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PROJECT OPTIMA:
Optimisation of Policies for Transport Integration
in Metropolitan Areas

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Project Co-ordinator: **Institute for Transport Studies**
University of Leeds

Partners:
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VTT
CSST
TT-ATM
TØI

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2. EXECUTIVE SUMMARY

2.1 OBJECTIVES OF THE PROJECT

The overall objectives of Project OPTIMA were:

(i) to identify optimal urban transport and land use strategies for a range of urban areas within the EU;
(ii) to compare the strategies which are specified as optimal in different cities, and to assess the reasons for these differences;
(iii) to assess the acceptability and feasibility of implementation of these strategies both in nine case study cities (Edinburgh, Merseyside, Vienna, Eisenstadt, Tromsø, Oslo, Helsinki, Torino and Salerno) and more widely in the EU; and
(iv) to use the results to provide more general guidance on urban transport policy within the EU.

2.2 TECHNICAL DESCRIPTION

Theses objectives were achieved by carrying out the following tasks:

1. specify two objective functions, one each for economic efficiency and sustainability, which are acceptable to, and can be applied in, all the cities being studied;
2. identify, separately for each city, an acceptable set of transport and land use policy instruments, and to extend this list to cover measures in use elsewhere in the EU;
3. conduct a series of tests of combinations of policy measures, in each city, using currently available transport models of these cities;
4. use the optimisation methodology, separately for each city, to identify strategies which are optimal in terms of economic efficiency and sustainability in each city.
5. draw policy conclusions for each city on the differences between the efficiency-optimal and sustainability -optimal strategies, the justification for those strategies, and the feasibility of implementation, in discussion with the city authorities;
6. draw project-wide conclusions by comparing the results for the different cities, explaining the differences between them, and discussing their applicability in other EU member states.

Definition of objective functions (Task 1)

The *Economic Efficiency Function* (EEF) reflects the cities' objectives of overall efficiency of the transport system, economising the use of resources, accessibility within the city and at least the *possibility* of economic regeneration. Essentially, the EEF performs a cost benefit analysis of the tested policy, while also imposing a shadow price on the financial support required.

The *Sustainability Objective Function* (SOF) differs from the EEF in that the exhaustible resource of fossil fuel is valued more highly than its market price, and that a penalty is incurred for those policies that do not meet a certain minimum requirement on fossil fuel savings. These features of the SOF reflect the aim to reduce CO_2 emissions. Also, costs and benefits are only considered for the horizon year, representing the interests of future generations.

Common set of measures

Based upon an inventory of measures carried out by the project (Task 2), a set of common measures was selected for use in the optimisation process. Table 1 shows these measures and the maximum ranges considered (some cities used narrower ranges where it was felt that the maximum range was simply infeasible).

Abbreviation	Name	Minimum Value	Maximum Value
IH	High public transport infrastructure investment	0	1 (dummy)
IM	Medium public transport infrastructure investment	0	1 (dummy)
CAP	Low cost increase/decrease of road capacity (whole city)*	-20%	+20%
FREQ	Increasing/decreasing public transport frequency (whole city)	-50%	+100%
RP	Road pricing # (city centre)	0	10.0 ecus
PCH	Increasing/decreasing parking charges (city centre)	-100%	+500%
FARE	Increasing/decreasing public transport fares (whole city)	-100%	+100%

Table 1: Measures tested

* Road capacity measures include various types of traffic management and transport telematics, but **do not** include road building

\# The value of the measure Road Pricing refers to the cost per trip incurred by the car driver

Optimisation process

Once measures and their ranges were defined, transport model runs were carried out (Task 3) to test an initial set of combinations of transport measures (*packages*). The number of packages in this set was the minimum number required to start up the optimisation process. The optimisation process (Task 4) was then applied to find the optimum set of values of these measures for each city, separately for each objective function.

Consultation process

Based on the initial review of the results, consultations were held with officials in each of the nine cities (Task 5). They were presented with the results, and invited to assess them against a set of criteria which focused on issues of feasibility and acceptability. Inevitably there was some overlap between the concerns under these two headings. The officials were also invited to suggest alternative strategies which they would wish to have tested. When these alternatives were tested, none of them performed better than the predicted optima (with respect to the objective functions), and the opportunity was taken to discuss these results. The output of these consultations was discussed with two other cities to test transferability, and then used to develop the conclusions specified below (Task 6).

2.3 RESULTS AND CONCLUSIONS

Policy results and recommendations

The results from the optimisation process are summarised in Table 2, which gives an overview of the relative benefit (over the nine case study cities) of each measure with respect to the two objective functions used.

	EEF	SOF
Public transport infrastructure	-	**
Low cost road capacity improvements	***	**
Increase in public transport frequency	*	**
Reduction in public transport fares	**	***
Road pricing and/or increased parking charges	**	***

* indicates there is (overall) a small benefit to using the measure
** indicates there is (overall) a medium benefit to using the measure
*** indicates there is (overall) a strong benefit to using the measure

Table 2 : Summary of beneficial measures

From the results in Table 2 and from other aspects of the research, the following recommendations can be made for policy makers

- strategies should be based on combinations of measures, and should draw fully on the synergy between success measures;
- economically efficient measures can be expected to include low cost improvements to road capacity, improvements in public transport (increased service levels or reductions in fares), and increases in the cost of car use;
- public transport infrastructure investment is not likely, in the majority of cases, to be a key element in economically efficient strategies;
- reductions in capacity to discourage car use are not likely to be economically efficient;
- the scale of changes in service levels and fares will be influenced by the current level of subsidy; in some cases a reduction in service levels or an increase in fares may be justified on economic grounds;
- the scale of increase in costs of car use will depend in part on current levels of congestion; the study suggests that road pricing and parking charge increases are broadly interchangeable, but this needs assessing in more detail;
- in most cases economically efficient strategies can be designed which are financially feasible, provided that revenues can be used to finance other strategy elements;
- the pursuit of sustainability is likely to justify investment in public transport infrastructure, further improvements to public transport services and/or fares, and further increases in the cost of car use;
- availability of finance will be a major barrier to implementation of many sustainability-optimal strategies, and further work is needed to investigate the extent to which financial costs can be reduced by strategies which are slightly sub-optimal;
- legislation will be needed to enable implementation of road pricing and to control parking charges; in the UK and Italy there is also a case for changing legislation to permit economically more efficient public transport strategies;

- public acceptability will be a significant barrier with those measures which reduce service levels or increase costs; this implies the need for effective public relations campaigns, and carefully designed implementation programmes;
- detailed measures to improve the environment and provide better facilities for cyclists, pedestrians and disabled people should be designed within the context of a preferred strategy.

Methodological conclusions and recommendations

- the optimisation procedure has been shown to be successful, and has attracted widespread interest; however, it is important that careful thought is given to the policy implications of each stage of the process;
- the frequent use of upper and lower bound values in the optima is a cause of some concern;
- strategic models are in many ways more appropriate than tactical models in the development of optimal strategies;

such models should include walking and cycling, both peak and off peak conditions, and the effects of public transport loadings on user costs;

2.4 COLLABORATION SOUGHT FOR EXPLOITATION

Academic exploitation

A search will be made for suitable collaborators as follows:

- Research organisations overseas (i.e. outside EU) who have an interest in strategic modelling and optimisation. In particular, research organisations in Asia and Latin America would be particularly appropriate.
- Research organisations involved in combining land use modelling with strategic transport modelling, who have an interest in optimisation.
- Research organisations involved with developing national/international models, who have an interest in optimisation.

Consultancy

Effort will be put into finding suitable partnerships with:

- Cities who already have existing strategic transport models, and would like to make extra use of these models by using the OPTIMA optimisation method.
- Cities/consultancies who are already building strategic transport models.
- Cities/consultancies who are planning to build strategic transport models in the future.

2.5 DISSEMINATION

Presentations/publications already made

- R.Barletta, S.Toffolo, G.Surace (1996) Optimisation of transport policy in metropolitan areas: implementation of the OPTIMA project in Turin. Paper presented to the Annual Conference of the Operational Research Society of Italy, 16-20 September, 1996.

- H.Minken (1996). Sustainable transport: A balance between the dictatorships of present and future generations. Samferdsel 35 (10), pp 20-22.

- H.Minken (1996). What is sustainable transport? Paper presented at the TØI-dagen, 3 October 1996. Working Paper TØI/937/96, TØI.

- H.Minken (1997). Efficient or sustainable transport: what does it mean in practice? Transportdagene i Oslo, 5-6 May 1997.

- A.D.May (1997) Transport strategies to improve the quality of European cities. Paper presented at “Moving On: Transport, Location and Economic Growth after the Election”. Cambridge Econometrics Annual Conference, Cambridge, 3-4 July 1997.

- S.P.Shepherd, G.Emberger, K.Johansen, T.Jarvi-Nykanen (1997) OPTIMA: Optimisation of Policies for Transport Integration in Metropolitan Areas: a review of the method applied to nine European cities. Paper presented to the 25th European Transport Forum, 1-5 September 1997.

- A.D.May, L.Rand, P.M.Timms, S.Toffolo (1997) OPTIMA: Optimisation of Policies for Transport Integration in Metropolitan Areas: a review of the results applied to nine European cities. Paper presented to the 25th European Transport Forum, 1-5 September 1997.

- H.Minken, P.M.Timms (1997) Optimal urban transport strategies: how do we find them and what do they look like? Presentation to Work Group 2 at the “COST Action 616” workshop on clean-air-oriented urban transport strategies. Copenhagen, 8-9 September 1997.

- A.D.May (1997) Can transport be sustainable? Proc. British Association for the Advancement of Science. Leeds. September 1997.

- H.Minken (1997) Optimal transport policy: examples from Norwegian and foreign cities. Paper presented at The Research Days of 1997, 25 September 1997.

3. OBJECTIVES OF THE PROJECT

The overall objectives of Project OPTIMA were:

(i) to identify optimal urban transport and land use strategies for a range of urban areas within the EU;
(ii) to compare the strategies which are specified as optimal in different cities, and to assess the reasons for these differences;
(iii) to assess the acceptability and feasibility of implementation of these strategies both in nine case study cities and more widely in the EU; and
(iv) to use the results to provide more general guidance on urban transport policy within the EU.

There is a wide range of objectives of transport policy in urban areas, but most can be grouped under the broad headings of **economic efficiency**, including economic development, on the one hand, and **sustainability**, including environment, safety, equity and quality of life, on the other. It is now generally accepted that the overall strategy for achieving these objectives must include an element of reduction of private car use and transfer of travel to other modes. The policy instruments for achieving these objectives can include infrastructure provision, management measures to enhance other modes and to restrict car use, and pricing measures to make public transport more attractive and to increase the marginal cost of car use. It is now widely accepted that the most appropriate strategy will involve several of these measures, combined in an integrated way which emphasises the synergy between them.

The most appropriate strategy for a city will depend on its size, the current built form, topography, transport infrastructure and patterns of use; levels of car ownership, congestion and projected growth in travel; transport policy instruments already in use; and the acceptability of other measures in political and legislative terms. These will differ from city to city. Policy advice cannot therefore be generalised, but must be developed for a range of different types of city. This is the approach adopted in this study, in which nine different cities in five countries (Edinburgh, Merseyside, Vienna, Eisenstadt, Tromsø, Oslo, Helsinki, Torino and Salerno) have been studied in detail, using a common study methodology. The main purpose of this deliverable is to present this methodology and the results obtained from using it. These results are expressed in terms of optimal strategies for each city with respect to both economic efficiency and sustainability.

4. MEANS USED TO ACHIEVE THE OBJECTIVES

The means used to achieve the objectives were to:

1. specify a standard set of objective functions for both economic efficiency and sustainability, which are acceptable to, and can be applied in, all the cities being studied;

2. identify, separately for each city, an acceptable set of transport and land use policy instruments, and to extend this list to cover measures in use elsewhere in the EU;

3. conduct a series of tests of combinations of policy measures, in each city, using currently available transport models of these cities;

4. use the optimisation methodology, separately for each city, to identify strategies which are optimal in terms of economic efficiency and sustainability in each city.

5. draw policy conclusions for each city on the differences between the efficiency-optimal and sustainability -optimal strategies, the justification for those strategies, and the feasibility of implementation, in discussion with the city authorities;

6. draw project-wide conclusions by comparing the results for the different cities, explaining the differences between them, and discussing their applicability in other EU member states.

These were achieved in Work Packages 10 to 60 respectively, extensive details of which are given in the respective Work Package Reports (OPTIMA, 1997a, 1997b, 1997c, and 1997d) also avialable on the ITS web page at:

http://www.its.Leeds.ac.uk/projects/optima/

As indicated in Table 3, the nine cities represent a wide range of conditions. Five, including Merseyside, are Metropolitan Areas (MA) including a major city and its suburbs. Unless stated otherwise, references in the text for these cities are to the whole MA. Three are large in population terms, three medium and three small. Three have much lower population density than the others. Car ownership varies widely, with much higher levels in Eisenstadt and Torino. Annex 1 gives further summary information about the nine case study cities.

	Edinburgh MA	Merseyside	Vienna	Eisenstadt	Tromsø	Oslo MA	Helsinki MA	Torino MA	Salerno
Population ('000)	420	1440	1540	10	57	919	891	1454	157
pop density/ha	29.9	22.2	37.9	2.4	0.3	1.7	12.0	23.7	26.2
car ownership per person	0.32	0.27	0.32	0.66	0.38	0.44	0.32	0.63	0.40
Trips by car (%)	51	78*	37	56	54	62	47	77*	40

* of motorised trips only

Table 3 : City Characteristics

5. SCIENTIFIC AND TECHNICAL DESCRIPTION OF PROJECT

5.1 INTRODUCTION

5.1.1 Overview of the optimisation process

The overall structure of the project can be understood by reference to the optimisation method used in WP40. A “basic method” for optimisation is illustrated in Figure 1.

Step 1 defines the objective functions used in OPTIMA: economic efficiency measured by Net Present Value (NPV) and the Sustainability Objective Function (SOF). The definition of these functions was part of WP10, and is described in Section 5.2.

Step 2 specifies the policy measures that have been used for finding optima. The work involved with this was part of WP20, and is described in Section 5.3. In particular, Section 5.3 lists the basic common set of measures tested in each city. These measures can be divided into “discrete” measures or “continuous” measures. Discrete measures are one-off infrastructure projects that are either fully built or not built at all. On the other hand, continuous measures could be implemented at any level within a range appropriate to the measure. Standardised ranges have been decided upon for OPTIMA. However, some cities have diverged slightly from some of the standard ranges where these were not considered appropriate. Section 5.3 also gives the cost assumptions made in each city for the measures.

Step 3 involves using a transport model in each city to model an **initial** set of 18 policy combinations, chosen according to an orthogonal design from the ranges specified in Step 2. A brief summary of the transport models used in OPTIMA is given in Section 5.4. In particular a distinction is made between two generic types of model used in the project: “strategic” models and “tactical” models. The work in Step 3 formed the early part of work in WP30.

Steps 4 to 6 involve an iterative process of linear regression and **further** transport model running. This process, which formed the latter part of WP30 and all of WP40, is described fully in Section 5.5. In general, there is a “basic” optimisation method and a “comprehensive” optimisation method, with the basic method being illustrated fully in Figure 1. In the comprehensive method, further objective functions and further measures can be introduced to the method, without the necessity of starting the whole process from the beginning.

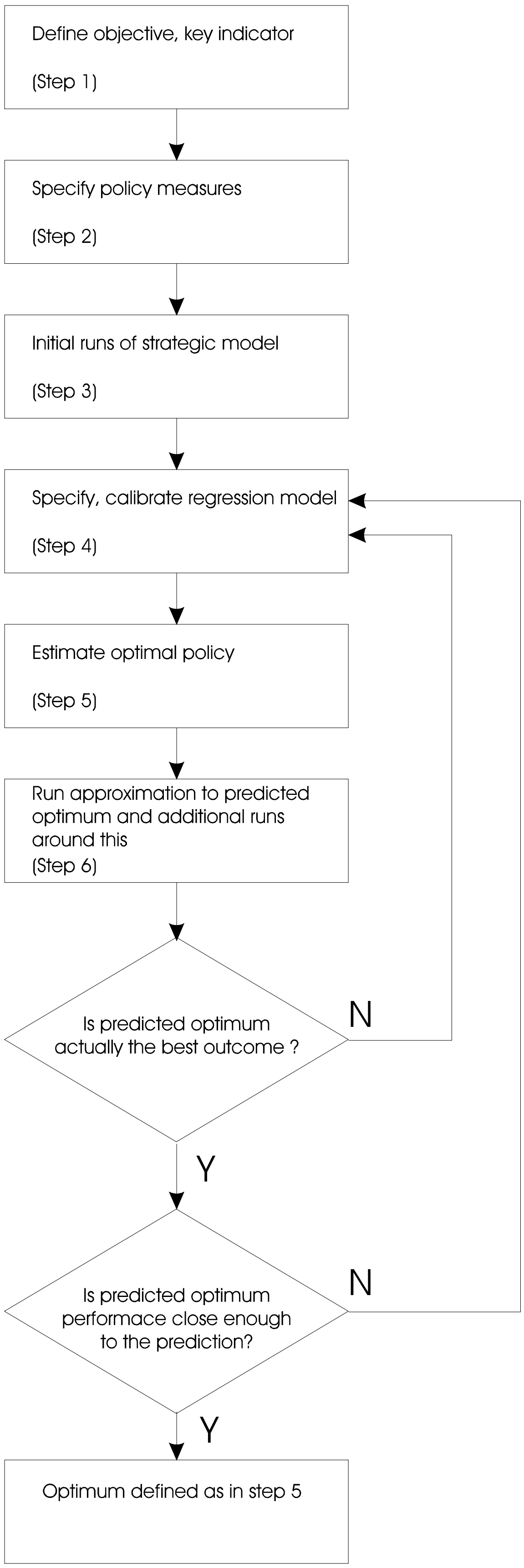

Fig. 1: The optimisation process

5.1.2 A "European" optimisation approach

A central feature of the OPTIMA project is that it is devising an approach that can be used throughout the whole of Europe. Whilst the formal discussion on the transferability of the **results** is dealt with later in this deliverable, this section reports on the attempts made to ensure that the OPTIMA **method** can be used in as widespread way as possible throughout Europe.

An important recognition to make here is that the OPTIMA method synthesises a number of already existing **core** planning tools. This section concentrates on how the synthesis of planning tools has been engineered to fit with a "European perspective" (a summary of how some of these planning tools have been further developed within OPTIMA is given below in Section 5.1.3).

The central ingredients of the OPTIMA method are threefold:

(i) One or more objective functions;
(ii) A transportation model;
(iii) An optimisation algorithm.

Of these, the objective functions need to be defined for the individual city, but the OPTIMA consortium has generated two commonly applicable functions (see Section 5.2). The optimisation algorithm is a direct output of OPTIMA, and is described in Section 5.5. Thus the only significant potential barrier to transferability is the availability of a transportation model.

An essential part of the OPTIMA philosophy is the recognition that a wide range of transportation models are already in use in cities throughout Europe; the OPTIMA methodology consists of a set of procedures for making the best use of these models. Two important points arise immediately from this philosophy. Firstly, it is the intention of the OPTIMA consortium that the method can be used with as many as possible different types of transportation model. To this end the project has consciously included a wide range of models in its test case study cities: more information on this is given in Section 5.4 below. Secondly, the OPTIMA method needs to be consistent with current transportation model usage throughout Europe. The project has identified a number of model characteristics which are important in facilitating the identification of optimal strategies, and these are discussed in Section 5.4.

