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1. INTRODUCTION AND BACKGROUND

1.1 Introduction to Part 2

The final report of project FATIMA is presented in two parts. Part 1 contains a summary of the FATIMA method and sets out the key recommendations in terms of policies and optimisation methodology from both project OPTIMA and project FATIMA. Part 1 is thus directed particularly towards policy makers. Part 2 contains the details of the methodology, including the formulation of the objective functions, the optimisation process, the resulting optimal strategies under the various objective function regimes and a summary of the feasibility and acceptability of the optimal strategies based on consultations with the city authorities. This part is thus mainly aimed at the professional in transport planning and modelling.

1.2 Options for private finance in transport

1.2.1 General

The concept of using private finance for transport has become more important in recent years, in particular because of constraints on public sector spending. This is the key issue underlying project FATIMA.

The private sector can contribute to the transport system in several ways:

- A tax can be imposed, reflecting the broad transport benefits obtained by the private sector; the French *Versement Transport* is an example.
- A more focused charge can be levied reflecting the specific transport benefits obtained by a particular property; the US concept of 'value capture' is based on this principle.
- The private sector can be involved directly in financing a new investment, as happens with many rail projects, with the operator of the infrastructure repaying the loan over its life.
- The private sector can be involved in operation, with the private sector operator obtaining its revenue directly from the user.

The first two of these have no direct effect on the specification of a transport strategy, but may well help to make the strategy financially feasible. The third introduces the impact of private sector objectives, which will emphasise a financial return on investment in the specific measures covered. In this case, the private sector may be more willing to invest in certain types of project than others, and this could bias the specification of the strategy. In the fourth case the charges on users, through fares, parking charges or road use charges and tolls, will be determined in part to maximise revenue, and this can significantly affect the performance of the overall strategy. For example, higher fares designed to produce a return on investment in a new urban rail system may reduce patronage and hence the contribution to congestion relief and environmental protection.

1.2.2 What is private finance and why use it?

The financing of a project can be said to be purely private if

- the private party runs all risks, and
- the investment is paid directly by its users, and
- the operation is based on user charges.

A key objective of private financing is to overcome the shortage of public funding, which constrains the range of possible transport strategies.

The private sector usually seeks for commercial profit that can be gained either as income from investment interests, or as value capture through an improvement in the transport system. Furthermore, despite higher cost of capital raised from commercial sources and the need to cover the risks and gaining commercial profit, it has been argued that the overall cost for the community could be lower with private financing, than if the government provides the facilities from taxation funds. If this is so, it would be due to the efficiency in management of capital and manpower that results from the profit motive of private enterprises.

The following objectives for private financing of infrastructure projects have been identified:

- minimisation of the impact of additional taxation, debt burden or financial guarantees on the finances of the government;
- introduction of the benefits of private sector management and control techniques in the construction and operational phases of the projects;
- promotion of private entrepreneurial initiative and innovation in infrastructure projects;
- increase in the financial resources that might be available for the projects.

In addition to the commercial profit that is dependent on the investment time, interest rates and risk management, participation in financing of the transport system can bring value capture benefits to the investor. Value capture appears as private contributions that result in increase in property values, attraction of customers, facilitation of employee’s travel to work and provision of cheaper and more reliable transport opportunities. Benefit sharing mechanisms can be grouped into two categories; land development or leasing arrangements and direct charges on benefiting parties.

1.2.3 Risks

The major issue in involving private financing for transport infrastructure investments concerns the sharing of risk. Investments in infrastructure include, like all investments, various types of risks. Because of the long time periods included, these risks may be very high. The following main classes of risk may be distinguished:

- political risks; for example, changes in transport policy, nationalisation, intervention/regulation by the government, etc.;

- financial risks; for example, fluctuations in interest rates, fluctuations in exchange rates, wrong expectations about inflation, etc.;
- construction risks; for example, delays, unexpected and higher costs etc.;
- operational risks; for example, damage by accidents, vandalism, demand shortfalls, etc.;
- commercial risks; for example, wrong cost estimates, wrong estimates of the traffic volume, unexpected competition, etc.

These risks may make the private investor generally more conscious of the necessity of efficient forecasting and appraisal techniques than the public sector, because transport projects have often been subject to cost overruns and delays. These, together with inadequate forecasts for the future, have previously resulted in low levels of interest by the private sector. It is also believed that, generally, investment in transport infrastructure is seen as having a higher risk than investment in other types of projects

1.2.4 Division of responsibility

Almost all European transport infrastructure has been financed and operated by governments or by public organisations tied to the government. In the case of railways in Sweden, Norway, Switzerland and the United Kingdom, there is at present a trend to separate the financing and operation of infrastructure. In this approach, the management and financing of infrastructure are under responsibility of the government. The operation takes place on a private basis, where the operator imposes user charges. In this situation there may be several suppliers of transport services, which allows competition. This model corresponds to recent EU regulations and is proposed or under discussion in several countries (Germany, Italy and the Netherlands).

The private sector is not always willing wholly to finance urban transport infrastructure due to the risks involved in recovering the high start-up costs, so public-private partnerships are often used, particularly through franchising agreements.

Franchising is a way of organising public-private partnerships. A franchise can be defined as a contract between a transport authority (the franchiser) and a private company (the franchisee), by which the latter obtains the right to operate a transport system, facility or service. Granting of an exclusive operating franchise is an incentive to operate the service without fear of competition for sufficient time to recuperate the investment and make a profit. Under a conventional franchise contract, the franchisee pays the franchiser for using his property rights. In the case of transport infrastructure, this situation may be reversed: the transport authority may compensate the private company for an expected operational deficit. These franchise contracts may be distributed by means of tendering. There may be two different kinds of contracts: a given transport system, facility or service is transferred to the company which offers to operate it at the lowest costs; alternatively, the contract is transferred to the company which offers the best transport system for a given budget. Such systems need detailed agreement on service levels and operating conditions, in order to meet both efficiency and equity criteria and other transport objectives. The following approaches to franchising may be identified:

- BOT: Build-Operate-Transfer (the usual approach: facility paid for by the investor/franchisee but is owned by the concessionaire/franchiser; the investor maintains and operates the facility during the concession period and then transfers ownership back to the franchiser), with the following variants:
- BOO: Build-Own-Operate: Investor retains ownership, operates in perpetuity via an open-ended franchise;
- DBOT: Design-Build-Operate-Transfer: as BOT, with the franchisee also designing the scheme;
- DBOO: Design-Build-Own-Operate: as BOO, but the franchisee also designs the scheme. (This is known as DBFO – Design-Build-Finance-Operate – in the UK);
- BOOS: Build-Own-Operate-Sell: at the end of the franchise period the state pays a (residual) value to the franchisee;
- BOOT: Build-Own-Operate-Transfer: as BOOS, without terminal payment;
- BOTT: Build-Operate-Training-Transfer: investor is required to provide training before the facility is transferred (mainly for developing countries).

Regarding public transport, when introducing competition to the public transport system, the authorities have to take into account scale economies, market size and the social service requirements of the system. Selection of the form of competition for public transport is a matter of finding the best combination of different objectives of government authorities, the technical and economic characteristics of the supplying modes, the nature of the local market demands, and what can be afforded, both by individuals and governments. The critical factor is the introduction of effective competition. The competition in the public transport system can be arranged in many ways, for example:

- concessions;
- comprehensive competitive tendering of service packages;
- competitive tendering of subsidised services; or
- completely free entry to the market.

The choice depends on technology, city size and complexity, environmental and distributional policy issues and the administrative capability of authorities. It is widely accepted that private sector participation needs to be part of a phased, comprehensive reform. This reform includes separation of regulatory and operational functions, liberalisation of entry, corporatization of former state enterprises and the consideration of appropriate systems of regulation.

In terms of public transport regulation, it is important to distinguish between two basic types of regime. Firstly there is a regime in which the public authorities set the policy (e.g. the levels of fare and frequency) and secondly there is a regime in which private operators are free to do so. In the latter case there is a distinction as to whether a perfect market is operating or whether the operators are monopoly providers, either informally or formally (through franchising). Although these distinctions are particularly relevant for public transport, they can also be used when considering the private financing of other sectors.

Public/private partnerships in general have the potential for creating synergy between the public service culture and the entrepreneurial approach. It is possible to specify five desirable features for a successful public/private partnership. These features are:

- a joint interest in delivering an effective service;
- a co-operative effort, with clear division of responsibility;
- shared cost and revenue relationships, with more flexibility than if the public sector operates alone;
- private sector interest in the well-being of the customer and quality of service;
- public sector concern for the wider public interest, especially the well-being of non-users.

These and other issues regarding the use of private finance in transport were reviewed as an early part of the FATIMA project, the review providing the basis for the development of a range of objective functions against which to assess integrated transport strategies. These objective functions are set out in the following section.

2. DEFINITION OF OBJECTIVE FUNCTIONS

2.1 Overview of objective functions

The objective functions used in FATIMA were arrived at through a review of current practice and future opportunities in private financing of transport, starting from the acknowledgement that public finance for transport is currently scarce. Information for the review was obtained through a literature search and from interviews with public officials, politicians and representatives of private companies. Based on this review, the FATIMA project defined a range of objective functions to be used in the modelling process, and these are described below.

Essentially, five new objective functions were defined for FATIMA; three of these corresponded to regimes in which private involvement is regulated by the city authority and two objective functions correspond to regimes in which private involvement is deregulated. Before defining these objective functions (in Sections 2.6 to 2.10), some preliminary definitions are given (in Sections 2.2 to 2.5) of components of the functions. A fuller specification of all the objective functions is given in Minken (1998).

2.2 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 FATIMA 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 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.

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

where: u is the net benefit to transport users in the target year, compared with the do-minimum scenario, calculated as described above;
and f, r are as described in Section 2.2.

The formula for EEF is then:

(2.3) EEF = B - I + 0.25PVF

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. This reflects the efficiency loss involved in raising extra taxes. The shadow price is identical to that used in OPTIMA and is justified there (OPTIMA 1997). However, while OPTIMA only applied it to negative values of PVF, in FATIMA it has been applied to both positive and negative values of PVF.

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

EEF = NPV + 0.25PVF

2.4 Economic Efficiency Objective Function with external costs (EEFP)

EEFP is an extension of the economic efficiency objective function EEF including external costs for pollution, noise and accidents.

(2.4) EEFP = EEF - EC

where EC = Change in external costs from the do-minimum

The external cost indicator for each mode is the sum of accident cost, noise cost and pollution costs per vehicle kilometre, times the number of vehicle kilometres for that mode. It is calculated for each strategy based on the vehicle kilometres of the mode in question as it is output from the transport model. Tinch (1995) is taken as the basis for the unit cost of accidents, noise and pollution of each mode. It is however necessary to adjust these values to the specific conditions of each city, such as population density (determining the number of people exposed to noise and pollution) and meteorological conditions (determining the stock of pollutant in the air of the city that results from a particular level of emission). The overall risks of accidents per vehicle kilometre may also differ between the cities, depending on average speed, the separation of walking and cycling from other modes etc. Summing over all modes gives us the external cost indicator EC for each strategy. Walking and cycling are however not assumed to have external costs.

