pro**S**pects

Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems

Deliverable No. 3

Key Modelling Issues

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Preface

PROSPECTS (Procedures for Recommending Sustainable Planning of European City Transport Systems) is a project funded under the European Commission's Environment and Sustainable Development Programme. It is designed to provide cities with the guidance they need in order to generate optimal land use and transport strategies to meet the challenge of sustainability in their particular circumstances. The PROSPECTS consortium is led by ITS, University of Leeds (Great Britain) and includes the partners TUW (Austria), TØI (Norway), KTH (Sweden), UPM (Spain) and VTT (Finland).

This document is the report on Task 31 in the third Work Package (WP30) of PROSPECTS, for which ITS has had the responsibility. It is the third formal deliverable of the project. In general, WP30 develops existing forecasting and analysis tools, and Task 31 is concerned with a review of the requirements for these tools arising from the review (in WP10) of decision-making requirements, and the ability of existing tools to meet those requirements. This work includes a review of the capabilities of the tools to produce indicators for use in the evaluation methods identified in WP20.

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SUMMARY

This report is the third deliverable of PROSPECTS: Procedures for Recommending Sustainable Planning of European City Transport Systems. PROSPECTS is funded under the European Commission's Environment and Sustainable Development Programme. It is designed to provide cities with the guidance which they need in order to generate optimal land use and transport strategies to meet the challenge of sustainability in their particular circumstances.

The report presents the results of the first task (Task 31) of the third Work Package (WP30), whose overall objective is to develop existing forecasting and analysis tools. This (first) task involves a review of modelling requirements arising from city decision making requirements (as identified in WP10), and analyses the ability of existing tools to meet those requirements. This work includes a review of the capabilities of the tools to produce indicators for use in the evaluation methods identified in WP20.

Two specific aspects of model capability are considered in this report. Firstly, it considers the representation and prediction of the supply effects which result from the implementation of transport instruments. These types of effect can be subdivided into first order effects (such as changes in capacity and direct user costs) and second order effects (such as accidents and pollution). Secondly, it considers the representation of behavioural responses by the various actors in the transport / land use system to the implementation of transport instruments. These can be further subdivided into: responses by system users (either individuals or organisations); responses by suppliers; and public opinion responses.

The report is structured as follows. Section 2 considers previous work in reviewing current and emerging model capabilities. Sections 3 and 4 discuss, respectively, the likely supply effects and behavioural responses following the implementation of an instrument. Section 5 reports the results of a questionnaire survey in which the PROSPECTS software package producers were asked whether or not the models/methods incorporated in their software packages could represent these supply effects and behavioural responses. Using the information from this survey and information from previous work, Section 6 describes significant gaps in modelling capabilities. Section 7 lists a number of areas for long term model development.

The suggested areas of model development are: representation of freight traffic in an urban environment; measurement and response to journey reliability, quality and information; improved air pollution modelling and the effects of air pollution upon health; improved modelling of distributional impacts; the responses to telecommunications; trip linking, including activity modelling and the pedestrian sub-links of complex trips; transport supplier responses; and impacts upon public opinion.

The report describes innovative approaches for fulfilling two of these recommendations: (1) Objective measurement of journey reliability, quality and information; and (2) Interaction of suppliers and users with political processes.

1. INTRODUCTION

The purpose of Task 31 is to raise, at an early date within the PROSPECTS project, issues about the capabilities of currently used land use / transportation models. The focus of this exercise is not so much on what such models can do already, but rather upon what they cannot do. In particular, it focuses upon those areas in which large scale developments in modelling will be needed in the future and hence leads directly to suggestions for new areas of research. As part of this overall review, the models used in PROSPECTS models are examined in some detail.

At the outset, a distinction needs to be made between:
- Models, which are mathematical representations of various phenomena; and
- Computerised modelling packages, which implement a collection of models for practical applications.

Two specific aspects of model capability are considered:
- The representation of the supply effects which result from the implementation of transport instruments. These effects are of two types. Firstly there are those effects which result automatically from the implementation of an instrument (without any behavioural response occurring). Secondly, there are those changes in supply that occur once such behavioural responses have taken place. Both types of effect can be subdivided into first order effects (such as changes in capacity and direct user costs) and second order effects (such as accidents and pollution).
- The representation of behavioural responses by the various actors in the transport / land use system to the implementation of transport instruments. These can be further subdivided into: responses by system users (either individuals or organisations); responses by suppliers; and public opinion responses. Due to the concentration in PROSPECTS upon sustainability (and the resulting need for fundamental changes in transport behaviour), the focus of behavioural responses is upon fundamental rather than incremental change.

The underlying method of Task 31 can be summarised in the following steps:
1. Transport / land use instruments (to be modelled) are identified (already done in WP10 and reported in PROSPECTS, 2001a).
2. Results are considered from previous work in reviewing current and emerging model capabilities. These are reported in Section 2.
3. Matrices are created showing the likely first order supply effects and the likely (user and supplier) behavioural responses following the implementation of an instrument. These matrices are given in Appendix 1 and are discussed in Sections 3 and 4. It is not considered useful to create matrices of instruments against second order supply effects and public opinion responses since they are likely to result from the implementation of all instruments.
4. Software package producers (involved with PROSPECTS) are asked whether or not the models/methods (incorporated in their software packages) can represent the effects and responses in Step 3.
5. From the information provided in Step 4, a second set of matrices is created, showing how each package models each first order supply effect and (user / supplier) behavioural response. This is reported in Section 5. A summary is also

given in Section 5 on how the packages in general model second order effects and public opinion responses.

6. By combining the information from Steps 3 and 5, significant gaps in modelling capabilities, with respect to policy instruments, are identified in Section 6.
7. A number of recommendations are given, in Section 7, for areas of long term model development.

In general, the following comment can be made about the themes that are covered in this deliverable. The focal point of PROSPECTS concerns sustainability, which can be considered to have three aspects: economic sustainability, social sustainability and environmental sustainability. The last of these is particularly significant in that current rates of traffic growth in European cities simply cannot be sustained in terms of the natural resources required by such high levels of traffic. It follows that there needs to be a "trend-break" with respect to this growth, and that land use / transport instruments must be found which can achieve this trend-break. Almost by definition, a trend-break leads to fundamental changes in transport behaviour. A challenging task for modelling is to try to predict such changes, in the knowledge that they are of a different order of magnitude to transport changes that have occurred in European cities in the recent past (i.e. the period during which transport models have been constructed). This issue will be a recurring theme of this deliverable.

2. BACKGROUND RESEARCH

Two model review studies provide a potential basis for the work in Task 31:

- The New Look Study (DSC, 2001) was commissioned by the Department of the Environment, Transport and Regions (DETR) in the UK to carry out a wide-ranging review of future needs for multi-modal modelling and of how these needs may be met.
- SPOTLIGHTS is an EU-funded Thematic Network concerned with transport modelling issues as part of the Fifth Framework's Competitive and Sustainable Growth Programme.

These two studies are summarised in this section.

2.1 New Look Study

The project brief of the New Look Study specified three areas of work:

- An assessment of future modelling requirements, taking account (for example) of changes in policy issues, in appraisal and in decision-making.
- A review of current and emerging possibilities with respect to modelling.
- An assessment of possibilities against requirements, taking account of practical issues (such as data needs), leading to recommendations.

2.1.1 Model requirements

The New Look Study identified 20 significant requirements for model development:

1. Models need to incorporate land use – transport interactions
2. Models need to reflect choices between telecommunications and travel
3. Models need to reflect a wider range of user responses, of which the most important are vehicle ownership, trip frequency and length, trip timing and chaining.
4. Models need to be able to reflect the changes in travel which users make in response to life cycle, location, and other external factors.
5. Models need to be able to predict the stream of changes over time, rather than simply conditions in the horizon year.
6. Models need to be able to represent the demand and supply impacts of a much wider range of policy measures, including land use, attitudinal and information measures, and those affecting cycling, walking and parking.
7. Models need to reflect the response of the private sector in influencing public transport supply and performance; parking and track-based systems in particular need to be better represented.
8. Models need to represent the causal chains which lead to changes in demand, supply and performance, and to do so through increased use of feedback loops within and between the demand and supply sides of the model.

9. Models need to predict the indirect influences of transport on social, health and economic impacts.
10. More complex models are needed for conurbation, regional, corridor and potentially national application, including greater spatial, temporal and person type differentiation.
11. Models need to be able to generate appraisal indicators relevant to sustainability, social, health and economic impacts.
12. Models need to be able to assess impacts of demand changes on quality and reliability of transport services; and models must be able to inform risk analysis of transport decisions (with reference to private and public sector concerns).
13. Models need to be able to represent the distributional impacts of strategies and measures on all impact groups of interest.
14. Models need to be able to present outputs at greater levels of spatial and temporal detail.
15. Models need to enable performance to be assessed accurately against specified targets and standards.
16. Models need to generate output of much greater quality to facilitate interaction with decision-makers and stakeholders.
17. There is a case for developing interactive decision-making models and decision support tools.
18. There may also be a need for models which assist in option generation and optimisation.
19. Public participation in decision-making should be used as an additional source of model enhancements and data provision.
20. More and higher quality data is needed for model development, calibration and validation, particularly for demand responses, and greater use should be made of monitoring programmes and innovative data capture methods.

Of these requirements, (1) to (13) are more relevant to Task 31, although Requirements (14) to (20) are of great importance to other aspects of PROSPECTS.

2.1.2 Current / emerging modelling possibilities and assessment of possibilities against requirements

The New Look Study considered current developments in the following four general modelling approaches:

- Best practice in mainstream modelling
- Dynamic modelling
- Activity modelling
- Land use / transport interaction modelling

In order to meet the requirements given above (specifically Requirements (1) to (13)), the study made the following recommendations:

> Developments aimed at the integration of these approaches are likely to be disaggregate in technique, and microsimulation methods may be appropriate, but the implication of using disaggregate sample-based models in either

conventional probabilistic or in microsimulation forms will need to be examined further.

A number of problem areas remain which are not readily addressed by the methodological advances we can currently envisage: these are:

- The treatment of quality in transport supply
- Walking and cycling
- Transport supply modelling in general

In summary, the New Look Study provides a very useful generalised basis for the work in Task 31, providing a platform for Task 31 to identify some specific concrete lines of model development. In particular, the three problem areas identified above provide recurring themes for this deliverable.

2.2 SPOTLIGHTS

2.2.1 Description of SPOTLIGHTS

The SPOTLIGHTS thematic network is constructing a European Model Directory (MDir). The following description of SPOTLIGHTS and MDir is taken from "The relevance of the European Transport Model Directory (MDir) for the European Transport Information System (ETIS)", a paper written by Arnaud Burgess of NEA for a SPOTLIGHTS workshop in December 2000.

> The main objective of SPOTLIGHTS is to develop and achieve an agreement within the European Modelling community in relation to four issues (the 4 SPOTLIGHTS discussion lines) which are considered "keys to bring advanced models to light":
>
> 1. Quality control procedures and deontologic codes for modellers and end-users (DCode)
> 2. Harmonised descriptions for models to be included in a common European Model Directory (MDir) (input to ATOM)
> 3. Data formats (GTF) for standardised data exchange between models and software tools
> 4. Long term opportunities (LT) for model's integration to decision support systems. Current Best Practices and Future Trends. Implication on organisational and institutional arrangements (input from ATOM)
>
> The long-term ambition of SPOTLIGHTS is helping policy makers and experts ("end-users" of scientific models) to make an effective use of advanced scientific models.
>
> The status of MDir is that 217 European transport models have been included in the MDir database. The MDir database consists of 57 characteristics on which models are described. In setting up the MDir structure the policy relevance is one of the important items, it gives the domain of the model (passenger / freight), the modes included, which level of detail (urban / regional / national / international). The 57 variables are distinguished in eight categories with each a number of sub-sections:

1. Name
2. Policy relevance
3. Accessibility
4. Input data
5. Formulation
6. Outputs
7. Software & hardware
8. Audits

2.2.2 Relationship between SPOTLIGHTS and Task 31

The first point to make when comparing SPOTLIGHTS and Task 31 is that the level of resources for SPOTLIGHTS is of the same order as that of the whole of the PROSPECTS project, and is clearly at a much higher level than that of PROSPECTS Task 31. It follows that there is no benefit to the EC for Task 31 to attempt to repeat, on a much lower budget, the SPOTLIGHTS methodological process. Rather, it is important that Task 31 finds a niche that, whilst complementary to SPOTLIGHTS, is substantially different in its approach.

SPOTLIGHTS is attempting to make a comprehensive overview of transport modelling practice throughout Europe. It has constructed detailed questionnaires for package producers to try to capture all the relevant aspects (in its "57 characteristics") that would be of interest to potential users of the package. Clearly this is a difficult task which can lead to particular software producers complaining that their packages have not been included. For example, none of the packages used in PROSPECTS were featured in the model list produced in December 2000.

The distinction between SPOTLIGHTS and Task 31 is achieved by the latter's focus upon a small number of specific areas of future model development as opposed to the SPOTLIGHTS comprehensive current state-of-the-art review.

3. SUPPLY EFFECTS

As stated in Section 1, two types of supply effects, resulting from the implementation of transport instruments, are considered here. Firstly there are those effects which result automatically from the implementation of an instrument (without any behavioural response occurring). Secondly, there are those changes in supply that occur once such behavioural responses have taken place. Both types of effect can be subdivided into first order effects (discussed in 3.1) and second order effects (discussed in 3.2).

3.1 First order supply effects

First order supply effects can be defined as those supply effects that lead directly to user responses in the land use / transport system. Five basic classes of first order supply effects are considered in Task 31:

- Capacity / congestion
- Direct user costs
- Reliability of journey time
- Quality of journey
- Information provision

Before listing the types of effect in each class (in Section 3.1.1 below) it is worthwhile making some general comments about these classes.

Capacity concerns the capacity of the whole transport system and results from the aggregation of the capacities of individual elements of the system, such as the capacity of a road. *Congestion* concerns the interaction between capacity and demand, and in particular how the level of system service deteriorates as demand increases.

Direct user costs are those costs which the land use / transport system user experiences subjectively. Typically, such costs include average journey time and finance costs and are aggregated to form a generalised cost function. It is usually argued that these costs are the most important to take into account when modelling behavioural responses. However, other user costs (for example those considered immediately below) can also be considered.

Reliability, quality and *information provision* are here understood to be objective characteristics of the land use / transport system which might be automatically altered by the implementation of an instrument. In order to represent such a change, it is firstly necessary to be able to measure (in some quantitative way) the overall level of reliability, quality or information in the system. It is important not to confuse such objective measures with the contribution that reliability, quality and information provision might make towards a user's subjectively experienced direct costs. Although it is likely that there would be a correlation between objective characteristics and subjective costs, they are essentially different elements of the land use / transport system.

3.1.1 List of types first order effects

The five classes of first order supply effect can be broken down as follows:

(i) Capacity / congestion
- Road capacity changes
- Road congestion
- Bus capacity changes
- Bus overcrowding
- Train capacity changes
- Train overcrowding
- Parking capacity changes
- Car park congestion

(ii) User costs
- Direct location costs of businesses
- Direct location costs of householders
- Direct travel costs of businesses
- Direct travel costs of road freight companies
- Direct travel costs of rail freight companies
- Direct costs of car travellers
- Direct costs of bus passengers
- Direct costs of train passengers
- Direct costs to users of other modes

(iii) Reliability of journey time, by:
- Car
- Bus
- Train
- Bicycle
- Walking
- Motorcycle

(iv) Quality of journey, by:
- Car
- Bus
- Train
- Bicycle
- Walking
- Motorcycle

(v) Information provision for:
- Car users
- Bus passengers

- Train passengers
- Bicyclists
- Pedestrians
- Motorcyclists

It should be noted that, for simplicity, the above supply effects are defined as if journeys are made by a single mode. However, since the issue of *intermodality* (using more than one mode on a single journey) is important, all the above classes of effect should take intermodal journeys into account where appropriate.