Whilst this philosophy is totally in line with the objectives of European-wide research, there are some inevitable drawbacks, which largely relate to the capabilities of the transportation models, and the feasibility of quantifying some transport policy objectives. In one specific way, these limitations led to one of the objectives of Project OPTIMA not being realised, since it proved infeasible to model the interaction of land use measures with transport policy measures. It should be emphasised that the OPTIMA consortium recognises that land use measures are of great importance in long-term transportation planning. However, the fact remains that, in the *typical* current usage of transportation models in cities across Europe, it is impossible to model the effects of land use measures in conjunction with transportation measures: the *typical* models used in the OPTIMA case studies confirm this statement. It follows immediately that any attempt to make land use modelling central to the OPTIMA method would have seriously undermined its current European-wide transferability. However, two comments should be made to qualify this statement. Firstly, land use measures are being considered in a marginal way in two of the OPTIMA case study cities and a summary of results of the impacts of transport on land use for Edinburgh is included in Section 5.6. Secondly, it will be extremely straightforward to adapt the optimisation algorithm to make it suitable for the time when land use modelling is in reality a central feature of transportation modelling.

5.1.3 Further development of core planning tools in OPTIMA

As explained above, the OPTIMA approach has generally been to create a method which can make best use of already existing transportation planning tools. However, in creating this method it has been necessary to develop further some of these tools. Notable examples include:

- The creation of a new type of objective function, the Sustainability Objective Function, as described in Section 5.2.

- The improvement of the already-existing (pre-OPTIMA) optimisation algorithm (described by May et al, 1995) to include a subjective stopping criterion, so that in practice the user does not stop the algorithm until s/he is convinced that convergence has been obtained, even when formal stopping criteria have been met. This (improved) algorithm, named the *Basic Method*, is described in Section 5.5.

- The development of a new framework of optimisation algorithms named the *Comprehensive Method*. This framework of algorithms has the Basic Method as a relatively simple example. Its development has explicitly taken into account the fact that a wide range of transportation models can be used, and that the run times of these models vary widely. Generally speaking, the Basic Method is more appropriate for transportation models with a long run time, whilst more complex approaches can be used for transportation models with a short run time. This framework is described in Section 5.5.

5.2 DEFINITION OF OBJECTIVE FUNCTIONS

Work Package 10 defined two objective functions: Economic Efficiency Function (EEF), measured by a variant of Net Present Value (NPV) and a Sustainability Objective Function (SOF). This section provides a detailed explanation of these two functions; further background information is available in a Working Paper (OPTIMA, 1997a). Section 5.2.1 makes introductory comments about the objectives of the nine case study cities, Section 5.2.2 addresses some limitations imposed by the transportation models used upon the scope of the objective functions, whilst Section 5.2.3 makes some comments about the exclusion of distributional and financial feasibility objectives from the objective functions. Following these introductory comments, Section 5.2.4 gives an overview of the rationale behind the two objective functions, EEF and SOF, actually used in OPTIMA. Section 5.2.5 defines Present Value of Finance (PVF) which is used in the calculation of the two objective functions, whilst Sections 5.2.6 and 5.2.7 make definitions of EEF and SOF respectively.

5.2.1 The objectives of the cities

A review of the transport policy objectives of the nine cities has been carried out. In all Metropolitan Areas except Merseyside and Helsinki, the consultation was with the authority responsible for the principal city. The general conclusion from the review is that the cities' transport policy objectives cover the whole range of objectives traditionally set out for urban transport policy. The aims of improving the quality of public transport and pedestrian and cycling facilities with the intention of reducing car use seems to be of importance to most of the cities. The Nordic and Austrian cities refer specifically to the need to reduce CO_2 emissions. Three cities (Merseyside, Helsinki and Oslo) aim at making the best use of the existing road network rather than adding to road capacity. The shift of policy towards priority for public transport and environmental goals is a relatively new tendency, and strategic highway investment plans will still be implemented for many years to come, in for example Oslo.

As is often the case, city authorities' stated objectives (as instanced above) are a mix of true objectives (such as reducing CO_2 emissions) and strategies for meeting those objectives (such as improving public transport). The OPTIMA project has stressed the distinction between these two, and sought a clear specification of actual objectives. All cities include economic efficiency, environmental and accessibility objectives. The British cities, especially Merseyside, put stress on economic regeneration. Edinburgh seems to stand out in putting safety as a top priority, while Helsinki and Vienna stand out in the weight attached to maintaining a dense city.

5.2.2 Limitations imposed by the models

Transport models will be unable to mirror the whole range of changes in the economic and physical conditions of a city and its inhabitants brought about by a transport strategy. They concentrate on changes in *some* aspects of travellers' behaviour, namely trip frequency, destination, mode and route choice. From a prediction of these changes, changes in travellers' benefits and costs as well as the immediate impacts on the number of accidents, pollution levels etc. may be obtained.

Some of the objectives of the cities do not depend for their fulfilment in a clear-cut way on these four aspects of travellers' behaviour. Instead, they depend directly on decisions made by the authorities, or on other changes in behaviour than those assessed by transport models, like decisions to relocate houses and businesses. It makes little sense to include such objectives in the objective functions.

Land use objectives. The models available in the case study cities are not integrated land use-transport models. This means that the impact of an exogenously given land use change on traffic flows, costs and benefits in the transportation sector could be assessed, but the impact of an exogenously given transport strategy on land use cannot. The objectives of preserving townscapes (Merseyside) and landscape and outdoor life (Tromsø) must therefore be taken care of when formulating the land use scenarios and investment strategies, and the degree of fulfilment of them will be immediately apparent from an inspection of these scenarios and strategies. Such objectives need not and cannot be included in the objective functions.

Dense city structure. Regarding the objective of a dense city structure (Helsinki, Vienna), this objective is not entirely an end in itself, but a means to reduce the need for travelling and increase the modal shares of public transport and walking and cycling. For a given dense land use scenario, the effects on travelling and modal split can be determined from the transport model. The effects on city structure from a transport strategy that reduces travel and travel by car in particular, can however not be assessed. To the degree that city structure is shaped by market forces, this makes it difficult to judge whether the objective is attained by any given combination of land use and transport policy instruments.

Economic regeneration objectives. The attainment of this objective can not be assessed fully by transport models. These models are static, and unable to mirror the process towards economic regeneration. Income levels are exogenously input, and no feedback from transport cost savings to income levels exists. Economic regeneration will depend in part on land use policy, and in turn have strong impacts on land use. None of these interactions are modelled. If, however, a consumer surplus measure is included in the economic efficiency objective function, the change in consumer surplus, especially for freight and business trips, will be a measure of the *possibilities* for economic regeneration brought about by a transport strategy.

National and international accessibility. This objective cannot be assessed because of the limited geographical area covered by the models, and so need not be included in the objective functions.

5.2.3 The exclusion of distributional and financial feasibility objectives from the objective functions

The perspective of the OPTIMA project is that of society as a whole. This means that to the extent possible, all benefits and disbenefits that flow from a given urban transport strategy should be included in the objective function, whether they are monetary or not, and whether or not they accrue to households, firms, government or other agencies.

Obviously, the question of who gets the benefits and disbenefits is a matter of concern to the cities. Some (Merseyside, Helsinki) single out benefits to commercial traffic as a special concern. There are concerns, for example in Tromsø, that benefits should be fairly distributed among all inhabitants, regardless of car ownership. Finally, it is only natural that local authorities are concerned that the benefits should accrue to the city, and not be siphoned off to the region as a whole.

Regarding the *sustainability* objective function, the concept of sustainability has obvious distributional connotations. To be sustainable, development will have to reduce the gap between rich and poor countries and be able to secure a decent standard of living for everybody. It is felt that these aspects of sustainability go beyond the scope of the distributional objectives of the cities, and so there is no need to include the distributional objectives of the cities in the sustainability objective function either.

The choice we have made is to disregard distributional concerns when formulating both of the objective functions. Although distributional objectives are not included in the objective functions, they are not lost sight of in the project. The results of each transport strategy is displayed in a way that permits judgements on distributional effects. This information will be utilised in the Work Packages 50 and 60, where the feasibility of implementation of the optimal strategies are judged both in terms of technical effectiveness and political and public acceptance, and ways to overcome barriers to implementation are sought.

Financial feasibility is captured in part by assigning a shadow price to the Present Value of Finance (PVF) (Section 5.2.5) where the PVF is negative, and a net financial outlay is thus required. However, the assumption is made in OPTIMA that if this shadow price can be justified by the benefits, the finance required will be provided. This assumption is not always realistic, and a subsequent project, FATIMA, is investigating further the impact of financial constraints and the potential for using private finance.

All the remaining objectives of the cities can be subsumed under the headings of economic efficiency and sustainability, broadly defined. However, to formulate the economic efficiency and sustainability objective functions, the definitions of efficiency and sustainability had to be narrowed down to be operational in the context of the transport models of the cities.

5.2.4 Overview of objective functions

The Economic Efficiency Function (EEF) reflects the cities' objectives of overall efficiency of the transport system, economising the use of resources, accessibility within the city and at least the *possibility* of economic regeneration. Essentially, the EEF performs a cost benefit analysis of the tested policy. The optimisation with regard to this function is to find the policy with the best Net Present Value (NPV) of social benefits and costs after including a shadow price for PVF.

The costs of accidents, noise and local pollution are not included in the EEF. Ideally, they of course ought to be. However, as usually calculated in cost benefit analyses, changes in these costs do not form a very large part of the net present value of most city-wide transport strategies. There is also a considerable uncertainty involved in the economic evaluation of these impacts. Moreover, not all city models predict all of these impacts.

The Sustainability Objective Function (SOF) differs from the EEF in that the exhaustible resource of fossil fuel is valued more highly than its market price, and that a penalty is incurred for those policies that do not meet a certain minimum requirement on fossil fuel savings. These features of the SOF reflect the aim to reduce CO_2 emissions. Also, costs and benefits are only considered for the horizon year, representing the interests of future generations. The higher than market-price shadow price of fuel consumption used in the SOF could also be taken to reflect approximately the impacts of local and regional pollution that follows from the use of fossil fuels.

In both objective functions, prices of resources include taxes. For investment costs, the reasoning behind this is that the investment packages that we consider are so large that resources will have to be drawn largely from other construction activity in the area. For labour costs, using wage rates including taxes and social expenses implies that labour is drawn from other productive uses, and not from the ranks of the unemployed. As for other operating costs, entering them with taxes included is not strictly correct, but is an expediency not thought to influence the results. For both objective functions, we also use a shadow price of public funds of 0.25, reflecting the loss in economic efficiency associated with taxation.

In the EEF, time savings are valued in the traditional way, by attaching a value of time to these savings. The value of time may differ between travel purposes. User benefits consist of travel time savings and monetary savings. Together they form a Consumer Surplus that is calculated by the so-called ‘rule of a half’.

For each of the tested transport strategies, the transport model of the city is run for the target year (2010 for most cities, 2015 for some). To provide a benchmark against which the other strategies can be assessed, a "Do minimum" strategy is carefully specified. The "Do minimum" strategy consists of investment projects and land use changes already decided upon or implemented, as well as present levels for other policy variables. For Oslo, it is part of the present toll ring scheme to abolish the toll in 2007. In such cases, the planned future level of the policy variable is used. For each strategy, both the EEF and the SOF are expressed not in absolute terms, but in terms of the change from the "Do minimum" strategy.

As is conventionally done, a 30 year planning horizon is assumed. As we only have an actual transport model outcome for one of these years, an assumption must be made about how the benefits and costs of the other years of the planning period relate to those of the target year. As our policy instruments are mostly pricing measures that can be quickly implemented once decided upon, and as transport users can be expected to adjust fairly quickly to new levels of the policies, it has been assumed that benefits and costs for each year in the planning period are the same as in the target year.

The discount rate used to form the present value of the benefit and cost elements of all the 30 years, varies between the cities. Whenever an official or recommended discount rate for a country exists, it has been used. The discount rate varies between 6 and 9%.

The results of these analyses are presented in Section 5.6. Sample calculations, which include the distribution of time savings, monetary benefits and costs among travellers, operators and tax payers are included in the Working Paper on WP30/40 (OPTIMA, 1997c).

5.2.5 Present Value of Finance (PVF)

The Present Value of Finance (PVF) of a measure is defined as the net financial benefit of the measure to government and other providers of transport facilities, both public and private.

In the OPTIMA study, where only one future target year is being modelled, PVF is defined as:

$$(2.1) \qquad PVF = -I + \sum_{i=1}^{30} \frac{1}{(1+r)^i} * f$$

where: I is the present value of the cost of infrastructure investment, compared to the do-minimum scenario;

f is the net financial benefit to transport suppliers and government in the modelled target year, compared to the do-minimum scenario, taking into account both revenue and operating costs;

r is the annual (country specific) discount rate.

5.2.6 Economic Efficiency Function (EEF)

The present value of net benefits, B, consists of net benefits to travellers, operators and the government.

The generalised cost of travel is defined as the monetary costs, plus in-vehicle time cost (in-vehicle time multiplied by the value of time), plus other elements of travel time costs, such as waiting time cost, access time cost etc. Consistent with the assumption underlying the transport models themselves, the demand for trips on a particular travel movement (e.g. origin-destination pair, mode, trip purpose) is defined as a function of the generalised travel costs of that movement and other movements. These demand functions need not be given an explicit analytical form, but are embedded in the transport model, and can be charted by running the model many times over with different generalised costs.

The net benefits to travellers are evaluated as the generalised consumer surplus from the change in generalised costs on all travel movements, assuming that the demand functions are linear in the relevant region of generalised costs. This is a standard evaluation procedure in cost benefit analyses of transport, and it goes by the name of the rule of a half.

The present value of net benefits, B, over a 30 year period is given by:

$$(2.2) \qquad B = \sum_{i=1}^{30} \frac{1}{(1+r)^i} * (f + u)$$

where: u is the net benefit to transport users in the target year, compared with the do-minimum scenario, calculated as described above;

f, r are as described in Section 5.2.5.

Two comments can be made here:

(i) Equations 2.1 and 2.2 implicitly assume that the transport strategy is implemented immediately and that benefits apply immediately. An alternative can be used in which revenues, benefits and costs are assumed to increase incrementally over the 30 year period.
(ii) The present value of net benefits for the do-minimum scenario is, by definition, zero.

The formula for EEF is then:

$$(2.3) \quad EEF = B - I + 0.25PVF \quad \text{if } PVF < 0$$
$$= B - I \quad \text{if } PVF \geq 0$$

Equation 2.3 expresses the EEF as consisting of net present benefits to travellers, operators and government. A shadow price of public funds of 0.25 has been added if the tested strategy requires increased public spending. This reflects the efficiency loss involved in raising extra taxes. As this element is not added if the strategy actually saves tax money, it is assumed that such savings are kept by the operating companies or government.

Since (B - I) is the Net Present Value (NPV) equation 2.3 can also be written

$$EEF = NPV + 0.25PVF \text{ if } PVF < 0$$
$$= NPV \quad \text{if } PVF \geq 0$$

5.2.7 Sustainability Objective Function (SOF)

Ideally, the sustainability objective function (SOF) is designed to reflect the benefits per year of the transport strategy in some future situation, characterised by sustainable levels of resource utilisation. Because that situation can ideally be sustained indefinitely, it will not matter exactly what year it is. This per year benefit consists of benefits to travellers, operators and the government, just as in the EEF. However, the requirement for sustainable levels of resource utilisation requires that fuel consumption stays below the level required for sustainability. Ideally, the sustainable situation should also be characterised by certain requirements on land use. Fuel consumption is here used directly as an indicator of CO_2 emissions, and indirectly as a proxy for other environmental impacts, like local and regional pollution and accident levels.

To make these requirements on the SOF operational in a simple way, the target year of the transport model runs has been used as the year in which these benefits are measured and in which the fuel consumption requirement is to be met. The land use requirement has been left out for the reasons given in Section 5.2.2. This can be taken as implying that this objective has to be fulfilled not by optimisation, but by direct planning by the city authorities.

A weak and a strong requirement on sustainability have been formulated. The weak requirement is designed to discourage higher levels of fuel consumption and is modelled by pricing all fuel consumption at four times the current fuel price. This can be taken as a shadow price of fuel to reflect the sustainability requirements. The strong requirement is that fuel consumption is less than in the "Do minimum" strategy. If that requirement is not met for a particular strategy, a strong penalty is incurred.
Let b be the per year benefit to travellers, operators and government. We measure these benefits in the same way as in the EEF calculations, so

(2.4) $b = f + u$

where f and u are defined in Section 5.2.6

The pure sustainability objective function (SOF) is given by:

(2.5) SOF = b - y - z (if fuel consumption exceeds do-minimum)
b - y (otherwise)

where y is the "weak penalty" on fuel consumption in the target year (calculated by multiplying the fuel consumption cost by a shadow price of 4) and z is the "strong penalty" on fuel consumption in the target year (a large value taken as 1000 Mecu, which ensures that no package of measures can be selected if it increases fuel consumption from the do-minimum)[1].

In this pure function, no costs and benefits incurred before the target year are included, so current investment carries no weight in the SOF. This is because while the EEF only reflects the interests of present generations, the SOF focuses entirely upon the interests of future generations, living in sustainable or near-sustainable conditions, resulting in part from investments made now.

The interests of both present and future generations can be included by defining a Weighted Sustainability Function (WSF) that is a weighted average of the EEF and the SOF.

Thus :

(2.6) $WSF_{\alpha} = \alpha EEF + (1 - \alpha) SOF$

Because the EEF tends to be about 10 times the level of the SOF (the first is a present value while the second is a per year value) an α of 0.1 will give approximately the same weight to the present as to all future generations. Although the WSF was not used in the optimisation process, sensitivity tests were carried out in some cities on how well the strategies with optimal strategies with respect to EEF and SOF would perform if the WSF were to be used. In general it was found that if α was greater than 0.1 the optimal strategies with respect to WSF were broadly the same as the optimal strategies with respect to EEF.

1 If the assumption is made that vehicle fuel efficiency will increase by 100% between the base year and the target year, it follows that the strong penalty is implemented if fuel consumption falls by less than 50% between the base year and target year.

5.3 POLICY MEASURES

5.3.1 Summary of measures

Work Package 20 made an inventory of traffic measures in each of the nine OPTIMA test case cities. A full description of this inventory is given in OPTIMA (1997b), and a summary is shown in Table 4. This inventory was based upon information supplied by city officials specifically for the OPTIMA project. It can be seen that there is a distinction between:

(1) Measures already in use
(2) Measures planned
(3) Measures considered but rejected.

		Edinbu			Merse			Vienna			Eisens			Helsin			Torino			Salern			Oslo			Troms		
		U	P	R	U	P	R	U	P	R	U	P	R	U	P	R	U	P	R	U	P	R	U	P	R	U	P	R
A	**Infrastructure measures**																											
1	New road construction		x	x	x	x		x			x				x			x			x		x	x		x	x	
2	Parking supply, off-street	x									x										x					x		
3	Rail services	x	x		x	x		x						x	x			x			x		x	x				
4	Light rail		x			x									x		x	x			x		x					
5	Bus (tram) lanes							x						x			x	x					x					
7	Park and ride	x	x		x	x		x						x				x			x							
9	Traffic calming (speed humps, wide pavements)							x			x			x									x	x				
10	Cycle routes, lanes, paths	x				x		x			x			x	x						x		x	x				
11	Pedestrian areas, pedestrianisation	x	x		x			x			x			x				x			x		x			x	x	
B	**Management measures**																											
3	Traffic calming in residental areas	x			x	x		x			x			x									x	x		x	x	
4	Traffic calming on radials			x																								
6	Regulatory restrictions on car use																x				x							
7	Reduce on-street parking	x			x	x								x										x			x	
8	Parking controls			x							x			x									x				x	
11	Bus (tram) priorities		x		x	x		x						x			x	x										
12	Bus lanes		x											x	x		x	x			x		x					
14	Modified service levels of bus and rail services		x		x						x			x	x						x		x				x	
15	Improve the reliability of bus services					x								x			x											
D	**Pricing measures**																											
2	Fuel taxes							x						x									x			x	x	
4	Parking charges	x			x	x		x			x			x			x	x					x				x	
6	Public transport fare levels		x					x						x			x	x					x				x	
8	Road pricing		x			x										x							x	x				x
E	**Land use measures**																											
2	Densities of population and employment																x	x			x						x	
3	Development within transport corridors													x									x	x				
4	Development mix																											

U IN USE
P PLANNED
R REJECTED

Table 4. Summary of the measures most commonly mentioned by all cities.