Expressing the external costs of each mode as a function of vehicle kilometres or total fuel consumption means that we are unable to model the benefits of rerouting traffic to less densely populated streets or parts of the city, or of separating motorised and non-motorised traffic. It may even be that such measures increase total kilometerage, and will count as disbenefits in our calculations. However, as traffic calming in residential areas is supposed to be carried out in all strategies, we consider that such rerouting effects can be ignored at the strategic level of the FATIMA study.

Our external cost indicator does not take into account the changes in average driving conditions brought about by a transport strategy, such as lengthening or shortening of peak hours, increase or decrease of average speed etc. As fuel consumption per vehicle kilometre, and thereby also pollution, is dependent on speed, this is a limitation.

Our indicators of pollution costs are only indicators of the costs of the city-wide or regional air pollution levels that result from a total level of transport and a certain modal split within the city, and cannot mirror changes at the level of particular locations within the city. The same applies to noise, but as noise is a very local impact, and strictly speaking has no city-wide effects, our noise indicator will have further limitations. Finally, accident costs are obviously not a simple function of kilometerage only, but depend very much on various accident prevention measures and on speed. It will have to be assumed that appropriate accident prevention measures are taken in all strategies.

While there are thus limitations in relating the costs of pollution, noise and accidents solely to changes in vehicle-kilometres, we concluded that, at a strategic level, this was a reasonable approximation. It was in any case imposed on us, since not all models were able to predict these impacts directly.

Let γ_{am}, γ_{nm} and γ_{pm} be the city specific costs per vehicle kilometre in mode m from accidents, noise and pollution respectively. Let k_{mi} be the vehicle kilometres by mode m in strategy number i in the test year. Our external cost indicator EC for strategy number i is:

(2.5) $$EC_i = \delta \sum_m \gamma_m k_{mi}$$

where $\gamma_m = \gamma_{am} + \gamma_{nm} + \gamma_{pm}$

and $\delta = \sum_{i=1}^{30} \frac{1}{(1+r)^i}$

Thus we form a composite external cost per vehicle kilometre for each mode, and sum costs over modes. Finally, we use the discount factor δ to make EC a present value.

The γ*δ values are shown in the following table. Edinburgh, Merseyside, Helsinki, Torino and Salerno used the Tinch-values (Tinch, 1995). For accidents, Vienna and Eisenstadt used their own calculated values with veh-km as the basis and for noise and pollution the Tinch-values as in other cities. The accident data for Eisenstadt showed a much higher rate was required compared to Vienna for car but that the reported rate for bus tended towards zero.

In Table 1 Helsinki has used its own values mainly for car noise and bus accidents (also tramway, train and metro differ slightly). Otherwise, the Tinch values were used because they were so close to the values that could be obtained from Helsinki's own research on pollution and accidents. The differences are due to relational effects between the modes based on that own research. The low car noise can be explained with the low population density outside the city and the bus accident cost happens to be low because normally injuries are minor.

The relatively low noise and pollution values for Tromsø are because of the weather conditions in the town and because Tromsø is not densely populated. People also mainly live quite a distance from the main roads. Tromsø also has relatively few big and complicated intersections. It is considered quite safe to be a pedestrian and cyclist in Tromsø. This is reflected in the accident figure for Tromsø.

The Gamma values for Oslo and Tromsø are generally some average of the Tinch values and some values from a Norwegian study Eriksen og Hovi (1995). The noise value for Oslo is low as the area is predominantly rural with low population density which therefore lowers the mean noise values.

	Edinburgh, M'side, Salerno, Torino	Vienna	Eisenstadt	Helsinki	Oslo	Tromsø
Dimension	[ECU/veh-km]	[ECU/veh-km]	[ECU/veh-km]	[ECU/veh-km]	[ECU/veh-km]	[ECU/veh-km]
Pollution						
Car	0.0275	0.0275	0.0275	0.027	0.016	0.0024
Bus	0.2176	0.0547[1]	0.2176	0.218	0.064	0.0096
Tramway	0.0	0.0547[1]	n.a	0.0	0.0	n.a.
Noise						
Car	0.0373	0.0373	0.0373	0.019	0.004	0.002
Bus	0.0746	0.0643[1]	0.0746	0.075	0.024	0.012
Tramway	0.0622	0.0643[1]	n.a.	0.075	0.028	n.a.
Train				0.063	0.032	
Metro				0.05	0.028	
Accidents						
Car	0.0222	0.0404	0.1680	0.023	0.016	0.012
Bus	0.0453	0.0135[1]	0.0001	0.023	0.0528	0.0396
Tramway	0.0453	0.0135[1]	n.a.	0.045	0.1024	n.a.
Train					0.0008	
Metro					0.00056	

[1] ***Includes all public transport for Vienna***

Table 1: Pollution, noise and accident costs per veh/km (γ-values) used in different cities

2.5 Sustainability Objective Function (SOF)

The sustainability objective function (SOF), which was fully defined in the OPTIMA project, is given by:

(2.6) $SOF = (1+\lambda)^* f + u - y + \text{hard penalty}$ (if fuel consumption exceeds do-minimum)

$(1+\lambda)^* f + u - y$ (otherwise)

where: y is a "soft penalty" on fuel consumption in the target year, calculated by multiplying the fuel consumption cost (relative to the do-minimum strategy) by a shadow price of 4;
"hard penalty" is a large negative number that ensures that optimal SOF policy will have less fuel consumption than the do-minimum;
u, f and λ are as defined above.

The main intention of the soft and hard penalties on fuel consumption is to generate "optimal" transport policies that preserve natural resources. The use of a hard penalty effectively ensures that such policies must use less fuel than those envisaged by the do-minimum transport strategy.

The SOF does not explicitly take into account external costs of the type calculated by EC above. The rationale for this approach is that the issue of external costs is catered for by the soft and hard penalties on fuel consumption. However, it could alternatively be argued that the sole purpose of these constraints is to preserve natural resources, and that air pollution, noise and safety should be considered separately. This issue is examined in the section on sensitivity tests on γ in Section 8.

The use of λ in SOF is entirely analogous to its use in EEFP as described above.

2.6 Benchmark Objective Function (BOF)

BOF (Benchmark Objective Function) is a combination of EEFP and SOF which balances the perspectives of current and future generations.

It is defined as:

$$(2.7) \quad BOF = \alpha EEFP + (1 - \alpha) SOF$$

For the main tests in FATIMA, α was set at 0.1. Since SOF is only concerned with a single target year whilst EEFP is concerned with a (discounted) period of 30 years, it follows that the size of EEFP will be approximately ten times[1] the size of SOF. Thus a value of 0.1 for α was chosen to ensure that the perspective of a future generation have approximately the same weight as the perspective of the present generation. Since α was a "new parameter" created by the FATIMA project, no previous literature can be cited as to its "best" value.

In some respects, the use of BOF (with a suitable value of α) is analogous to setting the discount rate r at 0, in the sense that both approaches put greater emphasis on the benefits and costs of future generations (than in a standard cost benefit analysis). However, BOF has the extra element of restricting fuel consumption (from its SOF component), and in particular specifies that fuel consumption should be less than in the do-minimum strategy.

2.7 Constrained Objective Function (COF)

COF (Constrained Objective Function) is an extension of BOF that takes into account that there is a fixed constraint on public money. For the sake of simplicity, it is assumed that public finance is constrained to the level implied in the do-minimum scenario.

$$(2.8) \qquad COF = BOF \text{ if } PVF > 0$$

[1] In fact, EEFP will be approximately δ times the size of SOF, where δ is defined by Equation 4.

= BOF + hard penalty if PVF < 0

2.8 Regulated Objective Function (ROF)

ROF (Regulated Objective Function) is an extension of COF, and recognises that extra (private) finance can be input to the transport system through value capture (VC). The transport system is regulated in the sense that the private finance has no direct control over the levels at which fares, frequencies, road pricing etc are set, which remain firmly under overall public control.

VC is defined as a proportion β of user benefits, which are seen as a measure of overall accessibility. The logic here is that companies in the city should (collectively) be prepared to pay for overall city-wide accessibility due to the benefits that they gain from this in terms of: efficiency of commuter trips and business trips, inward investment (due to city attractiveness) and general city regeneration. The political issue as to whether VC should be raised by compulsory means (through taxes) or voluntary means was not dealt with in FATIMA.

(2.9) ROF = BOF if PVF + VC > 0
= BOF + hard penalty if PVF + VC < 0

where:

(2.10) VC = $\beta * \delta * u$ if u > 0
= 0 otherwise

and where δ is as defined above.

For the main tests in FATIMA, β was set at 0.1. Since β was another "new" parameter defined by the FATIMA project, there has been no previous literature about a "best" value.

2.9 Deregulated Objective Function (DOF)

DOF (Deregulated Objective Function) is an extension of COF. It assumes that control of public transport is handed over to the private sector, who are free to set fares and frequencies, and to take any profits that result. On the other hand, there are no public subsidies for running public transport. The other measures in the transport system (road pricing, parking charges and road capacity changes) are assumed to stay under public control.

The public transport market is assumed to be an imperfectly contestable market (i.e. somewhere between a perfect market and a monopolistic situation). Under these conditions, the Internal Rate of Return (IRR) for the public transport market is assumed to be close to 15%.

(2.11) DOF = BOF + (penalty(IRR) if IRR_{PT} is not 15%) if PVF* > 0

= BOF + hard penalty if PVF* < 0

where: PVF* is the PVF for all publicly controlled transport sectors;
IRR_{PT} is the Internal Rate of Return for public transport;
penalty(IRR) increases as IRR_{PT} diverges from 15%.

2.10 Half regulated Objective Function (HOF)

HOF (Half-regulated Objective Function) is an extension of DOF, loosening the rule on subsidy for public transport. Under HOF, subsidies can be paid for public transport when in private control, subject to PVF* being positive. The precise purpose/mechanism for providing subsidy will vary between each city. However two examples are:

- Subsidy is paid for off-peak public transport
- Subsidy is paid to help finance the investment costs of public transport infrastructure

The assumption about profits to the private sector is the same as in DOF. Thus subsidy is not being used to increase private profits but (hopefully) to improve social benefit.

(2.12) HOF = BOF + (penalty(IRR) if IRR_{PT} is not 15%) if PVF*-S > 0
= BOF + hard penalty if PVF*-S < 0

where: S is a subsidy paid to the private sector for running public transport.
PVF*, IRR_{PT} and penalty(IRR) are as defined above.

2.11 City specific definitions of HOF

- **Edinburgh, Vienna, Eisenstadt, Oslo, Tromsø, and Helsinki :**

  In the subsidised half regulated regime (function HOF) the subsidy was assumed to be available for increasing frequency, reducing fares and implementing infrastructure.

  The subsidy requirement was calculated such that the public transport sector received a return of 15%, this subsidy was however subject to public funds being available i.e. the public PVF must be greater than or equal to zero after paying the subsidy.

- **Merseyside:**

Two HOF objective functions were used in the Merseyside case study:

1. The standard HOF as used in other case studies.

2. HOF1 is a Merseyside-specific definition of HOF for the Merseyside case study.

To understand HOF1 (in Merseyside), it must be remembered that public transport provision in all FATIMA case studies must be at least at a level of 50% of the do minimum scenario (i.e. the maximum decrease is 50%). HOF1 is then defined in Merseyside to be the same as DOF except that there is a possibility of public subsidy to operators if they run a higher frequency than the minimum level. This subsidy is calculated as the cost of the "extra" frequency, subject to the condition that the public PVF must always be positive.