3.1.2 Tables of first order effects resulting from instruments

Tables A1 to A10 in Appendix 1 give a summary of the first order supply effects resulting from the introduction of the set of land use / transport instruments created in WP 10. These tables have a large amount of information stored in them, which forms a backdrop to the discussion in the following subsections in 3.1. However, this discussion is self-contained so that the reader does not need to refer to the appendix if he/she does not wish to do so. In order to make the discussion compact, only the most relevant issues with regard to Task 31 will be covered, and it follows that only certain combinations of instruments and effects are discussed. Focus is put here on issues which will later be seen to be significant (in Section 5) with respect to modelling capability.

Table 3.1 shows where particular issues are discussed in Section 3.1 and the associated tables in Appendix 1.

	• Capacity / congestion • Direct user costs	• Reliability of journey time • Quality • Information provision
Land use measures	3.1.3 (A1)	3.1.3 (A2)
Attitudinal / behavioural measures	3.1.4 (A1)	3.1.4 (A2)
Infrastructure measures	3.1.5 (A3)	3.1.5 (A4)
Management of the infrastructure	3.1.6 (A5)	3.1.6 (A6)
Information provision	3.1.7 (A7)	3.1.7 (A8)
Pricing measures	3.1.8 (A9)	3.1.8 (A10)
Compensatory measures outside the transport field	3.1.9 (A9)	3.1.9 (A10)

TABLE 3.1 Organisation of Section 3.1 and appendix tables for first order supply effects

3.1.3 Land use measures

Most land use measures are unlikely to have a direct effect on transport capacity, although once users have responded to land use measures there are likely to be changes in system congestion (road, public transport and in car parks). The obvious exception to this general observation is that land use parking measures (for both passenger and freight traffic) will have a direct effect on parking capacity with a potential subsequent effect on parking congestion.

By changing peoples' location of home, work and other activities, land use measures will have a direct effect on user costs. Furthermore, f land use measures lead to homes, workplaces and shops being located close to each other, it is likely that the reliability of work journeys and shopping journeys will improve.

3.1.4 Attitudinal and behavioural measures

Attitudinal and behavioural measures will not have a direct effect on capacity. However, by triggering behavioural responses (as described in Section 4 below) they will have an effect on congestion.

Clearly, many attitudinal and behavioural measures (particularly public awareness campaigns and company travel plans) will have an effect of changing the (objective) level of information provided by the transport system. As stated above, in order to be able to quantify such changes in information, it is necessary to be able to measure it in a consistent way.

Furthermore, a measure of information provision for public transport users is required in order to be able to assess the behavioural responses due to certain transport instruments such as flexible working hours.

3.1.5 Infrastructure measures

Infrastructure measures clearly have direct effects upon capacity (and hence congestion) and upon user costs (in terms of money and average travel time), and it is these effects that are typically considered most in modelling and assessment exercises.

However, the effects of infrastructure provision upon (objective) quality and reliability are also important, especially concerning public transport infrastructure, since the behavioural responses of users are liable to be highly dependent upon such effects. In particular, the quality of “modern” rail-based urban infrastructure needs to be measured. Once this is accomplished, the value to the individual traveller of these factors will be subjectively weighed up with other costs and benefits such as fare and journey time (as discussed in Section 4 below).

3.1.6 Management of the infrastructure

Measures to manage infrastructure will have a direct effect upon capacity, and hence upon congestion and user costs. Furthermore, they will lead directly to changes in (objective) reliability, quality and information provision.

3.1.7 Information provision

The most direct effects of measures to increase information provision are, not surprisingly, upon the objective level of information in the transport system. Important secondary effects concern reliability, especially if real-time information systems are being implemented. Through the enhancement of information, user costs to the traveller will be altered.

3.1.8 Pricing measures

The most direct effects of pricing measures are upon user costs. As a general rule, it is essential that road users (both passenger and freight) are aware in advance of the costs that they are required to pay (at least within a range) and so it is essential for modelling purposes to be able to quantify the level of information provision that is actually associated with the implementation of any particular pricing measure.

3.2 Second order supply effects

3.2.1 Overview of second order effects

Second order supply effects are defined as those effects which occur outside the land use / transport systems being studied, in the sense that such effects are not assumed to change the behaviour or affect the choices of the users of the system. A broad range of effects may be considered under this heading, including environmental effects, accidents, implications for government budgets, and wider economic and social impacts. Some of these second order effects (especially global and regional environmental effects and some of the wider economic impacts) will be felt by residents living outside the studied area and even living far into the future.

Effects that are experienced by residents in the studied land use / transport system will also be second order effects provided they do not affect them in their capacity as travellers or influence their location choices. Thus a policy might affect them as taxpayers, but since their response to tax increases is not a part of the land use/transport system as we define it in most cases, this will be a second order effect in most cases. Also, travellers in the transport system are currently not assumed to change their decisions based on, say, the changes in the accident rates of different modes or the levels of local pollution experienced on a trip. This is why we can regard such effects as lying outside the studied system.

The concept of second order supply effects must therefore be defined relative to the studied system and the purpose of the study (strategic, tactical) being made. In an integrated land use / transport context, local pollution will perhaps be a borderline case. For the travellers in the transport system, local pollution is a second order effect, since the level of local pollution does not affect their trip behaviour. But the same individuals are also residents in the location system. If changes in local pollution levels in the zones affect their location choices, and if the link between traffic volumes and zonal levels of pollution is established in our model of the system, local pollution can clearly not be seen as a second order effect any longer. In fact, in the DELTA modelling system (to be discussed further in Section 5) local air pollution (along with noise pollution) from transport is considered to be a factor in the residential location choice model[1]. Hence, in the DELTA system, local pollution (both air and noise) from transport is a first order effect. Unfortunately, though, this approach is not common in land use modelling systems, and so local pollution is treated as a second order effect in this deliverable.

We consider the following second order effects:

- Environmental effects
- Traffic accidents
- Health effects
- Liveable streets and neighbourhoods
- Implications for government budgets
- Equity and social inclusion
- Economic growth

The concept of external costs / benefits and the concept of second order effects should not be confused. On the one hand, some external costs like traffic congestion and neighbourhood externalities might be studied as first order effects in the land use / transport system. On the other hand, some second order effects will clearly not be external costs and benefits. For instance, income distribution effects are not external effects, and economic growth effects are mainly propagated through the market. The only difference between a first and second order effect in our terminology is that the latter does not influence the behaviour of the users of the system as we conceive it.

Data to compute second order effects comes from either the land use/transport model input or from its output. More or less sophisticated processing of the data might be required to establish the effects. Examples of such post-modelling include equity analysis and air pollution modelling.

[1] However, a distinction needs to be made here between *zonal levels of pollution* (the subject of this discussion) and the *amount of emissions from traffic generated in each zone*. The latter does not take account pollution from non-transport sources or the dispersion effects of pollution due to, for example, weather conditions, and hence it is the former concept that more closely fits with standard perceptions of air quality. In the DELTA modelling package there is a link between traffic emissions generated in a zone and location choice. However, this link should be seen as a proxy for the link between zonal levels of pollution and location choice and is clearly a modelling simplification.

3.2.2 Types of second order effects

Second order effects are diverse, and we only list some of the more important ones here.

(i) Environmental effects
- Global air pollution (CO_2)
- Regional and local air pollution
- Severance effects
- Degradation of valuable sites and habitats
- Greenfields claimed for transport and building purposes
- Noise

(ii) Traffic accidents
- Accidents involving pedestrians and cyclists
- Other traffic accidents

(iii) Health effects
- Health effects of shifts to walking and cycling
- Health effects of shifts to public transport (walking and cycling to stations)

(iv) Liveable streets and neighbourhoods
- Safety, especially for children, in neighbourhoods
- Freedom of movement for pedestrians and cyclists
- Security in the public transport system

(v) Implications for government budgets
- Local
- National

(v) Equity (intergenerational and intragenerational) and social inclusion
- Distribution of benefits between the current generation and future generations
- Distribution of benefits between the studied region and other regions
- Geographical distribution of benefits inside the studied region
- Distribution of benefits among income groups
- Distribution of benefits among household types
- Accessibility for those without a car
- Accessibility for the mobility impaired
- Degree of segmentation in the location of socio-economic groups

(vii) Economic growth
- More efficient markets for goods and services
- Benefits to local firms after final redistribution of benefits
- Growth impacts of more efficient markets and benefits to firms

3.2.3 How policies affect second order effects

Many second order supply effects only emerge as the end result of the total behavioural changes in the land use and transport system, or even in wider international and interregional systems of production, trade and government intervention. Other effects depend crucially on the finer details of land use and transport planning, and can only be assessed in a very broad way at the strategic level. Consequently, it is difficult to use tables for second order effects such as those included in Appendix 1 for first order effects. Nevertheless, we indicate below how each group of policy instruments may influence the second order effects, with a view to assessing (in Section 5) if and how existing models might capture such influences.

Land use measures have a direct impact on environmental aspects such as the use of greenfields, the conservation of habitats and valuable sites, and severance effects. Furthermore they will have a direct impact upon health, equity, liveable streets and economic growth. Quite often, they also have important consequences for local government budgets, in the form of the considerable costs of providing public services to new areas and through attracting new taxpayers. Other effects, for example on air pollution and accidents, are achieved indirectly through responses in the transport and land use systems.

Attitudinal and behavioural measures are often thought to be vital to bring about a shift to greener policies and are widely used to achieve traffic safety and health goals. Their efficiency is however in doubt. Probably, these measures will work best when combined with regulatory and pricing measures, or when used to create sufficient support for such measures.

Infrastructure measures will usually lead to strong equity effects (both intergenerational and intragenerational). For public transport infrastructure such effects will typically be positive, though for road infrastructure such effects could be negative. Infrastructure measures will typically lead to economic growth, although (in the short term at least) at a cost to public finance budgets. Such measures can also create severance, influence accidents and the liveability of streets / neighbourhoods, and have health effects as a result of changes in mode of travel.

Management of the infrastructure is important for the level of particulates in the air near roads and for accidents (snow and ice clearing, road and rail maintenance, signals and traffic management). Likewise, it is vital to security in the public transport system, to accessibility to the mobility impaired and the creation of liveable streets and neighbourhoods. Since it indirectly influences infrastructure capacity, it has an impact on almost all the other second order effects.

Information provision is vital for accident effects and induces behavioural changes that increase the efficiency of transport and land use markets. This in turn affects other second order effects.

Pricing measures lead directly to changes in public finance, equity and economic growth and to other second order supply effects indirectly through behavioural changes in the transport and land use systems.

4. BEHAVIOURAL RESPONSES

As stated in Section 1, the representation of behavioural responses by the various actors in the transport / land use system can generally be classed as responses by system users (discussed in 4.1) or responses by suppliers (discussed in 4.2). However, there is a third class of response that does not fit neatly into either category. Such responses concern issues such as *public opinion*, both with respect to the population as a whole and with respect to specific interest groups. Insofar as these issues simply represent the impacts of transport policies upon public opinion, they can be considered as second order effects (as discussed in the previous section). However, since they also involve action with respect to changing the land use / transport system, they are more properly classed as responses: for the purposes of this deliverable they are defined as *public opinion responses*. They are discussed further in Section 4.3.

4.1 User responses

4.1.1 Overview of user responses

Demand/behavioural responses by system users can be separated into 4 categories:

- Strategic location responses
- Strategic transport responses
- Day-to-day responses
- Within-day responses

The meaning of *strategic location responses* is probably clear without further explanation. However, it is useful to explain further the categories of transport response, and such discussion will hopefully help to distinguish between them. Two types of *strategic transport responses* are considered. On the one hand, there are discrete one-off events which are likely to have a heavy consequential influence on transport behaviour. For example, buying a car, motorcycle or public transport season ticket are such events. The other type of strategic transport response simply concerns the overall quantity of travel carried out, without disaggregating between purpose, mode or other factors.

In the traditional context of equilibrium modelling, *day-to-day transport responses* correspond to average (equilibrium) behaviour. In fact, transport planners and modellers with a background of using such models would probably find it easier to use the term *average transport behaviour*. However, such terminology implicitly omits any sense of dynamic evolution of behaviour (as represented in a dynamic model). Thus the more generalised term *day-to-day transport responses* is used in Task 31. However, for those people who think in terms of equilibria, day-to-day transport responses could equate to *changes in average behaviour*.

Within-day responses concern one-off responses within a particular day. The definition here is less complex than the definition of the other two transport responses.

In general, within-day responses would not be expected to be of great significance in the context of the strategic systems being considered by PROSPECTS. However, if one-off responses lead to changes in strategic behaviour, as the result of a *bad experience* or a *specific incident*, such responses should be taken into account in a strategic context.

4.1.2 Lists of types of user responses

Lists of the types of responses in the categories given above are as follows:

(i) Strategic location responses

- Relocate home within study area
- Move house out of / into study area
- Relocation of business within study area
- Start up / close down business within study area
- Change employment
- Mainly work at home
- Mainly shop at home (e.g. catalogue/internet shopping)
- Change school

(ii) Strategic transport responses

- Change car-buying behaviour
- Buy/sell a bicycle / motorcycle
- Car-pool/share
- Buy public transport season ticket
- Buy parking season ticket
- Change trip length distribution (of trips lying wholly within study area) over long term period
- Change trip length distribution (of trips lying partially within study area) over long term period

(iii) Day-to-day transport responses

- Change number of work trips per week
- Change number of shopping trips per week
- Change number of leisure trips per week
- Change "first choice" destinations of shopping / leisure trips
- Change mode (motorised vehicle mode)
- Change mode (to / from soft mode and between soft modes)
- Change "normal" departure time
- Change strategy of trip-linking
- Change "first choice" car parks (including use of park and ride)
- Change “normal” route

(iv) Within-day transport responses

- Abandon proposed trip (e.g. work/shop from home)
- Change departure time

- Change route
- Changes to trip-linking in response to specific "one day" conditions
- Changes to destinations in response to specific "one day" conditions
- Pre-plan journeys using real-time information systems
- Change use of car parks (including park-and-ride) in response to "one day" conditions.

Whilst some of these responses concern only passenger traffic, other responses refer to both passenger and freight traffic.

As pointed out in 3.1.1, the issue of intermodality is important. This issue is significant with respect to a number of the responses listed above, such as in the following examples concerning passenger traffic:

- In general, any trip by public transport will be intermodal in that it will typically involve a walk connection at both the start and the end of the trip. Furthermore, most car trips will involve a walk connection either at the start of the trip (to get to a car park) or at the end (to get from a car park to the final destination).
- The ownership of a public transport season ticket might encourage the use of intermodal journeys using both rail and bus (assuming of course that the season ticket covers both modes).
- Car pooling might involve intermodal journeys in two respects. Members of a car pool group might travel individually by a non-car mode (walk, bicycle or public transport) to arrive at a car pool meeting point (such as in a work-based car pool). Alternatively, members of the car pool group might be picked up from their homes by the pooled car and taken to a park and ride site to finish their journeys by public transport (such as in an neighbourhood-based car pool).
- Use of “park and ride” explicitly concerns intermodality between car and public transport.

Furthermore the following examples concern intermodality for both passenger traffic and freight traffic:

- “Changing mode” could apply to only part of a journey, with the remainder of the journey using a previous mode.
- “Trip-linking” should generally be considered within an intermodal context, whereby the individual trips in a trip chain could use different modes.