Furthermore, there is a categorisation of measures into: infrastructure measures, management measures, pricing measures and land use measures[2]. An initial list of all possible measures was generated from an international review, which included practice in other EU countries. A brief description of the main measures in each of these categories (and their usage in the nine cities) is given in Section 5.3.2 below. Short summaries of the geography, transport system and transport policy measures for each city are given in Annex 1. A detailed description of the same items can be found in the working paper on WP20 (OPTIMA, 1997b).

From this list of measures, a condensed common set of measures was identified for use in the optimisation process. This set is presented in Section 5.3.3, along with the cost assumptions made for the measures.

5.3.2 Types of measure

Table 4 groups the measures as they were categorised in the survey of city authorities. Only those measures which were discussed widely are listed.

Infrastructure measures
In all cities road construction is seen as an important measure, as well as the construction of pedestrian areas. Construction of public transport infrastructure depends on the present public transport system and on the size of the city (and thus varies from city to city).

Bus and/or tram lanes are used or planned in the larger cities. Light rail systems are being planned in many cities and are already in use in Torino and Oslo. Park and ride facilities are being constructed in the larger cities and off-street parking facilities are being constructed in the smaller cities. Traffic calming infrastructure measures are used in the Austrian cities, Helsinki and Oslo. Construction of cycle routes, lanes and/or paths has been reported for most of the cities.

Management measures
Traffic calming through management measures is used in all other cities except the Italian ones. As an alternative, Torino has regulatory restrictions on car use; such a measure is also being planned for Salerno. On-street parking is being reduced in the British cities and in Helsinki, and there are plans to do likewise in the Norwegian cities.

Bus and tram priorities are used in many cities. Also promoting public transport by management measures such as improved level of service or reliability has been reported for all cities except for Vienna.

Pricing measures
All cities except Salerno are using parking charge levels as a demand management measure. Road pricing is used in Oslo, is planned in the British cities but has been rejected in Tromsø and Helsinki. Using public transport fare levels as a demand management measure has also been reported for most of the cities. Apart from the small cities, Merseyside is the only larger city not to report it.

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[2] Information measures were considered briefly. However, since it is not feasible to model them on the level required by the OPTIMA project, they are not considered further.

Land use measures
Land use measures are reported in less detail. Control of development, development within existing public transport corridors (preferably with track-based infrastructure) and making the city structure more dense are the most common measures reported.

The northern cities intend to retain the inner city as a residential area by improving its living conditions and by decentralisation of business. The tendency for mixed land use is favoured, as is regulatory control in the other areas of the cities, to reduce unnecessary car traffic, such as actions against car-based shopping centres outside densely populated areas.

As explained in Section 5.1.2 above, the transportation models used in OPTIMA were not adequate for representing land use measures. However, there is a parallel project to OPTIMA, involving ITS, in which the OPTIMA transportation model is linked up to a land use model to create a combined land-use- transportation model. This combined model is being used to make a land use sensitivity analysis on the OPTIMA results for Edinburgh, and the results are presented below in Section 5.6.3.

5.3.3 Measures tested in the optimisation process

Based upon the inventory of measures reported above, a set of common measures was selected for use in the optimisation process. Table 5 shows these measures and the maximum ranges considered (some cities used narrower ranges where it was felt that the maximum range was simply infeasible). The criteria for selection of measures were that the measures:

- Were common to all nine case study cities (either already used or planned)
- Could be modelled by all the nine city-specific transportation models
- Were likely to be used or planned in a large number of cities throughout Europe
- Were (or arguably should be) controlled by the city authorities.

Extra measures were introduced into the Merseyside optimisation process (as part of the "Comprehensive Method" to be defined in Section 5.5 below) by distinguishing between long-term and short-term parking charges and between peak and off-peak public transport frequency. The ranges for all these measures were as given in Table 5.

Tables 6 and 7 show the assumed costs used in the calculation of the two objective functions. These costs are based upon currently used costs in the cities for the purposes of cost benefit analysis.

Table 6 shows the assumed capital costs (in each of the nine cities) for road capacity changes, public transport infrastructure, and road pricing. It can be seen that there was wide variation across cities for both public transport infrastructure and road capacity changes. In the case of public transport infrastructure, this is not surprising since the infrastructure measures being considered varied widely between cities; in particular, Vienna and Torino envisaged new underground construction. In the case of road capacity changes, there might have been expected to be some correlation between cost and city size. In the sense that the "small cities" (Eisenstadt, Tromsø and Salerno) all had small costs for road capacity changes, this expectation is borne out. Even here there are differences; Salerno's much lower figure is based on an assumption that it could be achieved by using signal control alone. More generally, there is clearly wide variation amongst the larger cities. Merseyside's estimates were based on a much more thorough assessment, and are likely to be more defensible. Edinburgh took the view, in later consultation, that their costs should have been higher. A sensible way of dealing with this variation is to conduct sensitivity tests of the type which examine the impact on City A’s results if City B’s costs were to be used. Tests of this sort were carried out and are reported in Appendix B of the Report on Work Packages 30 and 40 (OPTIMA, 1997c). The costs of implementing road pricing also vary markedly. In the case of Oslo, road pricing already exists, and there is no additional capital cost. In Tromsø it is assumed that the city's remoteness will enable implementation through an increase in fuel tax. Vienna's particularly high charge is explained by the need to equip 200 charging points inside the city's inner ring.

Table 7 shows the annual operating costs (in each of the nine cities) for public transport frequency changes and road pricing. It can be seen that in some cities (notably Oslo and Helsinki) the cost of increasing public transport frequency (which must be paid out year after year) was high compared with the cost of a one-off increase road capacity.

Abbreviation	Name	Minimum Value	Maximum Value
IH	High public transport infrastructure investment	0	1 (dummy)
IM	Medium public transport infrastructure investment	0	1 (dummy)
CAP	Low cost increase/decrease of road capacity (whole city)*	-20%	+20%
FREQ	Increasing/decreasing public transport frequency (whole city)	-50%	+100%
RP	Road pricing # (city centre)	0	10.0 ecus
PCH	Increasing/decreasing parking charges (city centre)	-100%	+500%
FARE	Increasing/decreasing public transport fares (whole city)	-100%	+100%

Table 1: Measures tested

* Road capacity measures include various types of traffic management and transport telematics, but **do not** include road building

The value of the measure Road Pricing refers to the cost per trip incurred by the car driver

Road capacity changes	Edinburgh	M'side	Vienna	Eisen-stadt	Tromsø	Oslo	Helsinki	Torino	Salerno
-20%	50	176	40	4	12	93	5	137	0.02
-10%	31	88	20	2	6	46	4	69	0.01
-5%	16	44	10	1	3	23	2	34	0
+5%	2	44	53	0.2	6	46	11	28	0
+10%	15	194	106	0.3	12	93	22	48	0
+20%	34	494	*	*	25	185	86	*	*
P.T. infrastructure									
High p.t. infrastructure	564	360	4254	*	*	494	780	3459	45
Medium p.t. infrastructure	35	40	2127	*	*	*	420	671	0.5
Road pricing	2	4	52	3	0	0	4	0.3	0.1

* *indicates "not costed"*

Table 6: Capital costs of new measures (in million ecus)

Change in p.t. frequency	Edinburgh	M'side	Vienna	Eisen-stadt	Tromsø	Oslo	Helsinki	Torino	Salerno
-50%	-16	-69	-162	-1	-6	-170	-130†	-69#	-4
+50%	+16	+69	+163	+1	+6	+168	+130†	+54#	+2
+100%	+32	+139	+326	+2	+12	+340	+228†	*	*
Road pricing	+2	+3	+2	+0.1	+0.4	+9	+0.4	+0.03	+0.01

† *Different values were used when combined with new public transport infrastructure.*

 # The cost of a pt frequency decrease/increase of 30%, where this was the minimum/maximum considered.

Table 7: Operating costs of new measures (in million ecus per annum).

5.4 OVERVIEW OF TRANSPORT MODELS USED

The approach taken by OPTIMA has been to use city-specific transportation models which had already been set up, calibrated and used by the city authorities before the start of OPTIMA. This has allowed the project to make the working assumption that the models used are properly calibrated and, on an appropriate level of aggregation, transferable.

The OPTIMA project has used several different transportation models. Some of them are implemented with commercial software like EMME/2 whilst some are implemented in software packages developed by the OPTIMA partners themselves (before the start of OPTIMA). A full description of the models used is given in Appendix A of the Report on Work Packages 30 and 40 (OPTIMA, 1997c).

Broadly speaking, the models fall into two main categories: strategic and tactical models.

Strategic models are used for running simulations at a very high level of aggregation. The physical transport network is not directly represented and the number of spatial zones is low (typically less than 40). Travel costs are either calculated in terms of “area speed-flow” curves or (at the highest level of aggregation) are fixed inputs for each origin-destination zone pair.

The main advantage of using these models is that they are very fast to run, which can be an important factor if a large number of runs are required. Furthermore, the preparation time for creating the input files is typically short.

The major disadvantage of strategic models for optimisation work (such as in OPTIMA) is simply that, given a particular city, it is unlikely that there will already be a strategic model ready for use.

In OPTIMA, Edinburgh, Merseyside, Vienna and Eisenstadt all used strategic models.

Tactical models are more detailed than strategic models. Typically they represent each (significant) road and public transport link in the network. The output of tactical models is more complex than the output of strategic models. For OPTIMA purposes, there is a need for much aggregation of this output, which can be extremely time-consuming if done manually.

The main advantage of tactical models for optimisation work (such as in OPTIMA) is that they are already used in a large number of European cities to help design and assess various specific transport schemes.

The cities of Tromsø, Oslo, Helsinki, Salerno and Torino all used tactical models.

Because each model was used consistently to produce a series of runs which were compared with one another to find an optimum, there is no difficulty in comparing the optimum generated by a strategic model in one city with that obtained from a tactical model in another city. There were, however, some differences between models which will have affected the comparability of the results.

The most important of these are :-

(i) coverage limited to the peak periods in some models (Vienna, Eisenstadt, Torino, Salerno) while the others modelled both peak and off peak;

(ii) exclusion of walking and cycling from some models (Edinburgh, Torino) while the others allowed for transfer of travel to and from those modes;

(iii) inclusion of the effects of public transport overloading (Edinburgh, Merseyside), while in the other models it was necessary to detect packages in which public transport was overloaded, and make separate adjustments.

5.5 DESCRIPTION OF OPTIMISATION METHODOLOGY

This section describes the optimisation methodology used in the OPTIMA project. Firstly, a simple overview of the approach is given. This is followed by a description of a “Basic Method”, in which an optimum set of policy measures is found with respect to one objective function. Subsequently, this method is extended to a “Comprehensive Method” which allows the possibility to introduce extra objective functions and extra measures to the optimisation process after the process has started.

5.5.1 Overview

Once measures and their ranges have been defined (see Section 5.3), transport model runs are carried out to test an **initial** set of combinations of transport measures (*packages*). The number of packages in this set is the minimum number required to start up the optimisation process. The actual packages are chosen using an orthogonal design so that as many different types of combination of measure as possible are tested (subject to the limit on the overall number of initial runs).

The value of the objective function is calculated for each package, using the results from the relevant transport model run. It must be stressed that some packages are clearly ridiculous in real policy terms whereas others might, by good fortune, lead to good results. The important point of this step is to capture the effect that policy measures have on the objective function rather than to find an optimum.

Using the objective function values for these initial runs, a statistical regression is carried out, which aims to explain the (objective function) results in the form of an equation. The variables in this equation are the values of the measures. This equation has a quadratic form: i.e. it has linear terms and squared terms in it. It must be pointed out that this equation is a simplification: the true transport model results cannot be represented quite so easily (the actual true function representing them would be very complicated). The curve defined by the equation will have a maximum value either within the range of feasible values or else at the minimum or maximum values that have been specified. This maximum value of the curve gives an estimate of what set of transport measures give the highest value of the objective function, i.e. an estimate of the optimum set of measures within the ranges specified.

The transport model is next run to determine the true value of the objective function for this predicted optimum package. The true value is likely to differ significantly from the prediction at this stage, because the prediction is based on only the minimum number of policy runs. To improve on the estimate, the model run for the predicted optimum run, and runs for other packages close to the estimated optimum, are added to the set of model runs.

Then, using the results of the new transport model runs as well as the initial runs, a new regression estimate is made, leading to a new estimated optimum. Further transport models runs are then carried out to calculate the objective function for this new estimated optimum. This procedure (involving transport model runs and statistical regressions) carries on iteratively until the user is convinced that a true optimum has actually been achieved.

In order to focus the optimisation on packages close to the optimum, the objective function was typically weighted in the regression. The nature of the weighting used differed between objective functions, but this will not have affected the comparability of the results.

5.5.2 Basic Method

The basic method is summarised by the flow chart given in Figure 1. For the sake of simplicity, it is assumed in the following description that the objective function being considered is NPV. However, exactly the same procedure is used for other objective functions.

Step 1 concerns the precise definition of the objective function (as summarised in Section 5.2).

Step 2 covers the selection of transport policy measures for the optimisation process as described in Section 5.3.

Step 3 involves making a set of initial transport model runs of various combinations of these measures, selected according to an orthogonal design (so that as wide as possible "space" of transport measures is covered). The minimum number of initial runs, n, can be derived from the following rule of thumb:

$$n = (2 * c) + d + 5$$

where c is the number of "continuous" policy measures and d is the number of "discrete" policy measures. This number of runs will allow a linear regression to be made with both squared and linear terms for continuous measures and dummy variables for discrete measures. Hence in the case of OPTIMA, with five continuous variables and two discrete variables, the minimum number of initial runs is 18. Using the output from the transport model and other output, the NPV is estimated for each run. A standard set of 18 runs, covering the policy space as fully as possible, was conducted in each of the nine cities. It should be stressed that Step 3 was not designed to generate a credible optimum, but simply to start the subsequent iterative process.

Step 4 involves the creation of a regression model to explain the NPV in terms of the policy variables. Since there are five continuous variables and two discrete variables, the 18 runs will only (meaningfully) allow this regression to be made in terms of linear and squared terms: i.e. there is not enough data **at this stage** for cross-product terms (e.g. fare*frequency).

Step 5 uses the regression model from Step 4 to estimate the optimum set of transport policies.

Step 6 runs the transport model with the optimum set of transport policies estimated in Step 5. Other runs are carried out in this step which can be distinguished into two main types:

- packages that are "similar" to the estimated optimal set from Step 5, and which would be expected to yield high NPVs.
- sensitivity tests which can be carried out for two purposes. The first purpose is that they can help establish what is "driving" the optimal set of policies (i.e. which measures are dominating the attainment of high NPVs). The second purpose is that they can help identify if a local maximum has been achieved which is not globally optimal, thus indicating that "another hill must be climbed" in the optimisation process.

Steps 4 to 6 are then repeated iteratively until convergence is achieved. At this stage, cross-product terms are allowed in the regression in Step 4.

To test convergence, the user has the following **three** criteria (one subjective and two objective):

(a) Is the user satisfied that the latest regression model is qualitatively satisfactory? For example, the user might be able to make a suggestion, by observation, for a new optimum based upon the results around the existing optimum.

(b) Is the regression model quantitatively satisfactory? When creating a regression model, there are three conditions that should be satisfied, with the first being the most important:

(i) The standard errors for each variable should be less than half the absolute value of the estimated coefficient (otherwise the regression coefficient for that variable is meaningless).

(ii) The model should predict the highest runs (i.e. those with the highest NPV) better than lower runs.

(iii) Where possible the convexity or concavity of the quadratic function for each variable (i.e. whether they have a maximum or a minimum) should fit prior belief as to whether they would in fact be convex or concave; i.e. the regression should make sense in policy terms.

(c) Compare the "true" NPV for the latest optimal set of policies (as calculated by the transport model) with the "estimated" NPV (as calculated by the latest regression model). The process **has not converged** if [3]

(I) the regression value is more than 10% greater than the true value from the transport model run;

or (ii) the regression estimate is less than the value from the transport model run[4];

or (iii) the NPV from the "optimal" transport model run is less than the NPV from another run already carried out.

Comments on this process:

(i) It is likely that there will be more than one regression model that satisfies the conditions in (b). It is the user's judgement as to how much time to spend finding the best. This judgement must be dependent on how long it takes to run the transport model. For tactical models with long run times it is probably better to spend longer finding the best regression model than when a strategic model is used.

(ii) The number of extra runs to be carried out in Step 6 is inevitably dependent on how long it takes to run the transport model. If a transport model with a long time run is used (i.e. tactical models with large networks), it is probably best to do a regression after each run (since the time taken to do a regression is much less than the time taken to run the transport model).

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[3] These convergence criteria might need to be relaxed in certain cases. For example, it is sometimes difficult for the regression process to represent accurately the effect of a minor measure which contributes only a relatively small amount to the objective function. However, it is still useful for the optimiser to attempt to reach the criteria stated.

[4] If the regression estimate is less than the transport model run, it must generally be assumed that a better regression can be found by adding the "new" information from the latest transport model run. If a subsequent regression can represent this new run accurately, the regression is automatically superior to any other regression obtained before.

(iii) The algorithm outlined here is a standard procedure for finding the maximum of a function where the function can only be calculated by simulation (i.e. there is no explicit analytical form to it), and where it is approximated at successive iterations by quadratic functions. Using available literature on optimisation theory, it should be possible to develop more sophisticated algorithms (for example the last two quadratic approximations could be used to specify new runs as opposed to just the last one). This issue is not so important when a strategic transport model (with a short run time) is being used in the optimisation process. However, it is very relevant if a tactical model is being used.

5.5.3 Comprehensive Method

Two main additions can be made to the process of the Basic Method in order to get the Comprehensive Method. What these additions have in common is that they can be seen as part of an ongoing process: they can be injected into the Basic Method whenever it suits the user.

1. New objective functions can be added. Section 5.2 describes a sustainability objective function (SOF). Furthermore, it describes how other objective functions can be created by taking a weighted average of NPV and SOF. Whenever there is a desire to create an optimal set of policies with respect to a new objective function, the following steps can be inserted in the Basic Method:

Step 4a. Create a regression model to explain the new objective function in terms of the policy variables.

Step 5a. Make other transport model runs based upon the regression model from Step 4a.

The procedure then continues until both NPV and the new objective function are (separately) optimised. It is important to remember that it is probably not necessary to do twice as many runs (after Run 18) for two objective functions (compared to the Basic Method). Runs carried out for optimising sustainability will have useful information for runs carried out to optimise NPV, and vice-versa. This information will be particularly useful where a run yields high values for both objective functions.