- **Torino and Salerno:**

  In HOF it is supposed that the government will pay for the infrastructure (M and H) mainly if there is the construction of an underground. Furthermore a positive PVF* can be used freely as subsidy i.e. there is no restriction on subsidising operating costs as under COF and ROF.

2.12 Non-modelled benefits and disbenefits

Having described the regimes for regulated and deregulated systems it is necessary to note areas which are not modelled in FATIMA and which in reality may bring benefits or disbenefits to each regime. Those elements purposely not modelled are :-

- changes in efficiency (e.g. operating costs)
- attitudes towards risk in finance terms
- non-uniform changes to PT services
- payment of interest on loans
- quality of service
- incentives
- possible changes in vehicle size.

Each of the above was either difficult to implement within the models used or there was not sufficient evidence in the literature about the effects of private operation and deregulation to form assumptions for modelling the effects. For a fuller discussion see Minken (1998).

3. POLICY MEASURES

3.1 Summary of measures

There is a categorisation of measures into: infrastructure measures, management measures and pricing measures[1]. An initial list of all possible measures was generated from an international review in the previous project OPTIMA, which included also practice in EU countries not included in the project. The FATIMA list of policy measures is a refinement of the OPTIMA list, taking into account the response from city authorities in OPTIMA. From this list of measures, a condensed

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

common set of measures was identified for use in the optimisation process. This set is presented in Section 3.2, along with the cost assumptions made for the measures.

3.2 Measures tested in the optimisation process

Table 2 shows the measures used in the optimisation process 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 could be) controlled by the city authorities.

In most of the cities a subdivision into long-term and short-term parking charges and peak and off-peak values was made. The ranges for all these measures were as given in Table 2.

Tables 3 and 4 show the assumed costs used in the calculation of the objective functions. These costs are based upon currently used costs in the cities for the purposes of cost benefit analysis and are improvements on the OPTIMA estimates.

Table 3 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 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 negligible costs for road capacity changes, this expectation is borne out. However, there is clearly wide variation amongst the larger cities.

Table 4 shows the annual operating costs (in each of the nine cities) for public transport frequency changes and road pricing. It can be seen by comparing Table 3 and Table 4 that (with the exception of Merseyside) road capacity increases were generally costed at a much lower level than public transport infrastructure. Furthermore, 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. The operating costs of road pricing are based on city assumptions with the exception of Oslo where the figures are actual.

Abbreviation	Name	Minimum Value	Maximum Value
IH	High public transport infrastructure investment (rail or light rail based)	0	1
IM	Medium public transport infrastructure investment (bus based)	0	1
CAP	Increasing/decreasing of road capacity (whole city/town)	-20%	+10%
FREQ	Increasing/decreasing public transport frequency	-50% -30% for Torino	+100% +30% for Torino
RP	Road pricing #	0	5 ecus
PCH	Increasing/decreasing parking charges	-100%	+300% +100% for Torino
FARE	Increasing/decreasing public transport fares	-100% -50% for Helsinki	+100%

 # The value of the measure Road Pricing refers to the cost per trip incurred to the car driver (typically into a city centre)

Table 2: Measures tested

Road capacity changes	Edinburgh	M’side	Vienna	Eisen-stadt	Tromsø	Oslo	Helsinki	Torino	Salerno
-20%	34	55	80	7	12	93	20	24	0.04
-10%	15	28	20	2	6	46	10	12	0.02
-5%	2	14	6	0.5	3	23	5		0.01
+5%	2	28	54	0.1	6	46	15	24	5
+10%	15	55	218	0.4	12	93	30	48	10
P.T. infrastructure									
High p.t. infrastructure	564	360	4254	*	*	*	550	3459	45
Medium p.t. infrastructure	35	40	2127	*	*	185	*	671	0.5
Road pricing	2	4	33	3	0	0	7	3	1
P.T. Frequency with no infrastructure									
-50	0	-3.75	-387	-0.07	-5.6	0	-248		0
-30									
+30									
+50	3.99	3.75				44	275		5
+100	7.97	7.5	3015	1.77	13.2		550		
P.T. Frequency with Medium infrastructure									
-50		16.25					-300		
-30								614	
+30								791	
+50							325		
+100		87.5					650		
P.T. Frequency with High infrastructure									
-50									
-30								3052	
+30								3532	

* *indicates “not costed”*

Table 3: 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%			-19	-1		-170		-69#	-3.6
+50%			+163	+1		+168		+54#	+3.6
+100%			+326	+2		+340		*	*
p.t. frequency (peak) with IM[6]									
-50%		-14					-20		
+50%							+43		
+100%		+29					+85		
p.t. frequency (off-peak) with IM[6]									
-50%		-55					-45		
+100%		+110					+190		
p.t. frequency (peak) without IM[6]									
-50%	-8[7]	-14			-1.31		-27		
+100%	+15	+29			2.62		+60		
p.t. frequency (off-peak) without IM[6]									
-50%	-9[7]	-55			-2.48		-70		
+100%	+17	+110			4.96		+135		
Road pricing	+1	+1.25	+1	+0.1	+0.89	+9	+0.73	+0.3	+0.1
Road capacity									
-20%									0.02
-10%									0.01
+5%									1.25
+10%									2.4
Parking					0.625				

** indicates "not costed"*

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

6 Infrastructure Medium

7 the operating costs are based upon vehicle-km in the do-minimum peak and off-peak periods

Table 4: Operating costs of new measures (in million ecus per annum).

4. OVERVIEW OF TRANSPORT MODELS USED

The FATIMA project has used several different transportation models. Some of them are implemented with commercial software whilst some are implemented in software packages developed by the FATIMA partners themselves (and already used in OPTIMA). A full description of the models used is given in Appendix A of FATIMA (1998).

The approach taken by FATIMA 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 FATIMA. 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.

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.

Even though strategic models are well suited for optimisation work (such as in OPTIMA), their use is restricted because few cities have a strategic model ready for use.

In FATIMA, 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 FATIMA purposes, there is a need for much aggregation of this output, which can be extremely time-consuming if done manually.

Tactical models are widely available in a large number of European cities to help to design and assess various specific transport schemes.

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

5. RESULTS FOR THE NINE CITIES

5.1 Overview of the Optimisation Method

5.1.1 Edinburgh

The optimisation process for BOF was carried out successfully making use of the regression method as in OPTIMA. There were no major problems in finding regression models for BOF although the regression models did not give information on parking charges and these were adjusted via sensitivity tests.

For Edinburgh the optimal BOF solution has a positive public PVF and therefore the constrained public regimes COF and ROF are also optimal for this set of measures as the budget constraints are not broken. It follows that there was need to calculate separate COF and ROF optimal policies.

In the subsidised private regime (function HOF) the subsidy was calculated so that the public transport sector received a maximum of 15% return if and only if the public purse could afford this from other measures i.e. the subsidy is paid until PVF*=0 or until the PT sector return is 15%. Again the optimal BOF measures provided enough public funds under the private regime to subsidise the private PT sector so that the optimal HOF value is for the same combination of measures.

In the case of DOF it was impossible to form an initial regression model after 27 runs as all except one DOF value were negative and most runs incurred the maximum penalty for deviation from the required 15% internal rate of return. The rates of return were either too high or negative indicating loss making services. Rescaling of the penalty function was attempted but the DOF surface was such that it was either too flat, dominated by high penalties, or with lower penalties the loss making combinations dominated as they have higher BOF values but were infeasible in IRR terms. To overcome these problems another form of penalty was used and introduced in DOF2, based upon the present value of finance of the PT sector calculated at a discount rate of 15%. This penalty is basically a way of searching for more DOF runs with more reasonable rates of return. The PVF(PT) penalty used was a quadratic so that when the PVF(PT) equals zero the penalty is zero which coincides with the zero point of the original IRR penalty function used in DOF. In this way DOF2 was maximised not to find the optimal DOF2 but rather to find more positive DOF values. As can be seen from the results the DOF2 runs have provided a means of locating positive DOF values and eventually enough values were produced so that a regression model for DOF was possible.

5.1.2 Merseyside

The formal optimisation process worked successfully for BOF, while the “formal” optimisation process for COF and ROF was unsuccessful: i.e. it was impossible to find adequate linear regression models. It is likely that this is because the maximum values of COF and ROF are to be found when PVF =0 (in the case of COF) and PVF = -VC (in the case of ROF). When PVF goes below zero, a penalty of -1000 MECU is added to COF; the same penalty is added to ROF when it goes below -VC. It is impossible to find regression functions that can cope with this discontinuity.

The method in fact used to optimise COF and ROF was subjective judgement on the basis of the experience of optimising BOF, since both the former objective functions are based on BOF. The optimisation of BOF showed which transport measures drove the objective functions up or down the hardest. Coupling this information with an awareness of the extra constraints in COF and ROF (on PVF) it was reasonably straightforward to carry out a successful subjective optimisation.

The problems of discontinuities discussed with COF and ROF above are further accentuated in the case of DOF and HOF. Although a formal optimisation approach was initially used, it was abandoned after being unsuccessful. Instead a subjective optimisation approach was used.

5.1.3 Vienna and Eisenstadt

The optimisation of the regulated objective functions did not cause any problems in the optimisation method. The regression models were not difficult to build up and the convergence progress was rather quick. Unlike the regulated objective functions the deregulated objective functions caused some trouble in the optimisation process.

One main problem in optimising DOF and HOF is that the penalising and constraining of the discussed objective functions results in a very jagged multidimensional surface. This makes it hard and with an increasing amount of penalties and constraints even impossible to find an optimum with the regression method alone. Because of the jagged surface the regression model often predicts the optimum in a region which is in reality penalised and therefore highly negative. Thus it is possible that the convergence criteria never could be fulfilled.

A second problem is that the objective function, which should be optimised, and the objective functions of the previous runs (the BOF related ones for DOF and the BOF and DOF related ones for HOF) have their optima in different areas. Therefore the initial runs for DOF and HOF contain many points in useless regions and often it is hard to convince the regression model that the optimum it searches for has a completely different set of policy measures than the previous one.

These problems are arose in both cities. It was in both cities impossible to optimise the objective function DOF with the usual method. Also it was impossible for HOF in Eisenstadt. For the city of Vienna it was still possible to use the regression based method for HOF. Concerning the problems mentioned in the previous paragraph only the 26 initial runs and the runs with positive or nearly positive values for HOF found so far were used as initial runs for the HOF optimisation. For the other cases other methods to find the optimum were used (e.g. with Excel-solver and grid scans).

5.1.4 Oslo

The optimisation process worked successfully for BOF, making use of the regression method as in OPTIMA. The optimum policy was found after use of two regression models, and the convergence criteria were met rather quickly.

Because of the positive PVF in the BOF optimum, the COF and ROF optima are the same as the BOF optimum and so there is no need for separate optimisation of COF and ROF.