4.1.3 Incremental versus fundamental responses

Following the comments made in Section 1 about the need to address environmental sustainability issues, a useful distinction can be made between *incremental* and *fundamental* behavioural responses. These two concepts concern the aggregation of responses of individuals rather than the individual responses themselves. Incremental responses can be seen as those responses which are typical in the conditions currently existing in Western Europe, where traffic conditions are generally viewed as being "stable" (in the sense that growth is taking place in a smooth stable fashion). In general, such responses will not lead to a great change in lifestyle and working practices by most users of the land use / transport system; the only exception to this being the minority of people who are on the margin between distinct states such as owning or not owning a car. On the other hand, fundamental responses are those which lead to changes in lifestyle and working practices for a large number (maybe a majority) of the population. Obviously the boundary between incremental and fundamental is fuzzy to some extent, and some care needs to be taken when these concepts are used in discussion.

Given the fact that motorised traffic is growing in most (if not all) European cities, and that it is growing in an unsustainable fashion, there must inevitably be an interest upon transport instruments that lead to fundamental behavioural responses. Given that this issue is central to PROSPECTS, these responses (and their modelling consequences) will receive greater attention than incremental responses.

4.1.4 Tables of user responses resulting from instruments

Appendix 1 contains ten tables (Table A11 to A20) which contain information on user responses to the implementation of land use / transport instruments. A summary of these tables is given in Subsections 4.1.5 to 4.1.11 below. The organisation of these subsections and the associated tables in Appendix 1 is shown in Table 4.1.

	User responses • Strategic location responses • Strategic transport responses	**User responses** • Day-to-day transport responses • Within-day transport responses
Land use measures	4.1.5 (A11)	4.1.5 (A12)
Attitudinal / behavioural measures	4.1.6 (A11)	4.1.6 (A12)
Infrastructure measures	4.1.7 (A13)	4.1.7 (A14)
Management of the infrastructure	4.1.8 (A15)	4.1.8 (A16)
Information provision	4.1.9 (A17)	4.1.9 (A18)
Pricing measures	4.1.10 (A19)	4.1.10 (A20)
Compensatory measures outside the transport field	4.1.11 (A19)	4.1.11 (A20)

TABLE 4.1 Organisation of Section 4.1 and appendix tables for user responses

4.1.5 Land use measures

Clearly land use measures are likely to lead to strategic location responses, with consequent effects on both passenger and freight traffic. Furthermore, such measures are liable to have an important effect on car-buying behaviour and the possibility of car-pooling and car sharing. Of particular interest are those land use measures which bring homes, workplaces and shops close to one another, thus making "normal everyday" journeys much shorter. However, two issues need to be considered with such measures:

- It is possible that the shortening of "normal" journeys might lead to an increase in one-off journeys such as leisure journeys. This would occur, for example, under the behavioural hypothesis of a "fixed (individual) travel time budget". Interesting quality-of-life issues arise here, since leisure journeys would be expected to be inherently more pleasurable than work or shopping journeys, so that the replacement of the latter by the former will increase general social welfare. However, if there is no overall reduction in travel, the land use measures (by themselves) will clearly not lead to improvements in overall environmental sustainability.

- The make up of the household has a significant effect on the behavioural responses to land use measures, especially if there is more than one adult in the household who needs to travel regularly to work. If the workplaces are geographically distant, the concept of "workplaces closer to homes" becomes diluted. This issue leads directly to the issue of flexibility of workplace location, and to the possibility of using telecommunications in order to be less physically bound to (distant) workplaces, and is discussed in the next subsection.

4.1.6 Attitudinal and behavioural measures

Potentially, one of the most significant measures to affect travel patterns in the future will be telecommunications as an alternative to travel. On the simplest level, such a measure will reduce travel since work, shopping and leisure activities will be able to be carried out at home. However, there are a number of secondary location and transport effects connected with telecommunications that are more complex. Four examples of these are:

- A small number of large centralised workspaces (such as offices) could be replaced by a small number of geographically dispersed workspaces. Communication between these workspaces would largely be through telecommunications but there would be a need for a certain level of face-to-face contact between people working in different workspaces. Whilst the "daily" journey to work could be assumed to get shorter as a result of such decentralisation, the effects of the need for face-to-face contacts are not clear.

- From the point of view of certain types the individual employee, the possibility of working remotely is likely to encourage them to base themselves in a number of potentially dispersed "homes". Whilst telecommuting will reduce the numbers of (daily) "journeys to work" there is likely to be an increase in travel between these homes.

- The impact on leisure travel of telecommuting is extremely unclear. Arguably the lack of human contact resulting from working at home is likely to lead to increased needs for human contact through leisure activities. Furthermore, the possibility of working in multiple locations could result in the distinction between “work travel” and “leisure travel” becoming extremely unclear.

- Whilst “shopping from home” will reduce the need for people to travel to shops, the increase in traffic associated with the delivery of goods (from shops / depots to homes) needs to be taken into account.

Other attitudinal and behavioural measures (such as public awareness campaigns, flexible working hours and company travel plans) are likely to have significant effects on day-to-day transport responses. In particular, flexible working hours will lead to changes in: departure time; strategies for trip-linking; and choice of car park.

4.1.7 Infrastructure measures

Transport infrastructure measures are likely to lead to a number of location responses. Whilst these responses might not be immediate, they are significant when considered over a long term time horizon. On the other hand, strategic transport responses are liable to be more immediate, especially responses such as buying a public transport season ticket (in response to new public transport infrastructure). All infrastructure measures are liable to change trip length distributions for both passengers and freight, generally increasing the length of trips and the quantity of travel. However, transhipment facilities for freight can lead to increased use of rail for freight, by encouraging greater intermodality.

Infrastructure measures will lead to a large number of changes in different types of day-to-day transport responses, but will not usually lead to within-day transport responses.

4.1.8 Management of the infrastructure

The main management measures that would be expected to lead to location responses would be physical and regulatory restrictions. For example, the implementation of such measures around a city centre might lead households and/or businesses to locate within or away from the city centre, dependent upon their specific needs. Furthermore, the imposition of lorry bans on specific routes (or at specific times of day in a particular area) could lead to the relocation of freight depots.

Management measures would also be expected to lead to a number of different types of strategic transport responses. Of the other management measures that would lead to such responses, intelligent transport systems can be identified as being particularly significant.

Arguably, though, the main behavioural responses to management measures would be day-to-day responses, and in general all such measures will lead to a number of different such responses. Intelligent transport systems would be likely to lead to a number of different types of within-day transport response.

4.1.9 Information provision

It is unlikely that measures to change information provision will lead to location or strategic transport responses. Probably the main day-to-day transport responses resulting from such measures are upon the strategies that passengers and freight-movers use for trip-linking and upon their “normal” route choice decisions.

Real-time measures for information provision would be expected to lead to within-day transport responses. An issue of particular interest from a strategic modelling point of view concerns the aggregate effect of such within-day responses on “normal” day-to-day behaviour. Another issue of importance concerns tourists, who are likely to be strongly affected strongly by measures of information provision. Since the responses of tourists are virtually by definition one-off responses, the strategic aggregation of such responses is an important issue for planners in a city which wishes to encourage tourism.

4.1.10 Pricing measures

Pricing measures are liable to lead to a large number of behavioural responses in terms of location choice, strategic transport choice and day-to-day transport choice. Of particular interest here are the responses to well-focused urban road charging measures. Since such measures have not yet been implemented in Europe (except for Norway) on a widespread scale, a certain amount of speculation is currently required concerning the likely level of response of people to such measures. However, when urban road pricing schemes have been implemented, it will be important to quantify their behavioural effects.

4.2 Supplier responses

The assumption underlying all the tables shown in Appendix 1 is that there is a responsible "transport / land use authority" who is the main initiator of the instruments given in the rows of the tables. When considering supplier responses, the first issue of concern is whether this authority will itself bring in secondary transport measures in response to the main instruments that it has itself initiated. List of types of such response are given in Section 4.2.1.

Secondly, there is a need to consider whether *third party suppliers*, either in the private sector or other transport authorities, might make a response in terms of changing supply. This is discussed in Section 4.2.2

4.2.1 List of types of supplier responses made by an authority in reaction to the implementation of its "own" policy instruments

The land / transport authority that is responsible for implementing a land use / transport instrument might implement a number of subsidiary instruments to improve the effectiveness of the "main" instrument. Three important points can be made here:

- The underlying concept of a *subsidiary* instrument is that it is "less important" than the main instrument, and is hence different to the concept of a *complementary* instrument (as understood in the concept *package of measures*, as used in PROSPECTS). Whilst it might be considered, in real life applications, to be "good practice" to implement various subsidiary instruments, these are often omitted from plans at the early (strategic) planning stage. However, it might be the case that the design of the subsidiary instruments can turn the main instrument into a success or a failure.
- The transport authority will only be able to implement a subsidiary instrument if it is legally empowered to do so, and it might be the case that "third parties" (e.g. the private sector) have legal responsibility.
- There is no guarantee that a transport authority will implement "correct" subsidiary instruments even if it has the legal power to do so.

Examples of such subsidiary instruments are:

- Changes in traffic management (including traffic signal changes and changes in pedestrian provision)
- Changes in information provision
- Traffic calming
- Changing size of trains / buses
- Changing public transport quality
- Changing total car parking space
- Reallocating car parking space between "long term" and "short term"

4.2.2 Lists of third party supplier responses

An issue raised above in 4.2.1 concerned whether the transport authority had the legal power to enact subsidiary instruments. In fact, this a particular example of a more general issue that different organisations are responsible for different aspects of the land use / transport system. Where organisations different from the main transport authority have supplier responsibilities, they are termed *third party suppliers*. A problem with respect to modelling is that the definition of third party suppliers will differ between locations since different legal frameworks operate in different locations. Since such frameworks are not even standardised within single countries in Europe, there is clearly a wide variation when thinking about the EU as a whole. Even the concept of "an instrument initiator" to whom others "respond" (which underlies much of the discussion below) is rather simplistic for many real life situations. The challenge for transport models is to consider how they might be used to represent the actions of the various actors in complex organisational situations, and the effort in Task 31 should be seen as an early step towards this goal.

Given these provisos, the following examples of third party supplier responses can be given:

(i) Strategic location supply responses by third parties
- Building more (less) houses / workplaces / shops in a zone
- Changing the selling price of houses / workplaces / shops in a zone

(ii) Transport supply responses by third parties
- Changing rail / bus frequency
- Changing size of trains / buses
- Changing rail / bus fares
- Changing public transport quality
- Changing total car parking space
- Reallocating car parking space between "long term" and "short term"
- Changing car park charges

Furthermore, other land / transport authorities (such as neighbouring authorities or authorities on a higher/lower level) could make supplier responses by implementing any of the land use / transport instruments considered throughout this deliverable.

4.2.3 Tables of supplier responses

Appendix 1 provides five tables (Tables A21 to A25) showing likely supplier responses from implementing land use / transport instruments. These responses are summarised in Subsections 4.2.4 to 4.2.10 below. Table 4.2 gives information about how these subsections are organised and the associated tables in Appendix 1.

	Supplier responses • Responsible land / transport authority supplier responses • "Third party" supplier responses
Land use measures	4.2.4 (A21)
Attitudinal / behavioural measures	4.2.5 (A21)
Infrastructure measures	4.2.6 (A22)
Management of the infrastructure	4.2.7 (A23)
Information provision	4.2.8 (A24)
Pricing measures	4.2.9 (A25)
Compensatory measures outside the transport field	4.2.10 (A25)

TABLE 4.2: Organisation of Section 4.2 and appendix tables for supplier responses

4.2.4 Land use measures

The uncertainty about the responsibilities of different organisations (described above) makes it particularly difficult to categorise the behavioural responses of transport suppliers to land use measures. Very different types of categorisation emerge depending upon whether the land use authority is also responsible for transport or whether another public authority is responsible for transport, and the extent to which any public authority can control elements of transport policy (particularly with respect to public transport) if they are the responsibility of the private sector.

From a point of view of "easiness" of modelling, it would be advantageous to ignore these difficulties and make some simplifying assumptions concerning the transport results of implementing various land use measures, irrespective of who is responsible for doing so. However, such an approach could not distinguish between harmonious and contentious working relationships between various elements of the public and private sector. Almost inevitably, the approach would make some idealised (normative) assumptions about how organisations ought to respond to the implementation of land use measures, ignoring the observable reality as to how they actually do so. Such an approach is likely to bring models into disrepute.

The conclusion of these remarks is that land use / transport models are required which recognise the distinction between organisations with different responsibilities for planning and operation, and which represent their dynamic interaction. Furthermore these models need to be able to represent both cooperative and contentious behaviour between organisations.

4.2.5 Attitudinal and behavioural measures

Given the potentially different types of user response to telecommunications "as an alternative to travel" (as described in 4.1.6) it is important to question how suppliers of housing, office space and transport are likely to respond to such transport instruments. In practice, the responses of suppliers would be expected to vary widely. For the private sector, the level of appropriateness of such responses could lead to the difference between financial success or failure. As with land use measures, an assumption that the private sector will always act in a normative fashion is unrealistic, and fails to capture the essential concept of competition between firms as they respond to new opportunities and challenges.

4.2.6 Infrastructure measures

The argument was given in 4.2.1 that it was "good planning practice" for a transport authority to implement subsidiary measures when implementing a "main" instrument. This argument is particularly appropriate if the main instrument is an infrastructure measure. In certain locations, it might be clear from past experience that the transport authority does in fact adhere to good planning practice with regard to subsidiary instruments. However, it cannot in general (without such evidence) be assumed that a transport authority will in fact implement subsidiary instruments in an optimal fashion, and it would be a misleading simplification for a model to assume such behaviour automatically.

4.2.7 Management of the infrastructure

Responsibilities for managing public transport infrastructure (in terms of frequencies, fares and vehicle size) are liable to be shared between a number of organisations, both public and private. The representation of the interaction between these various parties is inevitably complex. For any particular action by one party, there are a number of possible responses by other parties. Take for example the situation where the private sector is responsible for setting fares and frequencies for public transport in response to a public authority providing road and rail infrastructure. Assume that the private sector has an objective of profit maximisation for its public transport services. It was shown in the FATIMA project (FATIMA, 2000) that, for a fixed level of road and rail infrastructure, there are a number of different combinations of public transport fare and frequency that produce the same profit. Hence there is no deterministic rule as to how the private sector will behave under an assumption of autonomous profit maximisation.

4.2.8 Information provision

Two instruments of information provision are of particular significance with respect to the behavioural response of transport suppliers. Firstly, the responses of organisations responsible for parking (in terms of supply and charge) have an important influence on the effects of parking guidance and information systems. Secondly, the responses of public transport suppliers are critical for the results of using operation information systems such as bus fleet management.

4.2.9 Pricing measures

Transport supplier responses to the implementation of pricing measures provide yet a further example of uncertainty as a result of varied practice as to which organisation is responsible for different aspects of the transport system. If the same organisation that introduces pricing measures is also responsible for public transport and parking, then it should be the case that these latter measures are coordinated with the pricing measure in order to maximise synergy. However, as pointed out above, such a normative assumption cannot simply be assumed without evidence appropriate to the transport authority concerned.

On the other hand, if a separate organisation is responsible for public transport and parking, the responses will be more complex. For public transport suppliers, two stereotypical responses can be identified, depending upon whether the supplier simply wants to maintain previous demand or increase it. Take fare levels as an example. Under the first stereotype, the public transport supplier might use the opportunity of increased road user charging to increase fares, on the realistic assumption that the mode split for public transport will not be reduced. Under the second stereotype, the public transport supplier might maintain previous fares, or even reduce them, in order to build up large levels of demand.

For suppliers of parking, their responses will depend heavily upon the type of pricing measure being introduced. This is particularly the case if the measure varies by geographical area and time of day, such as is the case for many forms of urban road pricing. Examples of supplier responses are: relocation of parking spaces outside the road pricing area; setting high charge on car park users who arrive before the road pricing “start time”; or selling parking sites in city centres to developers on the assumption that road pricing will throttle demand anyhow. Assuming that there is competition between parking suppliers, a particular response on the part of one supplier is likely to lead to differences in response by other suppliers.