2. New continuous variables can be added. It is the user's judgement as to which variables might be added. Typically they will be variables that were either left out of the original set of variables in order to minimise the number of initial runs or variables that merit inclusion as a result of the iteration results. Often they will be variables that are more disaggregated than those used in the original definition of transport measures. For example peak and off-peak public transport fares charges could be introduced (this will only lead to one extra variable since all-day public transport fares can then be dropped). It is the user's judgement when to introduce new variables. Certainly they cannot be introduced before the completion of 24 runs. When new variables are introduced, it should be straightforward to reformulate the results of previous runs in terms of 5+n variables (where n is the number of new variables to be introduced). In the bus fares example, the value of peak PT fare changes is the same as the value of off-peak fare changes for all those runs before the new variables are introduced.

Note on the statistical software packages used:
Three statistical software packages have been used in the OPTIMA project for the calculation of

regression models: SPSS, SAS and GLIM. Tests have been carried out within the project to ensure that they are being used in exactly equivalent ways: i.e. given a set of input data, the resulting regression model is independent of which package is used.

5.6 RESULTS FOR THE NINE CASE STUDY CITIES

5.6.1 Introduction

The full optimisation process, and the intermediate model runs, are described for each city in the working paper on Work Packages 30 and 40 (OPTIMA, 1997c).

Table 8 gives the modal splits (both by trip and by distance travelled) for the modelled do-minimum case in each city. Table 9 gives the set of measures for each city that leads to the best EEF (the *EEF optimum*), whilst Table 10 gives the set of measures leading to the best SOF (the *SOF optimum*).

Section 5.6.2 looks at the results on a city by city basis whilst Section 5.7 makes comparisons across cities. The initial results of the tests of the effects of transport on land use in Edinburgh are reported in Section 5.6.3.

Modal splits	Edinburgh	M'side	Vienna	Eisen-stadt	Tromsø	Oslo	Helsinki	Torino	Salerno
MS (trips)-car	63%	62%	39%	45%	73%	68%	49%	57%	59%
MS(trips)-public transport	37%	15%	34%	3%	11%	22%	30%	43%	14%
MS (trips)-others	n/a	23%	27%	52%	16%	10%	21%	n/a	27%
MS-(distance) car	72%	67%	46%	58%	80%	69%	63%	60%	88%
MS-(distance) public transport	28%	15%	44%	4%	12%	25%	37%	40%	n/a
MS-(distance) others	n/a	18%	10%	39%	8%	6%	n/a	n/a	12%

Table 8: Modal splits in the do-minimum case

Measures	Edinburgh	M'side	Vienna	Eisen-stadt	Tromsø	Oslo	Helsinki	Torino	Salerno
Infrastructure investment high (IH)	No	No	No	*	*	No	No	No	No
Infrastructure investment medium (IM)	Yes	Yes	No	*	*	*	No	No	No
Road capacity (CAP)	+20%#	+5%	+10%#	+10%#	+20%#	+20%#	+20%#	+10%#	+10%#
PT frequency (FREQ)	+85%	*	+100%#	+100%#	-35%	-26%	-30%	0%#	+50%#
Peak PT frequency	*	+60%	*	*	*	*	*	*	*
Off-Peak PT frequency	*	-30%	*	*	*	*	*	*	*
Road pricing (ecus)(RP)	1.6	0#	0#	0#	0#	1,2	0#	0#	1
Parking charges (PCH)	*	*	+226%	+149%	0%	-100%	0%	+500%#	-50%
Long term parking charges (LTP)	~	-100%#	*	*	*	*	*	*	*
Short term parking charges (STP)	*	+30%	*	*	*	*	*	*	*
PT fares (FARE)	-60%	-100%#	+31%	-100%#	-50%	-70%	+25%	-25%	-50%
Modal splits									
MS (trips)-car	52%	59%	35%	41%	72%	67%	52%	50%	56%
MS(trips)-public transport	48%	22%	39%	8%	12%	24%	25%	50%	17%
MS (trips)-others	n/a	19%	27%	51%	16%	9%	22%	n/a	27%
MS-(distance) car	60%	61%	42%	53%	79%	67%	69%	55%	87%
MS-(distance) public transport	40%	24%	49%	9%	12%	28%	31%	45%	n/a
MS-(distance) others	n/a	15%	9%	38%	9%	5%	n/a	n/a	13%
Cost model output									
PVF (million ecus)	+5	-2361	+127	-1	-2	+29	+999	+940	-58
EEF (million ecus)	**+1847**	**+2963**	**+1294**	**+20**	**+37**	**+1230**	**+341**	**+1675**	**+167**
SOF (million ecus)	+266	+352	+444	+2	+17	+227	-1012	+230	+18

** indicates that the measure was not tested*

~ indicates that the value of the measure was irrelevant at the optimum

 # indicates a boundary value of the measure

$ indicates that the value of the measure is uncertain (i.e. widely different values lead to similar NPV values at or near the optimum)

Table 9: Summary table - best EEF

Measures	Edinburgh	M'side	Vienna	Eisen-stadt	Tromsø	Oslo	Helsinki	Torino	Salerno
Infrastructure investment high (IH)	Yes	No	Yes	*	*	Yes	No	Yes	Yes
Infrastructure investment medium (IM)	No	Yes	No	*	*	*	No	No	No
Road capacity (CAP)	+20%#	+20%#	+1%	+10%#	+20%#	+20%#	0%	+10%#	+10%#
PT frequency (FREQ)	+100%#	*	+100%#	+100%#	-28%	-20%	0%	-30%	+50%#
Peak PT frequency	*	+59%	*	*	*	*	*	*	*
Off-Peak PT frequency	*	-42%	*	*	*	*	*	*	*
Road pricing (ecus) (RP)	2.8	0#	0#	0#	2,5	7	0#	0#	2
Parking charges (PCH)	*	*	+250%	+149%	-100%#	-100%#	+92%	+500%#	-100%#
Long term parking charges (LTP)	~	-100%#	*	*	*	*	*	*	*
Short term parking charges (STP)	*	+144%	*	*	*	*	*	*	*
PT fares (FARE)	-100%#	-100%#	+1%	-100%#	-100%#	-100%#	-100%#	-50%	-100%#
Modal splits									
MS (trips)-car	47%	59%	31%	41%	65%	53%	35%	49%	53%
MS(trips)-public transport	53%	22%	46%	8%	17%	37%	46%	51%	22%
MS (trips)-others	n/a	19%	22%	51%	18%	10%	19%	n/a	25%
MS (distance) car	54%	61%	37%	53%	73%	49%	44%	53%	88%
MS (distance) public transport	46%	24%	55%	9%	18%	46%	56%	47%	n/a
MS (distance) others	n/a	15%	8%	38%	9%	5%	n/a	n/a	12%
Cost model output									
PVF (million ecus)	-1230	-2604	-7077	-1	-17	+1874	-2815	-4169	-176
EEF (million ecus)	+1012	+2722	-2100	+20	+16	-2146	-915	-1958	+132
SOF (million ecus)	**+295**	**+407**	**+745**	**+2**	**+20**	**+526**	**+240**	**+270**	**+23**

** indicates that the measure was not tested*
~ indicates that the value of the measure was irrelevant at the optimum
 # indicates a boundary value for the measure

Table 10: Summary table - best SOF

5.6.2 Results for the individual cities

5.6.2.1 General comments

In this section the results for individual cities are reviewed. For each city the commentary considers in turn:

- the measures included in the EEF optimum;
- the measures included in the SOF optimum;
- the difference between these;
- the impacts of both on modal split;
- the differences between the EEFs;
- the differences between the SOFs;

- the differences between the PVFs.

Most of the results reported here are concerned with the EEF and SOF optima before they were reported to the cities as part of Work Package 50. However, as a result of the discussions with city representatives, a number of sensitivity tests were suggested. The results of these are reported below in cases where they are felt to be particularly significant.

5.6.2.2 Edinburgh

The EEF optimum involves medium infrastructure; the maximum increase (20%) in road capacity; an 85% increase in frequency; a road pricing charge of 1.6 ecu; and a 60% reduction in fares. Broadly these appear to be justifiable, and are reasonably consistent with previous policy recommendations. However, the question arises as to how far the maximum increase in road capacity is dependent upon the relatively low cost assumed for it. Sensitivity tests showed that the optimal change in road capacity only became less than +20% when the costs were multiplied by a factor of ten (which, from Table 5, would make the Edinburgh costs approximately the same as the Merseyside costs). Long stay parking charges were irrelevant, because parking activity was reduced to a minimum by road pricing and public transport improvements. Sensitivity tests showed that EEF could be increased from the EEF optimum by increasing short term parking charges, with the maximum increase in EEF arising from a maximum increase in charges of 500%.

The SOF optimum is similar, but with the high level of infrastructure investment; a 100% increase in frequency; a road pricing charge of 2.8 ecu and free fares. Long term parking charges are again irrelevant. Again these seem broadly reasonable. The main difference between the two optima is that that for SOF involves greater financial outlay. This is common to many of the cities studied, and can be explained by the exclusion from SOF of costs in other than the horizon year.

The EEF optimum reduces the car modal share from 63% to 52%, and the SOF optimum reduces it slightly further to 47%. Similar reductions, but from a higher base, occur in car-km. Since the Edinburgh model does not consider non-motorised modes, all of these transfer to public transport. These reductions appear consistent with the strategies implemented.

The optimum EEF is the second highest among the nine cities. The EEF for the SOF optimum is some 40% lower than this optimum, which can be explained by the high costs of the additional measures. However, this does demonstrate that there is a conflict between the two objective functions. The SOF for the EEF optimum is, however, only around 10% below the optimum, suggesting greater flexibility in the specification of the SOF strategy. The PVF for the EEF optimum is virtually zero, indicating that it is possible in Edinburgh to design an efficient strategy which is revenue neutral. Again, this confirms earlier strategy results for the city. The PVF for the SOF optimum is substantially negative, indicating the high financial cost of achieving optimal sustainability, mainly the high cost of light rail and free fares.

5.6.2.3 Merseyside

The EEF optimal strategy for Merseyside again involves medium infrastructure, this time together with a 5% increase in road capacity; a 60% increase in peak frequency and a 30% reduction off peak; free long term parking and a 30% increase for short term; and zero fares.

These results are less immediately plausible. The increase in peak frequency and reduction off peak can be explained by the higher benefits of inducing modal change and higher loading levels in the peak; but it should be noted that the costs of additional peak provision will in practice be higher. The reduction in long stay parking charges and the increase for short stay can possibly be explained if the remaining long stay parkers are seen as captive, while those parking for shorter periods can be induced to change mode or destination. A policy of charging less for long stay parking than for short stay would clearly need to be well-designed, and would probably involve issuing long-stay permits at the workplace. This measure would be particularly attractive if joined together with a car-pooling measure: i.e. providing free long-term parking to registered car-poolers.

The SOF optimum differs in increasing the road capacity by the maximum of 20%; reducing the off peak frequency further (by 42%); and increasing the short stay parking charges further (by 144%). This does not show as much emphasis on high cost measures as in Edinburgh. The further reduction in off-peak frequency for SOF (compared to EEF) is explained by the extra emphasis of SOF upon fuel consumption: the reduction in fuel consumption through decreasing bus frequency outweighs the increase in fuel consumption due to bus users switching to cars in response to decreased frequency.

The EEF and SOF optima have identical impacts on modal split, with the percentage using cars falling from 62% to 59% and the percentage of journey length by car falling from 67% to 61%. These reductions are relatively small, and in part reflect the low level of congestion currently in Merseyside. However, they result in a 50% increase in public transport use, primarily induced by the zero fares.

The optimum EEF, at 2963 Mecu, is the highest of all nine cities. This is consistent with Merseyside's position as the most populous city, but is still surprising given the low level of congestion currently experienced. The EEF for the SOF optimum is within 10% of this optimum, while the SOF for the EEF optimum is around 15% below the optimum. These results suggest that there is little difference in practice between the two objective functions in this case. Both PVFs are very negative, with that for the EEF optimum by far the lowest of the nine cities; both PVFs are almost certainly untenable in political/financial terms. It is important to note, however, that the high PVF for the EEF optimum is fully justified if the shadow price of finance used (see Section 5.2) is considered appropriate. Sensitivity tests showed that high EEFs could be still be obtained with dramatically improved PVFs by having a smaller reduction than 100% in fares. For example, if the reduction in fares was only 50% (with other measures the same as at the EEF optimum), an EEF of 2329 Mecus would be obtained with a PVF of -858 Mecus. Furthermore, a reduction in both fares and long term parking charges of only 30% (again with other measures at the EEF optimum) led to an EEF of 1465 Mecus with a PVF of only -281 Mecus.

5.6.2.4 Vienna

The EEF optimum for Vienna involved the maximum (10%) increase in road capacity; a 100% increase in frequency; a 226% increase in parking charges; and a 31% increase in fares. This seems broadly plausible, with parallel increases in both capacity and cost for public and private transport. Sensitivity tests showed that: if there were no fare increases, the EEF would fall by approximately 30% to 914 Mecus; and that if there were no increase in parking charges, the EEF would fall by approximately 65%.

The SOF optimum differs by introducing the high level of infrastructure investment; reducing the road capacity to virtually current levels; slightly increasing the parking charge; and reverting to approximately do minimum fare levels. Once again, the higher level of investment is explained by the concentration in SOF on future costs and benefits. The justification for reducing the road capacity is slightly less obvious, although it will limit the growth in fuel consumption, as will avoiding the fares increase.

The EEF optimum reduces the proportion of trips by car from 39% to 35%, and the SOF optimum reduces them further to 31%; in the former case all trips transfer to public transport, while in the latter public transport also attracts some travel from other modes. Broadly similar changes occur for the shares of trip-km. These changes are consistent with the policy changes introduced.

While the optimum EEF is the fourth highest among the cities, the EEF for the SOF optimum is strongly negative, largely because of the high costs of increasing public transport frequency. Conversely, the SOF for the EEF optimum is around 40% lower than the optimum; while this difference is still substantial, it suggests that SOF is less sensitive to policy specification than EEF around the optimum. The PVF for the EEF optimum is slightly positive, despite the high costs of increasing public transport frequency. However, the PVF for the SOF optimum is by far the most negative of all nine cities. This can be explained by the combination of the high costs of the high level of infrastructure investment, the maximum frequency increases (including the new public transport infrastructure) and the removal of the fares increase. A sensitivity test showed that if the frequency were to be decreased by 10%, the PVF would be at a much more acceptable level of -393 Mecus. However, the SOF would be reduced from 745 to 143 Mecus and the NPV from -2100 to -3596 Mecus.

5.6.2.5 Eisenstadt

The EEF optimum and the SOF optimum for Eisenstadt are identical, involving a maximum (10%) increase in road capacity; a 100% increase in frequency; an increase of 149% in parking charges and a reduction of 100% in fares. This strategy appears sensible; public transport is being substantially improved, albeit from a very low base, while the costs of car use are being substantially increased.

The combined optimum reduces the percentage of trips by car from 45% to 41%, and more than doubles the increase in the public transport share from 3% to 8%.

The combined optimum has a slightly negative PVF of -1 Mecu. Values of EEF, SOF and PVF are all small, given the small scale of the city.

5.6.2.6 Tromsø

The EEF optimum for Tromsø includes the maximum (20%) increase in road capacity; a 35% decrease in frequency; no change in parking charges; no road pricing; and a 50% fares reduction. The main focus is thus on using reduced fares to attract car users, and a reduced frequency to reduce resource costs. At first sight these appear incompatible but further checks have demonstrated that the public transport system is currently operating with excess capacity in the off-peak. A sensitivity test has shown that if frequency were to be reduced by a maximum 50% in the off-peak but increased by 10% in the peak, EEF would increase by 25%.

The SOF optimum involves a maximum road capacity increase; a decrease in frequency of 28%; a 100% reduction in both fares and parking charges; and a road pricing charge of 2.5 ecus. The main differences from the EEF optimum are an increase in the attractiveness of public transport and replacement of parking charges by road pricing. The first of these will be at the expense of an increase in financial costs. The second should increase the effectiveness of the strategy in reducing fuel consumption.

The EEF optimum generates a very slight reduction in the car share of all trips from 73% to 72%, whilst the SOF optimum induces a reduction to 65%. Virtually all of the transfer for the SOF optimum is to public transport; Tromsø is not well suited to encouraging an increase in walking and cycling. The effects on the car share of trip-km are similar.

The EEF optimum is 37 Mecus, and the EEF for the SOF optimum is 16 Mecus. The SOF optimum is 23 Mecus, and the SOF for the EEF optimum is 17 Mecus. This suggests that SOF is somewhat less sensitive to policy specification than EEF around the optimum.

The PVF is 17 Mecus for the EEF optimum, and -2 Mecus for the SOF optimum. This confirms that the EEF optimum is achieving greater economic efficiency primarily by reducing provision of public transport, while the SOF optimum is achieved at the expense of a small increase in financial outlay.

5.6.2.7 Oslo

The Oslo EEF optimum includes the maximum (20%) increase in road capacity; a 100% reduction in parking charges; a reduction of 26% in frequency; a road pricing charge of 1.2 ecus; and a decrease of 70% in fares. As in Tromsø, the reduction in both public transport frequency and fares seems surprising, but checks have shown that most of this can be achieved by reducing frequency in outer areas where crowding is not affected. A sensitivity test has shown that if peak frequency were to be decreased by only 20% but off-peak frequency were to be decreased by 31%, there would be a 5% improvement in EEF. Sensitivity tests have considered separate levels of change for bus and rail, reflecting the much higher costs of frequency increases for rail. These suggest that, with the other measures fixed, the best frequency change for bus would be -15%. The EEF optimum for Oslo also involves replacing parking charges by a road pricing charge, indicating that this is a slightly more effective way of reducing congestion costs.

The SOF optimum has high public transport infrastructure investment, a public transport frequency reduction of 20%, zero fares, a road pricing charge of 7 ecus and, as in the EEF optimum, a 20% increase in road capacity and zero parking charges. The main differences from the EEF optimum are the much increased road pricing charge, designed to reduce car use and hence fuel consumption, and the improvements to public transport. Checks indicated that this strategy may in practice not be feasible, since the public transport would be over capacity. Sensitivity tests indicated that, with bus and rail optimised separately, the best frequency change for bus was +25%.

The EEF optimum reduces car use slightly, from 68% to 67% of all trips, and slightly increases the public transport share from 22% to 24%. The SOF optimum has a strong impact on car use, which falls to 53% of all trips, while public transport use increases to 38%. These differences from the EEF optimum reflect the major differences in overall strategy.

The optimum EEF is 1230 Mecus, while the EEF for the SOF optimum is strongly negative, reflecting the high costs of infrastructure and restraint of car use to below the economic optimum. The optimum SOF is 526 Mecus, while the SOF for the EEF optimum is 227 Mecus, suggesting once again that SOF is less sensitive to policy specification. PVF for the EEF optimum is slightly positive, at 29 Mecus, while that for the SOF optimum is much higher, at 1874 Mecus. This result is in marked contrast to the PVFs for other cities' SOF optima. It appears that the high road pricing charge is more than sufficient to cover the financial costs of the strategy.

5.6.2.8 Helsinki

The EEF optimum for Helsinki includes the largest (20%) increase in road capacity; a reduction of 30% in frequency; no change in parking charges and a 25% increase in fares. This somewhat surprising result is explained by the current high level of public transport provision and one of the highest percentage subsidies of the case study cities. The fare income decrease due to lost passengers is compensated by an increase in fares. The travel speed of the increased number of cars is ensured by adding road capacity in the central areas. In other words, it is argued, resources can be saved by streamlining the public transport service.

