability. The coverage that alternative modelling approaches provide of objectives will be addressed in more detail in Section 6.3.

A particular concern regarding the relationship between objectives and prediction is the danger of *optimism bias* (Flyvbjerg, 2004). Experience suggests that planners may tend to assume the best case when predicting the outcomes of proposed schemes, leading to potential for underestimation of costs and overestimation of benefits. In the UK, this phenomenon has received formal government recognition (HM Treasury, 2003). In the case of road pricing, the cost of implementing appropriate technologies, collecting payments and enforcement are all areas where costs could quite conceivably be underestimated. It is also

possible that predicted outcomes of schemes may be affected. In particular, reliance on modelling approaches based on economic principles of rational behaviour may naturally tend to suggest that economic policy instruments perform better than non-economic alternatives, due to the limitations of their assumptions. However, this is unlikely to be a simple situation to interpret because road pricing involves a trade-off between efficiency, in terms of modifying travel behaviour, and raising revenue, which may then be spent on providing better alternatives to the private car. Existing evidence for optimism bias in the prediction process for road pricing schemes will be assessed in Section 6.3. This issue is also likely to be important for appraisal of road pricing schemes, discussed in the next chapter.

6.2.3 How important is it to decision makers?

Road pricing is being considered for widespread implementation because there is a large and longstanding body of research which suggests that it has the potential to improve the efficiency of road transport, reducing congestion and providing time savings to travellers while leading to economic and environmental benefits to society. As the number of real road pricing schemes that have been implemented is still quite small, much of the evidence to support this view comes from various forms of prediction, especially transport models. Therefore, prediction is likely to be central to the decision of an authority to formulate a road pricing policy and to play a key role in the technical process of scheme design and the political process of winning support for the policy among stakeholders. The robustness of prediction will have direct consequence for the appraisal of scheme benefits and for the identification of negative impacts that may require mitigation measures.

Using simple aggregate scoring, the UNAQ results have indicated that prediction ranks second among the themes considered, with only acceptability being rated as more important. However, these two themes are not mutually exclusive, because prediction is likely to be an important catalyst for or against acceptability. For example, predictions of improved travel conditions and enhanced environments might be expected to increase the acceptability of road pricing, while any doubts over the robustness of the predictive approaches being used to support such outcomes may tend to reduce it.

The emphasis placed on prediction in the UNAQ results may be viewed as an acknowledgement of the extent to which authorities rely on modelling approaches to help them choose the best policy options and to justify them, both as part of formal government processes and to their electorate / local stakeholders.

6.3 WHAT DO WE ALREADY KNOW ABOUT PREDICTION?

A considerable volume of work has been carried out over many years to attempt to predict the impacts of road pricing. It is not the purpose of this report to summarise everything that has been done. Rather, it is intended to focus selectively on issues of direct relevance to current and future road pricing schemes.

6.3.1 What does prediction cover?

A critical starting point for the prediction process is to define the range of impacts that need to be predicted. These may, perhaps, be listed to include:

- type of scheme; the best charging approach, the most appropriate locations and, ideally, the optimum charge level
- second order impacts; the impacts of road pricing when combined with other policies such as bus service improvements and fares.
- demand impacts; the effects of charging on road travel demand and the likelihood of switching to alternative modes, times of day, destinations etc

- supply impacts; the redistribution of traffic across transport networks and the consequent changes in travel times, travel distances and delays
- second order impacts; effects on economic wellbeing of the area and trends towards relocation of residence, employment and activity
- objective output indicators; such as - distributional impacts on *equity* affecting the population; changes in emissions, air pollution, noise etc affecting the *environment*; changes in the levels of marginal external congestion cost affecting *efficiency*; amount of *revenue* raised to be redistributed; in general the prediction process should cover impacts relevant to each of the agreed objectives of a given scheme
- short and long-run impacts; disruption during implementation, opening day effects, changes in impacts over time due to lagged responses, need for mitigation measures and migration strategies etc

As the outputs from prediction are the main inputs to the appraisal process, decisions regarding the scope of what is necessary to appraise may affect the scope and focus of prediction activities. In the UK, the Department for Transport has produced Transport Analysis Guidance (WebTAG), providing advice on all aspects of transport planning, including prediction and appraisal (DfT, 2008).

6.3.2 How does empirical work contribute to prediction?

Empirical survey work has tended to focus on people who are considered likely to be affected by road pricing schemes, collecting information about their characteristics and their expectations of how they will be affected alongside data that enables prediction of their behavioural responses. Other types of empirical survey work that may have an important role to play during the prediction process include the investigation of the driver behaviour impacts of road pricing technology and the exploration of expected business impacts and intentions in response to proposed schemes. However, in this study, these areas are being dealt with under other themes.