The formal optimisation process for DOF was partially successful. The prediction for the mix of policy measures for the DOF optimum after the initial runs was the same as the forecast for the BOF optimum. An internal rate of return of –6 was used for those runs where the calculation of IRR was impossible. After careful study of the previous results, a set of runs were devoted to finding the DOF optimum. A few feasible DOF-optima were found all having internal rates of return close to 15%, but they all have different characteristics regarding public transport fares, frequency and investment.

The runs devoted to the HOF regime were more like sensitivity tests than part of an optimisation process. There is subsidy for fares, frequency and the investment. A number of measure combinations that give lower IRR(DOF) than 15% and that were expected to improve on the policy were tried. The subsidy was set to give 15% IRR(HOF).

5.1.5 Tromsø

The overall optimisation process worked well for the BOF solution. However as the optimum BOF solution resulted in negative PVFs there were few solutions which did not incur the penalty for COF and ROF. This meant that extra runs were used to locate valid COF and ROF solutions, these runs being designed from analysis of previous runs.

A similar problem occurred for DOF and HOF in that there were few runs which were not penalised and so extra runs were again constructed to give positive values.

5.1.6 Helsinki

The results of the optimisation process of three of the five objective functions of the project, namely BOF, COF and ROF for Helsinki MA are given in this document. It was not possible to optimise either DOF or HOF for Helsinki MA because no positive values for the present value of finance of publicly-controlled money (PVF*) was obtained under the constraint of fuel consumption not exceeding the do-minimum level. This is mainly due to the present and do-minimum situation with the high level of subsidised public transport services on the other hand and, on the other hand, to the model structure of the Helsinki tactical model which allows users to change destination in consequence of general cost changes between the destination zones and thus avoid parking fees or road pricing.

The optimisation of BOF was carried out by using the regression method quite successfully. However, some exceptions from the correct use were made on the significance of either of the terms of a variable, either first or second power term, when the other term was strong, to get a hint of some possible intermediate values of the variable concerned. The main direction of the optimisation was not affected by using this method.

Because the optimal BOF solution is highly based on reduced public transport fares and big monetary savings for the users and thus has a big negative PVF the ROF and COF optima had to be found separately. With the inial set of runs the regression showed only to a total zero solution i.e. the present situation. The situation did not get better with any BOF runs made. By coincidence, trying some of our previous runs from a round of optimisation with faulty model behaviour we got positive values for ROF and COF. Using both sensitivity tests and optimisation process confirmed us of the optimal solution.

5.1.7 Salerno

The optimisation process of the city of Salerno follows the “basic method” described in the main part of the report. There is only one change about the criteria of penalising high values of the required government subsidy to public transport.

Italian law requires that the subsidy for the public transport company should not be greater than the 65% of the operational cost of the company (this law is not yet totally applied but will be strictly applied in the future), so a further penalty has been used when such a requirement is not obeyed.

Moreover over-crowding of public transport is taken into account as additional waiting time. If the increase in the public transport demand is not coupled by a sufficient increase of the frequency, some public vehicles can become overcrowded and the users of the lines corresponding to the overcrowded vehicles have to wait for other vehicles spending additional waiting time.

The optimisation process for all the objective functions was carried out using the regression method used in OPTIMA.

At the beginning of the process some problems arose as the objective function values deriving from the regression functions were very high considering the results obtained modelling the first set of runs by means of the transportation model MT.MODEL. Probably these high estimations were due to the fact that the majority of the 18 initial runs had a negative value for all the objective functions and that these values were also strongly negative.

After modelling more runs to find additional scenarios with positive values for the objective function BOF, the optimisation process was re-started and was applied successfully for BOF. The other functions being found by sensitivity tests and partial use of the regression method.

5.1.8 Torino

The optimisation process worked successfully for BOF, COF and ROF, making use of the regression method used in OPTIMA, with the same particular penalty for COF and ROF used for Salerno.

As the PVF is highly positive and the further Italian penalty is equal to zero, the BOF optimum is also the optimum for COF and ROF.

At the beginning of the process some problems arose as the objective function values deriving from the regression functions were all negative; probably this happened because the presence of the road pricing forces the car users to change their route, in such a way greatly to increase their travel time, so the car user benefits are negative and this forces the BOF to a negative value. Another reason for these negative values in some scenarios is the increase of fuel consumption compared to the do-minimum scenario: in these cases the penalty in the SOF function is invoked.

After modelling more runs to find additional scenarios with positive values for the objective function BOF, the optimisation process was re-started and was applied successfully.

For DOF and HOF, on the other hand, the optimum value was found by a partial use of the regression model and by some sensitivity tests, so as to obtain an internal rate of return close to 15%.

5.2 Results

This section presents tables showing the optimal policies under the BOF, COF, ROF, DOF and HOF regimes. Furthermore, various output indicators are given which show the trade-offs involved with optimal policies. These indicators are:

- Mode split of trips by car, public transport and other modes (where available)
- Percentage change in car-km (which serves as a proxy indicator for pollution, fuel consumption, congestion and accidents)
- Values of the objective functions
- PVF for the government sector (giving information about the finance implications of the policy)
- PVF for the private sector under deregulated regimes (showing the benefit to the private sector of deregulation)
- Value capture (which is defined as 10% of user benefits if these are positive)

In general, these indicators are defined as being relative to the do-minimum set of policies in each city. The exception here concerns mode splits, which are absolute figures. It follows that, in order to assess change, the figures for mode splits need also to be presented for the do-minimum strategies. This is done in Table 5. Also included in Table 5 are figures for mode split by distance and the absolute level of car-kms in the do-minimum.

Modal splits	Edinburgh	M'side	Vienna	Eisenstadt	Tromsø	Oslo	Helsinki	Torino[1]	Salerno[1]
MS (trips)-car	63%	62%	39%	45%	73%	68%	46%	57%	59%
MS(trips)-public transport	37%	15%	34%	3%	11%	22%	32%	43%	14%
MS (trips)-others	n/a	23%	27%	52%	16%	10%	22%	n/a	27%
MS-(distance) car	72%	67%	48%	57%	80%	69%	49%	63%	71%
MS-(distance)public transport	28%	15%	43%	4%	12%	25%	43%	37%	19%
MS-(distance) others	n/a	18%	9%	39%	8%	6%	8%	n/a	10%
Car-kms									
Car-km p.a. (millions)	2902		3016	14.3	228	5237	2118	4283	272

1: Italian city results are based upon the peak period only.

Table 5: Modal splits in the do-minimum case

Measures	Edinburgh*	M'side	Vienna*	Eisenstadt*	Tromsø	Oslo*	Helsinki	Torino*	Salerno
Infrastructure Investment high (IH)	0	0	0	-		-	0		0
Infrastructure Investment medium (IM)	1	1	0	-		1	-	0	0
Increasing/decreasing of road capacity (CAP)	10%	10%	-10%	-15%	10%	10%	0	10%	0%
PT frequency (PTC)	-	-	0%	-50%		-	-	30%	80%
PT frequency peak (PTCP)	85%	50%	-	-	46%	-15%	25%	-	-
PT frequency off-peak (PTCOP)	70%	-40%	-	-	0%	0%	13%	-	-
Road pricing (RP)	-	-	0	0		-	-	0	0
Road pricing peak (RPP)	1.6	0	-	-	2	5	0	-	-
Road pricing off-peak (RPOP)	1.6	0	-	-	1.6	5	0	-	-
Parking charges (PCH)	-	-	-	-	-100%	0%	-	100%	300%
Parking charges long term (PCHL)	~	-100%	0%	-50%		-	0	-	-
Parking charges short term (PCHS)	300%	100%	245%	115%		-	0	-	-
PT fares (PTF)	-	-	77%	-50%		-	-	100%	25%
PT fares peak (PTFP)	-90%	-100%	-	-	-100%	-5%	-50%	-	-
PT fares off-peak (PTFOP)	-35%	-100%	-	-	-50.5%	-15%	-50%	-	-
Modal Split									
MS (trips) private car	52%	58%	36%	41%	66%	60%	36%	56%	57%
MS (trips) public transport	48%	22%	32%	2%	18%	28%	46%	44%	14%
MS (trips) others	-	19%	32%	57%	17%	12%	18%	-	29%
Percentage change in car-km	-16%	-5%	-8%	-10%	-14%	-15%	-24%	-1%	-1%
Cost model output									
BOF [mio. ECU]	492	687	142.4	3.92	21.8	696	183	128	24
COF [mio. ECU]	492	-313	142.4	3.92	-78	696	-817	128	-976
ROF [mio. ECU]	492	-313	142.4	3.92	-78	696	-817	128	-976
DOF [mio. ECU]	-457	-1056	-1977	-16.41	#	657	-1765	-690	-973
HOF [mio. ECU]	490	-1056	-1977	-16.41	N/A	657	-1765	-690	24
PVF Government sector [mio. ECU]	233	-2120	3903	9.46	-84	5976	-1779	710	88
PVF Private sector [mio. ECU]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0
Value Capture [mio. ECU]	166	574	0	0.30	28	0	233	0	1.2

- not included, ~ indicates irrelevant around the optimum; * BOF=COF=ROF
no feasible solution with IRR close to 15%

Table 6: Summary table - best BOF

Measures	Edinburgh	M'side	Vienna	Eisenstadt	Tromsø	Oslo	Helsinki	Torino*	Salerno
Infrastructure Investment high (IH)	0	0	0	-		-	0		0
Infrastructure Investment medium (IM)	1	1	0	-		1	-	0	0
Increasing/decreasing of road capacity (CAP)	10%	10%	-10%	-15%	5%	10%	0	10%	0
PT frequency (PTC)	-	-	0%	-50%		-	-	30%	50%
PT frequency peak (PTCP)	85%	20%	-	-	25%	-15%	0	-	-
PT frequency off-peak (PTCOP)	70%	-50%	-	-	15%	0%	-10%	-	-
Road pricing (RP)	-	-	0	0		-	-	0	0
Road pricing peak (RPP)	1.6	1	-	-	2	5	0	-	-
Road pricing off-peak (RPOP)	1.6	1	-	-	3	5	0	-	-
Parking charges (PCH)	-	-	-	-	-100%	0%	-	100%	300%
Parking charges long term (PCHL)	~	0%	0%	-50%		-	20%	-	-
Parking charges short term (PCHS)	300%	200%	245%	115%		-	0	-	-
PT fares (PTF)	-	-	77%	-50%		-	-	100%	50%
PT fares peak (PTFP)	-90%	-65%	-	-	-50%	-5%	-10%	-	-
PT fares off-peak (PTFOP)	-35%	-40%	-	-	+40%	-15%	-7%	-	-
Modal Split									
MS (trips) private car	52%	59%	36%	41%	68%	60%	45%	56%	57%
MS (trips) public transport	48%	19%	32%	2%	13%	28%	33%	44%	13%
MS (trips) others	-	22%	32%	57%	19%	12%	22%	-	30%
Percentage change in car-km	-16%	-4%	-8%	-10%	-11%	-15%	-7%	-1%	0%
Cost model output									
BOF [mio. ECU]	492	404	142.4	3.92	17	696	46	128	24
COF [mio. ECU]	492	404	142.4	3.92	17	696	46	128	24
ROF [mio. ECU]	492	404	142.4	3.92	17	696	46	128	24
DOF [mio. ECU]	-457	-566	-1977	-16.41	#	657	-1959	-690	-975
HOF [mio. ECU]	490	394	-1977	-16.41	#	657	-1959	-690	24
PVF Government sector [mio. ECU]	233	32	3903	9.46	9	5976	52	710	129
PVF Private sector [mio. ECU]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0
Value Capture [mio. ECU]	166	147	0	0.30	4	0	1	0	0
Percentage subsidy for PT balance								34%	65%