The SOF optimum has no change in road capacity or frequency from the do-minimum; a 92% increase in parking charges; and introduces zero fares. This strategy is in marked contrast to the EEF optimum, since it removes the road improvements, reverses the public transport reductions and substantially increases the costs of car use in the city centre. Sensitivity tests indicated that zero fares were the key element in any SOF strategy, and that the effects of parking charges, road pricing and infrastructure were to some extent interchangeable.

The EEF optimum increases the car mode share, from 49% to 52%, and also increases non motorised travel, both at the expense of public transport. With the SOF optimum, however, car use falls dramatically, to 35% of trips. These results are consistent with the marked differences in strategy.

The EEF for the SOF optimum is negative, emphasising the marked difference between the requirements of the two objectives. The SOF value for the EEF optimum includes the hard penalty for an increase in fuel consumption, which is to be expected given the increase in car use. This again reinforces the difference between the two strategies. The PVF for the EEF optimum is strongly positive, which can be explained by the reduction in the current high level of expenditure on public transport. The removal of fares inevitably imposes a large negative PVF on the SOF optimum.

5.6.2.9 Torino

The EEF optimum for Torino involves the highest (10%) increase in road capacity; no change in frequency; no road pricing; the highest (500%) increase in parking charges; and a 25% reduction in fares. This strategy aims to encourage a transfer from car to public transport to reduce congestion. It is perhaps surprising that the optimum did not include an increase in public transport frequency, but the costs of such increases are high.

The SOF optimum also includes the highest increase in road capacity, the highest increase in parking charges and no road pricing. However, it also includes a reduction in frequency of 30%, high public transport infrastructure and a reduction in fares of 50%. The main differences from the EEF optimum are in the construction of the underground rail network, which permits a reduction in frequency on the existing service, and a further fares reduction. This strategy is explained by the lack of capital costs in the SOF optimisation.

The maximum increase in parking charges and the reduction in fares in the EEF optimum have, together, reduced the car mode share from 57% to 50% of trips, and from 60% to 55% of trip-km. Since non-motorised modes are not modelled, all of these reductions are reflected in increases in public transport use. In spite of the decrease in frequency, the further reduction in fares and high public transport infrastructure in the SOF optimum reduce the car mode share marginally further to 49% of trips and 53% of trip-kms.

The EEF at the EEF optimum is the third highest, at 1675 Mecu; this is justifiable, since Torino is the second largest city tested. The SOF at the EEF optimum is, at 230 Mecu, approximately 20% less than the SOF for the SOF optimum (270 Mecu), suggesting that SOF is not very sensitive to policy specifications where these are relatively near the optimum. However, the EEF at the SOF optimum is, at -1958 Mecu, the second worst EEF for a SOF optimum. This is explained by the very high costs of providing the underground system (3459 Mecus). This is reflected also in the differences in PVF. That for the EEF optimum is +940 Mecus, primarily because of the substantial increase in parking revenues. That for the SOF optimum is -4169 Mecus, reflecting the high cost of the underground system and the further loss of fares revenue.

5.6.2.10 Salerno

The EEF optimum for Salerno involves the maximum (10%) increase in road capacity; a maximum (50%) increase in frequency; a road pricing charge of 1 ecu; a reduction of 50% in parking charges; and a reduction of 50% in fares. All of these are consistent with an overall strategy of diverting travel from car to public transport. Sensitivity tests indicated that the parking charge and road pricing measures are largely interchangeable, since there is little through traffic in Salerno. A virtually identical EEF was obtained using a 75% increase in parking charge and zero road pricing.

The SOF optimum also includes maximum increases in road capacity and public transport frequency, as well as high infrastructure investment; a road pricing charge doubled to 2 ecu; removal of parking charges and zero fares. Again, road pricing and parking charges were interchangeable. These changes are consistent with the lack of initial investment costs in SOF, and with the need to induce an additional shift to public transport in order to reduce fuel consumption.

The EEF optimum produces only a small reduction in car use, from 59% to 58% of all trips, with the transfer being to non-motorised travel. This suggests that the effects of road pricing and parking charge reductions are roughly in balance. The SOF optimum reduces car use to 53% and also reduces non-motorised travel from 27% to 25% of trips. This is consistent with the strong emphasis on public transport in the SOF optimum.

The EEF for the SOF optimum is around 20% lower than the optimum, while the SOF for the EEF optimum is around 25% lower than its optimum. Both of these suggest a relatively small trade-off between the two objective functions, even though the strategies are quite different in their emphasis. The PVF for the EEF optimum is slightly negative, suggesting that the change in revenue from car users is not quite sufficient to finance the capacity and frequency increases. The PVF for the SOF optimum is much more markedly negative, as a result of the removal of fares and parking charges, and the costs of new infrastructure, partly offset by the doubling of the road pricing charge.

5.6.3 Land use effects in Edinburgh

Within the overall task of determining methods to help switch traffic to public transport, the objectives of OPTIMA intended that these methods should include land use as well as transport policy instruments. Due to the capabilities of the strategic models, it proved not to be possible to address the land use issue across the nine cities. However, for the city of Edinburgh, a separate study has been carried out, the objectives of which were:

(i) to increase understanding of the impact of accessibility and environmental quality on individuals' and firms' location decisions;
(ii) to use the findings of (i) to enhance a newly developed strategic transport and land use interaction model;
(iii) to use the enhanced model to assess the implications for urban sustainability of the impact of transport policy on location choice;
(iv) to use the enhanced model to assess the relative performance of different combinations of transport and land use strategy.

Literature reviews and interviews as part of the study demonstrated that the impact of transport on land use is perceived as a serious gap in policy understanding. Interviews also revealed that land use-transport models are treated with some scepticism, because there is insufficient understanding of such relationships within them and insufficient familiarity with existing models.

As a result of this lack of understanding, there is a danger that impacts of transport on land use might have counter-productive effects on the land use - transport strategy. For example, road pricing which, as has been shown in OPTIMA and elsewhere, may be a key element in a sustainable transport strategy, may reduce accessibility by private car, and hence lead to outmigration of business, thus producing a less sustainable land use pattern. Conversely it could enhance the city centre environment, and hence encourage certain firms to relocate to the centre. These twin impacts of transport policy on accessibility and on environmental quality are the key elements in predicting the resulting location decisions of individuals and firms, and need to be better understood if sustainable land use - transport strategies are to be developed.

This section reports the key elements of the Edinburgh study, as reported in Bristow *et al* (1997). It should be noted that Bristow *et al* is concerned with the initial tests on the land use impact of a range of transport measures for Edinburgh, based on initial runs of the START-DELTA model which was developed in response to objective (ii) above.

The land use analysis was based on a locational sub-model in which the change in the utility of location is defined in terms of a series of variables including accessibility and of transport-related environmental quality.

Seven basic transport strategies were tested with three levels of location response to accessibility and environmental indicators. The seven strategies were based upon: -

- do-minimum (described below);
- do-minimum plus Light Rapid Transit (LRT), (the OPTIMA high-infrastructure option) involving two lines North-South and East-West with a high frequency of 12 trains per hour;
- do-minimum plus two way road pricing cordon around the city centre (as in OPTIMA) with a charge of £1.50 per crossing in either direction;
- do-minimum plus a reduction in bus fares of 50%;
- do-minimum plus LRT and road pricing as above;
- do-minimum plus bus fare reduction and road pricing;
- do-minimum plus LRT, bus fare reduction and road pricing.

The do-minimum strategy, which was the same as in OPTIMA, had the following features: SCOOT traffic control, M8 extension, increases in city centre parking charges, switch from private to more public parking spaces, greenways on major radials (corridors with significant bus priority and traffic calming), fare inflation of 1.29 over 20 years, and earnings index 1.8 over 20 years.

The most striking result of the Edinburgh study in terms of strategies was the response to LRT strategies. The very high frequency LRT system as modelled in the study provided better alternatives to bus and some car routes for a majority of OD pairings within the Edinburgh area; it also provides limited park and ride facilities for some of the outer zones. The response to this increased accessibility was to centralise the population within the centre of Edinburgh where the changes in accessibility were greatest. This resulted in higher city centre rents and as a result of this the larger households, who are more sensitive to changes in accessibility, tended to dominate the city centre. This resulted in total trips increasing with LRT strategies; though it was not clear whether this increase in trips was a trips rate issue (with more people in the high trip rate zones) or whether it was related to the LRT system itself reducing generalised costs and thus allowing more trips to take place.

Conclusions

The overall conclusions resulting from the study were:

(i) At the response levels tested, the impacts of land use response were small in terms of trips, car trips and hence fuel consumption.

(ii) However, the impacts on location were significant, particularly for strategies involving LRT. The impact was less on jobs than on population.

(iii) Similarly the impacts on choice of public transport mode with response to accessibility included were substantial, with marked differences between those with and without LRT as an element.

(iv) At the levels tested the accessibility impacts on trip patterns were greater than the environmental ones, but the latter were also important, and for LRT strategies act in the opposite direction.

(v) In terms of response to the environment, only road pricing could improve the city centre environment significantly and so cause in-migration; however, when the responses are combined this is outweighed by the decentralising effect of the response to reduced accessibility.

5.7 COMPARISONS OF OPTIMAL STRATEGIES ACROSS CITIES

This section is concerned with comparing the cities in terms of their EEF and SOF optimal strategies as determined by the modelling process in Work Packages 30 and 40. It is not concerned with feasibility or acceptability which are dealt with in Sections 5.8 and 5.9.

5.7.1 Public transport infrastructure investment

No city had high public transport infrastructure investment in its EEF optimum, although medium infrastructure investment was included in the EEF optima of Edinburgh and Merseyside. The problem here for comparison is that the definition of "large" and "medium" public transport infrastructure is extremely city-dependent. Table 6 shows the cost of high and medium public transport infrastructure for all cities where it was tested, and it can be seen that there is a wide variation in costs. This variation is largely explained by the different nature of infrastructure measures. The problem of lack of comparability of public transport infrastructure, which also applies to road infrastructure investment, has been acknowledged since the start of the OPTIMA project, and explains why a majority of the measures being tested are "continuous" (which are by nature more comparable across cities).

With regard to SOF optima, five cities (Edinburgh, Vienna, Oslo, Torino and Salerno) had high infrastructure in their optimal sets of measures. Helsinki included high infrastructure in several close to optimal strategies. Given that the Merseyside SOF optimum included medium infrastructure and that neither Eisenstadt nor Tromsø tested any form of public transport infrastructure, it follows that public transport infrastructure is generally a key element of the SOF optimum. The difference here, compared to the EEF optima case above, can be explained by the fact that present day investment costs play no role in the SOF so that, in general, SOF would be more likely than EEF to favour infrastructure measures.

5.7.2 Road capacity changes

Eight of the nine cities included the maximum increase in road capacity in their EEF optima, while Merseyside had a marginal increase. The position for the SOF optima was similar, although Helsinki rejected the measure, Vienna substantially reduced it, and Merseyside increased its use. The different approach in Merseyside can be explained by the much higher cost of the measure, and the lower level of congestion in the do-minimum. The other cities assumed a low cost for these changes (Table 6), which will not allow for remedying any negative side effects of such changes. This increase in road capacity is at first sight somewhat counter-intuitive. However, it should be stressed that it provides a relatively low cost way of improving efficiency, while other measures in the strategy can be used to control car use. Possible impacts on cyclists or pedestrians may need to be examined.

5.7.3 Public transport frequency

The changes in public transport frequency in the EEF optima are extremely variable across cities. The Vienna, Eisenstadt and Salerno optima contain maximum frequency increases (100%, 100% and 50% respectively) and the Edinburgh EEF optimum contains a near-maximum increase (85%). On the other hand, the Helsinki, Oslo and Tromsø EEF optima all include a frequency reduction of around 30%. One explanation for the mixed results can be found by looking at the Merseyside results where there are clearly different results for peak and off-peak frequency. If this result were common to all cities, the aggregate frequency changes would be heavily dependent on the already-existing allocation of resources between peak and off-peak. Sensitivity tests in Oslo have confirmed this.

The public transport frequency changes in the SOF optima were the same as in the EEF optima for three cities (Vienna, Eisenstadt and Salerno). The frequency increases for the Edinburgh, Oslo and Tromsø SOF optima were approximately the same as for the EEF optima (within 15% of each other), although in all three cases the frequency was higher in the SOF optimum than in the EEF optimum. In Merseyside the peak frequency change in the SOF optimum was approximately the same as in the EEF optimum, whilst the off-peak frequency change in the SOF optimum was slightly more negative than in the EEF optimum (-42% compared to -30%). Helsinki and Torino showed the greatest change, with Helsinki reversing the capacity reduction in its EEF optimum, and Torino introducing one: the latter is explained by the replacement by high infrastructure provision.

Generally the policy on public transport frequency appears to be highly sensitive to the current level of provision, with those cities with the highest percentage subsidies most likely to have a reduction in frequency recommended.

5.7.4 Road pricing

Only three cities, Edinburgh, Oslo and Salerno, had a road-pricing charge in the EEF optima. All these charges were relatively modest (1.6, 1.2 and 1.0 ecu respectively). In the SOF optima, four cities (the above three plus Tromsø) had road pricing charges, all of which were at a higher level than for the EEF optima. The increase in Oslo, from 1.2 to 7.0 ecus, was particularly marked, and helps explain the substantially positive PVF and negative EEF of this strategy. Generally it appears, as noted below, that road pricing and parking charges are broadly interchangeable in their effects.

5.7.5 Parking charges

For the EEF optima, three cities (Vienna, Eisenstadt and Torino) had increases in parking charges of over 100%. On the other hand, the EEF optimum of Oslo had free parking; that of Salerno had a 50% decrease in charges; whilst the EEF optimum of Merseyside had free long-term parking but an increase of 30% in short-term parking. Moreover, the EEF optimum for Edinburgh was insensitive to parking charges because of the impact of road pricing. In all cases except Merseyside, low parking charges were consistent with the introduction of road pricing.

In the case of SOF optima, the results are even more polarised than in the EEF optimum case. The three cities with the largest increases in parking charges for EEF optima (Vienna, Eisenstadt and Torino) had approximately the same increases in the SOF optima. On the other hand, the SOF optima in three cities (Tromsø, Oslo and Salerno) had 100% reductions in parking charges. Helsinki introduced a 92% increase, while in Edinburgh the SOF optimum was again insensitive to parking charges. Finally, the SOF optimum of Merseyside (where long-term and short-term parking charges were considered separately) had a 100% decrease in long-term parking charges and a 144% increase in short-term parking charges.

The likely conclusion from these results is that the optimum level of parking charges is highly dependent on synergies with other measures. It is significant that in the EEF optima, six cities (Vienna, Eisenstadt, Oslo, Torino, Edinburgh and Salerno) had either large parking charge increases (more than 100%) or road pricing, but that none of them had both. This result would confirm the intuitive expectation that the two measures would be roughly equivalent, since they both concentrate on restricting traffic into the city centre (however, road pricing clearly affects through-traffic in the city centre whilst parking charges do not). In the case of the SOF optima, all cities either had large parking charge increases (over 90%) or road pricing.

5.7.6 Public transport fares

There was wide variation between cities on the public transport fares policies in the EEF optima, although there was more emphasis upon fares reduction rather than fares increase. The Merseyside and Eisenstadt EEF optima had free fares, whilst in Edinburgh, Tromsø, Oslo and Salerno there were also substantial decreases in fare of at least 50%. On the other hand, Vienna and Helsinki had increases in fare. The result from Vienna is partly explained by the increase in frequency and the overall emphasis on increased cost. That for Helsinki appears to be due to current high levels of subsidy.

On the other hand, seven cities (all except Vienna and Torino) had free public transport fares in their SOF optima, while Torino had a reduction of 50% and Vienna only had a tiny increase of 1%. Whilst free or reduced public transport fares are likely to have contributed significantly to the high negative PVFs of SOF optima in Merseyside, Edinburgh, Helsinki, Torino and Salerno, one city (Oslo) was able to achieve a highly positive PVF with a package including free public transport fares. Furthermore, it is ironic that the city with the highest negative PVF for a SOF optimum (Vienna with a PVF value of -7077 Mecus) was the only city to increase public transport fares.

It is interesting to note that three cities (Tromsø, Oslo and Salerno) all had “free public transport and free parking” policies in the SOF optima, whilst Merseyside had a “free public transport and free long-term parking” policy.

5.8 THE CONSULTATION PROCESS

The city authorities of each city were consulted as the work progressed in order to ensure co-operation and to gather their suggestions and opinions, which were then taken into account during the study.

The process began with a meeting with the city authorities in which the purpose of the OPTIMA project was explained and the methodology described. At this meeting the cities were asked to indicate whether they were interested in such a project and also if they were willing to co-operate by providing suggestions, ideas and opinions during the different phases of the study.

In general the responses were all positive: all the cities showed interest and curiosity and agreed that the project could be useful to identify optimal urban transport strategies, to assess the acceptability and feasibility of implementation of these strategies and to provide more general guidance on urban transport policy. This initial discussion in some cases was also useful to define the ranges of each policy measure to be tested in the optimisations.

When intermediate optimisation results became available, new meetings were planned in order to establish the opinion of the city authorities and to incorporate their suggestions in the continuing work. On this occasion the cities provided some indication of new combinations of the different measures which could be tested, based on the results obtained so far. This also included in some case tests on single measures (sensitivity tests) as well as tests on strategies preferred by the cities, where these differed significantly from the optimisation results.

At the end of the project a questionnaire was given to the city authorities in order to enable them to summarise their comments on the whole project and its final results. The questionnaire consisted of a series of open questions to which it was also possible to give a numerical score that represented the level of agreement or satisfaction with the item referred to in the question. The questions are summarised in Table 11. The completed questionnaires made it possible to analyse the feasibility and acceptability of the optimum strategies and any barriers to their implementation. Final comments on the each city’s strategy could thus also take into account the opinions expressed by the city itself.

The complete version of every questionnaire can be examined in the WP50 report of the corresponding city (OPTIMA, 1997d). A summarised version of the results of all the questionnaires is shown in Table 12.