A further complication arises in the case where parking and public transport are explicitly linked, as in the case of park and ride. It might be the case that one organisation is responsible for both, or it might be that there is a partnership agreement between more than one organisation. A large combination of responses in terms of combined fares, charges, public transport frequencies and number of parking spaces are possible.

4.3 Public opinion responses

As indicated at the opening of section 4, the term *public opinion responses* encompasses both the impacts on public opinion from implementing particular instruments as well as the action taken by the public in response to these impacts. In general, the term *public opinion* includes both the majority opinion of society (as expressed through democratic processes) or as the opinion of special interest groups who have the power to affect transport policy. Examples of the latter are business organisations, the media, the police and environmental organisations.

Public opinion responses are in general more complex and hence more difficult to classify than the user responses discussed in 4.1 or the supplier responses discussed in 4.2. In fact current land use / transportation models do not generally represent public opinion responses and it is legitimate to question why they might do so. The simple answer here is that if planners are attempting to make predictions about the future development of the land use / transport system, they need to take into account all the actions of participants in this system that are liable to change it. These actors include users, suppliers and the public. If actors are missing from the representation of the system, predictions about it are liable to be wrong.

A subsequent question might concern whether public opinion responses need to be considered as something separate to the aggregation of individual user responses. There is clearly an ideological argument underlying this issue with respect to an understanding of society. However, whatever ideological standpoint is taken in this debate, it is empirically obvious that elections and other political events do occur and that they change public policy (including transport policy). Such events cannot simply be understood in terms of the type of individualistic user responses described in 4.1.

There are a number of different levels at which this interaction between public opinion and policy-making takes place. On the one hand, there is the level of city-wide elections and other "large political events" such as public campaigns. On a more mundane level, there is the "flow" of planning permissions that allow a particular development to take place.

As a result of the above considerations, the theme of public opinion and public opinion responses will be maintained throughout this deliverable.

5. OVERVIEW OF HOW PROSPECTS MODELS REPRESENT EFFECTS AND RESPONSES

Software producers in PROSPECTS were asked to complete questionnaires to show which (first order) supply effects and (user and supplier) behavioural responses are currently represented by the models in their software packages. Summaries and discussions of these questionnaires are given in this section, along with general comments about second order supply effects and public opinion responses.

The software packages concerned area:

- PLUTO (Bonsall, 1995)
- Sketch Planning Model (SPM) (Knoflacher et al, 2000; Pfaffenbichler and Emberger, 2001) (used in the Vienna, Madrid, Edinburgh, Helsinki, Stockholm and Oslo Case Studies)
- TRAM / DELTA (Bates et al, 1997; Simmonds and Still, 1999; MVA and DSC, 2001; Simmonds, 2001) (used in the Edinburgh Case Study[2])
- SAMPERS / IMREL (Lundqvist and Mattsson, 2001) (used in the Stockholm Case study)
- RETRO / IMREL (used in the Oslo Case Study)

The land use model IMREL, as used in both the SAMPERS/IMREL and RETRO /IMREL combinations, is described by Johannsson and Mattsson (1994), Anderstig and Mattsson (1998) and Boyce and Mattsson (1999).

Tables 5.1 to 5.11 below are based upon the questionnaire results, and give √s and Xs depending upon whether a software package represents an effect or response. Thus a box in a table contains a √ if the effect or response is represented, and an X if it is not. At the outset, it is important to recognise that the models discussed in this section represent the land use / transport system at very different levels of detail. It follows inevitably that, in general, a more aggregate model will represent the effect or response more simplistically than a more detailed model. Thus the number of √s and Xs in the following tables should not be taken as an indication that one package is "better" than another package. In general, it should be stressed that the intention of this exercise is not to compare one modelling package against another since it is not of great interest to Task 31 if one particular modelling package represents an effect / response whilst another does not. Rather, it is of interest if none of the PROSPECTS modelling packages represent an effect / response. The exercise in making a comparison between modelling packages is the task of the SPOTLIGHTS project, as described in Section 2.

[2] In fact, for various organisational reasons, an early and less developed version (START) of TRAM is being used in the Edinburgh Case Study.

5.1 First order supply effects

Tables 5.1 to 5.5 show whether the models in the PROSPECTS software packages predict changes in first order supply effects:

- Capacity / congestion (Table 5.1)
- User costs (Table 5.2)
- Reliability of journey time (Table 5.3)
- Quality of journey (Table 5.4)
- Information provision (Table 5.5)

It can be argued that the first order supply effects contained in Tables 5.1 and 5.2 are more important (with respect to understanding location and travel behaviour) than the effects in Tables 5.3 to 5.5. In fact, there are a large number of √s in Tables 5.1 and 5.2 showing that, in general, current modelling packages are well able to predict changes in capacity, congestion and user costs (in terms of time and money). The main exception to this observation is that (as shown in Table 5.2) travel costs to road and rail freight companies are not included in the models (however a number of the models take into account changes in costs to road freight companies simply due to route switching).

On the other hand, there are no ticks in Tables 5.3 to 5.5, showing that changes in reliability, quality and information are not currently predicted in modelling packages.

	PLUTO	SPM	TRAM / DELTA	SAMPERS / IMREL	RETRO / IMREL
Road capacity changes	√	√	√	√	√
Road congestion	√	√	√	√	√
Bus capacity changes	X	X	√	√	√
Bus overcrowding	X	X	√	X	X
Train capacity changes	X	X	√	√	√
Train overcrowding	X	X	√	X	X
Parking capacity changes	X	X	√	X	X
Car park congestion	√	X	√	X	X

TABLE 5.1 Capabilities of model packages to predict changes in capacity / congestion

	PLUTO	SPM	TRAM / DELTA	SAMPERS / IMREL	RETRO / IMREL
Direct location costs of businesses	X	ν	ν	X	X
Direct location costs of householders	X	ν	ν	X	ν
Direct travel costs of businesses	X	ν	ν	ν	ν
Direct travel costs of road freight companies	X	X	X	X	X
Direct travel costs of rail freight companies	X	X	X	X	X
Direct costs to car travellers	ν	ν	ν	ν	ν
Direct costs to bus passengers	ν	ν	ν	ν	X
Direct costs to train passengers	X	ν	ν	ν	X
Direct costs to users of other modes	ν	X	ν	X	X

TABLE 5.2: Capabilities of model packages to predict changes in user costs

	PLUTO	SPM	TRAM / DELTA	SAMPERS / IMREL	RETRO / IMREL
Car	X	X	X	X	X
Bus	X	X	X	X	X
Train	X	X	X	X	X
Bicycle	X	X	X	X	X
Walking	X	X	X	X	X
Motorcycle	X	X	X	X	X

TABLE 5.3: Capabilities of model packages to predict changes in reliability of journey time

	PLUTO	SPM	TRAM / DELTA	SAMPERS / IMREL	RETRO / IMREL
Car	X	X	X	X	X
Bus	X	X	X	X	X
Train	X	X	X	X	X
Bicycle	X	X	X	X	X
Walking	X	X	X	X	X
Motorcycle	X	X	X	X	X

TABLE 5.4: Capabilities of model packages to predict changes in quality of journey

	PLUTO	SPM	TRAM / DELTA	SAMPERS / IMREL	RETRO / IMREL
Car users	X	X	X	X	X
Bus passengers	X	X	X	X	X
Train	X	X	X	X	X
Bicycle	X	X	X	X	X
Walking	X	X	X	X	X
Motorcycle	X	X	X	X	X

TABLE 5.5: Capabilities of model packages to predict changes in information provision.

5.2 Second order supply effects

From the definition given in Section 3.2, there can be no feedback from second order supply effects to user responses: if there were such feedbacks, the effects would be first order rather than second order. The models used in PROSPECTS implicitly assume that all the effects listed in Section 3.2 are in fact second order effects[3]. However, considering the list of such effects (environmental effects, accidents, equity, economic growth etc.), an important question arises as to whether there should ideally be such feedback. This question is taken up in Section 6.2.

Assume, though, for the purposes of this section, that it is acceptable that there are no such feedbacks. Then the review of modelling capabilities with respect to second order effects should not so much ask if the model packages can represent these effects, but rather should ask:

- if the model output and input have a format and level of disaggregation that is suitable for the computation of indicators of these effects, and
- if modules or add-on models to perform these computations are actually in place.

[3] As previously noted, the exception to this statement is that DELTA considers local air and noise pollution as first order effects with respect to residential location choice.

The answers to these two questions depend on the precise definition of the indicators and their level of disaggregation. In Tasks 11 and 21 of PROSPECTS (PROSPECTS, 2001a) indicators were defined that could be used in planning for a sustainable urban land use and transport system. These indicators covered all the second order supply effects considered in Section 3.2 above, with the exception of health effects. In Task 21, a survey was made of the model systems available in PROSPECTS with respect to their ability to produce the data to compute the indicators. Modelling package producers were also asked if the indicators could be computed at the current time and, if not, what resources would be needed to establish this capability.

Not unexpectedly, quite a few of the proposed indicators could not currently be computed (see the Task 21 report (PROSPECTS, 2001b) for details). However, some rough indicators for all of the second order supply effects (not counting health and security) were found in all instances. Whether or not these are too rough even for strategic planning is a matter of judgement.

The main problem areas are:

- Even if energy use and CO_2 emissions from transport could easily be computed in most model systems, energy use is usually not made a function of speed. Also, there is no use of technological forecasts of fuel efficiency or models to predict the composition of the vehicle fleet with respect to types of fuel and fuel efficiency. With respect to energy use in housing, none of the models provides estimates of that (for example by basing such estimates on a model of the choice of type and size of housing), nor forecast improvements in energy efficiency.
- The air pollution models in the PROSPECTS modelling systems suffer from similar deficiencies. Furthermore, the link between emissions and local air pollution levels is not modelled. This would require a statistical model based on empirical evidence from the particular urban area, or a convection model taking the particular climatic and topological conditions into account.
- There is no proper noise model, as noise emissions are not linked to the populations living close to the transport links[4].
- The availability of land for housing and production purposes in the zones is often set in a rough manner, and the land requirement per housing unit is often set roughly as a constant that does not take the types of houses into account.
- Walking and cycling trips are not assigned to links in a network in any of the models. Whether or not this can be done at all in a meaningful way is questionable. However without it, it is difficult to assess the level of interaction between pedestrians, cyclists and motorists on the road links. Such assessment is vital to building a model of accidents along the lines of Jansson (1994) and to assess the change in accidents involving pedestrians and cyclists and a car. Lacking this, fixed accident rates per vehiclekilometre by different modes will have to be used. However, fixed accident rates may be available for different types of road, and may also be influenced by the total level of

[4] As previously noted, in DELTA noise emissions produced on the road are considered as a factor in residential location choice. However, DELTA does not represent exposure, in the sense of estimating the numbers of people experiencing different levels of noise. Clearly such levels will decline as a function of distance from the roads concerned.

walking and cycling in a zone. None of the models have implemented such features.

- Severance effects are not measured. Accident rates on access and egress links are not available. Health effects of walking and cycling are not quantified. Good and comprehensive indicators of "liveable streets and neighbourhoods" have not been found.
- Implications for government budgets are easily computed. However, we would also like to know the effects of taxes on the economy as a whole. Government deficits will have to be met through taxation, and conversely, the revenue from transport and land use taxes and fees can be used to reduce other taxation. When pricing measures are used, therefore, the structure of the tax system is changed. The wider implications for economic efficiency of raising taxes with the present tax structure is captured by the shadow price of public funds. Estimates of this parameter vary and are uncertain. There are still greater problems with the correct level of the shadow price of public funds when transport taxes are used as instruments, as little is known about how transport taxes affect the labour market and other important markets.
- As long as there are different socio-economic groups and different person-types (for example children, working, working-age not-working and retired) in the model system, intraregional distributional consequences of the policies can be assessed. Although such analyses have been made in some of the land use and transport models within PROSPECTS, further development is required in this area.
- The initial distribution of benefits between the studied region and other regions can be studied, assuming only a portion of the tax revenue – and portions of the air pollution benefits – stays inside the region. However, these benefits will be redistributed through trade and this phenomenon must be represented in a model if one wants to study the wider distributional effects and growth effects (SACTRA 1999). Although this issue is tackled to a certain extent in the PROSPECTS models, further development is required.
- Improvement needs to be made to the modelling of freight transport in the PROSPECTS models. A difficulty arises here in that the land use and transport instruments that have a direct effect on freight (with the exception of route and time-of-day responses) are typically those that are implemented for a regional area that is larger than an individual city level. Thus freight in the city modelling system needs to be represented in the context of a wider regional modelling system.
- Finally, the models are not particularly suited to study the effects for mobility impaired travellers.

5.3 User responses

5.3.1 Overview of user responses

Tables 5.6 to 5.9 show the capabilities of the PROSPECTS modelling packages to represent user responses:

- Strategic location responses (Table 5.6)
- Strategic transport user responses (Table 5.7)

- Day-to-day transport user responses (Table 5.8)
- Within-day transport user responses (Table 5.9)

A difficulty when creating these tables has been to distinguish between two different, though legitimate, interpretations of model capability:
(i) On the one hand, it could be argued that the tables should show whether the models represent the specific behavioural complexities associated with particular land use / transport instruments (of the type discussed in Section 4).
(ii) On the other hand, it can be argued that the tables need only show whether the models represent responses to the aggregate effects from implementing an instrument, such as changes in general traffic conditions, and do not need to represent detailed responses of type (1).

In many circumstances, the distinction between interpretations (i) and (ii) is unimportant. However, in some cases it is crucial. Consider, for example, the instrument "telecommunications as an alternative to travel" and one of its associated responses "change number of work trips per week". Under interpretation (i) above, the models should only be given ticks for this response if they represent the various attributes of telecommuting, such as the benefits of a changed lifestyle. Under interpretation (ii), it is sufficient for a model to get a tick for this response if it includes a relationship between number of work trips and general traffic conditions.

In general, there needs to be a pragmatic balance between the two interpretations given above. If the response being considered is clearly related to one or a small number of instruments (such as "change number of work trips per week" in the above example) then the first interpretation should hold. If, on the other hand, the response is associated with a large number of instruments (such as "change mode") then the second interpretation is sufficient. Due to this rather imprecise distinction, there will inevitably be a number of cases in which either interpretation could sensibly be argued. An attempt has been made to balance out the ticks and crosses in the following tables with respect to such borderline cases.

5.3.2 Specific results

From Table 5.6 it can be seen that none of the five modelling packages represent the responses "change employment", "mainly work at home", "mainly shop at home" and "change school". All these responses are arguably instrument-specific responses, and the first interpretation of model capability given in 5.3.1 above should be applied.

With respect to strategic transport responses, Table 5.7 shows that two of the modelling packages represent changes in car-buying behaviour. However, it should be pointed out that this response is simply due to changes in traffic conditions (particularly public transport accessibility), and thus the second interpretation of model capability in 5.3.1 is being applied. None of the modelling packages represents the responses "buying/selling a motorcycle" or "buying/selling a bicycle". Given the potential reductions in congestion that could arguably result from car-pooling, it is significant that none of the modelling packages represents this response. Car-pooling is example of a response which leads to only small changes in the transport system if it is incremental, but could lead to large changes in the system if it is a fundamental response. Models need to be able to represent the behavioural barriers to the latter occurring, and identify the circumstances in which such barriers could be overcome.

From the relatively large number of √s in Table 5.8, it can be seen that there is generally high representation of day-to-day transport responses provided by the models. Given the history of development of transport models within the "four stage paradigm" this is perhaps not surprising. The exceptions to this observation are the responses: "change number work trips per week"; "change number of shopping trips per week"; "change number of leisure trips per week" and "change strategy of trip-linking". These responses are understood here to be instrument-specific responses, as described above. The lack of representation of trip-linking reinforces the need to incorporate activity modelling in land use / transport models, as recommended by the new Look Study (DSC, 2001).