- not included, ~ indicates irrelevant around the optimum, # no feasible solution with IRR close to 15%

Table 7: Summary table - best COF

Measures	Edinburgh	M'side	Vienna*	Eisenstadt*	Tromsø	Oslo	Helsinki	Torino*	Salerno
Infrastructure Investment high (IH)	0	0	0	-		-	0		0
Infrastructure Investment medium (IM)	1	1	0	-		1	-	0	0
Increasing/decreasing of road capacity (CAP)	10%	10%	-10%	-15%	5%	10%	0	10%	0
PT frequency (PTC)	-	-	0%	-50%		-	-	30%	50%
PT frequency peak (PTCP)	85%	20%	-	-	25%	-15%	0	-	-
PT frequency off-peak (PTCOP)	70%	-50%	-	-	15%	0%	-10%	-	-
Road pricing (RP)	-	-	0	0		-	-	0	0
Road pricing peak (RPP)	1.6	1	-	-	2	5	0	-	-
Road pricing off-peak (RPOP)	1.6	1	-	-	3	5	0	-	-
Parking charges (PCH)	-	-	-	-	-100%	0%	-	100%	300%
Parking charges long term (PCHL)	~	0	0%	-50%		-	20%	-	-
Parking charges short term (PCHS)	300%	100%	245%	115%		-	0	-	-
PT fares (PTF)	-	-	77%	-50%		-	-	100%	50%
PT fares peak (PTFP)	-90%	-75%	-	-	-50%	-5%	-10%	-	-
PT fares off-peak (PTFOP)	-35%	-40%	-	-	+40%	-15%	-7%	-	-
Modal Split									
MS (trips) private car	52%	59%	36%	41%	68%	60%	45%	56%	57%
MS (trips) public transport	48%	19%	32%	2%	13%	28%	33%	44%	13%
MS (trips) others	-	22%	32%	57%	19%	12%	22%	-	30%
Percentage change in car-km	-16%	-4%	-8%	-10%	-11%	-15%	-7%	-1%	0%
Cost model output									
BOF [mio. ECU]	492	425	142.4	3.92	17	696	46	128	24
COF [mio. ECU]	492	-575	142.4	3.92	17	696	46	128	24
ROF [mio. ECU]	492	425	142.4	3.92	17	696	46	128	24
DOF [mio. ECU]	-457	-526	-1977	-16.41	#	657	-1959	-690	-975
HOF [mio. ECU]	490	-526	-1977	-16.41	#	657	-1959	-690	24
PVF Government sector [mio. ECU]	233	-152	3903	9.46	9	5976	52	710	129
PVF Private sector [mio. ECU]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0
Value Capture [mio. ECU]	166	180	0	0.30	4	0	1	0	0
Percentage subsidy for PT balance								34%	65%

- not included, ~ indicates irrelevant around the optimum, # no feasible solution with IRR close to 15%

Table 8: Summary table - best ROF

Measures	Edinburgh	M'side	Vienna	Eisenstadt#	Tromsø	Oslo	Helsinki	Torino	Salerno
Infrastructure Investment high (IH)	0	0	0			0		0	0
Infrastructure Investment medium (IM)	1	1	0			1		0	0
Increasing/decreasing of road capacity (CAP)	10%	10%	-9%		5%	10%		10%	0%
PT frequency (PTC)	-	-	3%			-		30%	50%
PT frequency peak (PTCP)	50%	10%	-		-21%	-15%		-	-
PT frequency off-peak (PTCOP)	0%	-50%	-		0%	-30%		-	-
Road pricing (RP)	-	-	0			-		0	1
Road pricing peak (RPP)	3.3	1	-		3	5		-	-
Road pricing off-peak (RPOP)	3.2	1	-		3	5		-	-
Parking charges (PCH)	-	-	-		-100%	0%		100%	300%
Parking charges long term (PCHL)	~	0	0%			-		-	-
Parking charges short term (PCHS)	300%	100%	250%			-		-	-
PT fares (PTF)	-	-	4%			-		70%	100%
PT fares peak (PTFP)	-35%	-50%	-		+1%	20%		-	-
PT fares off-peak (PTFOP)	0%	-25%	-		+40%	20%		-	-
Modal Split									
MS (trips) private car	53%	60%	35%		69%	62%		56%	56%
MS (trips) public transport	47%	17%	35%		11%	26%		44%	12%
MS (trips) others	-	22%	30%		20%	13%		-	32%
Percentage change in car-km	-13%	-3%	-9%		-9%	-11%		-1%	-2%
Cost model output									
BOF [mio. ECU]	442	346	111.9		12	683		107	16
COF [mio. ECU]	442	346	111.9		12	683		107	16
ROF [mio. ECU]	442	346	111.9		12	683		107	16
DOF [mio. ECU]	440	337	107.6		12	653		99	14
HOF [mio. ECU]	440	337	107.2		N/A	653		99	14
PVF Government sector [mio. ECU]	1864	309	1193		58	6757		313	144
PVF Private sector [mio. ECU]	29	35	55		19	1176		83	4
Value Capture [mio. ECU]	0	87	0		-	0		3	0

- not included, ~ indicates irrelevant around the optimum

Table 9: Summary table - best DOF

Measures	Edinburgh	M'side	Vienna	Eisenstadt	Tromsø	Oslo	Helsinki	Torino	Salerno
Infrastructure Investment high (IH)	0	0	0	-		-			0
Infrastructure Investment medium (IM)	1	1	0	-		1			0
Increasing/decreasing of road capacity (CAP)	10%	10%	-9%	-12%		10%		10%	0%
PT frequency (PTC)	-	-	3%	-20%		-		30%	80%
PT frequency peak (PTCP)	85%	20%	-	-		-15%		-	-
PT frequency off-peak (PTCOP)	70%	-50%	-	-		-15%		-	-
Road pricing (RP)	-	-	0	0		-		0	0
Road pricing peak (RPP)	1.6	1	-	-		5		-	-
Road pricing off-peak (RPOP)	1.6	1	-	-		5		-	-
Parking charges (PCH)	-	-	-	-		0%		100%	300%
Parking charges long term (PCHL)	~	0%	0%	-56%		-		-	-
Parking charges short term (PCHS)	300%	200%	250%	107%		-		-	-
PT fares (PTF)	-	-	4%	-90%		-		70%	25%
PT fares peak (PTFP)	-90%	-65%	-	-		20%		-	-
PT fares off-peak (PTFOP)	-35%	-40%	-	-		20%		-	-
Modal Split									
MS (trips) private car	52%	59%	35%	41%		61%		56%	57%
MS (trips) public transport	48%	19%	35%	3%		26%		44%	14%
MS (trips) others	-	22%	30%	56%		13%		-	29%
Percentage change in car-km	-16%	-4%	-9%	-9%		-12%		-1%	-1%
Cost model output									
BOF [mio. ECU]	492	404	111.9	3.19		691		107	24
COF [mio. ECU]	492	404	111.9	3.19		691		107	-976
ROF [mio. ECU]	492	404	111.9	3.19		691		107	-976
DOF [mio. ECU]	-457	-566	107.6	-16.74		665		99	-973
HOF [mio. ECU]	490	394	107.2	3.19		658		99	24
PVF Government sector [mio. ECU]	203	0	1185	0.65		6603		313	82
PVF Private sector [mio. ECU]	30	32	63	0		1161		83	6
Value Capture [mio. ECU]	166	147	0	1.12		0		3	1.2

- not included, ~ indicates irrelevant around the optimum

Table 10: Summary table - best HOF

5.3 Comments on results

5.3.1 Regulated regimes

In general, due to the way that the objective functions are constructed, the following relationships must always apply to optimal values of each function (optima denoted by an asterisk):

(5.1) BOF* ≥ ROF* ≥ COF*

It is useful to distinguish classes of city according to whether equalities or inequalities apply in (5.1). These city classes correspond to those set out in Section 2.2 of Part 1 of this report:

Class 1: Cities where BOF optimal strategies are supportive of both car and public transport users, so that the city must provide finance, and where there is significant possibility for value capture in COF optimal strategies. These give:

(5.2) BOF* > ROF* > COF* ⇒ PVF(BOF*)<0, and VC(COF*) > 0

Class 1 includes only Merseyside.

Class 2: Cities where BOF optimal strategies are supportive of both car and public transport users, so that the city must provide finance, but where there is no significant possibility for value capture in COF optimal strategies. These give:

(5.3) BOF* > ROF* = COF* ⇒ PVF(BOF*)<0 and VC(COF*)=0

As in Class 1, the PVF for the BOF optimum BOF* is negative, but the value capture at COF* is zero, implying no or negative user benefits. Any positive value capture element would make it possible for ROF* to improve upon the COF* solution, moving towards the optimum BOF* solution with a negative PVF but not breaking the ROF constraint of PVF+VC>0. Helsinki and Tromsø are included in Class 2 since their value capture elements under COF* were very small (i.e. approximately zero).

Class 3: Cities where BOF optimal strategies place financial restrictions on cars but are supportive of public transport users, so that the former are subsidising the latter. In this case the city is unlikely to make either a large surplus or deficit. For these:

(5.4) BOF* = ROF* = COF* and PVF(BOF*)>0 (but small surplus only)

Class 3 includes Edinburgh, Eisenstadt and Torino and applies if PVF is positive for the BOF-optimum BOF*.

According to the standard FATIMA definition of COF, Salerno is also a Class 3 city as the PVF for BOF* is positive. However, due to the Italian rules on subsidy (the subsidy cannot exceed 65% of the public transport operating costs) there is a special COF_{IT} defined, and COF_{IT} * < BOF*.

Class 4: Cities wherre BOF optimal strategies place restrictions on both cars and motorised public transport, and the city raises revenues from both user types through road user charges and increased public transport fares. For these:

(5.5) BOF* = ROF* = COF* and PVF(BOF*)>0 (large surplus)

Class 4 includes Vienna and Oslo.

5.3.2 Deregulated regimes

For deregulated regimes (see Section 2) the following must apply given optimal solutions which have a return of 15% for the public transport sector for DOF* and HOF*:-

(5.6) DOF* ≤ HOF* < BOF*

this condition applies to all cities in the FATIMA project (except Eisenstadt and Helsinki which have no solutions for DOF*).

A further condition which also holds under the FATIMA assumptions for optimal solutions is that :-

(5.7) DOF* ≤ HOF* < COF* ≤ ROF* ≤ BOF*

which implies that under the FATIMA modelling assumptions there are no social benefits of deregulation in any case study city[1]. The only benefits modelled in this project come from finance made available from value capture in the case of Class 1 cities where ROF* > COF* and, more generally, from the reduction in public sector financial costs.

There are also other benefits which may arise, as described by Minken (1998), but which have not been modelled. These include:

- changes in efficiency (i.e. through reduced operating costs, see sensitivity tests)
- attitudes towards risk in raising finance
- payment of interest on loans
- non-uniform changes to PT services across routes
- quality of service (which could rise or fall).