QUESTION	**DESCRIPTION**	**RESULT/SCORE** (0=not at all, 5=yes)
1	Interest in the set of measures that were tested	0-5
2	Before knowing the final result was an optimum EEF strategy forecast?	yes/no
3	Before knowing the final result was an optimum SOF strategy forecast?	yes/no
4	Is the selected EEF optimum sensible?	0-5
4.1	Is it feasible?	0-5
4.2	Is it publicly acceptable?	0-5
4.3	Is it politically acceptable?	0-5
4.4	Are there any barriers to its implementation?	0-5
4.5	Can these barriers be overcome?	0-5
5	Is the selected SOF optimum sensible?	0-5
5.1	Is it feasible?	0-5
5.2	Is it publicly acceptable?	0-5
5.3	Is it politically acceptable?	0-5
5.4	Are there any barriers to its implementation?	0-5
5.5	Can these barriers be overcome?	0-5
6	Does the concentration on sustainability explain the difference between the EEF and SOF optima?	0-5
7	Was another new more acceptable or feasible strategy suggested?	yes/no
8	Degree of satisfaction with the methodology used to analyse and select the strategies	0-5
9	Degree of satisfaction with the criteria used to analyse costs and benefits of strategies	0-5
10	Are the data presented the ones you would like to know for choosing a strategy?	0-5
11	Degree of satisfaction with the whole method	0-5
12	Additional requirements or suggestions to improve the method	(specify)
13	Other specific suggestions	(specify)

Table 11 The questionnaire for the cities

	EDINBURGH	EISENSTADT	HELSINKI	MERSEYSIDE	OSLO	SALERNO	TORINO	TROMSØ	WIEN		
Answer (1=yes 0=no)										total	average
1. Interest in measures	5	5	4	5	4	5	4	4	2	39	4.3
2. NPV optimum forecast?	yes	yes	yes	yes	yes	yes	yes	yes	yes		
3. SOF optimum forecast?	yes	yes	yes	yes	yes	yes	yes	yes	yes		
4. NPV optimum	4	1	1.5	0	3	5	3	1	1	20	2.2
4.1 feasible?	4	4	1	0	1	4	0	4	1	19	2.1
4.2 publicly acceptable?	4	4	1	2	0	4	0	2	3	20	2.2
4.3 politically acceptable?	3	4	1.5	2	1	3	0	4	3	22	2.4
4.4 barriers?	2	3	1	0	2	3	0	3	1	15	1.7
4.5 possible to overcome barriers?	3	5	5	0	3	4	0	3	1	24	2.7
5. SOF optimum	5	0	3	0	2	4	3	2	1	20	2.2
5.1 feasible?	4	4	2	0	3	1	0	2	1	17	1.9
5.2 publicly acceptable?	5	4	2.5	2	0	5	0	2	5	26	2.8
5.3 politically acceptable?	2	4	2	2	0	1	0	2	4	17	1.9
5.4 barriers?	1	2	2	0	3	1	0	2	3	14	1.6
5.5 possible to overcome barriers?	1	0	2	0	2	2	0	4	3	14	1.6
6. sustain. explain different strategies?	5		4.5	3	3	5	3	3		27	3.8
7. another strategy suggested?	no	yes	yes	yes	yes	no	yes	yes	no		
7.1 feasible?		5	3.5	4	4		5	4			4.3
7.2 publicly acceptable?		5	4	4	2		5	4			4.0
7.3 politically acceptable?		4	4	4	2		5	4			3.8
7.4 barriers?		5	2.5	3	1		1	3			2.6
7.5 possible to overcome barriers?		3	3	4	4		5	3			3.7
8. methodology and strategies?	4	3	3	3	3	5	1	1	0	23	2.6
9. cost-benefit criteria?	4	0	2.5	5	4	4	2	1	0	23	2.5
10. used data?	3	3	2.5	4	3	4	3	3	1	27	2.9
11. satisfaction with method?	4	3	3	4	3	4	2	1	1	25	2.8
12. Cities suggestions for method improvement	see text										
13. Other specific suggested by cities	see text										

Table 12: Results of city consultations

All the city authorities considered the set of measures in the OPTIMA project to be of great interest. Naturally, some also showed interest in other measures unique to their own situation (for example, changes in fuel tax) which were not covered in the optimisations. Opinions on the methodology were also generally good. All the cities agreed that the final results represented the optimum strategies from the economic and sustainability point of view, though in many cases the optima did not conform to their own ‘best strategies’. It was considered that the difference between the optima and cities’ own best strategies were due to the city objectives not being fully represented in the specification of the objective functions. The comments from the cities on the method and on the results form an important input to the development of Europe-wide application of the OPTIMA results and methods.

The results of the consultations on the feasibility and acceptability of the optima are reported in Section 5.9 and comments on the method in Section 5.10.

5.9 FEASIBILITY AND ACCEPTABILITY

5.9.1 General

Once the optimum strategies had been identified, they were analysed and discussed, both among the project partners and with the respective city authorities. This was done in terms of feasibility (financial, practical or legislative) and of acceptability (to the public and to politicians). In addition, the authorities were asked to indicate any barriers to the implementation of the optimal strategies. These observations could be general in nature or be made in terms of advantages and disadvantages to particular user classes. The city officials were also invited to suggest alternative strategies which they would wish to have tested, and the opportunity was taken to discuss these results. None of the alternatives proposed performed better than the predicted optima.

In practice, during the course of the consultations, it was frequently found that the feasibility, public acceptability, political acceptability and barriers to implementation were inter-connected, with particular issues (e.g. insufficient finance, unacceptably high road pricing charge) coming up under several of these headings. In the sections which follow the results have been restructured to some extent to reduce this repetition. In addition, it was often the case that ‘feasibility’ and ‘barriers to implementation’ seemed to be considered to be the same by the cities. Consequently, in the following sections, ‘barriers to implementation’ are included under the appropriate ‘feasibility’ section.

This section reports the results of this consultation process. The next sub-section (5.9.2) contains the results for each city, which report the feasibility (including barriers to implementation), public acceptability and political acceptability of the city’s EEF and SOF optima. The following sub-sections (5.9.3 and 5.9.4) in then summarise the results in a systematic way over all cities, in a format followed thereafter through the remainder of the report.

It should be noted that only the issues related to the best strategies (EEF and SOF optima) are reported.

5.9.2 Results for each city

This sub-section reports all the comments made by each city on the OPTIMA method; and on the feasibility, public acceptability, political acceptability and barriers to implementation of the EEF and SOF optimum strategies.

5.9.2.1 Edinburgh

Edinburgh were generally happy with the approach adopted and were very interested in the results. However, there were several issues of importance to Edinburgh which are not accounted for in the transport model and which would need to be addressed within an overall strategy, before adoption and implementation. These included encouragement of cycling and walking and issues of land take, noise and health. In addition, Edinburgh would have liked to have taken into account supply and charges for private non-residential parking and to have a distinction between central area and non-central measures.

EEF optimum strategy

The optimum strategy considered to be broadly a logical one to maximise NPV, though there was some surprise that the best 35 strategies for Edinburgh in NPV terms all included increases in road capacity. This is important, as it was considered that a 20 per cent increase in capacity would almost certainly need some new road construction and such construction would form the largest barrier to public acceptability. Overall, however, the EEF optimum was considered to be generally feasible provided that suitable legislation for road pricing could be enacted and provided that there could be changes to the regulatory framework of public transport (currently deregulated). Both of these would require a long time, certainly several years.

There could be difficulties with public acceptance of EEF strategy if the increases in road capacity (+20%) required new highway construction. Public acceptance could also be increased if there is a clear link between road pricing charges and transport investment.

There were two major barriers to political acceptance: any road construction needed to attain the capacity increases (+20%) and the political difficulties of introducing road pricing (1.6 ecu). In the case of the latter measure, the political difficulty could be reduced if similar schemes could be shown to be successful elsewhere and (as mentioned) if the public could see the income from road pricing being used on transport system improvements.

Political and public acceptance problems could also occur if it became necessary to raise local taxes to finance the costlier elements: fares reduction (-60%) and public transport frequency increase (+85%).

SOF optimum strategy

In Edinburgh the measures suggested by the SOF optimum strategy (-100% public transport fare, +100% public transport frequency, high public transport infrastructure, +20% road capacity) were considered to be a sensible combination in order to maximise the SOF. They were also considered to be feasible, but only in a purely transport terms, because they are too expensive to be realistically implemented.

It was considered that the free fares component would tend to make the SOF optimum more attractive than the EEF optimum for the public, especially if this could be seen to be a direct result from the road pricing charge. However, as with the EEF optimum, there could be difficulties with public acceptance of the SOF strategy if the increases in road capacity (+20%) required new highway construction. The higher road pricing charge (2.8ecu) in the SOF optimum might also cause problems of public acceptability as could the high cost of constructing the LRT.

The political problems would be similar to those for the EEF optimum. The higher road pricing charge (2.8 ecu) could be an additional problem. The high cost would also be difficult to justify politically.

5.9.2.2 Merseyside

Merseyside were generally satisfied with the method, including the data components and the cost-benefit analysis criteria, and were very interested in the results. They suggested that it would be useful to include parking supply, rather than just parking charges, in the measures for testing. As can be seen below, both optima were considered financially infeasible and consequently a number of additional runs were carried out to try to find optima with high EEF and SOF values but with less extremely negative PVF values: these additional strategies included those suggested by Merseyside itself.

EEF optimum strategy

Though the EEF optimum strategy was considered to be in some respects a desirable one, it was considered overall to be neither sensible nor feasible. The main reason for this is the high cost: the free fares component would be particularly difficult in this respect. A further main barrier (to both optima) is that the introduction of the public transport fare and frequency changes would need a change in the regulatory framework for public transport: even if this were to come about, it would probably take several years and so could affect the timing and sequence of implementation of the components of this strategy.

From the point of view of public acceptability of the EEF optimum, there could be a contradiction: though the reduction in fares and long-term parking charges and the increases in road capacity would generally please the public, they would also be aware of the high cost of both strategies. However, if financed through increased local taxes (or a reduction in other services) this would be likely to cause it to be largely unacceptable to the public, particularly as Merseyside in an economically depressed area which already has high local taxes.

All the best EEF and SOF results include free public transport and free long-term parking, both very costly to the local authority. As these are ongoing costs, presumably to be financed by increasing local taxes, it is unlikely therefore that these strategies would be politically acceptable. There could also be problems of political acceptability because the strategy does not greatly alter the modal split towards public transport compared to the do-minimum case.

SOF optimum strategy

As for the EEF optimum, the SOF strategy would not be financially feasible. In any case, Merseyside were puzzled by the increase in road capacity in a supposedly pro-environment strategy which should seek to reduce car travel, particularly for commuters.

Overall, the level of acceptance of the SOF optimum by the public and politicians can be expected to be as for the EEF strategy. It was considered that the only way to overcome the barriers to acceptance would be through a major re-allocation of central government funds and partnerships with the private sector.

5.9.2.3 Vienna

Vienna were interested in the OPTIMA methods and results, and welcomed the opportunity the project gave to review transport problems and analytical methods of other European cities. Regarding the objective functions, they considered that time savings, a main component of the functions, were not the best way to evaluate options and that it would be better to examine modal split to ensure that it was compatible with that proposed in the master plan for the city. Vienna would also have liked to have extended the list of measures to include fuel taxes, city structure changes and specific facilities for pedestrians and cyclists.

EEF optimum strategy

The barrier to the EEF strategy is that it is politically unacceptable.

The Vienna EEF strategy has a combination of measures that were considered to be unrealistic and so not feasible: in particular to increases in road capacity (+10%) and at the same time to increase public transport frequency (+100%).

Overall, the strategy would be on the whole publicly acceptable, with the improved conditions for both the public and the private transport systems users, though this is offset by the increase in parking charges.

One political problem which arises is the increase in parking charges (+226%): only if this measure could be implemented gradually over time might the problem be overcome. A further important political problem could arise as the modal split from the OPTIMA optimum is contrary to that set out in the master plan for transport development in Vienna.

SOF optimum strategy

The combination of measures in the best SOF strategy is similar to the city’s transport plan (‘Transport Concept 1994’). Even the modal split of 45% for public transport is close to the planned modal split. On this basis, the best SOF strategy has been judged to be acceptable: the increased attractiveness of the public transport system through the doubling of the frequency this strategy should be acceptable to public transport users. On the other hand car users might resist the increased parking charges (+250%). Again, the similarity in the modal split figure resulting from this strategy with that specified in Vienna’s master plan renders the SOF optimum politically acceptable on balance.

The high cost of the strategy, however, renders it infeasible.

5.9.2.4 Eisenstadt

The Eisenstadt representatives were very interested in the results, particularly as they had not had a strategic model of the city before the OPTIMA project. They pointed out that some measures tested were perhaps not suited to a small city, for example the ‘high’ public transport infrastructure option. They also had some misgivings about the objective functions similar to Vienna’s: that time savings are not an optimal indicator as they only have temporary effects. They considered a major objective to be the preservation of the city’s compact urban structure.

Given that most journeys are now either on foot, bicycle or private car (little public transport) they would also like to have known the specific effects on walking and cycling as a means of monitoring reductions in $C0_2$ emissions.

EEF optimum strategy

For Eisenstadt city all the measures in the EEF optimum strategy were judged to be feasible, provided the financial barriers could be overcome, as it was believed they could be.

The EEF strategy would also be publicly acceptable because of the improvements to the public transport system (increasing the frequency by 100% and simultaneously reducing fares to zero) and to the car transport system. The disbenefit to motorists from the increase in parking charges (+149%) will be compensated for by the increase of 10% in road capacity.

The strategy would generally be acceptable politically but the increase in public transport frequency (+100%) and the free fares could be a financial problem for the city. In particular it is uncertain whether it would be politically acceptable to use the income from the increased parking charges (+149%) for subsidising public transport.

SOF optimum strategy

As with Edinburgh, the measures are considered feasible but only in theory as there are economic constraints on their implementation. There would be particular problems relating to free fares because it is not clear who would pay the subsidy to the public transport company to support the loss of revenue: this could be a barrier which might prove difficult to overcome.

The public and political acceptability of the SOF optimum would be as for the EEF optimum.

5.9.2.5 Tromsø

The city officials were very interested in the method used, though they found the objective functions to be rather too restrictive: they would have like to have included specifically the benefits to pedestrians and cyclists and any costs to these groups. They pointed out that accidents and local pollutants, including noise, are normally explicitly taken account of when assessing any local transport scheme in Norway and they were not convinced that OPTIMA's assumptions took these fully into account.

EEF optimum strategy

The EEF optimum strategy was considered to be feasible in general, but it is important to emphasise that the decrease in public transport fares by 50% is possible only if the authorities increase subsidies to the public transport companies.

Some problems of public acceptability could be anticipated as, though it favours both cars and public transport, pedestrians and cyclists would be critical.

On the whole the EEF strategy would be politically acceptable.

SOF optimum strategy

In Tromsø the main problems of feasibility of the SOF optimum are the financial barriers resulting from the free public transport and the free parking. Free public transport can only be supported if the authorities increase subsidies and free parking is not feasible unless the authorities give grants to the private parking company which has invested in and is currently operating the parking facilities. There could also be legal barriers to free parking.

Public transport users could experience acceptability problems deriving from the overcrowding caused by the free fares and the reduction in frequency and public transport users might find this unacceptable. Car users would find the strategy acceptable: though they incur a loss through the higher road pricing charge (2.5 ecu), they are compensated by the free parking and by the savings in travel time following from the increased capacity (+20%).

Political barriers to the SOF optimum could arise from implementation of the new road pricing charge (2.5 ecu) because this cost would add to an existing local fuel tax already levied on the inhabitants, which is dedicated to improve the road system of Tromsø.

5.9.2.6 Oslo

The Oslo representatives were interested in the methods and results. However, for both optima they pointed out that reducing the public transport fare and simultaneously decreasing the frequency could result in an irrational modal split (empty streets and congestion on public transport vehicles).

EEF optimum strategy

Public and political opposition can be expected to arise, particularly from the road pricing increase (to 1.2 ecu), the means to achieve the road capacity increase of 20 per cent and the 26 per cent reduction in public transport frequency.

Despite this, no financial, institutional, legal or physical barriers were considered likely to hinder implementation of the strategy for very long, provided the technical feasibility issues are solved and political support is provided. However, some short term concerns remain, due to the limited powers of city authorities in parking policy matters, concerns about walking and cycling conditions after a 20% road capacity increase and the possibility of unforeseen costs on the public transport side.

SOF optimum strategy

Very strong public and political opposition can be expected to arise on the matter of the extreme road pricing increase (7 ecu). At best, the implementation of this measure would have to be gradual.

5.9.2.7 Helsinki

The methods and results were of great interest to Helsinki, and they had a number of comments on both. Although the Helsinki results were somewhat surprising to the city officials, the method itself seemed interesting and attractive in that it may give totally new ideas about feasible transport measure combinations. For it to be widely adopted it should be more easily applicable: for example the more detailed tactical model systems with a long model-run-time, currently used in Helsinki, should be replaced by more aggregate strategic models.

They also believed that the OPTIMA approach did not fully take account of environmental and other external effects of the transport system and they felt that transport system quality was not fully assessed.

They also questioned, in the benefit calculations, the fact that government taxes on fuel etc. were calculated as benefits for the system although they are not reimbursed as a whole to be used for the metropolitan area transport system.

EEF optimum strategy

The feasibility of the EEF optimum strategy in Helsinki could be in doubt because the fuel consumption of this strategy exceeds the do-minimum level and this is contrary to international contracts agreed.

In Helsinki very few car users could approve of the suggested strategy: the vast majority would not although the strategy promotes car use. Common opinion is that public transport should be frequent and less expensive (the strategy suggests an increase in fares of 25% and a decrease in frequency of 30%). Constructing enough off-street parking places instead of the present on-street parking would surely be a public acceptability problem as it seems unnecessary because the streets in the city are fairly wide and suitable for parking and the removal of on-street parking (to increase road capacity) would not please car drivers.

The politicians are representatives of the public so the same comments as for the public can be applied, but in this case costs of environmental and other external effects should be incorporated. In addition, the EEF optimum strategy may not be acceptable to politicians because the frequency reduction (-30%) on public transport and the fare increase (+25%) together with the road capacity increase (+20%) runs counter to the city’s goal of promoting the use of public transport and keeping car use at its present level in the inner city. This problem is intensified as there is no increase in car travel costs to correspond to the increase in fares.

SOF optimum strategy

With regard to the SOF strategy there would be problems of financial feasibility relating to free fares because it would be difficult to obtain money to pay the subsidy to the public transport company to compensate for lost revenue. There could also be problems of technical feasibility because if public transport becomes free of charge, as it is suggested, public transport capacity should be increased simultaneously (the SOF optimum does not include this) and maybe the infrastructure should also be improved.

The SOF optimum strategy for Helsinki includes free fares which obviously wouldn’t in itself cause problems of public acceptability, but it also includes no change in frequency and so this measure could cause overcrowding of vehicles, which would decrease the level of service and consequently increase the dissatisfaction of users.

The high cost of the strategy could be a barrier.

5.9.2.8 Torino

The Torino authorities were very interested in the study methods and in the results, even though the results were quite different from those they would have expected. Regarding the method, they would have preferred to have seen the costs and benefits of the strategies indicated separately for the different users, e.g. car users, bus users, pedestrians and so on.

EEF optimum strategy

Problems of acceptability are perhaps greater for Torino than for any of the other cities. The main barriers to the EEF optimum are, firstly, that the reduction in fares (-25%) does not agree with the legal requirement to increase incomes from tickets sales and to decrease subsidy from government; thus the EEF optimum was considered to be infeasible. It is not possible to decrease the public transport fare by 25% because this would adversely affect the public company's balance sheet. The increase in capacity (+10%), though feasible in a theoretical way, could be difficult to implement in reality.

The increase of +500% in the parking charge will be unacceptable to the public and would cause resistance from pressure groups e.g. lobbies of shop owners, automobile clubs, etc.. Finally, some methods of increasing road network capacity (e.g. sidewalk width reductions, removal of parking places, etc.) may cause public acceptance problems.

A main political acceptance problem would be the cost.

SOF optimum strategy

As for the EEF strategy, problems of acceptability of the SOF strategy are greater for Torino than for any of the other cities, being similar to those of the EEF optimum, but rather greater, as public transport fares are reduced by 50 per cent rather than by 25 per cent.

Public objections would also be similar to the EEF optimum. In addition, it is possible that the reduction of the public transport frequency (-30%) can cause some problems even with the fare reduction of 50%. The parking charge increase (+500%) would also be considered to be too high. The public transport frequency reduction (-30%) might also seem contradictory in view of the public transport system improvement policy (high infrastructure).

Political problems would be as for the EEF optimum, made worse by the higher (50 per cent) fare reduction.

5.9.2.9 Salerno

The Salerno authorities, both the technical officers and the politicians, were interested in the final results of the OPTIMA study. They agreed with the methods used and the measures examined.

Although they did not agree with the components of the EEF or SOF optima, they agreed that the difference between the two optima could be explained by the different objective functions.

EEF optimum strategy

The EEF strategy would be generally feasible, though the 50% decrease of the public transport fare could not be sustained unless the government provides a subsidy. This barrier could be overcome by, for instance, reducing the season ticket costs without acting on single-journey tickets; by simply improving the season ticket service or perhaps by increasing the number of different season tickets including creating season tickets aimed at particular groups of users (employees of central offices, pensioners, etc.).