6.3.3 How do models contribute to prediction?

Model-based work has centred on approaches that use economic generalised cost to represent the impacts of road pricing upon travel decisions, road networks, multi-modal transport systems, land use, the environment and the economy. The AFFORD project gave detailed consideration to the use of models for representing road pricing and produced the following classification of alternative modelling approaches (Milne *et al*, 2000):

- detailed simulation models:
features: provide very detailed estimates of network and junction delays that are, potentially, vehicle specific; allow travel conditions to vary continuously during the modelled time period
road pricing applications: may provide sophisticated approach for improving understanding of how marginal external congestion costs occur on road networks; relatively little usage so far except as a calculation tool for delays as part of wider modelling frameworks; city applications becoming increasingly widespread
- tactical network models:
features: focus on spatial redistribution of traffic on transport networks in response to changes in travel costs (assignment); some software packages are able to represent junction delays in detail; some software packages allow travel demand to vary due to changes in cost; “static” models, which are most common, assume that all users experience average travel conditions throughout the modelled time period; “dynamic” models attempt to represent variations in travel conditions and their effects on different users over time
road pricing applications: widespread use for investigating the network effects of urban road pricing (eg May and Milne, 2000; May and Milne, 2004; Santos, 2004); also widespread city applications and have been frequently used as partial (and in some cases primary) modelling approach for investigating the impacts of road pricing schemes; potential problems for robust analysis of demand impacts if used in

- isolation; currently the basis for research to identify optimal locations for road pricing cordons (May *et al*, 2002)
- **strategic transport models:**
features: focus on travel demand choices, especially modal splits and time periods; frequently rely on very coarse estimates of transport supply, including limited spatial / temporal detail and lack of explicit transport networks; main strength lies in testing packages of measures affecting different parts of the transport system
road pricing applications: widespread use for testing the potential economic benefits of road pricing, as part of optimal packages of measures (OPTIMA, FATIMA, PROSPECTS, AFFORD); also widespread city applications and have been used to investigate the impacts of road pricing schemes, both alone and in conjunction with tactical network models
 - **geographic models:**
features: focus on the long-run interaction of transport systems land use decisions; do not normally include detailed representation of transport supply or explicit networks, but are frequently used in conjunction with tactical network models; relationships based on relatively limited understanding / evidence and outputs hard to verify due to long-run nature of responses
road pricing applications: have been used to test the land use impacts of road pricing schemes both in a research environment (MEPLAN+EMME/2 in Helsinki; MARS – Milne *et al*, 2004 and PROPOLIS, Lautso *et al*, 2004) and in practice (MVA *et al*, 2004); still a relatively small number of city applications
 - **general equilibrium models:**
features: focus on the impacts of the transport sector within the wider economy, including the labour and property markets; include very little by way of spatial detail
road pricing applications: generally restricted to high level economic research applications (such as the models developed as part of the TRENEN model (Van Dender *et al*, 1998); may be useful for investigating broad principles, such as the efficiency impacts of alternative uses of charging revenue

From this classification, it is clear that most evidence from modelling exercises to predict the impacts of road pricing comes from the medium levels of detail represented by tactical network, strategic transport and geographic models. The story over the last quarter century is one of increasing degrees of complexity in attempts to predict the impacts of road pricing. During the 1980s and 1990s, it was common for individual models to be used to investigate road pricing schemes in isolation. However, this now tends to be considered insufficient, due to the inconsistencies it implies regarding the range of responses represented by alternative modelling approaches, which would mean that the predicted benefits from a scheme in one city using one type of model could not easily be compared with those in another city with a different model. Thus, it is now becoming standard practice to construct larger modelling frameworks, involving models of different types being used together with passage of data between them. This passage of data between models that have very different features may result in significant definitional issues that have so far not been explored in depth.

Table 6-1 shows how alternative modelling approaches provide coverage of the different objectives of road pricing. The judgments made in constructing this table are subjective, based on previous experience, so should not be considered to apply to all situations. Taken in tandem with Table 2-1, this information should help illustrate how particular modelling approaches may be better suited to some schemes rather than others.

Table 6-1 Coverage of Objectives by Alternative Modelling Approaches

Modelling Approach	Objectives of Road Pricing								
	Efficiency	Liveability	Health	Equity	Safety	Environment	Economic Growth	Future Generations	Raising Revenue
Detailed Simulation	Dark	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Tactical Network	Dark	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Strategic Transport	Dark	Medium	Medium	Dark	Medium	Medium	Medium	Medium	Medium
Geographic	Dark	Medium	Medium	Medium	Medium	Medium	Medium	Dark	Medium
General Equilibrium	Dark	Medium	Medium	Medium	Medium	Medium	Dark	Medium	Medium

Key: dark cells represent the primary functions of the models; medium cells show where models may be able to produce some significant relevant data, both directly and for input to other prediction processes