5.4 Comparison of policies by city and objective function

Table 11 summarises the policy measures for each city by objective function in terms of strength and direction/sign of change for each measure. (N.B. where a measure was modelled as all-day, it was recorded with the peak measures.) This table allows a comparison in general terms of measures across cities for each function and across

[1] with the possible exceptions of Torino and Salerno where extra money is available for the HOF regime to finance large infrastructure projects.

functions for each city. The following sections take each city in turn and make observations about the changes in measures due to each function.

5.4.1 Edinburgh

The BOF policy is to increase capacity, increase frequencies all day, reduce fares in the peak with a lower reduction in the off-peak, implement road pricing at 1.6 ECU all day, increase parking charges (short) by 300% and to implement the medium level of infrastructure (guided bus).

Edinburgh is a Class 3 city as defined above and so BOF*=ROF*=COF* and for Edinburgh the HOF* solution has the same set of measures for its optimum. The only changes are for DOF* which has no increases in frequencies in the off-peak and less of an increase in the peak, lower fare reductions in the peak and no reductions in fare in the off-peak. Also for the DOF* solution the road pricing charge is doubled to around 3.2 ECU, this is required to produce the mode switch from car to public transport to ensure a return of 15%.

The DOF* solution is 11% worse in terms of social objectives (as measured by BOF) than BOF*.

5.4.2 Merseyside

The BOF* solution is to increase capacity, increase peak frequency, decrease off-peak frequency, provide free fares all day, no road pricing, reduce long stay parking charges whilst increasing short stay charges and to implement the medium level of infrastructure (SMART Bus).

The ROF* policy lies between the BOF* and COF* policies, although it is closer to the latter. The two differences between ROF* and COF* are: ROF* has a larger decrease in peak fares and a smaller increase in short-stay parking charges.

DOF* is similar to COF* but has lower increases in peak frequencies, smaller fare reductions and with smaller increases in parking charges.

In terms of the social objective function (BOF), ROF* is 40% lower than BOF* (the PVF of ROF* is -152 MECU, which is clearly much more acceptable than the -2120 MECU of BOF*). The BOF-value of COF* (which has, by definition, a positive PVF) is 5% lower than that for ROF*. Since the COF* set of measures led also to HOF*, the latter is also 5% lower than ROF* (in terms of BOF), whilst DOF* is 19% lower than ROF*.

5.4.3 Vienna

The BOF* solution for Vienna is to reduce capacity, increase short stay parking charges, no change in long stay parking charges, with no changes to public transport frequencies, but with an increase in fares of 77%.

This increase in fares gives a high public PVF and is generated by the shadow price effect on revenue generation. The 77% fares increase has obviously reduced the need for subsidy to public transport and generated a high PVF. Sensitivity tests were conducted for the value of shadow price in Vienna and decreases in fares were found for a shadow price of zero.

Vienna is a Class 3 city and so BOF*=ROF*=COF*.

The DOF* solution is similar to BOF* but includes small increases in frequencies with much smaller increases in fares as the private sector is limited to a 15% return.

The HOF* solution is identical to DOF* for Vienna in terms of measures and the subsidy is used to increase the private sector return from 14% under DOF* to 15% under HOF*. No improvements in services are implemented with subsidy as the value of revenue generation outweighs the benefits to users of improved services. This effect is due to the shadow price of 0.25 as discussed for BOF*.

The DOF* solution is 24% worse in terms of social objectives than BOF*.

5.4.4 Eisenstadt

The BOF* solution for Eisenstadt is to reduce capacity as in Vienna, reduce frequencies and fares, reduce long stay parking charges whilst increasing short stay charges.

For Eisenstadt BOF*=COF*=ROF*. HOF* is similar but has a lower reduction in capacity, smaller reductions in frequencies, greater fare reductions and greater reductions in parking charges for long stay. Eisenstadt is a special case and has no feasible DOF* solution.

The HOF* solution is 19% worse in terms of social objectives than BOF*.

5.4.5 Tromsø

The BOF* solution for Tromsø is to increase road capacity, increase peak frequencies (with no change to off-peak), introduce free fares in the peak and halve the fares in the off-peak with road pricing of 2 ecu in the peak and 1.6 ecu in the off-peak substituting for the free parking. This BOF* solution yielded a negative PVF.

For Tromsø COF*=ROF* as there was only a small element of value capture under COF* and no improvements were possible by further expenditure. This seems to be contrary to the BOF* solution and given time other runs may have been able to improve upon ROF*. The COF* solution has smaller decreases in peak fares and increases in off-peak fares coupled with smaller increases in peak frequencies and increases in the off-peak frequency. The road pricing charges for peak and off-peak have also increased and the capacity increase is lower than for BOF*.

The DOF* solution is based upon COF* but has no fare reductions and frequency decreases in the peak rather than increases. The road pricing charges have increased in the peak to give a charge of 3 ecu all day under DOF*. There is no HOF* for Tromsø.

The DOF* solution is 45% worse in terms of social objectives than BOF* which was financially infeasible but only 29% worse than COF*.

5.4.6 Oslo

The BOF* solution is to increase capacity and reduce peak frequencies and fares slightly, with a greater fare reduction in the off-peak than in the peak. It features road pricing at the maximum level of 5 ECU all day (as explained below, using variable demand in the optimisation process later showed that 3 ECU would have been a better value,). There is no change to parking charges and medium infrastructure is implemented. Overall there are no user benefits in Oslo under BOF* due to the high road pricing charges which are used primarily to give benefits from reduced veh-km and hence increased SOF values rather than from the removal of congestion which could have been achieved with lower charges. The high charges also yield a highly positive PVF.

Oslo is a Class 3 city and so BOF*=ROF*=COF*.

The DOF* solution has further decreases in off-peak frequencies, increases rather than decreases in the peak and off-peak fares and has medium infrastructure as in BOF*.

HOF* is similar to DOF* but has lower reductions in off-peak frequency due to the subsidy option.

The DOF* solution is only 6% worse than BOF* in terms of social objectives.

5.4.7 Helsinki

The BOF* solution for Helsinki increases public transport frequencies in both peak and off-peak and reduces fares by 50% in the peak and off-peak (which is the lower limit for Helsinki due to modelling constraints). Parking charges are not changed. No capacity changes, road pricing or infrastructure measures are implemented. This set of measures yields a highly negative PVF.

The COF* solution is to reduce frequencies in the off-peak and to reduce fares slightly in the peak and off-peak. There is a modest increase in long stay parking charges but no changes to all other measures.

For Helsinki COF*=ROF* as under COF* there is only a very small value capture element. The COF* solution is 75% worse in terms of social objectives than the financially infeasible BOF* solution.

DOF* and HOF* were not calculated for Helsinki because no correct and sensible capital cost was available.

However, it is very unlikely that the public transport could make a much better profit under the DOF* or HOF* regimes, because:

- the present subsidised fares are too low to cover the cost of any viable solution (this rules out investing in increased frequency)
- the model is quite sensitive to cost changes: because there is so little congestion in Helsinki, considerably increased fares would cause mode change from PT to car. (This would lead to a penalty from increased fuel consumption)
- using road pricing or parking charges to increase car costs to encourage a switch to public transport system would be unsuccessful because, according to the model, users would either change mode (if feasible) or change destination to zones where car costs are less or zero. (Parking charges are implemented only in the inner city, where the public transport is always very good, and in a few suburban centres).
- if, due to mode change from car to PT, extra capacity is needed, the problem of operating costs versus fare revenue again arises.

5.4.8 Torino

The BOF* solution for Torino features a strong increase of both road capacity and public transport frequency, no change in public transport infrastructure, no presence of road pricing and the highest possible increase of both public transport fares and parking charges (100% in both the cases). These changes yield a highly positive PVF.

Because of the positive PVF and the absence of the subsidy penalty BOF* = COF* = ROF* for Torino.

The HOF* solution is identical to DOF* as the IRR=15% for DOF* and improvements in service are outweighed by revenue losses when multiplied by the shadow price. The solution is quite similar to the BOF* solution. It consists of an improvement of both the public and private supply (increase of the private capacity of 10% and increase of the public transport frequency of about 30%) coupled with an increase of public transport fare by 70% and of the parking charge by 100%. The fares increase is limited to reduce the rate of return of the public transport sector to 15%.

The DOF*=HOF* solution is 16.5% worse in terms of social objectives than BOF* (=COF*=ROF*).

5.4.9 Salerno

The BOF* solution for Salerno is also the HOF* solution. It consists of no changes in road capacity, large increases in frequency (+80%) with 25% increases in fares, no road pricing but a 300% increase in parking charges and no infrastructure. The increased revenue yields a positive PVF.

For Salerno although the BOF* solution resulted in a highly positive PVF the COF* penalty on the subsidy allowed to the public transport sector (subsidy should be less than 65% of operating costs) was invoked and thus the BOF* public transport measures were not optimal for COF*.

Thus the COF* solution has slightly lower increases in frequency with 50% increases in fares and all other measures as for BOF*. AS BOF has a positive PVF, Salerno belongs to the special case of Class 3 cities in which COF*=ROF*.

The HOF* solution has the same set of measures as the BOF* solution as the constraint on subsidy to the public transport sector is not binding and the measures are self-financing.

The DOF* includes increases in frequencies of 50% with fares increased by 100%. It also introduces all day road pricing of 1 ECU and increase parking charges of 300%. It should be noted that the DOF* given here has an internal rate of return of 16%.

The DOF* solution is 42% worse than BOF* (and HOF*) in terms of social benefit. The COF* solution is 2% worse than BOF* in terms of social objectives.

City	Function	Cap	Freq (Peak/ all day)	Freq (off-peak)	Fares (Peak/ all day)	Fares (off-peak)	RP (Peak/ all day)	RP (off-peak)	PCH Long/ all day	PCH Short	INF
Ed	BOF	+++++	++++	+++	----	--	+	+	+++++	+++++	M
	ROF	+++++	++++	+++	----	--	+	+	+++++	+++++	M
	COF	+++++	++++	+++	----	--	+	+	+++++	+++++	M
	DOF	+++++	++	0	--	0	++	++	+++++	+++++	M
	HOF	+++++	++++	+++	----	--	+	+	+++++	+++++	M
Mer	BOF	+++++	+++	---	-----	-----	0	0	-----	++	M
	ROF	+++++	++	-----	----	--	+	+	0	++	M
	COF	+++++	++	-----	---	--	+	+	0	+++	M
	DOF	+++++	+	-----	--	-	+	+	0	++	M
	HOF	+++++	++	-----	---	--	+	+	0	+++	M
Vien	BOF	---	0		++++		0		0	++++	0
	ROF	---	0		++++		0		0	++++	0
	COF	---	0		++++		0		0	++++	0
	DOF	---	+		+		0		0	++++	0
	HOF	---	+		+		0		0	++++	0
Eise	BOF	----	-----		--		0		--	++	
	ROF	----	-----		--		0		--	++	
	COF	----	-----		--		0		--	++	
	DOF	NS	NS		NS		NS		NS	NS	
	HOF	---	--		----		0		---	++	
Trom	BOF	+++++	++	0	-----	---	+++	++	-----		
	ROF	++	+	+	---	++	++	+++	-----		
	COF	++	+	+	---	++	++	+++	-----		
	DOF	++	--	0	0	++	+++	+++	-----		
	HOF	NS	NS	NS	NS	NS	NS	NS	NS		
Oslo	BOF	+++++	-	0	-	--	+++++	+++++	0		M
	ROF	+++++	-	0	-	--	+++++	+++++	0		M
	COF	+++++	-	0	-	--	+++++	+++++	0		M
	DOF	+++++	-	--	+	+	+++++	+++++	0		M
	HOF	+++++	-	-	+	+	+++++	+++++	0		M
Hels	BOF	0	++	+	---	---	0	0	0	0	0
	ROF	0	0	-	-	-	0	0	+	0	0
	COF	0	0	-	-	-	0	0	+	0	0
	DOF	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	HOF	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Torin	BOF	+++++	++		+++++		0		++		0
	ROF	+++++	++		+++++		0		++		0
	COF	+++++	++		+++++		0		++		0
	DOF	++++	++		++++		0		++		0

		+									
	HOF	++++ +	++		++++		0		++		0
Saler	BOF	0	+++		+		0		+++++		0
	ROF	0	++		+++		0		+++++		0
	COF	0	++		+++		0		+++++		0
	DOF	0	++		+++++		+		+++++		0
	HOF	0	+++		+		0		+++++		0

Table 11 : Summary of policies by city and objective function

+ indicates increase, - decrease, 0 no change, M medium, shaded= not modelled, NS=no solution

5.5 Comparison across cities by function

This section compares the policy measures across cities by each objective function in turn, aided by Table 12.