As might be expected for strategic models, none of the modelling packages represents any of the within-day transport responses considered (as shown in Table 5.9). In general this is not a problem since the PROSPECTS modelling packages are dealing with strategic planning issues for which within-day decisions typically count as noise in the system. However, two points should be made here:

- Care needs to be taken that day-to-day responses do in fact represent a true average of the responses made on individual days.
- It can often be the case that particularly bad one-off experiences resulting from abnormal incidents can lead to profound changes in strategic behaviour on the part of an individual. Such incidents could include both predictable incidents (such as increased demand resulting from a sporting event) or incidents resulting from an unfortunate combination of circumstances (such as a broken down car at a time of higher than average demand). Strategic models should be able to take account of the effects of such one-off incidents upon strategic behaviour, even if they are not making a full representation of what happens every day.

	PLUTO	**SPM**	**TRAM / DELTA**	**SAMPERS / IMREL**	**RETRO / IMREL**
Relocate home within study area	√	√	√	√	√
Move house out of / into study area	√	X	√	X	X
Relocation of business within study area	√	√	√	√	√
Start up / close down business within study area	√	X	√	X	X
Change employment	X	X	X	X	X
Mainly work at home	X	X	X	X	X
Mainly shop at home	X	X	X	X	X
Change school	X	X	X	X	X

TABLE 5.6: Capabilities of model packages to represent strategic location responses

	PLUTO	**SPM**	**TRAM / DELTA**	**SAMPERS / IMREL**	**RETRO / IMREL**
Change car-buying behaviour	v	X	v	X	X
Buy / sell a motorcycle	X	X	X	X	X
Buy / sell a bicycle	X	X	X	X	X
Buy public transport season ticket	X	X	X	X	X
Buy parking season ticket	X	X	X	X	X
Car-pool / share	X	X	X	X	X
Change trip length distribution (of trips lying wholly within study area) over long term period	v	v	v	v	v
Change trip length distribution (of trips lying partially within study area) over long term period	X	X	X	v	X

TABLE 5.7: Capabilities of model packages to represent strategic transport user responses

	PLUTO	SPM	TRAM / DELTA	SAMPERS / IMREL	RETRO / IMREL
Change number of work trips per week	X	X	X	X	X
Change number of shopping trips per week	X	X	X	X	X
Change number of leisure trips per week	X	X	X	X	X
Change "first choice" destinations of shopping / leisure trips	√	√	√	√	√
Change mode (motorised vehicle mode)	√	√	√	√	√
Change mode (to/from soft mode and between soft modes)	√	√	√	√	√
Change "normal" departure time	√	√	√	X	√
Change strategy of trip-linking	X	X	X	X	X
Change "first choice" car parks (including park and ride)	√	X	√	X	X
Change "normal" route	√	X	√	√	√

TABLE 5.8: Capabilities of model packages to represent day-to-day transport user responses

	PLUTO	SPM	TRAM / DELTA	SAMPERS / IMREL	RETRO / IMREL
Abandon proposed trip (e.g. work/shop from home)	X	X	X	X	X
Change departure time	X	X	X	X	X
Change route	X	X	X	X	X
Change trip-linking	X	X	X	X	X
Change destination	X	X	X	X	X
Pre-plan journeys using real-time information	X	X	X	X	X
Change use of car parks (including park and ride)	X	X	X	X	X

TABLE 5.9: Capabilities of model packages to represent within-day transport responses

5.4 Supplier responses

5.4.1 Explanation of tables

Tables 5.10 and 5.11 show the capabilities of the PROSPECTS modelling packages to predict supplier responses. These responses were described 4.2 and are of two general types. Firstly these are those responses that might be made by the authority responsible for the main instrument: such responses will typically concern the implementation of secondary instruments to support the main instrument. These are shown in Table 5.10. Secondly, there are third party supplier responses, which are shown in Table 5.11. These comprise both supplier responses by the private sector and supplier responses by other land use / transport authorities.

The list of supplier responses in Table 5.11 breaks down into two land use supplier responses (concerning the private sector building houses and changing their selling price) and a number of transport supplier responses. Following the discussion in 4.2.1 and 4.2.2 above there is a difficulty in interpreting the results of Table 5.11 for transport supplier responses since the legal responsibility for implementing transport instruments varies between cities. In particular, sometimes the private sector is responsible for certain instruments (concerning parking and public transport) and sometimes a public authority is responsible. If it is a public authority it might be the same one that implements the main instrument (as shown in Table 5.10) or it might be a different authority.

The division of legal responsibilities between authorities clearly has an effect on the interpretation of the last response in Table 5.11, i.e. "supplier responses by other land use / transport authorities". To avoid unnecessary duplication and confusion, such responses are assumed to be different in type to the other third party supplier responses considered in Table 5.11, i.e. they might include any of the instruments considered in the tables in Appendix 1 except those included in Table 5.11.

5.4.2 Results shown in tables

Table 5.10 shows that none of the modelling packages predicts subsidiary responses by the main transport authority, with the exception of changing the size of trains and buses.

It can be seen from Table 5.11 that there is a high level of prediction of land use supplier responses in the PROSPECTS models. Furthermore, it can be seen that third party transport supplier responses concerning public transport (except for public transport quality) are predicted in the PROSPECTS models, whilst responses concerned with parking are not included. However, a question arises as to how well the supplier responses for public transport represent the real life interaction between different suppliers in a context of deregulation and competition. Thus, an assumption that supply varies proportionately to demand is likely to be oversimplistic except under limited circumstances. On the other hand, the more realistic assumption of fixed profit margins leads to a number of differing possible combinations of fare and frequency that could attain such margins. It is generally arbitrary, in a context of equilibrium, as to which of these combinations would actually be chosen by the supplier (as shown by FATIMA (2000) and reported above in 4.2.7).

It can also be seen from Table 5.11 that none of the modelling packages predicts supplier responses by other transport authorities (as defined above).

	PLUTO	**SPM**	**TRAM / DELTA**	**SAMPERS / IMREL**	**RETRO / IMREL**
Changes in traffic management	X	X	X	X	X
Changes in information provision	X	X	X	X	X
Traffic calming	X	X	X	X	X
Changing size of trains / buses	X	X	X	∨	X
Changing public transport quality	X	X	X	X	X
Changing total car parking space	X	X	X	X	X
Reallocating car parking space between long term and short term parking	X	X	X	X	X

TABLE 5.10: Capabilities of model packages to represent subsidiary supplier responses by transport authority responsible for main instrument

	PLUTO	SPM	TRAM / DELTA	SAMPERS / IMREL	RETRO / IMREL
Private sector building more houses / workplaces / shops in a zone	ν	X	ν	ν	ν
Private sector changing the selling price of houses / workplaces / shops in a zone	ν	X	ν	ν	ν
Changing rail / bus frequency	ν	X	ν	ν	ν
Changing size of trains / buses	X	X	X	ν	X
Changing rail / bus fares	ν	X	X	ν	X
Changing public transport quality	X	X	X	X	X
Changing total car parking space	X	X	X	X	X
Reallocating car parking space between long term and short term parking	X	X	X	X	X
Changing car park charges	X	X	X	X	X
Responses by other land use / transport authorities	X	X	X	X	X

TABLE 5.11: Capabilities of model packages to represent third party supplier responses

5.5 Public opinion responses

Out of the modelling packages considered in this section, only PLUTO considers public opinion, by representing:

- Public satisfaction (with the land use / transport measures);
- Votes in a local election;
- Business confidence

However, PLUTO does not predict the precise effect of public opinion upon changes in political decisions over land use and transport, on the either of the levels mentioned in 4.3 (the wide policy level or the local planning permission level). Thus, in the terms used in this report, PLUTO only represents "second order type effects" with respect to public opinion.[5]

However, by representing the effects on viewpoints both of the general population and of a sectional interest (the business community) PLUTO provides a platform for further model development in order to represent public opinion responses that change the land use / transport system.

[5] However, these effects are of a different nature to the second order effects discussed in Section 3.2. Models for the latter would generally be based upon natural science theory (e.g. level of pollution) or economic theory (e.g. economic growth"), whilst the public opinion effects in PLUTO require political science theory.

6. SIGNIFICANT GAPS IN MODELLING CAPABILITIES

Sections 3 and 4 could be seen as being concerned with the "demand for modelling capabilities" whilst Section 5 was concerned with the "supply of modelling capabilities". The results of these two inputs are now combined in order to understand significant gaps in modelling capability (i.e. where supply does not meet demand). This discussion makes use of the New Look Study described in Section 2 in order to consider current and emerging modelling capabilities in general, and hence not to restrict attention only to the PROSPECTS modelling packages.

As stated previously, it is not the intention of this deliverable to compare the modelling capabilities of the PROSPECTS modelling packages, and those cases are not of interest where an effect / response gets ✓s for some packages and not for others. Rather, the focus is upon those effects and responses that get Xs for all packages.

6.1 First order supply effects

With regard to first order supply effects, there is a lack in modelling capability for representing changes in the transport costs of freight companies, both road and rail (except for the costs for road freight due to route reassignment). There is a consequent lack of modelling capability for representing the responses of freight companies to the implementation of instruments. This problem is part of a more general problem, mentioned in 5.2, concerning freight traffic. The problem is that a city model (of the type considered in PROSPECTS) is too geographically limited to make adequate representation and prediction of the generation, distribution and mode split characteristics of freight traffic. A regional model is required for this purpose, in which the city features as a sub-area of the region (and is consequently modelled more coarsely than it is modelled in most of the PROSPECTS models). In such a (regional) model, the behaviour of firms sending and receiving goods, as well as the freight-moving companies themselves, needs to be represented.

The other main gaps with regard to first order supply effects concern the prediction of changes in objective reliability, quality and information provision. Arguably, such a lack is, in the first instance, a result of the lack of methods for defining objective quantitative measurements for these system factors. The lack of capability of modelling them leads directly to the lack of possibility of making subjective quantification of them in terms of user costs. Thus user costs are restricted to money costs and average journey time.

An essential difficulty for modelling reliability, quality and information supply effects is that whilst their importance is often recognised by transport planners, they are generally treated in a qualitative manner. Such an approach is insufficient for use in quantitative behavioural modelling, where the responses to such supply effects might be of comparable importance to changes in money cost and average journey time. Thus any model that ignores the former factors in its quantitative representation of behaviour is likely to produce inaccurate and hence misleading results.

The following examples (which draw upon material from previous sections in the deliverable) illustrate the above points.

6.1.1 Reliability: Incidents

It has already been suggested that a particularly "bad" experience on the part of a transport system user resulting from an incident might have a significant effect on his/her future behaviour. This issue is closely tied up with the concept of reliability. Since the PROSPECTS models do not represent within-day responses, it is difficult for such models to capture particularly bad one-day effects. The question arises as to how the strategic effects of one-day incidents can be can be incorporated in a strategic modelling system. The solution suggested here is that there is a need to make an aggregate quantitative measurement of reliability, as an objective system factor, which takes into account the existence of incidents and variation in travel time in general. This measurement should be computed on an appropriate level of detail to the land use / transport model. The aggregate behavioural responses can then be calibrated by using a more detailed model "off-line".

6.1.2 Quality: Pedestrian connections

The lack of representation (in current models) of objective quality in transport supply was one of the key "problem areas" identified by the New Look Study (DSC, 2001), as described in Section 2 above. Clearly, this issue covers a wide range of transport system factors. One such factor of particular interest concerns the quality of pedestrian connections in journeys whose predominant mode is by car or public transport. Specifically, the pedestrian connection between a destination (or origin) and a car park or public transport facility could have a significant effect on an individual's overall mode choice, destination choice and trip-linking behaviour. Typically there is no money cost attached to such a connection. Furthermore, to attach a user cost to the connection simply based upon walking time is liable to misrepresent seriously the attractiveness or otherwise of the connection. If the pedestrian is in a pleasant environment (with, for example, protection from extreme weather conditions) the cost attached to walking time could be extremely low (and in fact in some cases it could be negative, if the use of the connection is seen as a leisure activity). On the other hand, a stressful environment could lead to a high subjective penalty being put on the connection. The difference between these two situations cannot be explained by walk time and needs to be explained by (differences in) objective quality. Hence it is necessary to formulate quantitative measurements of quality, and for models to predict changes in such quality as a result of the implementation of instruments, in order to represent adequately system behaviour. In order to maintain model coherence, it is important that such measurements of quality are consistent across the transport system and hence apply to measurements of quality when using public transport or car.

6.1.3 Information provision: Tourism

It has long been recognised that one of the major disadvantages of equilibrium models in transport planning is that they typically assume that system users have "perfect information" about the system. Under such an assumption, it is by definition unnecessary to represent the level of objective information provision in the transport system. Whatever the advantages in pragmatic terms might be of making such simplified assumptions, they are clearly inappropriate for modelling any transport instrument that is based upon improving information provision. An important example here concerns tourism. Virtually by definition, tourists require information about the transport system in the city that they are visiting. In order to design appropriate transport facilities for tourists, it is essential to be able to make an aggregate quantified measurement of the level of information provided for tourists and to be able to predict how various transport instruments change this level. As in the case of reliability (discussed above), aggregate responses to different levels of information can be calculated by running a more detailed model off-line.

6.2 Second order supply effects

Major strategic objectives of urban land use and transport planning concern the level of second order supply effects resulting from the implementation (or lack of implementation) of transport instruments. Consequently, the ability of model systems to compute indices of such effects is important. (The conclusions 9-11 and 13-15 of the New Look Study, given in 2.1.1 above, concern some of these issues). We consider briefly the following questions:

1. Is there a need to integrate the modelling of these effects with the rest of the model system, that is, to create feedbacks from the second order effects to land use and transport user behaviour?
2. Is there a need for very detailed modelling of the second order supply effects, or are rough indicators sufficient for strategic planning purposes?
3. Which of the effects would require considerable effort to be modelled properly, and what kinds of models are required?

Underlying Question (1) is the associated question as to whether or not the users of the land use/transport system will internalise the second order effects and take them into account in their decision-making. In general, if they do so, it would be difficult for current modelling tools to represent this process. The one exception to this observation might concern the responses to the impact from traffic on the environmental qualities of a zone, which ideally ought to influence destination choice and housing location and perhaps even mode choice (using public transport to zones where walking is pleasant).

Associated with Question (2), we can ask "Is there a danger that rough modelling of second order effects can produce very inaccurate and misleading results?" With respect to local air pollution, we think that there might be such a danger. This is because in congested conditions with very low speed, the exact speed is important for emission rates, and the link from emissions to air quality is sensitive to emission volumes. On the other hand, this need not require the building of very complicated air pollution models, but rather to have correct volume-delay functions and to get the link flows right.

The "softer" second order effects like "liveable streets and neighbourhoods" will depend very much on measures that are not usually regarded as strategic measures, and which are not well modelled in model systems of the kind we are considering. This is also the case for effects accruing to pedestrians and cyclists and the mobility impaired. We cannot expect these measures and effects to be fully reflected in strategic models, which is why rough indicators are the most that can be achieved. Nevertheless, getting it approximately right with respect to accidents, benefits to walking and cycling, liveable street benefits and health benefits is a challenge.

In answer to Question (3), the areas that require large new models to complement existing model systems seem to be:

- Air pollution effects (as discussed above) and related health effects.
- The wider distributional impacts of land use / transport instruments with respect to economic growth. As pointed out in Section 5.2, spatial computable equilibrium modelling seems to be the most promising area to capture such effects, provided market power, returns to scale etc. can be included in a realistic way. Much work remains to be done in this area before such models can produce anything more than hints about the probable types of effect.