All types of model are shown to produce efficiency outputs as a primary function. However, it should be recognised that the definitions and levels of detail will vary significantly. While *detailed simulation* and *tactical network* models focus on producing estimates of operational efficiency on the road network, *strategic transport* models calculate economic benefits across a multi-modal urban transport system. *Geographic* and *general equilibrium* models extend the scope of economic benefit calculations to include long-run impacts on land use patterns and the economy, respectively. As the scope of coverage is broadened, there are inevitable reductions in detail. Models which produce estimates of area-wide economic benefits tend to operate at coarser levels of spatial aggregation and be less well suited to producing outputs for predicting location specific impacts related to objectives such as liveability, health and safety. On the other hand, models that employ greater levels of spatial detail tend to be less able to provide outputs for predicting long-run effects on economic growth and future generations. Predicting the environmental impacts of transport schemes is normally carried out externally, using data from transport models as inputs to specialised approaches. While all types of model may be able to provide estimates for the total volume of motorised travel (required to calculate carbon dioxide emissions), only those models that include significant spatial detail have the potential to provide the location specific outputs required to estimate exposure of the population to local air pollution, noise, accidents and hence liveability and health.

In the UK, the range of impacts that needs to be considered by models during prediction is increasingly being specified by government (DfT, 2008). However, it is important to understand that merely specifying the range of responses to be represented may not be sufficient to reduce variability in the outputs of alternative prediction approaches to insignificant levels. Much will depend on the details of how each modelling framework has been constructed and applied. Where more than one type of model is capable of producing a given output, such as the total volume of motorised travel mentioned above, there are a variety of reasons (including model structure and levels of aggregation) that might cause different models to produce different results. Indeed, even where an identical software package is being applied to the same situation by different users there is scope for variability of outputs resulting from seemingly minor details of how the work is carried out. Among the relevant features where issues of detail may be important are: breadth and scope of spatial and temporal coverage of the models; and levels of aggregation of input data describing patterns of movement and features of travellers.

One particularly important feature of modelling detail for representing road pricing may be the degree of segmentation of the travel demand profile based on willingness to pay. From economic literature we know that responses to road pricing should be expected to vary by users' values of time (Hau, 1992). Francsics and Ingrey (2000), commenting on the EUROTOLL findings, pointed to the distinction between those travellers who modified their behaviour to obtain net increases in utility and other road users who chose to "stay and pay", gaining from the improved travel conditions resulting from reduced traffic. The approach adopted for segmenting travel demand within a modelling framework will affect the extent to which this type of response is catered for in model outputs. The most recent modelling guidelines in the UK require scheme promoters to apply segmentation using values of time derived from research and to perform sensitivity analysis to test the robustness of model outputs based on a single set of segmentation assumptions (DfT, 2008).

In conclusion, a range of alternative modelling approaches is available for representing road pricing schemes. No one type of model is able to shed light on all objectives and the use of different models, separately or in combination, raises many complex issues about the reliability of outputs and the potential for making comparisons. Prescribing features of model-based analyses may go some way towards addressing these issues, but there will still be issues of detail that may be expected to affect predictions. Regarding the relationship between prediction and objectives, it is clear that there are many issues of definition between the specification of desired outcomes of road pricing at a high level and the detailed outputs of the prediction process that provide selective examples of how successful a given scheme might be. Alongside the possibility of *optimism bias*, discussed in section 5.2, it may also be important to consider the extent to which objectives are subtly redefined during the prediction process to fit in with the approaches that are readily available. This seems most likely to occur when models are employed.

6.3.4 What are the main activities of the prediction process?

A summary of the main activities / dimensions that can be considered part of the prediction process may include:

1. surveys to assess traveller attitudes to / acceptance of proposed road pricing schemes;
2. surveys to gauge behavioural responses to particular scheme designs, including higher level responses such as changes to weekly schedules (to minimise travel costs) and to household budgets (to absorb the extra costs);
3. designing a schedule of prediction activities (including a modelling framework) to provide sufficient representation of the schemes being considered in terms of scale, scope and detail;
4. modelling and forecasting of traffic and interactivity between decision makers (e.g; transportation authorities, users, operators etc). This includes issues such as the forecasting of modal splits and route choices following the introduction of road pricing;
5. formulating adequate strategies to deal with the above forecasted scenarios, to ensure that public transport and the surrounding road networks have sufficient capacity to accommodate the expected changes resulting from road pricing;
6. calculation of the revenues generated by road pricing, leading to assessment of the feasibility of proposals for recycling them, such as through investment in the transport system, investment in measures to reduce the need to travel, or (as generally preferred by economists) reductions in taxation outside the transport sector;
7. consideration of long-run planning issues including, potentially, modelling of land use changes, since the main long-run benefits of road pricing may come from the evolution of development and activity patterns to be more transport-efficient;
8. modelling the distributional impacts of road pricing across the population of travellers, residents, business etc in order to assess equity impacts;
9. modelling the environmental impacts of road pricing schemes in terms of vehicle emissions, noise etc, to assess the extent to which existing environmental problems are likely to be reduced, increased or transferred as a result of the scheme; and

10. modelling / surveys to assess the expected effects on business and economic activity.

6.3.5 What examples exist of modelling frameworks used to predict the effects of urban road pricing?

There are many examples of models being used to test the possible impacts of urban road pricing. The following paragraphs do not attempt to cover all of them or even the full range of models. Rather, the emphasis is on the use of models in situations where there is a clear intention to implement a road pricing scheme, as opposed to more speculative policy studies and during research.