5.5.1 BOF* solutions

Class 1 cities include only Merseyside and have a negative PVF for the optimum BOF* solution. The characteristics of the optimal policies are to provide large decreases in fares (-100% for Merseyside) with improvements in frequency in the peak (though not in the off-peak for Merseyside) and improvements via the introduction of some form of infrastructure. In other words the public transport system gives large user benefits. The private car measures are generally favourable to the car user with increases in capacity, decreases in long stay parking charges and no road pricing. However the short stay parking charge is increased in Merseyside.

Overall Class 1 cities are dominated by user benefits at the expense of revenue generation. The user benefits outweigh the revenue losses even when factored by the shadow price λ.

Class 2 cities include Tromsø and Helsinki. Here the BOF* solution has a negative PVF and the user benefits once again outweigh any revenue losses even when factored by the shadow price. The frequencies are increased and fares reduced for public transport with neutral measures for the private car user. Tromsø can introduce road pricing whilst increasing the BOF* value.

Class 3 cities include Edinburgh, Eisenstadt and Torino and Salerno, and produce a small positive PVF for the optimum BOF* solution. Revenue generation is balanced against user benefits with the exception of Torino, where user benefits are negative and revenue generating measures dominate the solution; thus Torino generates revenue through increased fares at the expense of the users, the solution probably being dictated by the shadow price λ. Those cities which provide user benefits do so through overall improvements in the public transport system and balance these with revenue generating measures for private car such as road pricing or parking charges. Those cities which reduce user benefits overall and instead generate revenue do so through a high road pricing charge or a combination of high fares and high parking charges.

Eisenstadt is a special case as only 2% of trips are made by public transport. In general the public transport systems make a loss compared to the do-minimum, with the exception of Eisenstadt, which implies that revenue loss from changes to the system are out-weighed by user benefits for loss making systems.

For the private car however the measures are designed to increase revenue where possible (with the exception of increases in road capacity). Edinburgh can introduce road pricing whilst increasing the BOF* value. All cities increase short stay parking charges where this option is modelled. The long stay/all day parking charges have no pattern, but it is interesting to note that some cities reduce long stay parking charges whilst increasing short stay parking charges which merits further investigation.

The capacity measure favours the car for most cities but is decreased in Eisenstadt. This difference is due to the benefits of reduced delay to pedestrians in the Eisenstadt model as road capacity is reduced.

Class 4 cities include Vienna and Oslo and produce a large positive PVF for the BOF* solution. User benefits are negative and revenue generation dominates the strategy. These cities thus raise revenues from both public transport (higher fares, with no frequency increases) and private transport (road pricing and/or parking charges) user charges. Oslo provides no user benefits and sets road pricing to the maximum of 5 ECU. Like the Class 2 city Tromsø, Oslo can introduce road pricing whilst still increasing the BOF* value. Vienna generates revenue through increased fares at the expense of the users, with (like Torino) the solution probably being dictated by the shadow price λ.

5.5.2 ROF* and COF* solutions

For Class 1 cities such as Merseyside the ROF* solution is similar to the BOF* solution with revenue losses reduced by smaller reductions in fares, smaller increases in frequency, no decreases in parking charges and the introduction of revenue generation by road pricing. For ROF* a balance is required between user benefits which determines the value capture which in turn determines the amount of revenue which can be lost in providing the user benefits.

The COF* solution is an extension of the ROF* solution requiring a positive PVF. Hence revenue loss making measures are restricted further while revenue generation is increased slightly in the form of short stay parking charges.

For Class 2 cities the COF*=ROF* and is a restricted version of BOF* which trades user benefits for revenue generation to such an extent that user benefits are now negative or near zero compared to positive user benefits under BOF*.

For Class 3 and 4 cities the ROF* and COF* solutions are equal to the BOF* solution as the PVF is positive. Salerno is a special case of Class 3 cities where the COF*=ROF* solution is a restricted version of BOF* not because of the PVF but because of the special penalty on subsidies implemented for Italian cities. Thus the frequency is reduced and fares increased compared to BOF*.

5.5.3 HOF* solutions

The HOF* optimum measures for all cities lie between the COF* and DOF* optimum set of measures (with the exception of Salerno where HOF*=BOF* set of measures as the subsidy penalty is invoked for these measures under COF*). The use of the subsidy falls into two categories as follows :-

(a) Loss making public transport systems under COF* optimum

Edinburgh, Merseyside, Oslo and Salerno have loss making public transport systems under the COF* optimum and so the subsidy is used primarily to increase the rate of return to 15%. For Edinburgh and Merseyside the PVF available is sufficient to subsidise the same set of measures for HOF* as were used for COF*. For Salerno the subsidy is used freely to subsidise the same set of measures as BOF* which for Salerno is greater than COF*. In Oslo the solution moves from the COF* set of measures towards the DOF* set with increases in fares and reductions in frequency applied in the off-peak. The subsidy is used to prevent even further frequency reductions as under DOF* and is therefore subsidising an otherwise loss making system.

(b) Profit making public transport systems under COF* optimum

Vienna and Eisenstadt have profit making public transport systems under the COF* optimum and so the subsidy could be used to improve the system compared to the COF* measures with lower fares and increased frequencies whilst maintaining the 15% return to operators as in Eisenstadt.

Vienna and Torino are special cases where the measures for HOF*=DOF* and no use of subsidy to improve the system gives overall benefits as the user benefits do not outweigh the loss in revenue when factored by the shadow price λ. The subsidy is used to raise the IRR under DOF* from 14% to 15% for Vienna whilst no subsidy is used in Torino as the IRR is already 16% under DOF*.

There were no HOF* solutions for Tromsø and Helsinki.

5.5.4 DOF* solutions

There is no DOF* solution for Eisenstadt as there is only a small public transport system with only 2% of the trips. Theoretically there may be a solution but the resolution of the modelling does not allow the solution to be found i.e. the IRR is ultra-sensitive to changes in measures.

There is no DOF* solution available for Helsinki as explained in Section 5.4.7.

For other cities the optimum DOF* solutions are based upon the HOF* or COF* optima with restrictions in changes to frequencies and fare reductions. In Edinburgh and Merseyside the fare reductions and frequency increases remain but at lower levels, also in Edinburgh the road pricing charge is doubled to create the demand necessary for the return of 15%.

In Oslo further frequency reductions are made in the off-peak period compared to HOF*.

In Vienna however the frequencies are increased compared to COF* and this is paid for by the modest fare increases. These fare increases are lower than in COF* as they are limited to give a 15% return, whereas under COF* this is not the case and the shadow price on revenue generation induces high fare increases.

In Salerno the frequencies are the same as for COF* but high fares are used to pay for these increase. Salerno introduces road pricing as a key element in DOF* to induce the mode switch given the 100% increase in fares.

In Torino the frequencies are the same as for COF* but the public transport fare increase is limited to +70% which yields user benefits overall.

City	Function	Cap	Freq (Peak/ all day)	Freq (off-peak)	Fares (Peak/ all day)	Fares (off-peak)	RP (Peak/ all day)	RP (off-peak)	PCH Long/ all day	PCH Short	INF
Ed	BOF	+++++	++++	+++	----	--	+	+	+++++	+++++	M
Eise	BOF	----	-----		--		0		--	++	
Hels	BOF	0	++	+	---	---	0	0	0	0	0
Mer	BOF	+++++	+++	---	-----	-----	0	0	-----	++	M
Oslo	BOF	+++++	-	0	-	--	+++++	+++++	0		M
Saler	BOF	0	+++		+		0		+++++		0
Torin	BOF	+++++	++		+++++		0		++		0
Trom	BOF	+++++	++	0	-----	---	+++	++	-----		
Vien	BOF	---	0		++++		0		0	++++	0
Ed	ROF	+++++	++++	+++	----	--	+	+	+++++	+++++	M
Eise	ROF	----	-----		--		0		--	++	
Hels	ROF	0	0	-	-	-	0	0	+	0	0
Mer	ROF	+++++	++	-----	----	--	+	+	0	++	M
Oslo	ROF	+++++	-	0	-	--	+++++	+++++	0		M
Saler	ROF	0	++		+++		0		+++++		0
Torin	ROF	+++++	++		+++++		0		++		0
Trom	ROF	++	+	+	---	++	++	+++	-----		
Vien	ROF	---	0		++++		0		0	++++	0
Ed	COF	+++++	++++	+++	----	--	+	+	+++++	+++++	M
Eise	COF	----	-----		--		0		--	++	
Hels	COF	0	0	-	-	-	0	0	+	0	0
Mer	COF	+++++	++	-----	---	--	+	+	0	+++	M
Oslo	COF	+++++	-	0	-	--	+++++	+++++	0		M
Saler	COF	0	++		+++		0		+++++		0
Torin	COF	+++++	++		+++++		0		++		0
Trom	COF	++	+	+	---	++	++	+++	-----		
Vien	COF	---	0		++++		0		0	++++	0
Ed	HOF	+++++	++++	+++	----	--	+	+	+++++	+++++	M
Eise	HOF	---	--		----		0		---	++	
Hels	HOF	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mer	HOF	+++++	++	-----	---	--	+	+	0	+++	M
Oslo	HOF	+++++	-	-	+	+	+++++	+++++	0		M
Saler	HOF	0	+++		+		0		+++++		0
Torin	HOF	+++++	++		++++		0		++		0
Trom	HOF	NS	NS	NS	NS	NS	NS	NS	NS		
Vien	HOF	---	+		+		0		0	++++	0
Ed	DOF	+++++	++	0	--	0	++	++	+++++	+++++	M
Eise	DOF	NS	NS		NS		NS		NS	NS	
Hels	DOF	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Mer	DOF	+++++	+	-----	--	-	+	+	0	++	M
Oslo	DOF	+++++	-	--	+	+	+++++	+++++	0		M
Saler	DOF	0	++		+++++		+		+++++		0
Torin	DOF	+++++	++		++++		0		++		0
Trom	DOF	++	--	0	0	++	+++	+++	-----		
Vien	DOF	---	+		+		0		0	++++	0