6.3 User responses

From Section 5 and the discussion in Section 6 above, it can be seen that the main lack of modelling capability with regard to user responses concerns the following:

- Responses both by companies that send freight and by companies that move freight
- User responses in relation to changes in reliability, quality and information provision
- Changing employment
- Mainly working at home
- Mainly shopping at home
- Changing school
- Buying / selling a motorcycle or bicycle
- Car-pool / share
- Changing number of work trips / shopping trips / leisure trips per week
- Changing strategy of trip-linking

In a number of cases, these responses will involve changes in intermodal behaviour.

It needs to be stressed that some of these omissions are with respect to the modelling the responses to particular instruments that will have a fundamental effect on travel behaviour (a good example being telecommunications as an alternative to travel).

6.4 Supplier responses

An important gap in modelling capability concerns the prediction of supplier responses in a context of deregulation and competition. Traditional modelling practice assumes a "command and control" perspective in which there is a solitary supplier providing land use and transport facilities to users. However much this perspective was an accurate reflection of real life in the past, it is certainly not appropriate in the present day. There are now a plethora of different types of supplier (both public and private) providing various land use and transport services, all of whom must interact dynamically both with each other and with users.

6.5 Public opinion responses

It was argued in 4.3 that public opinion and the views of pressure groups can change the land use / transport system through the political process. It can be argued that if such changes can occur in real life, they should be represented in a modelling system that is attempting to predict the future. This should be done on a number of different levels, including a "high level" city policy-making level as well as on a more detailed level considering the flows of planning permissions that allow development to take place.

At present, the PLUTO model provides output indicators that could provide a starting point for modelling public opinion response. However, no land use / transport model currently represents the mechanism by which public opinion can make changes to the planning of land use / transport system. If this avenue of modelling is to be pursued, clearly a great deal of research needs to be carried out. A suggestion for a way forward on this front is given below in 7.3.

7. LONG TERM RECOMMENDATIONS

7.1 Summary of recommendations

Following the discussion in Section 6, a large number of areas of model development can be identified. Arguably, the following areas are of particular importance:

- Representation of freight traffic in an urban environment
- Objective measurement of journey reliability, quality and information
- Subjective responses to journey reliability, quality and information
- Improved air pollution modelling and the effects of air pollution upon health
- Improved modelling of distributional impacts
- The responses to telecommunications
- Trip linking, including activity modelling and the pedestrian sub-links of complex trips
- Transport supplier responses
- Impacts upon public opinion.

Furthermore, it can be argued that there is a need for further research into predicting how public opinion, through political processes, actually changes plans for implementing future transport instruments.

Innovative approaches for fulfilling two of these recommendations are described below.

7.2 Objective measurement of journey reliability, quality and information

In order to be able to make objective measurements of reliability, quality and information provision, it is necessary to construct scales of measurement; then any particular situation can (in theory) be given scores on these scales. A useful first step to constructing such scales is to identify particular key points on a scale that have some common sense interpretation in real life. One approach to identifying such points might be to define "pure" archetypal points. For example, for information provision, we might consider such states as "perfect information" or "no information at all". However, whilst the former concept is arguably easier to understand than the latter concept, both are rather difficult to understand in practical terms.

As an alternative to archetypal definition, we could use the more pragmatic concept of bench-marking. Thus, if there were to be a consensus that a "good" state of information provision were evident in a particular European city, this state could translate into a high numerical score for information provision. Analogously, an (observably) "bad" state of information could translate into a low score. Thus observable situations are used to create a scoring system. One particular advantage of such an approach is that it arguably corresponds with how transport planners view the world in practice. If asked the question "how should City X be in the future?", a typical response for a transport planner is to base the answer on how City Y is currently (or how it was in the past), even if this is not actually made explicit.

However, the disadvantages of relying solely upon this type of benchmarking system are obvious. Subjective prejudices about particular cities would be likely to create biased scoring, thus completing negating the objective aspect of measurement required by the modelling. The solution to this problem is to extract the specific criteria about the cities that lead to them attaining a particular score. Thus the chosen cities, whilst providing material for descriptive purposes in order to explain the scoring system, are not an essential aspect of the definition of the scoring system.

Similar remarks can be made about the objective measurement of quality. In the case of reliability, it could be argued that the task is to a certain extent made easier in that the concept of a completely reliable system is straightforward to understand: such a system would have no congestion and all public transport would be punctual. Even here, though, there is a problem with real life definition. Specifically, it could be argued that a "pure uncongested state" occurs only when there are no vehicles using the transport system, and that as soon as one vehicle starts using it, the (system) speed of flow is affected. There is thus also a need for pragmatism for defining "good" reference states for reliability.

7.3 Interaction of suppliers and users with political processes

The complex interaction of transport suppliers, users and political processes has been an important theme running throughout this deliverable. It has been pointed out that the current genre of land use / transport models are not well-suited to dealing with the underlying issues. One suggestion for improvement is the development of a new genre of *microsimulation organisation models*. Such models would use the mathematical techniques currently used in *individual traveller microsimulation* models, but whose basic entities are transport suppliers. These suppliers (both public and private) would interact with each other dynamically, exhibiting various different types of behaviour.

This type of model needs to have extreme flexibility. Following the discussion about democratic control, it can be argued that organisations such as city governments, national governments, NGOs, resident groups and special interest groups need to be represented as actors in the model. In general, the behaviour represented in these models should be based both upon observed past behaviour and/or upon predicted likely behaviour, according to theories from economics, political science and sociology. The behaviour should not generally be normative unless it concerns a relatively unimportant subsidiary system within the model.

Given the uncertainty about the response of different organisations to one another, the underlying technique of the models should be stochastic rather than deterministic. In general, they should aim to predict, given the implementation of a land use / transport instrument, a probability distribution of likely end-states of the system rather than a single end-state.

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APPENDIX 1

Tables of instruments versus supply effects (first order) and behavioural responses

The following 25 tables show:

- Supply effects of land use / transport instruments (Tables A1 to A10)
- User responses to land use / transport instruments (Tables A11 to A20)
- Supplier responses to land use / transport instruments (Tables A21 to A25)

In each table the importance of effects and responses is classified as follows:

1. Very important responses / effects (indicated by ⬤)
2. Responses / effects of medium importance (indicated by ●)
3. Responses / effects of small importance (indicated by •)
4. Responses / effects of no importance (not indicated)

TABLE A1 **SUPPLY EFFECTS**	**Capacity / congestion**									**User costs**								
LAND USE MEASURES **And** **ATTITUDINAL / BEHAVIOUAL MEASURES**	Road capacity changes	Road congestion	Bus capacity changes	Bus overcowding	Train capacity changes	Train overcrowding	Parking capacity changes	Car park congestion		Direct location costs of businesses	Direct location costs of householders	Direct travel costs of businesses	Direct travel costs of road freight companies	Direct travel costs of rail freight companies	Direct costs to car travellers	Direct costs to bus passengers	Direct costs to train passengers	Direct costs to users of other modes
LAND USE MEASURES																		
Development densities, involving an increase in density of development		•		•		•		·		●	●	●	●	●	•	•	•	•
Development pattern, including transport corridor-based developments		•		•		•		·		●	●	●	●	●	•	•	•	•
Development mix in which homes, jobs and shops are placed close together		•		•		•		·		•	•	•	•	•	•	•	•	•
Protection of certain sites from development;		•		•		•		·		●	●	●	●	●	·	·	·	·
Parking standards for new development;		·		·		·	●	●										
Commuted payments, whereby developers can provide less parking, but pay for public space;							●	●										
Developer contributions to the financing of infrastructure;															•	●	●	·
Value capture taxes																•	•	
Other land use taxes, including property taxes.		·		·		·												
ATTITUDINAL / BEHAVIOURAL MEASURES																		
Public awareness campaigns		•		•		•		•										
Flexible working hours		●		●		●		●							●	●	●	·
Telecommunications as alternative to travel		●		●		●		●				●			●	●	●	·
Company travel plans		•		•		•		•										

TABLE A2	**Reliability of journey time**							**Quality**							**Information provision**					
LAND USE MEASURES **And** **ATTITUDINAL / BEHAVIOUAL MEASURES**	Reliability of journey time by car	Reliability of journey time by bus	Reliability of journey time by train	Reliability of journey time by bicycle	Reliability of walk journey time	Reliability of journey time by motorcycle		Quality of journey by car	Quality of journey by bus	Quality of journey by train	Quality of journey by bicycle	Quality of walk journey	Quality of journey by motorcycle		Information provision for car users	Information provision for bus users	Information provision for train users	Information provision for bicyclists	Information provision for pedestrians	Information provision for motorcyclists
LAND USE MEASURES																				
Development densities, involving an increase in density of development																				
Development pattern, including transport corridor-based developments																				
Development mix in which homes, jobs and shops are placed close together																				
Protection of certain sites from development; Parking standards for new development;																				
Commuted payments, whereby developers can provide less parking, but pay for public space;																				
Developer contributions to the financing of infrastructure;																				
Value capture taxes																				
Other land use taxes, including property taxes.																				
ATTITUDINAL / BEHAVIOURAL MEASURES																				
Public awareness campaigns															●	●	●	●	●	●
Flexible working hours																●	●			
Telecommunications as alternative to travel																				
Company travel plans															●	●	●	●	●	●

TABLE A3	**Capacity / congestion**									**User costs**								
INFRASTRUCTURE MEASURES	Road capacity changes	Road congestion	Bus capacity changes	Bus overcowding	Train capacity changes	Train overcrowding	Parking capacity changes	Car park congestion		Direct location costs of businesses	Direct location costs of householders	Direct travel costs of businesses	Direct travel costs of road freight companies	Direct travel costs of rail freight companies	Direct costs to car travellers	Direct costs to bus passengers	Direct costs to train passengers	Direct costs to users of other modes
Measures to influence car use																		
New road construction	●	●						●		●	●	●	●		●	●		●
New off-street parking		•					●	●				●	●		●			
Measures to influence public transport use																		
Upgrades to existing fixed infrastructure			●	●	●	●						•		●		●	●	
Reopening closed railway lines					●	●				●	●	•		●			●	
New rail stations					●	●				●	●	•		●			●	
New rail services on existing lines					●	●				·	·	•		●			●	
Light rail systems	●	•			●	●				•	•	•					●	
Guided bus systems	●	•	●	●						·	·	•				●		
Park and ride			●	●			●	•		·	·	•				●	●	
Terminals and interchanges	•	•	●	•	●	•				●	●	•		●		●	●	
Enhancement of bus and rail vehicles			●	●	●	●						•		●		●	●	
Provision for cyclists and pedestrians																		
Cycle routes	●	•																●
Pedestrian routes	•	•																●
Pedestrian areas	●	•								●	●							●
Provision for freight																		
Lorry parks							●	●		●		●	●					
Transhipment facilities					●	●	●	●		●		●	●	●				

TABLE A4	**Reliability of journey time**							**Quality**							**Information provision**					
INFRASTRUCTURE MEASURES	Reliability of journey time by car	Reliability of journey time by bus	Reliability of journey time by train	Reliability of journey time by bicycle	Reliability of walk journey time	Reliability of journey time by motorcycle		Quality of journey by car	Quality of journey by bus	Quality of journey by train	Quality of journey by bicycle	Quality of walk journey	Quality of journey by motorcycle		Information provision for car users	Information provision for bus users	Information provision for train users	Information provision for bicyclists	Information provision for pedestrians	Information provision for motorcyclists
Measures to influence car use																				
New road construction	●	●		•	•	•		●	●		•	•	●		●			●	•	●
New off-street parking	●			•		•		●							●			•		•
Measures to influence public transport use																				
Upgrades to existing fixed infrastructure		●	●						●	●						●	●			
Reopening closed railway lines			●							●							●			
New rail stations			●							●							●			
New rail services on existing lines			●							●							●			
Light rail systems			●							●							●			
Guided bus systems		●							●							●				
Park and ride															●					
Terminals and interchanges		●	●						●	●						●	●			
Enhancement of bus and rail vehicles		●	●						●	●						●	●			
Provision for cyclists and pedestrians																				
Cycle routes				●											•			●		
Pedestrian routes					●										•			•	●	
Pedestrian areas					●										•			•	●	
Provision for freight																				
Lorry parks																				
Transhipment facilities																				

TABLE A5	**Capacity / congestion effects**									**User costs**								
MANAGEMENT OF THE INFRASTRUCTURE	Road capacity changes	Road congestion	Bus capacity changes	Bus overcowding	Train capacity changes	Train overcrowding	Parking capacity changes	Car park congestion		Direct location costs of businesses	Direct location costs of householders	Direct travel costs of businesses	Direct travel costs of road freight companies	Direct travel costs of rail freight companies	Direct costs to car travellers	Direct costs to bus passengers	Direct costs to train passengers	Direct costs to users of other modes
Measures to influence car use																		
Road maintenance	•	•										•	●		●			●
Conventional traffic management	●	●										•	●		●	●		●
Conventional speed controls	●	●										•	●		●	●		●
Urban traffic control systems	●	●										•	●		●	●		●
Intelligent transport systems	●	●										•	●		●	●		●
Accident remedial measures	•	•										•	●		●			●
Traffic calming measures	●	●										•	●		●			●
Physical restrictions	●	●										●	●		●			●
Regulatory restrictions	●	●										●	●		●			●
Parking controls	•	•					●	●				●	●		●			●
Car sharing / pooling	•	•										•			●			
Measures to influence public transport use																		
Maintenance of existing fixed infrastructure			●	●	●	●								●		●	●	
New bus services			●	●												●		
Bus priorities	●	●	•	•												●		
High occupancy vehicle lanes	●	●	•	•												●		
Changes in bus and rail frequencies			●	●	●	●								●		●	●	
Timetabling strategies																●	●	
Bus service measures to improve reliability																●		
On-bus cameras for traffic regulation enforcement	?	?	?	?	?	?	?	?		?	?	?	?	?	?	?	?	?
Provision for cyclists and pedestrians																		
Cycle lanes and priorities	●	●																●
Cycle parking provision	•	•																●
Pedestrian crossing facilities	•	•																●
Safe routes to school																		●
Provision for freight																		
Lorry routes and bans	●	●								•	•	●	●		•	•		•
Lorry parking and loading restrictions	●	●					●	●				●	●		•	•		•

TABLE A6	**Reliability of journey time**							**Quality**							**Information provision**					
MANAGEMENT OF THE INFRASTRUCTURE	Reliability of journey time by car	Reliability of journey time by bus	Reliability of journey time by train	Reliability of journey time by bicycle	Reliability of walk journey time	Reliability of journey time by motorcycle		Quality of journey by car	Quality of journey by bus	Quality of journey by train	Quality of journey by bicycle	Quality of walk journey	Quality of journey by motorcycle		Information provision for car users	Information provision for bus users	Information provision for train users	Information provision for bicyclists	Information provision for pedestrians	Information provision for motorcyclists
Measures to influence car use																				
Road maintenance	•	•		•		•		•	•				•							
Conventional traffic management	●	●		•	•	•		•	•				•		●			●	●	●
Conventional speed controls	●	●		•	•	•		•	•				•		●			•	•	●
Urban traffic control systems	●	●		•	•	•		•	•				•							
Intelligent transport systems	●	●		●	●	●		•	•				•		●					
Accident remedial measures	•	•		•	●	•		●	•		•	●	•		●					
Traffic calming measures	•	•		•	●	•		●	•		●	●	•		●			●	●	●
Physical restrictions	●	●		●	●	●		•	•		●	●	•		●			●	●	●
Regulatory restrictions	●	●		●	●	●		•	•		●	●	•		●			●	●	●
Parking controls	●	●		•	●	•		•			•	•	•		●			•		●
Car sharing / pooling	●							●												
Measures to influence public transport use																				
Maintenance of existing fixed infrastructure		●	●						●	●						●				
New bus services		●							●											
Bus priorities		●													●					
High occupancy vehicle lanes		●													●					
Changes in bus and rail frequencies		●	●						●	●						●	●			
Timetabling strategies		●	●						●	●						●	●			
Bus service measures to improve reliability		●							●											
On-bus cameras for traffic regulation enforcement	?	?	?	?	?	?		?	?	?	?	?	?	?	?	?	?	?		
Provision for cyclists and pedestrians																				
Cycle lanes and priorities				●							●				●			●		
Cycle parking provision				●							●							●		
Pedestrian crossing facilities					●							●			●				●	
Safe routes to school					●							●			•				●	
Provision for freight																				
Lorry routes and bans	•	•		•		•														
Lorry parking and loading restrictions	•	•		•		•														