In Singapore, the Land Transport Authority⁵ uses a strategic transport model (STM) in conjunction with a tactical network model (EMME/2) to make transport planning decisions, including issues related to the road pricing scheme. STM is multi-modal and can be used to estimate modal shift in response to changes in the supply of or demand for transport. EMME/2 provides a network representation which allows for more detailed analysis of road user behaviour, including changes in route and consequent congestion impacts. It can also be used to test traffic management measures that may be considered to tackle undesired behaviour. Following major enhancement involving household interview surveys in 2004, the modelling framework has been shown to produce estimates of road traffic and public transport ridership within 10-15% of observed values.

In Hong Kong, a number of Comprehensive Transport Studies have investigated the potential of road pricing. The latest study (CTS-3) completed in 1999 used a four-stage modelling approach (trip generation, trip distribution, modal split and assignment) and placed particular emphasis on providing a detailed spatial zoning system in the areas of interest. The four-stage modelling framework differs somewhat from the classification provided above, because the first two stages (trip generation and trip distribution) involve estimating travel patterns from geographic data about population, land use and travel opportunities rather than observing them through household, workplace and travel surveys. However, the mode choice and assignment stages are essentially strategic transport and tactical network models, respectively. Four-stage models were favoured in the UK until the 1980s, but fell into disuse due to concerns about the costs of data acquisition (which tended to be high, as all stages operated at the tactical network modelling level of detail) and the shortcomings of their incremental modelling structure in the face of increased awareness about the complexities of transport systems. Thus, more specialised models that focussed on particular transport system problems started to emerge. The current trend towards constructing modelling frameworks that incorporate more than one specialised model represents a conceptual shift back towards the multi-stage modelling approach, but with concerns about inability to reflect complex interactions replaced by concerns about the errors introduced through inconsistent definitions of data transferred between models.

In Stockholm, predictions of the impacts of road pricing have been produced using a strategic transport model (SAMPERS) in combination with a tactical network model (EMME/2). The SAMPERS model covers the whole of the Stockholm urban region and uses a nested logit approach to estimate trip frequency, trip destination and mode choice for six trip purposes that have access to six travel modes. EMME/2 then uses a fixed road trip matrix to estimate route choice and network delay. A separate “add-on” model is also used to predict departure time effects. The models were used to inform scheme design and select the best performing alternative, as well as predicting outcomes of the road pricing scheme that was implemented during a trial that took place in 2006 (Eliasson and Brundell-Freij, 2007). The decision to conduct the trial was taken independently, before detailed prediction work began, with a commitment to hold a referendum at the end to help decide whether the scheme should be made permanent. Thus, the role of prediction in this case was both to attempt to ensure the success of the trial and to improve understanding of the features of the system to allow any problems to be addressed before a possible permanent implementation.

⁵ Body corporate responsible for surface transportation in the island republic.

In Edinburgh, a large and complex modelling framework was constructed to test transport policy options, including the proposed road pricing scheme and the associated investment package. The framework includes a geographic model (DELTA) and a strategic transport model (TRAM), operating in parallel, providing travel demand information for more detailed models of park and ride (ADJPNR), road traffic assignment (HDAM) and public transport assignment (PTDAM). In the strategic transport model, journeys to and from home are described as tours (i.e. outbound and return journeys are linked) rather than individual trips, a level of detail that is still quite uncommon. The park and ride model, also an unusual level of detail, attempts to represent explicitly one of the most important potential responses to urban road pricing and cater for the awkward issue of mixed mode trips that few models include. It sits between the demand modelling and assignment stages and requires data passed downwards to be disaggregated to a greater level of spatial detail, a potential source of error and inconsistency. The two assignment models fall within the tactical network modelling category defined above. Again, it is relatively rare to find detailed route choice and delay modelling of public transport networks as well as road networks (MVA, 2003). As for the traditional four-stage modelling approach, this framework could potentially be criticised for its incremental nature which does not incorporate feedback loops from the more detailed supply models to produce improved demand predictions. However, it represents a good example of a modelling framework that has been carefully designed to include the range of responses and impacts that are considered most important to the policy context. It was initially estimated that the modelling framework would take six months to develop, but in practice it took eighteen months due to both problems associated with obtaining the considerable amount of land use and transport data required to populate the models and the time required to ensure that new software developments were bug free. This is potentially an example of optimism bias, as the costs of the planning process can easily be underestimated. But, it is also important to acknowledge the role that such ambitious prediction exercises play in advancing understanding of modelling capabilities.