There would be no problem from the public acceptability point of view, especially with the reduction in public transport fares (-50%) and the parallel increase in public transport service frequency by 50%.

There could be moderate political acceptability problems relating to public transport because of the need for the public transport company to be subsidised to reduce fares and increase frequency

SOF optimum strategy

With regard to the SOF strategy the main barrier to implementation is the necessity that the government subsidises the public transport company to make up for the loss of income resulting from free fares. This may not be feasible.

There would be no problems with this strategy from the public acceptability point of view, as it favours the users of both the private and the public networks.

Free fares for public transport, however, would not be politically acceptable if the subsidy is from local government.

5.9.3 Overall feasibility

The EEF optimum strategies for the medium and small sized cities tended to be feasible, with Edinburgh, Eisenstadt, Salerno and Tromso being given a good feasibility score by the city authorities. The EEF optimum strategies for the bigger cities, however, tended not to be feasible. In some case the authorities of the bigger cities stressed the fact that some measures were not realistic in their specific cases or that the values of the measures suggested by the optimisation process were too big or too small.

The SOF optimum strategies suggested by the optimisation process in general were considered not to be feasible, especially because some components appeared to be incompatible with each other or were considered not to be applicable. Edinburgh and Eisenstadt were the only cities that provided a positive judgement from the SOF feasibility point of view, but they stressed anyway the economic difficulties of implementing those strategies.

The results of the questions concerning the feasibility of the optima suggested that feasibility is viewed by the cities under three headings: financial feasibility, practical feasibility and legislative feasibility. Each of these is dealt with in turn below.

5.9.3.1 Financial feasibility

By far the most frequent concern of the city authorities has been the financial feasibility of the proposals. It is important to note that this was reflected in part by including a shadow price of 0.25 on the PVF, hence indicating that strategies with a positive EEF were a justifiable use of the public funds required.

In five cases (Edinburgh, Vienna, Oslo, Helsinki, Torino) the PVF for the EEF optimum is in fact positive, while in the two smallest cities (Eisenstadt and Tromsø) the PVF, while negative, is very small. The problem of affordability is only serious for Merseyside, and, to a lesser extent, Salerno. This is an important result, because it indicates that it should be financially feasible to introduce economically optimal strategies in most cities relying, in some cases, on the ability to finance new measures in part from revenue from fares, road pricing or parking charges. However, this will depend on the willingness of governments to allocate these revenues to the city authorities.

For the SOF optimum, the problem is more widespread. Only Oslo generates sufficient finance from other measures to pay for its optimal strategy, and most cities express concern about the financial costs. However, Vienna considered the financial cost worth incurring to achieve a more acceptable strategy. It is clear that pursuit of the most sustainable strategies will imply substantial financial outlay in most cities, and that there is a need to try to find slightly sub-optimal strategies which are significantly more affordable. This is a key task for the follow-up project FATIMA.

In summary, the EEF optimal strategies appear in the main to be financially feasible, as evidenced by the positive or only slightly negative PVF values for seven of the of nine cities. Thus both the public and politicians can have an expectation that, provided the revenues generated are re-invested in transport, implementation of EEF optima need not be an ongoing cost. For the SOF optima this is not generally the case: the implementation of such strategies therefore depends on whether the strength of feeling of the public and politicians to improve environmental quality exceeds their reluctance to pay for it.

5.9.3.2 Practical feasibility

In a few cases, city authorities expressed doubts about the feasibility of the measures tested, and this was reinforced by the tendency to include the upper or lower bound measures in the optimal strategy. Specific concerns included the higher levels of road capacity increase, which were considered in some cases only to be achievable by new road construction and potentially to cause environmental damage; public transport service reductions, which would result in increased loadings, whose effect was not always modelled; and zero fares and zero parking charges, which would both result in major changes in operating practices and costs. These issues will be tackled in the follow-up project FATIMA.

5.9.3.3 Legislative feasibility

In the UK and Italy examples were identified of the need for new legislation to enable optimal strategies to be implemented. These concern ability to introduce road pricing and to control private parking (for which legislation would in practice be needed in all countries), changes in the UK bus deregulation regime to permit city authorities to influence service levels and fares more directly, and changes in the Italian anti-inflation legislation, which currently requires public transport operators to increase fares and reduce subsidies. These are important conclusions, and imply that legislative changes should be sought to facilitate optimal strategies.

5.9.4 Overall public acceptability

In three cities of the nine (Edinburgh, Eisenstadt and Helsinki) the EEF optimum strategy was generally publicly acceptable. The lack of public acceptability in the other cities was cited as being a result of the penalisation of cyclists and pedestrians (Tromso), the increase of the local taxes likely to be necessary to implement some new measures (Merseyside), the increases of some charges such as road pricing and parking (Torino and Oslo) and the decrease of public transport fare coupled with the increase of frequency (Salerno).

In four cities of the nine (Edinburgh, Eisenstadt, Vienna and Salerno) the SOF optimum strategy was generally publicly acceptable. Public acceptance problems for the other cities included the increase of the local taxes necessary to implement some new measures (Merseyside), the increases of charges such as road pricing and parking (Oslo and Torino) and the overcrowding problems which could arise from decreasing public transport fares while decreasing frequency (Helsinki and Tromso).

It is important to stress that these views are based on officials' judgements rather than on public consultation.

The main concerns overall, taking the EEF and SOF optima together, related to road capacity increases and, as might be expected, reduced services, increased fares, road pricing and increased parking charges. Not surprisingly the deterioration in public transport in Helsinki was considered particularly unacceptable. The first of these is the most interesting; it suggests that the public are more likely to be concerned by the environmental impacts of such measures than by the benefits of reduced congestion. In all cases these concerns highlight the need for an effective public relations campaign and for a carefully designed implementation programme. Where strategies are fully justified, it will be important to present these arguments clearly and allay the fears of the public. Where a strategy involves both positive and negative measures, the latter need to be preceded, where possible, by the former.

5.9.5 Overall political acceptability

The EEF optimum strategies are acceptable from the political point of view in only two of the tested cities, (Eisenstadt and Tromso) with the political acceptance for Edinburgh, Salerno and Vienna being 'neutral'. In general the main problems are similar to those cited for public acceptability: the penalisation of cyclists and pedestrians, the increase in local taxes necessary in some cases to implement new measures, the increases of charges such as road pricing and parking and the decrease in fares coupled with the increase in frequency.

The SOF strategies were acceptable from the political point of view in only two of the tested cities; Eisenstadt and Vienna. The main problems are by and large the same as for public acceptability and for EEF political acceptability.

Overall, city officials' assessments of political acceptability were inevitably influenced by their views of feasibility and public acceptability, as reported above. However, Vienna commented that the SOF optimum was more acceptable than the EEF, since it accorded more closely with their overall approach and the modal split target contained in their master plan.

5.10 COMMENTS ON THE METHODOLOGY

Sub-section 5.9.2 contained the comments on the methodology of OPTIMA made by the individual cities. This section summarises those comments in terms of the overall method and evaluation used (Sub-section 5.10.1), the specification of the objective functions (5.10.2) and the set of measures tested (to the extent that they impinge on the methodology) (5.10.3). The implications for FATIMA are set out later, mainly in 5.12.3.

5.10.1 The overall method and assessment of strategies

The opinion of the cities on the whole method was, on balance, generally good (though with Tromsø and Vienna less enthusiastic than the others). Though the OPTIMA results were often at variance with the actual policies of the cities, in general it was considered that the final results represent the optimum strategies from the economic and sustainable point of view and that difference between the OPTIMA results and the existing policies of the cities were due to the different objectives and calculation of the functions. Most cities were also satisfied (exceptions being Tromsø, Torino and Vienna) with the method used specifically to select and analyse the strategies.

In some cases, (such as in Torino and Vienna) the authorities thought that when assessing strategies and their effects it is important to take into account some indicators of the quality of transport supply and the effect on city structure resulting from the changing attractiveness of zones caused by transport system changes.

The value of the models in assessing strategic issues was widely recognised but some concern was expressed about certain features of some models; for example for Helsinki it was pointed out that the model may not be capable of handling the highest peaks within the peak period which could have indicated deficiencies in public transport capacity. It was also suspected that the model was not able to predict fully the effects of free public transport, which is outside the range of data on which the model was calibrated.

5.10.2 The objective functions

Though the method was in general considered a good method of evaluation, almost every city involved in the project would have changed the objective functions by adding some factors that the city authorities believed fundamental for the planning of their specific city. The most frequent concern was with impacts on the local environment and safety; some would also have preferred a greater emphasis on accessibility and land use. The reasons for omitting these objectives were outlined earlier in this paper. However, it is intended both to analyse accessibility impacts (as an indication of the potential for value capture) and to include fuel consumption in the EEF (as a proxy for environmental and safety implications) in the FATIMA project. Some concern was also expressed over the emphasis on time savings in the EEF calculation.

Some city officials would also like to have seen more inclusion of land use measures (which were omitted as not being able to be modelled) and of measures to improve conditions for cyclists, pedestrians and disabled travellers. These latter measures are, in practice, better designed within the context of an overall optimal strategy.

Specific points made were as follows.

Edinburgh suggested taking into account in the objective functions factors which were directly sustainability related, such as land take, noise and health. On the same lines, both Vienna and Eisenstadt felt that time savings should not be the main indicator of transport system quality and that other effects, including those on urban form as mentioned above, should be incorporated.

Edinburgh, Eisenstadt and Tromsø would have preferred the modal split between motorised and unmotorised (pedestrians and cyclists) to have been specifically included in the evaluation process.

It was also pointed out by Tromsø and by Helsinki that accidents and externalities such as local pollutants (including noise) should be incorporated and it was further noted by Tromsø that these are normally explicitly taken into account when assessing local transport schemes in Norway.

Torino would have liked further disaggregation of costs and benefits for the various users (car users, bus users, pedestrians and so on) and providers (public transport authority, government and so on.

Eisenstadt did not agree with the formulation of the objective functions which they felt should have reflected more clearly the structure of the city.

In summary, the main suggestions included:

- subdivision of costs into central government, city government, companies, residents, etc.;
- inclusion of quality variables;
- placing constraints on the costs for the different actors;
- inclusion of other variables: modal split between motorised and unmotorised trips, noise, land use, environment, etc.

The consultations were very valuable in reviewing the objective functions. This will be an important input to the project FATIMA, (the follow-up to OPTIMA), where there is an opportunity to take into account the suggestions made in the consultation stage of this study.

5.10.3 The tested measures

As the tested measures were based in part on prior consultation with the cities, the broad set of measures used in OPTIMA were of course universally of great interest. However, some criticism arose on the details of the measures; this included the limits chosen for some measures as some of them were considered not to be feasible for some cities and, despite giving good results in the optimisation, might not be acceptable in practice. Further, the frequent use of the upper and lower bound values in the optima was sometimes seen as a weakness. Specific comments made on the measures were as follows.
Edinburgh would liked the effect of varying supply and charges specifically for private non-residential parking to be taken account of in specifying the measures, and to distinguish more

clearly between measures for the city centre and measures for other parts of the city.

Merseyside would have preferred parking supply to be included, not just parking charges.

Vienna would have liked a wider range of measures, especially the effects of fuel taxes, city structure changes and the provision of facilities for pedestrians and cyclists. On the other hand Eisenstadt would have omitted measures which they considered not suitable for a city of this size (for example the high infrastructure investment).

5.11 CONSULTATION WITH TWO ADDITIONAL CITIES

5.11.1 General

It is part of the OPTIMA project to consult on the outputs, not only with the nine main cities but also more widely in the EU. To this end two further cities were sought in countries other than those included in the main study. Though it was not easy to find cities who were prepared to comment on methods and outputs that did not directly concern them, two cities agreed to be approached. They were the small city of Idstein, close to Frankfurt in Germany, and Stockholm.

The purpose was to gain professional outsiders' impartial opinions of the project and the method developed in it and also of its practicability more generally in European cities. With this in mind, the OPTIMA project with its preliminary results was introduced to technical officers of the two cities prior to eliciting their opinions through consultation.

Key data for these cities is as follows:

	Idstein	Stockholm
Population ('000)	21	1600
Area (ha)	4330	345500
Density (persons/ha)	4.74	4.63
% pedestrian trips	23	13
% cycling trips	4	8
% car trips	65	31
% public transport trips	8	47

Generally, both cities were happy to give comments on the OPTIMA approach and method but neither was anxious to comment on the results obtained from other cities. Despite this, Stockholm did provide limited comments on the results from the other Nordic capital cities, Oslo and Helsinki.

5.11.2 Comments on the method

Stockholm

The Stockholm discussions on methods began with a review of the model system used in Stockholm. This is similar to the ones used in Oslo and Helsinki, a so-called tactical model system including network assignment. In Stockholm there are two distinct basic models in use called TIRIM and FREDRIK of which the former is used by the Office of Regional Planning and Urban Transportation and the latter mainly by its developer - a consultancy called Transek AB. Both of the basic models are complemented by the EMME/2 model for the network assignment for both car traffic and public transport. In addition a land use model called IMREL has been linked to the system. The model system is fairly detailed but consequently slow.

The Stockholm officials were very interested in the OPTIMA strategic approach, and wondered whether it would be possible to replace discrete EEF and SOF optimisations with a single 'optimum' objective function satisfying both the politicians and the public, which would result in a strategy that ensures an economic efficient transport system with a high level of quality resulting in sustainable conditions. (They acknowledged that this is a target and can hardly be completely achieved). (This single objective function approach is to be examined in FATIMA).

In the Stockholm case, expert judgement has been the key to strategic decisions, with some model runs made to check that judgement, together with some runs to test sensitivity. This approach seemed to be related to the lack of an appropriate strategic model for Stockholm, meaning that only a tactical model is available to assess strategic issues, for which it is not designed. Despite running on a fast computer, the Stockholm tactical model takes several hours to test a single alternative.

Stockholm has made some steps towards developing their own strategic model, but have so far not been impressed with the often counter-intuitive results it gives. There was a discussion on the issue of the correct balance between simplicity and detail in a strategic model and after a short examination of some of the OPTIMA results they wondered whether some of the models used produced results which were rather too uncertain.

The officials agreed that if a fast and trustworthy strategic model was made available to them they would find it useful in strategic decision-making and they would not have any objection to testing the OPTIMA method for Stockholm. With the detailed and slow tactical model suite they currently have, they could not even think of doing the many runs required, however.

In conclusion, they found the method to be interesting but would be very time-consuming if only a tactical model is available. The definition of the objective function was felt to be of great importance and thus a difficult task, as is the method of cost-benefit analysis of the outcome.

Idstein

The Idstein representatives found the method interesting. They were particularly interested in the transport model outputs, especially the change in modal split towards cycling and walking, which is an important issue for a small city like Idstein. Because of this they felt that there should be more explicit emphasis on encouraging non-motorised modes. In the same vein, with regard to the objective functions, they pointed out that not everything of importance in the system can be given monetary values and it was noted by the Idstein officials that even the sustainability objective function is strongly economically orientated. The emphasis on the benefits from time savings was of particular concern in this respect and they would have preferred the inclusion of more social criteria in the process.

5.11.3 Comments on the results

As mentioned above, only Stockholm felt able to make useful comments on the results.

The Stockholm reviewers preferred to make their comments on the results from the other Nordic capitals of Oslo and Helsinki as they had a good knowledge of these cities. They also considered the traffic systems and the traffic behaviour of the people to be similar in large cities of Scandinavia. Interestingly, they considered the optima for these two cities, particularly Oslo, to be generally less feasible than did the officials of those cities themselves.

The results for Helsinki were considered not to be feasible in all respects: this brought the discussion back to the subject of the cost-benefit analysis of the results of the model runs. In the optimisation process the balance between user savings/costs and public authority or operator revenues/costs is of great importance. As an example the time values used for travellers may affect the results significantly as can be seen in the results of Helsinki in comparison with the other cities that have used higher values of time.

The results for Oslo were also considered infeasible. In both Helsinki and Oslo the public transport frequency was reduced. This is not feasible nor acceptable to politicians or the public in any of the Nordic countries.

It was acknowledged, however, that the results were logical given the OPTIMA assumptions and cost-benefit approach used and they were thus convinced of the correct functioning of the method.

6. POLICY IMPLICATIONS AND GUIDELINES FOR THE EU

6.1 THE NATURE OF THE OPTIMAL STRATEGIES

6.1.1 The need for an integrated approach

The most important conclusion to be drawn from all the nine cities is that the optimal strategies involve a combination of measures, and rely on synergy to be gained from implementing them together. There is no single best measure for any city, and there is certainly no best solution for European cities more generally.

6.1.2 The Economic Efficiency optimum

The economic efficiency optimum is likely to involve :-

- no new infrastructure investment;
- low cost improvements in road capacity;
- no use of road capacity reductions to discourage car use;
- improvements in public transport by increasing frequency and/or reducing fares; and
- restrictions on car use involving either road pricing or increased parking charges.

There are, however, exceptions to this, and we comment on each in turn below.

Public transport infrastructure investment is included in the two UK case studies, where the level of public transport subsidy is currently lowest. However, they are included only at the medium level, which implies bus-based improvements. Elsewhere, the high resource cost of investment makes such measures economically inefficient.

Road capacity improvements are included in all nine cities, on the assumption that the cost of implementing them would be small. This assumption has since been questioned, and one task in the subsequent project, FATIMA, will be to provide improved estimates for these costs. However, the overall result is important, and at first sight counter-intuitive. The implication is that it is worth increasing road capacity to generate increased efficiency provided that the costs of doing so are low, and the growth of car use is controlled by other means. Conversely there is no justification on efficiency grounds, for using road capacity reductions to discourage car use.

Public transport changes may include an increase in fares (Vienna) or a reduction in service level (Tromsø, Oslo). It appears that these occur where the current level of public transport subsidy is highest, suggesting that some reduction in the resources used for public transport may improve efficiency. In particular, this appears to be the justification for the strategy in Helsinki, where both a reduction in service level and an increase in fares are proposed.

Restrictions on car use may involve introduction of a road pricing charge, or an increase in parking charges, but never both. In all cases the models treat these measures as largely interchangeable, although road pricing will impact on through traffic in the city centre, and parking charges will not, in practice, apply to private parking. Typically, road pricing charges are combined with a reduction in parking charges, while still achieving a reduction in car use. In three cases (Merseyside, Tromsø and Helsinki) no restriction is imposed on peak period car use. This appears to be associated with lower levels of congestion in the do-minimum conditions.

6.1.3 The Sustainability optimum

When compared with the economic efficiency optimum, the weighted sustainability optimum is most likely to involve :-

- investment in new public transport infrastructure;
- similar levels of low cost improvement in road capacity;
- further improvement in public transport by increasing service levels and/or reducing fares; and
- further restrictions on car use, involving either road pricing or increased parking charges.

Public transport infrastructure investment becomes more acceptable when less emphasis is given to initial investment costs (which are given approximately a half weight in the WSF) and the importance of reducing fuel consumption, and hence car use, is increased. Of the seven cities testing such investment, all but two included the high level of investment (typically rail-based) while Merseyside included the bus-based medium level, and Helsinki included high investment in several close to optimal strategies.

Road capacity improvements are typically at the same level as for the economic efficiency optimum, and the arguments in (6.1.2) above apply. Merseyside, whose costs of road capacity increases are greatest, adds to them when the investment costs are given less weight; Vienna and Helsinki reduce them, presumably because of their impact on fuel consumption.