TABLE A7	**Capacity / congestion effects**									**User costs**								
INFORMATION PROVISION	Road capacity changes	Road congestion	Bus capacity changes	Bus overcowding	Train capacity changes	Train overcrowding	Parking capacity changes	Car park congestion		Direct location costs of businesses	Direct location costs of householders	Direct travel costs of businesses	Direct travel costs of road freight companies	Direct travel costs of rail freight companies	Direct costs to car travellers	Direct costs to bus passengers	Direct costs to train passengers	Direct costs to users of other modes
Measures to influence car use																		
Conventional direction signing		•										•	●		•			
Variable message signs		•										●	●		●			•
Real-time driver information systems and route guidance		•										●	●		●			
Parking guidance and information systems		●						●				•	•		●			•
Measures to influence public transport use																		
Conventional timetable and other service information																●	●	
Real time passenger information				•		•										●	●	
Trip planning systems which provide information before the start of journey															●	●	●	•
Operation information systems such as bus fleet management																		
Provision for cyclists and pedestrians																		
Static direction signs																		●
Tactile footways																		●
Provision for freight																		
Static direction signs												●	●					
Fleet management systems												●	●					

TABLE A8	**Reliability of journey time**							**Quality**							**Information provision**					
INFORMATION PROVISION	Reliability of journey time by car	Reliability of journey time by bus	Reliability of journey time by train	Reliability of journey time by bicycle	Reliability of walk journey time	Reliability of journey time by motorcycle		Quality of journey by car	Quality of journey by bus	Quality of journey by train	Quality of journey by bicycle	Quality of walk journey	Quality of journey by motorcycle		Information provision for car users	Information provision for bus users	Information provision for train users	Information provision for bicyclists	Information provision for pedestrians	Information provision for motorcyclists
Measures to influence car use																				
Conventional direction signing	●			●	●	●									●			●	●	●
Variable message signs	●			●	•	●		•							●			●	•	●
Real-time driver information systems and route guidance	●							•							●					
Parking guidance and information systems	●							•							●			•		●
Measures to influence public transport use																				
Conventional timetable and other service information		●	●						•	•						●	●			
Real time passenger information		●	●						•	•						●	●			
Trip planning systems which provide information before the start of journey	●	●	●												●	●	●			
Operation information systems such as bus fleet management																				
Provision for cyclists and pedestrians																				
Static direction signs				●	●						●							●	●	
Tactile footways												●								
Provision for freight																				
Static direction signs																				
Fleet management systems																				

TABLE A9	**Capacity / congestion effects**									**User costs**								
PRICING MEASURES And COMPENSATORY MEASURES OUTSIDE THE TRANSPORT FIELD	Road capacity changes	Road congestion	Bus capacity changes	Bus overcowding	Train capacity changes	Train overcrowding	Parking capacity changes	Car park congestion		Direct location costs of businesses	Direct location costs of householders	Direct travel costs of businesses	Direct travel costs of road freight companies	Direct travel costs of rail freight companies	Direct costs to car travellers	Direct costs to bus passengers	Direct costs to train passengers	Direct costs to users of other modes
PRICING MEASURES																		
Measures to influence car use																		
Parking charges		●						●				●	●		●			•
Charges for ownership of private parking space		●						●				●	●		●			•
Urban road charging, including area licensing and road pricing		●						●				●	●		●			•
Vehicle ownership taxes		●						●				●	●		●			•
Fuel taxes		●						●				●	●		●			•
Measures to influence public transport use																		
Fare levels				●		●										●	●	
Fares structures, such as flat fares, zonal fares and monthly passes				●		●										●	●	
Integrated ticketing systems				●		●										●	●	
Concessionary fares				●		●										●	●	
COMPENSATORY MEASURES OUTSIDE THE TRANSPORT FIELD																		
Changes in local taxes											●							
Changes in business taxes										●								
General subsidies for specific groups											●							
Targeted assistance for specific groups											●							

TABLE A10	**Reliability of journey time**							**Quality**							**Information provision**					
PRICING MEASURES And COMPENSATORY MEASURES OUTSIDE THE TRANSPORT FIELD	Reliability of journey time by car	Reliability of journey time by bus	Reliability of journey time by train	Reliability of journey time by bicycle	Reliability of walk journey time	Reliability of journey time by motorcycle		Quality of journey by car	Quality of journey by bus	Quality of journey by train	Quality of journey by bicycle	Quality of walk journey	Quality of journey by motorcycle		Information provision for car users	Information provision for bus users	Information provision for train users	Information provision for bicyclists	Information provision for pedestrians	Information provision for motorcyclists
PRICING MEASURES																				
Measures to influence car use																				
Parking charges	•	•		·		•									●					•
Charges for ownership of private parking space	•	•		·		•		●					•		●					•
Urban road charging, including area licensing and road pricing	●	●		•		•									●					•
Vehicle ownership taxes	·	·		·		·									•					•
Fuel taxes	•	•		·		•									•					•
Measures to influence public transport use																				
Fare levels		•	•													●	●			
Fares structures, such as flat fares, zonal fares and monthly passes		●	●						●	●						●	●			
Integrated ticketing systems		●	●						●	●						●	●			
Concessionary fares																●	●			
COMPENSATORY MEASURES OUTSIDE THE TRANSPORT FIELD																				
Changes in local taxes																				
Changes in business taxes																				
General subsidies for specific groups																				
Targeted assistance for specific groups																				

TABLE A11	**Strategic location responses**									**Strategic transport responses**							
LAND USE MEASURES **And** **ATTITUDINAL / BEHAVIOUAL MEASURES**	Relocate home within study area	Move house out of / into study area	Relocate business within study area	Start up / close down business within study area	Change employment	Start / stop (mainly) working from home	Start / stop (mainly) shopping from home	Change school		Change car-buying behaviour	Buy / sell a motorcycle	Buy / sell a bicycle	Buy public transport season ticket	Buy parking season ticket	Car-pool/share	Change trip length distribution of trips lying wholly within area	Change trip length distribution of trips lying partially within area
LAND USE MEASURES																	
Development densities, involving an increase in density of development	●	●	●	●						●	•	•	·	·	●	●	●
Development pattern, including transport corridor-based developments	●	●	●	●						●	•	•	·	·	●	●	●
Development mix in which homes, jobs and shops are placed close together	●	●	●	●		•	•	•		●	•	•	·	·	·	●	●
Protection of certain sites from development;	●	●	●	●						●	•	•	·	·			
Parking standards for new development;	·	·	·	·						•	•	•	·	●			
Commuted payments: developers provide less parking, but pay for public space;	·	·	·	·										●			
Developer contributions to the financing of infrastructure;	·	·	·	·										·			
Value capture taxes	·	·	·	·										·			
Other land use taxes, including property taxes.	·	·	·	·										·			
ATTITUDINAL / BEHAVIOURAL MEASURES																	
Public awareness campaigns															•		
Flexible working hours	·	·	·	·	•										●		
Telecommunications as alternative to travel	●	●	●	●		●	●	●		●	·	·	·	·		●	●
Company travel plans			●		•					•	·	·	●		●		

TABLE A12	**Day-to-day transport responses**										**Within-day transport responses**						
LAND USE MEASURES And ATTITUDINAL / BEHAVIOUAL MEASURES	Change number of work trips per week	Change number of shopping trips per week	Change number of leisure trips per week	Change "first choice" destinations of shopping / leisure trips	Change mode (motorised vehicle)	Change mode (to / from / between soft modes)	Change "normal" departure time	Change strategy of trip-linking	Change "first choice" car parks (including park and ride)	Change "normal" route	Abandon proposed trip	Change departure time	Change route	Change trip-linking	Change intended destinations	Pre-plan trips using real-time information	Change use of car parks (including park and ride)
LAND USE MEASURES																	
Development densities, involving an increase in density of development				●		●											
Development pattern, including transport corridor-based developments				●	●												
Development mix in which homes, jobs and shops are placed close together				●		●											
Protection of certain sites from development;																	
Parking standards for new development;					●	•			●								
Commuted payments, whereby developers can provide less parking, but pay for public space;																	
Developer contributions to the financing of infrastructure;																	
Value capture taxes																	
Other land use taxes, including property taxes.																	
ATTITUDINAL / BEHAVIOURAL MEASURES Public awareness campaigns	•	•	•		●	●											
Flexible working hours	●	•	•				●	●	●								
Telecommunications as alternative to travel	●	●	●														
Company travel plans	●				●	●	●										

TABLE A13	Strategic location responses									Strategic transport responses							
INFRASTRUCTURE MEASURES	Relocate home within study area	Move house out of / into study area	Relocate business within study area	Start up / close down business within study area	Change employment	Start / stop (mainly) working from home	Start / stop (mainly) shopping from home	Change school		Change car-buying behaviour	Buy / sell a motorcycle	Buy / sell a bicycle	Buy public transport season ticket	Buy parking season ticket	Car-pool/share	Change trip length distribution of trips lying wholly within area	Change trip length distribution of trips lying partially within area
Measures to influence car use																	
New road construction	●	●	●	●	●	●	●	●		●	•	·	·	·	●	●	●
New off-street parking	·	·	•	•	·	•	•	•		·				●	·	•	•
Measures to influence public transport use																	
Upgrades to existing fixed infrastructure										•			●			●	●
Reopening closed railway lines										•			●			●	●
New rail stations	●	●	●	●	●	●	●	●		•			●			●	●
New rail services on existing lines										·			●			●	●
Light rail systems	●	•	●	•	•	●	●	•		•			●			●	●
Guided bus systems										·			●			●	•
Park and ride														●		•	•
Terminals and interchanges													●			●	●
Enhancement of bus and rail vehicles													●				
Provision for cyclists and pedestrians																	
Cycle routes												●					
Pedestrian routes																●	•
Pedestrian areas																●	•
Provision for freight																●	•
Lorry parks			●	●													
Transhipment facilities			●	●													

TABLE A14	Day-to-day transport responses										Within-day transport responses						
INFRASTRUCTURE MEASURES	Change number of work trips per week	Change number of shopping trips per week	Change number of leisure trips per week	Change "first choice" destinations of shopping / leisure trips	Change mode (motorised vehicle)	Change mode (to / from / between soft modes)	Change "normal" departure time	Change strategy of trip-linking	Change "first choice" car parks (including park and ride)	Change "normal" route	Abandon proposed trip	Change departure time	Change route	Change trip-linking	Change intended destinations	Pre-plan trips using real-time information	Change use of car parks (including park and ride)
Measures to influence car use																	
New road construction	•	●	●	●	●	●	●	●	●	●							
New off-street parking	•	●	●	●	●	•	●	●	●	●							
Measures to influence public transport use																	
Upgrades to existing fixed infrastructure	·	·	•	●	●	•	•	•	•	●							
Reopening closed railway lines	·	•	●	●	●	•	●	●	●	●							
New rail stations	·	•	●	●	●	•	●	●	●	●							
New rail services on existing lines	·	•	●	●	●	•	•	●		●							
Light rail systems	·	•	●	●	●	•	•	●	●	●							
Guided bus systems	·	·	•	●	●	•	•	•	•	●							
Park and ride	·	·	•	●	●	•	●	●	●	●							
Terminals and interchanges	·	•	●	●	●	•	●	●	●	●							
Enhancement of bus and rail vehicles	·	•	●	●	●	•	•	•	•	•							
Provision for cyclists and pedestrians																	
Cycle routes	·	•	●	●	·	●	•	•		●							
Pedestrian routes	·	•	●	●	·	●	●	•		●							
Pedestrian areas	·	●	●	●	·	●		•		●							
Provision for freight																	
Lorry parks					●		●	●	●	●							
Transhipment facilities					●		●	●	●	●							

TABLE A15	**Strategic location responses**									**Strategic transport responses**							
MANAGEMENT OF THE INFRASTRUCTURE	Relocate home within study area	Move house out of / into study area	Relocate business within study area	Start up / close down business within study area	Change employment	Start / stop (mainly) working from home	Start / stop (mainly) shopping from home	Change school		Change car-buying behaviour	Buy / sell a motorcycle	Buy / sell a bicycle	Buy public transport season ticket	Buy parking season ticket	Car-pool/share	Change trip length distribution of trips lying wholly within area	Change trip length distribution of trips lying partially within area
Measures to influence car use																	
Road maintenance										•	•	•				•	•
Conventional traffic management										•	•	•	•	•	•	•	•
Conventional speed controls										•	•	•	•	•	•	•	•
Urban traffic control systems										•	•	•	•	•	•	●	•
Intelligent transport systems										⬤	•	•	•	⬤	⬤	⬤	⬤
Accident remedial measures										•	•	•	•	•	•	•	•
Traffic calming measures										•	●	⬤	●	•	•	●	•
Physical restrictions	⬤	⬤	⬤	⬤						●	●	⬤	⬤	⬤	⬤	⬤	⬤
Regulatory restrictions	⬤	⬤	⬤	⬤						⬤	●	⬤	⬤	⬤	⬤	⬤	⬤
Parking controls	●	●	●	●						●	●	●	●	⬤	⬤	⬤	⬤
Car sharing / pooling										⬤	●	●	•	⬤	⬤	⬤	⬤
Measures to influence public transport use																	
Maintenance of existing fixed infrastructure										•	•	•	⬤				
New bus services	●	●				●	●			•	•	•	⬤			⬤	⬤
Bus priorities										•	•	•	⬤			⬤	●
High occupancy vehicle lanes										•	•	•	⬤		⬤	⬤	●
Changes in bus and rail frequencies	●	●				●	●			•	•	•	⬤			⬤	⬤
Timetabling strategies										•	•	•	⬤			●	●
Bus service measures to improve reliability										•	•	•	⬤			⬤	⬤
On-bus cameras for traffic regulation enforcement													?			●	●
Provision for cyclists and pedestrians																	
Cycle lanes and priorities										•	•	⬤				⬤	⬤
Cycle parking provision										•	•	⬤				●	●
Pedestrian crossing facilities																	
Safe routes to school								⬤									
Provision for freight																	
Lorry routes and bans			⬤	⬤												⬤	⬤
Lorry parking and loading restrictions			⬤	⬤												●	●