In the Netherlands, road pricing schemes are normally modelled using the National Model System. This employs a strategic transport model to represent different travel choices, based on discrete choice approaches that have been estimated using stated preference surveys. In addition, a tactical network model based on static assumptions and without the ability to represent junction delays is used to determine route choices and network flows. Recent developments in macroscopic dynamic assignment and departure time choice models have suggested that travel times from static models are potentially unreliable. Travel time is an important determinant in travel choices, so that in networks which suffer from congestion and which have strong interactions between motorways and other urban roads, dynamic assignment models yield better results. Dynamic models have, therefore, been applied to a number of road pricing studies. Results from these transport models have also been used to estimate the environmental effects of road pricing.

Thus it seems that, although there are clearly significant differences between individual modelling studies, the use of strategic transport and tactical network models represents a common theme throughout.

6.3.6 What can be learned from the outputs of previous prediction studies?

Of the many research studies that have been carried out involving predictions of the impacts of road pricing schemes, the following short paragraphs provide just very limited summaries of the work that is currently known to the authors and that appears to be relevant.

The TRANSPRICE project used Stated Preference surveys to investigate the modal shift potential of various pricing-based policies in nine European cities and used this data to calibrate parameters for a model-based analysis (Ghali *et al*, 2000). Subsequently, numerous studies have used similar approaches to investigate changes in all travel behaviour in response to road pricing (May and Milne 2004). The general finding of these studies is that travellers are sufficiently responsive to road pricing to produce significant benefits on the road network under the best performing schemes.

UK research has used tactical network modelling approaches (e.g. SATURN) to investigate the network effects of alternative road pricing systems, focussing primarily on the spatial redistribution of traffic, both with and without demand response. This work has shown fairly conclusively that cordons (as designed judgmentally by policy-makers) tend to perform less well than continuous charges, such as charging related to distance travelled (May and Milne 2000; May and Milne 2004). It has also suggested (backing up work carried out for Leeds during TRANSPRICE) that the performance of cordon-based systems may be critically dependent on network design and decisions about precisely where charges should be levied.

Following on from the above work, there is a continuing theme of UK research investigating how the performance of road pricing schemes can be improved from initial policy-maker driven scheme designs. This work has suggested that substantial improvements are possible (Sumalee, 2005) and, having initially been reliant on complex models and small synthetic networks, is now moving towards some relatively simple modelling techniques for practical implementation (Shepherd *et al*, 2006).

A number of EU funded studies (e.g. OPTIMA, FATIMA and PROSPECTS) have used strategic transport models to assess the potential of transport policy packages including road pricing to lead to benefits across multi-modal transport systems. These studies have shown that policy packages including road pricing schemes tend to perform best. They have also confirmed the suggestion from more detailed work that continuous charges may tend to perform better than judgmental cordons (Fridstrøm *et al*, 2000).

A small number of studies, including the EU funded AFFORD project, have used geographic models to represent road pricing schemes. These have shown that pricing may be expected to have quite significant long-run impacts on land use and activity. The general trends suggested appear to be towards encouraging closer proximity of homes and workplaces and increasing the desirability of living close to public transport networks. Dependent on the design of the road pricing scheme, the models suggest it may also have the potential to reduce urban sprawl (Fridstrøm *et al* 2000; Milne *et al*, 2004). Other relevant work in this area has been undertaken by Ho *et al* (2005).

Environmental impacts of road pricing schemes have been investigated by linking tactical network models (which are able to provide spatially disaggregate data about traffic flows and network speeds) to models that predict vehicle emissions and resulting atmospheric pollution level (e.g. SATURN+TEMMS work in Leeds, Mitchell *et al*, 2003). This work has shown that road pricing schemes can lead to environmental benefits due to reduced travelling, but it has also demonstrated the potential for spatial transfer of environmental problems and has shown that, where road pricing leads to longer distances being travelled to reduce / avoid charges, reductions in numbers of trips may not be matched by reductions in vehicle kilometres, emissions and pollution.

The modelling work carried out by the PROGRESS cities was variable in nature, scope and detail, representing the range of planning cultures that exist across the EU. In the UK cities (Bristol and Edinburgh) quite complex and sophisticated modelling frameworks, involving surveys and the construction of multiple model applications of different types, were undertaken prior to implementation. This seems to be a reflection of the current trends towards increasing complexity in UK government guidelines relating to prediction (DfT, 2008). In contrast, in the Italian cities (Genoa and Rome), the effort expended on predictive modelling prior to implementation was smaller. Rather, the emphasis was more on using implementation trials for data collection purposes in advance of constructing more sophisticated models to use for longer term planning (PROGRESS).

The objective of the PROPOLIS project (Lautso *et al*, 2004) was to research, develop and test integrated land-use and transport policies to find sustainable long term urban strategies and to demonstrate their effects in seven European cities (Bilbao, Brussels, Dortmund, Helsinki, Inverness, Naples and Vincenza). Policy instruments tested were based on a package approach that combined investment, pricing and land use policies. With regard to pricing, the main focus was on cordon pricing and distance based charging. Results suggested that

charging can produce positive benefits, but the land use outputs showed that road pricing tended to encourage inhabitants and jobs to move to locations where payment was avoided. This raised concerns that road pricing may affect the vitality of central areas, an issue that merits further consideration under the theme of Economy, which can be found in Chapter 8.