Public transport changes may still include service level reductions (in Tromsø, Oslo and Torino) but the reductions are typically lower than with the economic efficiency optimum. The one exception is Torino, where the service level is reduced to reflect the provision of an extensive new underground system. Fares are reduced in all cases except Vienna, where there is a minor increase. In all cases, the public transport service provided (considering service levels and fares combined) is better than for the economic efficiency optimum.

Restrictions on car use still involve either road pricing charges or increases in parking charges, and the same arguments as in (6.1.2) apply. However, the charges now apply in all cities and are (except for Eisenstadt and Torino) higher than in the economic efficiency optimum.

6.2 FEASIBILITY

The most frequent concern of the city authorities has been the financial feasibility of the proposals. However, the problem of affordability for the EEF optima is only serious for Merseyside, and, to a lesser extent, Salerno. This is an important result, because it indicates that it should be financially feasible to introduce economically optimal strategies in most cities relying, in some cases, on the ability to finance new measures in part from revenue from fares, road pricing or parking charges. For the SOF optima, the affordability problem is more widespread with only Oslo generating sufficient finance from other measures to pay for its optimal strategy. This too is an important result as it is clear that pursuit of the most sustainable strategies will imply substantial financial outlay in most cities, and that there is a need to try to find slightly sub-optimal strategies which are significantly more affordable.

In a few cases, city authorities expressed doubts about the feasibility of some of the more extreme measures, including the higher levels of road capacity increase, public transport service reductions, free fares and zero parking charges.

Finally, examples were identified, particularly in the UK and Italy, of the need for new legislation to enable optimal strategies to be implemented.

6.3 ACCEPTABILITY

Several cities expressed concern over the public acceptability of certain measures, in particular road capacity increases and, as might be expected, reduced services, increased fares, road pricing and increased parking charges. Not surprisingly the deterioration in public transport in Helsinki was considered particularly unacceptable. The first of these is the most interesting; it suggests that the public are more likely to be concerned by the environmental impacts of such measures than by the benefits of reduced congestion.

City officials' assessments of political acceptability were inevitably influenced by their views of feasibility and public acceptability, as reported above. Some cities also expressed doubts about the objective functions used, with the most frequent concern being impacts on the local environment and safety; some would also have preferred a greater emphasis on accessibility and land use as well as measures to improve conditions for cyclists, pedestrians and disabled travellers.

The methods used in the project were generally acceptable and attracted considerable interest. The frequent use of the upper and lower bound values in the optima was, however, seen as a weakness and some concern was expressed about the capabilities of certain models: these most often were the difficulties of using tactical models for strategic analysis (some cities only possess tactical models) and the general lack of model capability to synthesise land use policies or to produce a land use response to transport system changes.

As a result of the comments made on the method, the following will be addressed in FATIMA :

- use of a wider range of objective functions;
- reduced ranges for certain measures;
- improved estimates of the costs of all measures;
- distinction between peak and off peak application where the model permits;
- distinction between applications in the inner city and outside it, where relevant;
- more severe constraints on the availability of finance.

6.4 CONCLUSIONS AND RECOMMENDATIONS

6.4.1 Recommendations for policy makers

- strategies should be based on combinations of measures, and should draw fully on the synergy between success measures;
- economically efficient measures can be expected to include low cost improvements to road capacity, improvements in public transport (increased service levels or reductions in fares, and increases in the cost of car use;
- public transport infrastructure investment is not likely, in the majority of cases, to be a key element in economically efficient strategies;
- reductions in capacity to discourage car use are not likely to be economically efficient;
- the scale of changes in service levels and fares will be influenced by the current level of subsidy; in some cases a reduction in service levels or an increase in fares may be justified on economic grounds;
- the scale of increase in costs of car use will depend in part on current levels of congestion; the study suggests that road pricing and parking charge increases are broadly interchangeable, but this needs assessing in more detail;
- in most cases economically efficient strategies can be designed which are financially feasible, provided that revenues can be used to finance other strategy elements;
- the pursuit of sustainability is likely to justify investment in public transport infrastructure, further improvements to public transport services and/or fares, and further increases in the cost of car use;
- availability of finance will be a major barrier to implementation of many sustainability-optimal strategies, and further work is needed to investigate the extent to which financial costs can be reduced by strategies which are slightly sub-optimal;
- legislation will be needed to enable implementation of road pricing and to control parking charges; in the UK and Italy there is also a case for changing legislation to permit economically more efficient public transport strategies;
- public acceptability will be a significant barrier with those measures which reduce service levels or increase costs; this implies the need for effective public relations campaigns, and carefully designed implementation programmes;
- detailed measures to improve the environment and provide better facilities for cyclists, pedestrians and disabled people should be designed within the context of a preferred strategy.

6.4.2 Methodological conclusions and recommendations

- the optimisation procedure has been shown to be successful, and has attracted widespread interest; however, it is important that careful thought is given to the policy implications of each stage of the process;
- the frequent use of upper and lower bound values in the optima is a cause of some concern;
  strategic models are in many ways more appropriate than tactical models in the development of optimal strategies; cities wishing to develop integrated transport policies should develop or acquire appropriate strategic models;
- such models should include walking and cycling, both peak and off peak conditions, and the effects of public transport loadings on user costs;
- most strategic models have no direct land use capability; models should therefore be developed which have the capability of predicting the land-use effects of changes in transport policy and the transport implications of changes in land use patterns;
- the issues listed in 6.3 above should be addressed in FATIMA.

7. REFERENCES

N.B. all references are available on the WEB address http://www.its.leeds.ac.uk/projects/optima/

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ANNEX 1

DESCRIPTION OF THE CITIES

Each test city is represented in a section of its own comprised of a short overall description of the city, its transport system and policy measures.

A1.1 Edinburgh MA

General description of the city
Edinburgh is the capital city of Scotland. The study area includes the city and its immediately surrounding commuter towns, including the southern part of Fife Region, immediately north of the Forth road and rail bridges. It is the principal centre for government, finance and legislation for Scotland, a regional shopping centre, and a base for high technology industry linked to its three universities. It is also a major centre for tourism focused on the castle and Old Town, and the Georgian New Town.

The population of Edinburgh MA is 420 000, 58 % of households own cars and car ownership is 0.32 cars per inhabitant.

Transportation system
The transport network of the study area is constrained by the Forth Estuary, to the north of the city, and ranges of hills to the south. The city’s road network includes a purpose-built outer ring road, and motorway connections to Glasgow and Fife, but most of the roads within the city are of variable standard. Most public transport is by bus, supplemented by urban rail services, predominantly to the west and across the River Forth.

51 % of all trips are made by car and 65 % of motorised trip-km are by car with most of the rest by bus.

Transport policy measures
In Edinburgh a combination of infrastructure, management and pricing measures is used to reduce car traffic in the city centre. The intention is to forbid long-stay trips by car but allow short-stay trips. On street parking is being reduced. There are also schemes for new highway construction and increasing capacity, but the attitude is changing towards encouraging public transport instead of building more roads. In residential areas traffic calming is being introduced.

The public transport network has recently been expanded by a new rail line and a new light rail system is being planned. Better information systems for both public transport and car drivers are under preparation.

There are several ongoing measures for enhancing non-motorised-traffic and its facilities, pedestrianisation in city centre, wide pavements, cycle lanes, parking facilities for bicycles etc. Also totally car-less development areas are planned.

A1. 2 Merseyside

General description of the city
The Merseyside conurbation, centred on the city of Liverpool, lies on the west coast of England. Liverpool itself is a regional centre for shopping and business, as well as being the main west coast port and a university centre. It is bordered by the boroughs of Sefton, including the seaside

resort of Southport, and Knowsley, which has several distinct town centres within an area of suburban development. St Helens lies further to the east, while the Wirral District, including Birkenhead, is separated from Liverpool by the Mersey estuary.

Merseyside has a population of 1 440 000 of which Liverpool accounts for 700 000. The average population density is 22.2 inhabitants per hectare.

Car ownership in Merseyside is low, 0.69 cars per household in 1991 compared to the national average of 0.88.

Transportation system
The area has several motorways and high capacity roads including two toll tunnels linking Birkenhead and Liverpool under the Mersey. It also has an extensive suburban rail network, centred on Liverpool, with a tunnel linking Liverpool to Birkenhead and towns on the Wirral.

78 % of motorised person-km are by car, 19 % by bus and 3 % by rail.

Transport policy measures
Merseyside aims at improving the accessibility and efficiency of the transport system. For public transport the rail network and park and ride system will be extended, a light rail system is under consideration and new technology will be used to promote public transport.

Also measures improving car traffic are being implemented. Parking measures are however used to favour short-stay trips to the centre and encourage commuters to choose public transport. A road pricing cordon around the centre has been planned if the ongoing measures are not enough to prevent congestion. Traffic calming measures are used in residential areas and residential centres. Improving facilities of non-motorised traffic elsewhere includes pedestrianisation and new cycle routes and other facilities.

A1.3 Vienna

General description of the city
Vienna is the capital city of Austria. It is the principal centre for government, finance and legislation of Austria, a regional shopping centre, a focus for culture and industry, and contains a concentration of universities. The traditional city centre, the many famous buildings and cultural associations have made Vienna a major centre for tourism.

Table A1. The population, area and population density for different zones in Vienna.

Zone	Population	Area (Ha)	Density (Person/Ha)
City Centre	18 002	301	59.81
Inside Districts	385 933	3 711	103.99
Outside Districts	828 038	19 248	43.02
Wide-area Districts	307 875	17 348	17.75
Total	1 539 848	40 609	37.92

Source : Statistiches Jahrbuch der Stadt Wien, 1993, Tab. 1.08., 2.02, 2.03.E.

Around 80 % of households own cars.

Transportation system
The city road network includes three ring roads and a north-south and east-west motorway. Reorganisation of the road network has been in planning to restructure the network based upon

its function (PT main streets, Private car main streets, and PT/Private car main streets). Most public transport is by metro and trams supplemented by urban rail services and buses. Vienna public transport modes are: tram, bus, underground, commuter train, regional train and bus. The city centre is mostly pedestrianised.

Around 37 % of all trips are made by car, 37 % on public transport and the rest are as pedestrians and cyclists.

Transport policy measures
Several measures for reducing car traffic in the city centre and promoting public transport, walking and cycling have been introduced already since 1970s in Vienna. Large pedestrian areas, wide and/or raised footpaths were needed and a wide cycle path network has been introduced. Also public transport has been promoted by continuous upkeep and construction, reserving separated lanes, giving priority at intersections as well as pricing policy and information.

Also necessary car traffic has been taken care of by restructuring the road network, by building parking garages and park and ride facilities, by reducing on-street parking and by increasing levels of parking charge.

A1.4 Eisenstadt

General description of the city
Eisenstadt is the capital of the province of Burgenland, one of the 9 provinces in Austria. The study area includes the whole of the city. Eisenstadt is the principal centre for local government, an education centre, and also a regional shopping centre. Tourism has increased through publicity as the City of Haydn. The city centre is a traditional shopping area and has the largest pedestrian zone (2.1 m^2 / person) in Austria. The city of Eisenstadt is a very rare case in that the city makes a profit out of the traffic system.

Eisenstadt has a relatively small developed area and low population density. Car ownership is 0.66 cars per person and 1.66 cars per household.

Table A2. The population, area, and population density for the zones of Eisenstadt.

Zone	Population	Area (Ha)	Density (Person/Ha)
City Centre	767	66	11.63
Central city area	2 584	162	15.97
Residential area	3 521	741	4.75
Distinct town centres	3 037	2 432	1.25
Business/Industrial area	440	889	0.49
Total	10 349	4 290	2.41

Transportation system
Eisenstadt has a large pedestrian zone, a city taxi system in operation 24 hours a day as public transport, supported by regional buses and rail. The network of the study area includes the nearby motorways and the main street.

Transport policy measures
Car traffic in the centre of Eisenstadt has been restricted by severe parking policy and land use measures by dedicating a separate area for commerce and industry use. Public transport has been promoted by introducing a single tariff for all modes and integrating and improving PT

operation. A speciality of Eisenstadt is a city taxi system which is highly subsidised.

A1.5 Helsinki MA

General description of the city
Helsinki, the capital city of Finland, lies in Southern Finland by the Gulf of Finland in the Baltic Sea. It is surrounded by three other cities: Espoo, Kauniainen and Vantaa; and they together form the Helsinki Metropolitan Area, which is the study area. The old city centre of Helsinki lies on a peninsula which has its influence on the traffic system.

Table A3. The population, area, and population density for Helsinki MA.

	Population		Area (land)	Population density
	1995	1990	hectares	inh./ha 1995
Helsinki	525 031	492 400	18 450	28.53
Espoo	191 247	72 629	31 190	6.15
Kauniainen	8 298	7 889	590	14.07
Vantaa	166 480	154 933	24 080	6.94
Total	891 056	827 851	74 310	11.99

Car ownership is one of the lowest in Finland, at 320 cars/1000 inhabitants. Slightly over 60 % of households have a car at their disposal.

Transportation system
The road network creates a system of seven radial and two orbital roads. The public transport trunk network is based on both rail traffic and buses. There are three local railway lines and one metro line radial to the city centre. Only the western corridor relies on buses only. In the inner city there are seven tram lines as well. The public transport system operates very well.

In Helsinki MA 47 % of all trips are made by car, 29 % on public transport and 24 % as pedestrians or cyclists.

Transport policy measures
Helsinki has determinedly promoted public transport to keep it in a competitive position with private car. The means have been introducing new lines, improving frequency, speed and reliability, a simple price system, subsidies and especially good information with timetable booklets delivered free of charge to each household in the area.

A very strict parking policy in the city centre is the main measure for restraining unwanted car traffic. Traffic calming using several measures has been implemented in residential areas both in the inner city and suburbs. Cycling and walking have been promoted by ongoing construction of separate lanes for non motorised traffic all over the area. Also good and safe parking facilities especially for park and ride are under development.

A1.6 Torino MA

General description of the city
Torino is a regional capital. It is one of the most industrialised cities of Italy. Torino Metropolitan Area is composed of Torino and 22 municipalities of the conurbation.

Table A4. The population, area, and population density for Torino.

	Population (1995)	Area (ha)	Density (inh./ha)
Torino	924161	13017	71.0
Belt	529667	48208	11.0
Total	1453828	61225	23.7

Car ownership in 1992 in Torino was 0.63 cars per inhabitant (from ACI data).

Transportation system
The available means of public transport in the area are a railway system used principally by commuters and for long distance trips, and the public transport system for urban and suburban trips which has 79 lines (11 of which are tramway lines and the remainder bus).

The public transport share of motorised trips in Torino MA is 23 %, but 39 % for trips made inside Torino city itself.

Transport policy measures
In Torino many measures have already been implemented to improve the efficiency of the transportation system of the city, save time and decrease pollution and noise. There is a city-wide traffic control system with public transport priorities, streets and lanes reserved for PT and pricing measures used to encourage PT and reduce long-stay parking in the centre. The most powerful measure was introduced in 1990, namely the Traffic Limited Zone where no private car traffic is allowed without a permit between 7.30 am and 1.00 pm.

Public transport network extensions are planned for especially all rail modes, light rail, tram and metro. A park and ride system will be introduced.

The ongoing large 5T-project in Torino (Telematic Technologies for Transport and Traffic in Torino) is a great step forward in developing and controlling the transport system.

A1.7 Salerno

General description of the city
Salerno lies on the Tyrenian Sea, not far from Naples. It is a typical Italian medium-sized city: it has a large concentration of activities and movements towards the central zones, a rather homogeneous daily distribution of mobility with three peaks at 8.00 a.m., at 1.00 p.m. and at 8.00 p.m., and finally a significant quota of movements to and from with the outlying areas that account for 50% of all movements.

Table A5. Population by zone in Salerno (1981 Census):

ZONE	POPULATION	%
centre	26915	17
central area	82746	53
suburban area	36105	23
peripheral area	11619	7
TOTAL	157385	100

Population density in Salerno is 26.2 inhabitants per hectare and car ownership is around 0.4

cars per inhabitant.

Transportation system
The modal split for internal trips is 40 % by car, 7 % by public transport, 6 % on bicycle and 47 % on foot. For commuters the modal split is 77 % by car, 19 % by bus and 4 % by train.

Transport policy measures
Salerno is at the moment at the planning stage of introducing transport policy measures. It envisages improving public transport by new investments, lane separation, information, promoting walking and cycling by good facilities and making car traffic smoother by increasing road capacity and off-street parking places.

A1.8 Oslo MA

Oslo is the capital city of Norway. The green belt areas in the north and east of Oslo combined with the Oslo Fjord result in three corridors leading to the central parts of Oslo. Oslo Metropolitan Area, which is the study area, includes the city itself and the county of Akershus consisting of several municipalities. It is by far the greatest metropolitan area of Norway with a population of 918 500.

Table A6. The population, area and population density for the zones of Oslo MA.

Zone		Area (hectares)	Population	Inhabitants/hectare
1	Central business district	259	2000	8
2	Inner city	2306	143000	62
3	Outer city west	3789	97000	26
4	Outer city east	8940	240000	27
5	Green belt	30104	1500	0.05
6	Akershus	491600	434000	1

Transportation system

The available means of transport in Oslo MA are walking, cycling and car (driver and passenger), and the following public modes: bus, tram/light rail, metro, railway, boat and taxi.

The metro system comprises 100 km of track in an 8-armed star structure, on which 5 lines are operated. Oslo is also the hub of the Norwegian rail system, with lines to the west, north, east and south. The length of tramway lines is 128 km. The structure of the trunk road system is three orbital rings and five radials, concentrated in three corridors: west, east and south.

The modal split in the area is car 62 % of the trips, public transport 16.4 % and slow modes (walk and cycle) 21.6%.

Transport policy measures
A variety of transport policy measures are in use in Oslo. These include a highway construction plan for the period 1988-2007, partly financed by a toll ring. Bus lanes on the new and old highways are an important part of this policy. A new airport is being built, and a high speed rail connection is to secure a high share of public transport to the airport. The metro system has been constantly improved, and measures such as signal prioritisation and own rights of way are taken

to increase journey speed of buses and tramways. On the other hand, traffic calming measures has been introduced in most residential areas. Parking policy has been restrictive in the inner city. Public transport fares policy has been changing, from rather big increases in the ‘80s to stable fares in the ‘90s. A unitary fare system for the whole region exists, and is shortly to be improved by electronic ticketing.

There are high taxes both on cars and fuel in Norway. The major feature of the land use policy is the ban on building in the green belt area.

A1.9 Tromsø

General description of the city
Tromsø is a regional centre with a large hospital and several educational centres. The topology of Tromsø is special, with a large part of the town area on an island with bridges to both sides, and with steep hills and distinctive ribbonlike stretches of built up areas along the coast lines.

Table A7. The population and working places for the zones of Tromsø (1996).

	Population	Students	Working places
City centre	4147	0	9459
Tromsø island (rest)	24210	8713	16585
Mainland	13696	0	2079
Kvaløya	6784	0	1074
Other	7778	0	717
Total	56615	8713	29914

The average population density is 0.26 inhabitants per hectare. Car ownership was 0.382 cars per inhabitant in 1990.

Transportation system
The available motorised means of transport are local and regional bus lines, private car and taxi.

54% of trips are made as car driver, 10% as car passenger, 14% by bus and 22% by walking and cycling.

Transport policy measures
Tromsø lies on an island and thus is physically separated from mainland. There are two special provisions; the first one is a local fuel tax for road construction and the second a private road tunnel crossing the island financed by toll collection. There is also another road tunnel crossing the Tromsø strait implemented by national and local authorities and a third tunnel for reducing overground car traffic is under consideration.

Promoting public transport and restricting car traffic using parking policies are under preparation.