TABLE A16	**Day-to-day transport responses**										**Within-day transport responses**						
MANAGEMENT OF THE INFRASTRUCTURE	Change number of work trips per week	Change number of shopping trips per week	Change number of leisure trips per week	Change "first choice" destinations of shopping / leisure trips	Change mode (motorised vehicle)	Change mode (to / from / between soft modes)	Change "normal" departure time	Change strategy of trip-linking	Change "first choice" car parks (including park and ride)	Change “normal” route	Abandon proposed trip	Change departure time	Change route	Change trip-linking	Change intended destinations	Pre-plan trips using real-time information	Change use of car parks (including park and ride)
Measures to influence car use																	
Road maintenance	•	•	•	•	•	•	•	•	•	●							
Conventional traffic management	•	•	•	●	●	●	●	●	⬤	⬤							
Conventional speed controls	•	•	•	●	•	⬤	⬤	●	●	●							
Urban traffic control systems	•	•	•	●	●	●	●	●	●	⬤							
Intelligent transport systems	●	●	●	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤
Accident remedial measures	•	•	•	•	•	•	•	•	•	•							
Traffic calming measures	•	•	•	⬤	●	●	●	●	⬤	⬤							
Physical restrictions	●	●	●	⬤	⬤	⬤	⬤	⬤	⬤	⬤							
Regulatory restrictions	●	●	●	⬤	⬤	⬤	⬤	⬤	⬤	⬤							
Parking controls	●	●	●	⬤	⬤	⬤	⬤	⬤	⬤	⬤							
Car sharing / pooling	●	●	●	●	⬤	⬤	⬤	⬤	⬤	⬤							
Measures to influence public transport use																	
Maintenance of existing fixed infrastructure	●	●	●	●	●	●	●	●	●	⬤							
New bus services	●	●	●	⬤	⬤	⬤	⬤	⬤	⬤	⬤							
Bus priorities	●	●	●	●	⬤	⬤	●	●	●	⬤							
High occupancy vehicle lanes	●	●	●	●	⬤	●	⬤	⬤	⬤	⬤							
Changes in bus and rail frequencies	●	●	●	⬤	⬤	⬤	⬤	⬤	●	⬤							
Timetabling strategies	•	●	●	●	●	●	●	⬤	●	⬤							
Bus service measures to improve reliability	●	●	●	●	⬤	⬤	⬤	⬤	●	⬤							
On-bus cameras for traffic regulation enforcement																	
Provision for cyclists and pedestrians																	
Cycle lanes and priorities	●	●	●	⬤		⬤	⬤	⬤	●	⬤							
Cycle parking provision	•	●	●	⬤		⬤	●	●	⬤								
Pedestrian crossing facilities										⬤							
Safe routes to school										⬤							
Provision for freight																	
Lorry routes and bans	⬤				⬤		⬤	⬤	⬤	⬤							
Lorry parking and loading restrictions	●				●		⬤	⬤	⬤								

TABLE A17	**Strategic location responses**									**Strategic transport responses**							
INFORMATION PROVISION **Measures to influence car use**	Relocate home within study area	Move house out of / into study area	Relocate business within study area	Start up / close down business within study area	Change employment	Start / stop (mainly) working from home	Start / stop (mainly) shopping from home	Change school		Change car-buying behaviour	Buy / sell a motorcycle	Buy / sell a bicycle	Buy public transport season ticket	Buy parking season ticket	Car-pool/share	Change trip length distribution of trips lying wholly within area	Change trip length distribution of trips lying partially within area
Conventional direction signing																	
Variable message signs																	
Real-time driver information systems and route guidance																	
Parking guidance and information systems **Measures to influence public transport use**																	
Conventional timetable and other service information																	
Real time passenger information																	
Trip planning sytems which provide information before the start of journey																	
Operation information systems such as bus fleet management																	
Provision for cyclists and pedestrians																	
Static direction signs																	
Tactile footways																	
Provision for freight																	
Static direction signs																	
Fleet management systems																	

TABLE A18	**Day-to-day transport responses**										**Within-day transport responses**						
INFORMATION PROVISION	Change number of work trips per week	Change number of shopping trips per week	Change number of leisure trips per week	Change "first choice" destinations of shopping / leisure trips	Change mode (motorised vehicle)	Change mode (to / from / between soft modes)	Change "normal" departure time	Change strategy of trip-linking	Change "first choice" car parks (including park and ride)	Change "normal" route	Abandon proposed trip	Change departure time	Change route	Change trip-linking	Change intended destinations	Pre-plan trips using real-time information	Change use of car parks (including park and ride)
Measures to influence car use																	
Conventional direction signing				•					•	●	•		●	•	•		●
Variable message signs										●	•	·	●	●	●		•
Real-time driver information systems and route guidance					•			●		●	●		●	●	●		●
Parking guidance and information systems					•				●	●	•		•		•		●
Measures to influence public transport use																	
Conventional timetable and other service information					•					●							
Real time passenger information					•			●		●		·	•	•	•		
Trip planning systems which provide information before the start of journey								●		●		●	●	●	●	●	
Operation information systems such as bus fleet management																	
Provision for cyclists and pedestrians																	
Static direction signs				•		•				●							
Tactile footways						●				●							
Provision for freight																	
Static direction signs										●							
Fleet management systems										●							

TABLE A19	**Strategic location responses**									**Strategic transport responses**							
PRICING MEASURES **And** **COMPENSATORY MEASURES OUTSIDE THE TRANSPORT FIELD**	Relocate home within study area	Move house out of / into study area	Relocate business within study area	Start up / close down business within study area	Change employment	Start / stop (mainly) working from home	Start / stop (mainly) shopping from home	Change school		Change car-buying behaviour	Buy / sell a motorcycle	Buy / sell a bicycle	Buy public transport season ticket	Buy parking season ticket	Car-pool/share	Change trip length distribution of trips lying wholly within area	Change trip length distribution of trips lying partially within area
PRICING MEASURES																	
Measures to influence car use																	
Parking charges	•	•	•	•		•	•			●	•	•	•	●	●	●	●
Charges for ownership of private parking space	●	●	●	●	·	•	•	·		●	•	•	•	●	●	●	●
Urban road charging, including area licensing and road pricing	●	●	●	●	·	●	●	·		●	•	•	•	•	●	●	●
Vehicle ownership taxes						•	•	·		●	●	●	●	•	●		
Fuel taxes	·	•	·	•		•	•			●	•	•	•	•	●	●	●
Measures to influence public transport use																	
Fare levels	•	•	•	•	·	●	●	·		•	•	•	●	•	●	●	●
Fares structures, such as flat fares, zonal fares and monthly passes	·	·	·	·						·	·	·	●		·	●	●
Integrated ticketing systems										·	·	·	●			●	●
Concessionary fares						•	•			●	•	•	●			●	●
COMPENSATORY MEASURES OUTSIDE THE TRANSPORT FIELD																	
Changes in local taxes	●	●	●	●													
Changes in business taxes		●	●	●													
General subsidies for specific groups	•		•														
Targeted assistance for specific groups	•		•														

TABLE A20	**Day-to-day transport responses**										**Within-day transport responses**						
PRICING MEASURES **And** **COMPENSATORY MEASURES OUTSIDE THE TRANSPORT FIELD**	Change number of work trips per week	Change number of shopping trips per week	Change number of leisure trips per week	Change "first choice" destinations of shopping / leisure trips	Change mode (motorised vehicle)	Change mode (to / from / between soft modes)	Change "normal" departure time	Change strategy of trip-linking	Change "first choice" car parks (including park and ride)	Change "normal" route	Abandon proposed trip	Change departure time	Change route	Change trip-linking	Change intended destinations	Pre-plan trips using real-time information	Change use of car parks (including park and ride)
PRICING MEASURES																	
Measures to influence car use																	
Parking charges	•	●	●	●	●	●	•	●	●								
Charges for ownership of private parking space	•	•	•	•	●	●	•	•	●								
Urban road charging, including area licensing and road pricing	•	●	●	●	●	●	●	●	●	●							
Vehicle ownership taxes					●	●											
Fuel taxes	•	●	●	●	●	●	•	●	●								
Measures to influence public transport use																	
Fare levels	•	●	●	●	●	●	•	●									
Fares structures, such as flat fares, zonal fares and monthly passes	•	●	●	●	●	●	•	●		●							
Integrated ticketing systems					●	●	●	●		●							
Concessionary fares	•	●	●	●	●	●	•	●									
COMPENSATORY MEASURES OUTSIDE THE TRANSPORT FIELD																	
Changes in local taxes																	
Changes in business taxes																	
General subsidies for specific groups																	
Targeted assistance for specific groups																	

TABLE A21	**Responsible transport authority supplier responses**																
LAND USE MEASURES **And** **ATTITUDINAL / BEHAVIOUAL MEASURES**	Changes in traffic management (including traffic signals and pedestrian facilities)	Changes in information provision	Traffic calming	Change size of trains / buses	Change public transport quality	Change total car parking space	Reallocating car parking space between long term and short term	"Öther transport authority" responses	Build more (less) houses / workplaces / shops	Change the selling price of buildings	Change rail / bus frequency	Change size of trains / buses	Change rail / bus fares	Change public transport qulaity	Change total car parking space	Reallocate car parking space between long term and short term	Change car park charges
LAND USE MEASURES																	
Development densities, involving an increase in density of development								●	●	●	●	●	●	●	•	•	•
Development pattern, including transport corridor-based developments								●	●	●	●	●	●	●	•	•	•
Development mix in which homes, jobs and shops are placed close together			●					●	●	●	•	•	•	•	•	•	•
Protection of certain sites from development;								?	●	●	·	·	·	·	·	·	·
Parking standards for new development;						●	●	?	•	•	·	·	·	·	●	●	●
Commuted payments, whereby developers can provide less parking, but pay for public space;						●	●	?	•	•	·	·	·	·	●	●	●
Developer contributions to the financing of infrastructure;								?	●	●	●	●	●	●	•	•	•
Value capture taxes								?	●	●	•	•	•	•	•	•	•
Other land use taxes, including property taxes.								?	●	●	·	·	·	·	·	·	·
ATTITUDINAL / BEHAVIOURAL MEASURES																	
Public awareness campaigns								?			•	•	•	•			
Flexible working hours								?			●	•	·	·	·	●	·
Telecommunications as alternative to travel								?	●	●	●	●	●	•	●	•	●
Company travel plans								?									

TABLE A22	**Responsible transport authority supplier responses**							**"Third party" supplier responses**									
INFRASTRUCTURE MEASURES	Changes in traffic management (including traffic signals and pedestrian facilities)	Changes in information provision	Traffic calming	Change size of trains / buses	Change public transport quality	Change total car parking space	Reallocating car parking space between long term and short term	"Other transport authority" responses	Build more (less) houses / workplaces / shops	Change the selling price of buildings	Change rail / bus frequency	Change size of trains / buses	Change rail / bus fares	Change public transport qulaity	Change total car parking space	Reallocate car parking space between long term and short term	Change car park charges
Measures to influence car use																	
New road construction	●	●	•					●	●	●							
New off-streetp arking	●	●	●			●	●	?									
Measures to influence public transport use																	
Upgrades to existing fixed infrastructure				●	●			?			•	●	•	●	•	•	•
Reopening closed railway lines	●	•		•	•	•	•	?	•	•	•	•	•	•	●	•	•
New rail stations	●	●		•	•	•	•	?	•	•	•	•	•	•	●	•	•
New rail services on existing lines	•			•	•	·	·	?	·	·	●	●	•	•	•	•	•
Light rail systems	●	●		•	•	●	●	?	•	•	●	●	•	•	•	•	•
Guided bus systems	●	●		•	•	•	•	?	·	·	●	●	•	•	•	•	·
Park and ride	●	●		•	•	●	●	?	•	•	●	•	•	•	●	●	●
Terminals and interchanges	●	●		•	•	●	●	?	●	●	●	•	•	●	•	•	•
Enhancement of bus and rail vehicles				●	●			?	·	·	•	•	•	●	·	·	·
Provision for cyclists and pedestrians																	
Cycle routes	●	●	●					?									
Pedestrian routes	●	●	●														
Pedestrian areas	●	●	●						●	●							
Provision for freight																	
Lorry parks	●	●				●	●	?							●	●	●
Transhipment facilities	●							?							●	●	•

TABLE A23	**Responsible transport authority supplier responses**							**"Third party" supplier responses**									
MANAGEMENT OF THE INFRASTRUCTURE	Changes in traffic management (including traffic signals and pedestrian facilities)	Changes in information provision	Traffic calming	Change size of trains / buses	Change public transport quality	Change total car parking space	Reallocating car parking space between long term and short term	"Other transport authority" responses	Build more houses / workplaces / shops	Change the selling price of buildings	Change rail / bus frequency	Change size of trains / buses	Change rail / bus fares	Change public transport qulaity	Change total car parking space	Reallocate car parking space between long term and short term	Change car park charges
Measures to influence car use																	
Road maintenance																	
Conventional traffic management																	
Conventional speed controls																	
Urban traffic control systems																	
Intelligent transport systems																	
Accident remedial measures																	
Traffic calming measures																	
Physical restrictions								?									
Regulatory restrictions								?									
Parking controls						⬤	⬤	?							⬤	⬤	⬤
Car sharing / pooling																	
Measures to influence public transport use																	
Maintenance of existing fixed infrastructure				•	●			?			?	?	?	?			
New bus services				⬤	●			?			?	?	?	?			
Bus priorities				●	●			?			●	?	?	?			
High occupancy vehicle lanes				●	●			?			●	●	•	●			
Changes in bus and rail frequencies				●	●			?			?	?	?	?			
Timetabling strategies											?	?	?	?			
Bus service measures to improve reliability											?	?	?	?			
On-bus cameras for traffic regulation enforcement											?	?	?	?			
Provision for cyclists and pedestrians																	
Cycle lanes and priorities																	
Cycle parking provision																	
Pedestrian crossing facilities																	
Safe routes to school																	
Provision for freight																	
Lorry routes and bans								⬤									
Lorry parking and loading restrictions								●								?	?

TABLE A24	**Responsible transport authority supplier responses**							**"Third party" supplier responses**									
INFORMATION PROVISION	Changes in traffic management (including traffic signals and pedestrian facilities)	Changes in information provision	Traffic calming	Change size of trains / buses	Change public transport quality	Change total car parking space	Reallocating car parking space between long term and short term	"Other transport authority" responses	Build more houses / workplaces / shops	Change the selling price of buildings	Change rail / bus frequency	Change size of trains / buses	Change rail / bus fares	Change public transport qulaity	Change total car parking space	Reallocate car parking space between long term and short term	Change car park charges
Measures to influence car use																	
Conventional direction signing																	
Variable message signs																	
Real-time driver information systems and route guidance																	
Parking guidance and information systems						●	●								●	●	●
Measures to influence public transport use																	
Conventional timetable and other service information				?	?						?	?	?	?			
Real time passenger information				?	?						?	?	?	?			
Trip planning systems which provide information before the start of journey																	
Operation information systems such as bus fleet management				●	?						●	●	•	?			
Provision for cyclists and pedestrians																	
Static direction signs																	
Tactile footways																	
Provision for freight																	
Static direction signs																	
Fleet management systems																	

TABLE A25	**Responsible transport authority supplier responses**							**"Third party" responses**									
PRICING MEASURES **And** **COMPENSATORY MEASURES OUTSIDE THE TRANSPORT FIELD**	Changes in traffic management (including traffic signals and pedestrian facilities)	Changes in information provision	Traffic calming	Change size of trains / buses	Change public transport quality	Change total car parking space	Reallocating car parking space between long term and short term	"Other transport authority" responses	Build more houses / workplaces / shops	Change the selling price of buildings	Change rail / bus frequency	Change size of trains / buses	Change rail / bus fares	Change public transport qulaity	Change total car parking space	Reallocate car parking space between long term and short term	Change car park charges
PRICING MEASURES **Measures to influence car use**																	
Parking charges	●	●		?	?	⬤	⬤	?			●	●	⬤	●	⬤	⬤	?
Charges for ownership of private parking space				?	?	⬤	⬤	?			•	•	●	●	⬤	⬤	⬤
Urban road charging, including area licensing and road pricing	⬤	⬤		?	?	⬤	⬤	?			●	●	⬤	●	⬤	⬤	?
Vehicle ownership taxes				?	?	•	•	?			•	•	●	●			
Fuel taxes				?	?	•	•	?			●	●	⬤	●			
Measures to influence public transport use																	
Fare levels				⬤	⬤	●	●	?			⬤	⬤	?	?			
Fares structures, such as flat fares, zonal fares and monthly passes				●	●	•	•	?			?	?	?	?			
Integrated ticketing systems				●	⬤	•	•	?			?	?	?	?			
Concessionary fares				●	●	•	•	?			●	●	?	?			
COMPENSATORY MEASURES OUTSIDE THE TRANSPORT FIELD																	
Changes in local taxes									●	●							
Changes in business taxes									●	●							
General subsidies for specific groups									●	?							
Targeted assistance for specific groups																	