Similar results were also shown in the UK's Road Pricing Feasibility Study (MVA *et al*, 2004), in that there would be a migration of households and employment away from the charged area. This same study also pointed out that, although it is known that mode switching from car-driving to car-passenger (increasing vehicle occupancy) is regarded as a possible impact of road user charging, none of the tactical network models utilised for the prediction work could represent this response effectively.

Even from this relatively short list of studies, it is clear that a significant amount of knowledge already exists about the predicted impacts of road pricing. However, it is also evident that findings will be dependent on the detailed features of individual schemes. For example, the use of geographic modelling during the AFFORD study has suggested that road pricing may be effective at containing urban sprawl, while other work to investigate environmental impacts and during the PROPOLIS study has suggested spatial transfers to areas further afield including longer distances being travelled. This may seem to be contradictory, but is explained by the difference in impact between road pricing schemes which apply charges across the urban region (in the case of AFFORD) and those which only charge for access to more congested central areas (in the case of most other urban road pricing studies).

6.3.7 How successful has prediction been in representing observed outcomes?

There are only a small number of cases where there has been an opportunity to compare the predicted impacts of urban road pricing with observed outcomes, due to the limited number of schemes that have been implemented. Two recent examples are London and Stockholm.

In London, predictive modelling work prior to the introduction of the London Congestion Charge reportedly suggested maximum reductions in traffic of up to 15% in response to the £5/day tariff. In practice, when the scheme was introduced in February 2003, the immediate effect was a 25% reduction in traffic during the first week (a school holiday), settling down to a 15-20% reduction over the following months. This experience suggests that predictive work may actually tend to underestimate the scale of behavioural response, leading to higher than predicted reductions in road travel demand (TfL, 2004). The corollary was that, with fewer vehicles in the charged area, revenues were also significantly lower than had been predicted, allowing opponents of the scheme to point out that a higher than expected proportion of revenues has been required to cover running costs. The charge was increased to £8/day in June 2005 (a 60% rise), producing only a relatively small increase in revenues (c10%) and the most recent impact monitoring report has found that traffic levels within the charged area appear to have stabilised around 16% lower than 2002 levels.

In Stockholm, predictive modelling suggested a 25% reduction in traffic crossing the cordon into the charged area, a 13% reduction in movements (as vehicle kilometres) within the cordon and an associated 7% increase in traffic on the uncharged Essinge bypass route, with greater impacts during the peak periods. The predicted time distribution of trips across the cordon suggested that, although there would be reductions in all charged time periods, the greater impacts during the peak would result in a much flatter demand profile and that the highest demand level would be seen in the early evening, immediately after the charging system was turned off. Planners believed that the 25% reduction in traffic entering the charged area predicted by the model was probably an overestimate, but that there might be a greater increase in traffic and congestion than suggested by the model on the bypass. In practice, the overall picture suggested by the models was found to be quite a good representation of actual impacts. Measurements taken during the evaluation found a circa 22% reduction in traffic crossing the cordon into the charged area and a circa 16% decrease in vehicle kilometres within the cordon, while the increase in traffic on the bypass fell in the range of 0-5%. Although there were, as predicted, reductions in trips across the cordon during all charged time periods, the loss of clearly defined peak periods did not happen and there

was actually a decrease in evening traffic rather than an increase. Other comparisons include significantly greater than predicted reductions in travel times across a wider area but smaller than predicted revenues. Thus, it appears that at an overall, daily level, model predictions were reasonably accurate and tended towards a slight underestimate of the observed impacts. However, it is clear that the model of departure time choice, used to predict how impacts would be distributed across the day, was much less successful and consistently overestimated traveller responses. This is maybe not so surprising, as there is much less experience in the area of developing and calibrating models of departure time than for models of most other travel choices.

In Section 6.2, the potential for prediction activities to be affected by optimism bias was raised. In the cases of both London and Stockholm, it appears that predictions have actually tended towards underestimation of efficiency benefits in terms of traffic levels within charged areas and congestion throughout the wider areas affected by the schemes. However, the picture is complex because of the trade-offs that exist between: (i) effects within charged areas compared to effects on uncharged areas immediately outside; and (ii) effectiveness in bringing about efficiency benefits compared to potential for raising revenues. In both cases, revenues have been lower than expected linked to some aspect of the scheme proving more effective than predicted. In addition, both sets of planners have identified errors in values of time as the most likely reason for predictions being inaccurate. This raises the issue that data describing behavioural responses to road pricing schemes may be subject to significant errors. Previous research using a range of survey techniques to measure responses to road pricing schemes found that drivers appeared to value road pricing charges differently from other moneys (May and Milne, 2004). This may suggest that surveyed valuations have the potential to be distorted in situations where respondents either have no experience of making direct payments for road use or may have perceptions affected by acceptability issues of the proposed scheme. Once a scheme has been introduced successfully and been fully understood and accepted by users, it may be that valuations will change. Therefore, more work may be necessary to explore the robustness of behavioural response data from surveys conducted before implementation of road pricing schemes, in comparison to revealed behavioural outcomes. This is particularly relevant given the difficulty, time and cost involved in acquiring behavioural data for input to prediction activities.

6.4 WHAT ARE THE POLICY IMPLICATIONS?

Prediction exists to inform policy and aid decision-making processes. Unlike some of the other themes of this report, it does not itself have policy implications for the success of road pricing schemes. However, there will be policy implications leading from previous prediction work related to the technical practice of approaches to prediction and to the findings about the performance of road pricing.

At present, there is no set standard for approaches to predicting the impacts of road pricing schemes. The evidence from research studies and real applications suggests that considerable variations exist in the scope and approaches adopted. In the UK, government guidelines are moving towards standardising the range of responses that predictive modelling exercises need to include, but this does not yet mean that results from different situations can be considered directly comparable. The degree of variation is much greater where international comparisons may be desired. This presents a challenge for all those involved in the prediction process and may have particularly significant impacts for transferability.

Nevertheless, results of previous prediction work have consistently suggested benefits from road pricing schemes, regardless of the approaches adopted. However, alternative modelling approaches have produced rather variable predictions about the performance of particular scheme designs. Cordon pricing, which has traditionally performed well in models with coarse levels of spatial detail and limited transport networks, has tended to show much lower benefits in tactical network models due to the provision of greater opportunities for avoidance behaviour. Therefore, experience suggests that policy-makers should exercise caution when

interpreting outputs from any individual prediction exercise and should seek to draw knowledge from a broader base.

6.5 WHAT IMPLICATIONS DOES PREDICTION HAVE FOR OTHER THEMES?

There are the following implications for other themes:

- **Objectives:** The objectives of road pricing schemes will determine the outcome indicators that need to be predicted. The ability to represent impacts in faithful and informative ways is likely to be important in demonstrating the extent to which objectives can be met. On the other hand, the inability to predict impacts in some areas may act as a significant constraint on the pursuit of related objectives.
- **Scheme design:** Prediction has, potentially, an extremely important role to play in informing scheme design, through representation of the impacts of a range of alternative scenarios. Depending on design details, traffic flows may be reduced on some routes but increased on others.
- **Technology:** Predictive work that focuses on the performance of technology may help to show which options are feasible and may also assist with technological design details.
- **Appraisal:** As will be discussed in Chapter 7, information for appraisal and, to some extent, evaluation is generally derived from predictive models. Hence these areas are inextricably linked.
- **Economy:** Prediction of the wider economic impacts of road pricing is one of the most problematic / least well developed areas of research. In economic theory, road pricing is considered to improve efficiency in the travel market leading to benefits throughout the economy. In practical policy-making, concerns exist about whether real road pricing schemes will lead to positive or negative benefits for economic activity within charged areas and whether unilaterally implemented schemes may affect economic competition between localities.
- **Equity:** Prediction of distributional impacts of road pricing across the population is likely to be central in determining equity effects but is difficult because many models do not reflect different user groups. This may also be expected to feed into consideration of mitigation measures within scheme design.
- **Acceptability:** The acceptability of road pricing may be related to perceptions of its effectiveness and how its impacts are distributed across the population. Prior to implementation, prediction is likely to be the most reliable source of this information and may play a critical role in the political process. In particular, evidence about the robustness of predicted outcomes will affect the levels of trust that politicians and the public will be prepared to place in the policy-making processes.
- **Transferability:** The ability to predict the impacts of road pricing may sometimes be critically dependent on whether information can be transferred reliably between different situations. In particular, variations in approaches to prediction and appraisal between different locations may affect how transferable outputs from one road pricing study are to another.

6.6 WHAT GAPS EXIST IN OUR CURRENT KNOWLEDGE ABOUT PREDICTION?

In addition to problems already raised, the DISTILLATE project has carried out a wide-ranging review to identify knowledge gaps within the context of modelling and prediction of the impacts of road pricing schemes (Shepherd *et al*, 2006). These gaps are summarised below:

The first 4 issues relate to the difficulty in modelling of schemes themselves...

- 1) Modelling of different schemes. In general distance based charging and cordon schemes can generally be modelled reasonably accurately. However, because conventional modelling makes a per trip assumption, it is difficult to model area-based charging schemes. There are now models that provide tour-based representations of

- travel patterns but these have not yet been adopted widely. The recent work of Maruyama and Sumalee (2007) uses a simple trip-chain model to attempt to compare area-based and cordon charging to address this issue.
- 2) Modelling of exemptions or discounts. Within the conventional modelling framework as cited above, it is difficult, if not impossible to match data to trips in the assignment. The conventional approach would be to apply some factors outside the main modelling process. This could reduce the robustness of forecasts without further thorough sensitivity testing. In Edinburgh, the congestion charging proposals involved limiting the maximum charge to £2 a day and if trips crossed the first cordon to enter the innermost cordon, they would not be charged twice (Saunders, 2005). Unfortunately, attempting to model this form of exemption within most tactical level models is not feasible at present.
 - 3) Models used for road pricing prediction tend to be static and they are quite unable to handle dynamic changes e.g. predicting the influx of traffic into the charge area at the end of the congestion charge period.
 - 4) Modelling the possibility of purchasing monthly tickets/passes. If users can purchase a fixed price monthly pass, this would affect their timing, frequency and mode choice, since once that pass is purchased, the marginal cost of using that pass is zero.

The remaining issues relate to the modelling of changes in travel behaviour as a result of the introduction of road user charging scheme:

- 1) The possibility of trip chains being formed as a result of a congestion charging scheme is difficult to represent unless sophisticated modelling techniques are used. Even if the models are available, the data collection and the effort required to do these will be extremely demanding.
- 2) The possibility of changes in vehicle occupancy. Vehicle occupancies are normally assumed to be fixed in most models, yet road user charging would give an incentive to increase vehicle occupancy (Glaister and Graham, 2004)
- 3) Park and ride could possibly be important and it is still quite difficult to model these with much robustness.
- 4) Modelling of land use changes. It is uncertain whether cordons for entry into the city centre may lead to extensive development of out of town urban development sites which can be accessed by un-priced routes and what implications these outcomes might have on future urban form.
- 5) Lack of integration between private car modelling and public transport modelling. This is important if the extent of the Mohring effect is to be quantified and exploited as advantageous to public transport operators within the framework.

These gaps imply that there might be problems using outputs generated from predictive models to support the appraisal process. Other relevant areas where doubts exist over the abilities of the prediction process to produce accurate outputs include:

- parking policies
- equity and accessibility (and their interactions)
- distinctions between private and business traffic
- departure time changes (as experienced in Stockholm)
- destination changes
- impacts of using revenues outside the transport sector

In addition, it is difficult to predict the acceptability of a scheme with conventional modelling tools. At present, our understanding of what constitutes an acceptable scheme is limited. More discussion of this theme is contained in Chapter 11.

6.7 CONCLUSIONS

This chapter has summarised the current state of the art for predicting the impacts of urban road pricing schemes. It has found that prediction is considered to be a crucial element of the decision-making process and has shown that models play a central role. It has also described a range of alternative modelling approaches that are available and has illustrated ways in which variations in both the approach adopted and the details of how models are applied to individual situations may affect outcomes. It has also told a story of increasing complexity of prediction work and associated models over time, in response to increasing awareness of the complex relationships that govern the outcomes of transport policy innovations and to increasing demands for accurate predictions to feed into political decision-making.

The role of politics in setting the background to prediction should not be overlooked. Although the aims of the prediction process, when viewed from within, are primarily technical, attempting to ensure that resources are used to best effect to improve the transport system, from the outside the role that prediction plays in decision-making is sometimes rather less clear cut. Demonstrating that a proposed scheme will broadly achieve the objectives used to justify its implementation is always likely to be a desirable prerequisite in a democratic society. But, the importance of being able to do so may vary dependent on issues such as the nature of the scheme, the ability of the prevailing approaches to provide accurate predictions and the range of other reasons that may influence the final decision on whether or not to implement. In the case of road pricing, a decision to commit resources to implementing a scheme is not irreversible to the extent that is the case when, for example, building a new road. If a road pricing scheme does not produce the desired benefits it can be modified or withdrawn. In addition, it is clear that there are known to be significant issues of uncertainty which may affect ability to produce accurate predictions. So, it follows that the main motivation for placing high emphasis on prediction (as shown by the UNAQ results), is the perception of policymakers that as much evidence as possible of the benefits of road pricing is required in order to gain sufficient acceptance from politicians and a sceptical public. The initial implementation of road pricing is essentially a short-term political risk rather than a long-term planning commitment. The differences that have been observed in approaches to prediction during the PREGRESS project between UK and Italian cities, and the role that prediction has played in Stockholm, point to significant variations in the political decision-making culture within the EU that affect the prediction activities undertaken and attitudes towards outputs.

Questions that frequently arise when prediction is discussed include whether it may have become over-reliant on complex models, whether the nature of the outputs (including levels of coverage and accuracy) are fully understood by all those who use them and whether it is worth the cost in terms of time and money. There are obvious attractions in using simple models that are easy to understand and relatively cheap to implement. There is also likely to be an important relationship between the revealed accuracy of model predictions and the levels of trust that people are prepared to place in future modelling activities. Where well founded doubts exist over the ability of models (or other prediction approaches) to produce reliable outputs for particular indicators, it is potentially unwise to attempt to estimate them in that way as it may only reduce respect for the prediction process in the longer term. In Stockholm, model-based predictions for the road pricing trial were generally not trusted and turned out to be more accurate than expected. On the other hand, each proposal to implement a road pricing scheme represents an opportunity to acquire data to improve understanding of the processes at work leading to more accurate predictions. However, as already argued, external political factors may ultimately dictate the nature of prediction activities undertaken and expectations about the uses of outputs.