Table 12 : Summary of policies by city and objective function

+ indicates increase, - decrease, 0 no change, M medium, shaded= not modelled, NS=no solution

5.5.5 Other feasible DOF solutions

Some of the cities had the opportunity to identify other feasible DOF solutions i.e. where the IRR = 15% for the private sector operation of public transport. Following Webster et al (1980), it would be expected that there would be a large number of combinations of fare and frequency that would be feasible: these combinations would vary depending upon other measures (such as road pricing) being implemented. Some general solutions arising from the FATIMA case studies were as follows :-

- there is usually a feasible solution which has small increases in fares from the do-minimum (with small increases in frequency) (Vienna)
- large fare increases with large increases in frequency (with or without new infrastructure) (Edinburgh, Merseyside)
- fare decreases with a decrease in frequency (Vienna)
- for fare decreases and frequency increases (with or without new medium infrastructure) other measures such as road pricing or parking charges must be used to increase car costs and so create the demand necessary for the public transport system to give a return of 15% (Edinburgh, Merseyside)
- for frequency increases and new high infrastructure fares must be increased along with other measures such as road pricing or parking charges which must be used to increase car costs and so create the demand necessary for the public transport system to give a return of 15% (Edinburgh)

In theory there are a vast number of solutions for different combinations of measures which will satisfy the IRR=15% condition. In all cities (except Eisenstadt and Helsinki) the regression method with sensitivity tests was able to find the optimum DOF solution. The optimum DOF* solution used other measures to create the demand for an otherwise loss making public transport system. In other words the optimum system was to invest in public transport and in some cases to reduce fares slightly but to have other “stick” measures to ensure a 15% return.

However in some cases it was thought that the optimum DOF solution was not necessarily the most likely DOF solution to be implemented. One such case is that of Oslo where the optimum DOF solution was to provide the rail based infrastructure as this provided the best system in terms of social benefits. However it was shown that to provide this infrastructure the fares had to be increased and a sensitivity test showed that the provision of infrastructure was unprofitable for the private operator. Another feasible solution existed where no infrastructure was implemented with fare decreases which was thought to be more feasible.

5.6 Financial Implications of Value Capture and PVF

5.6.1 General

Firstly there is no value capture under any regime for Vienna and Oslo. For Vienna this is due to the shadow price on public funds effectively out-weighing user benefits whilst for Oslo the high road pricing charges are used to reduce fuel consumption and hence reduce external costs in EEFP and increase the fuel benefit in SOF at the expense of user benefits. For other cities it can be seen from tables 6-10 that the value capture is highest for the BOF* solution with the exception of Eisenstadt where it is highest for HOF*. The value capture is always lowest for the DOF* solution and only Merseyside has a positive value capture element under DOF* which implies negative user benefits for all other cities.

Coupled with this is the fact that, for all cities except Vienna, the PVF for the Government sector is always lowest for the BOF* solution and greatest for the DOF* solution (where one exists). Hence from a Government sector financial point of view the DOF* solution becomes the most attractive and in all cases provides substantial revenue which could be spent elsewhere. At first sight this seems like a tax on travel without consideration of the user, however the DOF* solutions imply reductions in the COF* values of only 11% (Edinburgh), 17% (Merseyside), 6% (Oslo), 29% (Tromsø) and 42% (Salerno). This coupled with benefits from revenue spent elsewhere could form a basis for accepting the DOF* solution in these cities. The shadow price λ models the value of revenue in taxation terms but it does not include benefits of spending that revenue elsewhere.

Vienna is a notable exception to this rule and the PVF under BOF* is higher than under DOF*. This is due to the shadow price effect under BOF* encouraging revenue generation from increased fares which under DOF* is limited to a return of 15% which in any case is not factored by the shadow price.

5.6.2 Availability of finance in year zero

In the FATIMA models the budget restrictions have been for the 30 year period with no limits on initial expenditure. One of the key reasons stated for involving private finance is due to the lack of capital in year zero. The following table shows the initial year zero investment for the Government sector and the Private sector investment under COF*, DOF* and HOF* solutions for each city. BOF* is implicitly included for Class 3 cities where BOF*=COF*, however COF* was thought to be more representative of a realistic strategy for Class 1 and Class 2 cities.

Note that under DOF* and HOF* the Government sector only pays for capacity and road pricing in year 0. Table 13 shows that if year zero capital restrictions were applied to COF at certain city specific levels e.g. 20 million in Edinburgh, 60 million in Merseyside, 100 million in Oslo, 17 million in Vienna, 3 million in Eisenstadt, 2 million in Salerno, and 50 million in Torino then a good case for using either HOF* or DOF* solutions may exist. Add this to the earlier point that Government sector PVF under DOF* is higher than under COF* optima for all cities where DOF* solution is calculated and a strong case for DOF* may exist.

	COF* year 0 capital (Million Ecu)		DOF* year 0 capital (Million Ecu)		HOF* year 0 capital (Million Ecu)	
City	Government	Private	Government	Private	Government	Private
Edinburgh	59.6	0	17.5	39.3	17.5	42.1
Merseyside	124.5	0	58.75	56.25	58.75	65.75
Vienna	20	0	16	90	16	90
Oslo	265	0	92.6	172	92.6	172
Eisenstadt	4.08	0	N/A	N/A	2.66	-0.03
Tromsø	N/A	N/A	N/A	N/A	N/A	N/A
Helsinki	0	0	N/A	N/A	N/A	N/A
Salerno	5	0	1	5	5.5	2.5
Torino	145	0	48	97	48	97

Table 13 : Year Zero Capital for each city by function.

5.7 Changes in car-km by function

Table 14 shows the percentage changes in car-km for each function (taken from tables 6-10). This indicator shows how the functions perform with respect to reducing fuel consumption by car and therefore also how they perform with respect to reducing external costs (assuming that a majority of external cost reductions are brought about by reductions in car-km).

Function	Edinburgh	Mersey-side	Vienna	Eisenstadt	Tromsø	Oslo	Helsinki	Torino	Salerno
BOF*	-16	-5.3	-8.3	-9.6	-14.4	-15	-24	-1	-1
ROF*	-16	-4.4	-8.3	-9.6	-10.5	-15	-7	-1	+0
COF*	-16	-4.2	-8.3	-9.6	-10.5	-15	-7	-1	+0
HOF*	-16	-4.2	-9.2	-8.6	#	-12	#	-1	-1
DOF*	-13	-2.9	-9.2	#	-8.8	-11	#	-1	-2

no feasible solution with IRR close to 15%

Table 14: Percentage changes in car-km by function.

The greatest reductions in car-km are under BOF* with the exception of Vienna (where DOF* includes increases in frequency relative to BOF* and a slightly lower reduction in road capacity) and Salerno where DOF* introduces a road pricing charge.

Of note are the relatively small changes in car-km in Torino and Salerno, in Salerno there are no significant changes in car-km under ROF* and COF*.

For Helsinki there is a much larger change for BOF* than for COF*=ROF*. This is due to a combination of reduced fares and increased frequency both in the peak and off-peak which proves financially infeasible for BOF*. The restricted measures under COF* provide a much smaller reduction in car-km.

6. OPTIMA : EEF AND SOF OPTIMA

6.1 Changes between OPTIMA and FATIMA

All cities performed a re-run of the OPTIMA project optimum strategies for EEF and SOF regardless of the input ranges for variables. In this way a direct link between the OPTIMA strategies and the FATIMA strategies is provided and the BOF value is evaluated for the OPTIMA measures.

A number of significant changes were made during the course of FATIMA partly in response to the city authorities' comments on the OPTIMA results and partly due to the objectives of FATIMA.

These changes include :

- the introduction of external costs into EEFP
- the application of the shadow price to positive and negative PVF
- weighted sum of EEFP and SOF used for BOF
- changes made to costs of measures
- reducing the range of valid input measures
- the introduction of time of day measures by peak and off-peak in some cities
- changes to values of time
- changes in some transport models

The re-runs of the OPTIMA strategies produced BOF values which were in all cases lower than the new FATIMA optimum BOF combination or which were no longer valid input measures. The differences in the two sets of measures could be attributed to one or more of the above list of changes made in the modelling approach.

Table 15a shows the optimal EEF and SOF measures from OPTIMA, whilst Table 15b shows the values of BOF for these optima. The tables also give information about BOF* for comparison. The text following these tables gives general details about the changes from OPTIMA to FATIMA, on a city-by-city basis.

A summary description of OPTIMA is provided at Annex 3.

City	Function	Infra structure	Road Cap %	PT Freq %	PT Fare %	Road Price ecu	Park Charge %
Edinburgh	EEF	M	+20	+85	-60	1.6	-
Edinburgh	SOF	H	+20	+100	-100	2.8	-
Edinburgh	BOF	M	+10	+85 +70*	-90 -35*	1.6 1.6*	+300L +300S
Eisenstadt	EEF	-	+10	+100	-100	0	+149
Eisenstadt	SOF	-	+10	+100	-100	0	+149
Eisenstadt	BOF	-	-15	-50	-50	0	-50L +115S
Helsinki	EEF	-	+10	-30	+25	0	0
Helsinki	SOF	-	0	0	-100	0	+92
Helsinki	BOF	-	0	25 13*	-50 -50*	0 0*	0L 0S
Merseyside	EEF	M	+5	+60	-100	0	-100
Merseyside	SOF	M	+20	+59	-100	0	-100
Merseyside	BOF	M	+10	+50 -40*	-100 -100*	0 0*	-100L +100S
Oslo	EEF	-	+20	-26	-70	1.2	-100
Oslo	SOF	H	+20	-20	-100	7.0	-100
Oslo	BOF	M	+10	-15 0*	-5 -15*	5 5*	0
Salerno	EEF	-	+10	+50	-50	1.0	-50
Salerno	SOF	H	+10	+50	-100	2.0	-100
Salerno	BOF	-	0	+80	25	0	+300
Torino	EEF	-	+10	0	-25	0	+500
Torino	SOF	H	+10	-30	-50	0	+500
Torino	BOF	-	+10	+30	+100	0	+100
Tromsø	EEF	-	+20	-35	-50	0	0
Tromsø	SOF	-	+20	-28	-100	2.5	-100
Tromsø	BOF	-	+10	+46 0*	-100 -50*	2 1.6*	-100
Vienna	EEF	-	+10	+100	+31	0	+226
Vienna	SOF	H	+1	+100	+1	0	+250
Vienna	BOF	-	-10	0	+77	0	0L +245S

*= off-peak L=Long Stay S=Short Stay

Table 15a: Optimal EEF and SOF measures from OPTIMA

Function	Edinburgh	Mersey-side	Vienna	Eisenstadt	Tromsø	Oslo	Helsinki	Torino	Salerno
BOF*	492	687	142	3.9	22	696	183	128	24
OPTIMA EEF optimum	458	651	-875	-7.0	19	271	-969	91	15
OPTIMA SOF optimum	412	736	-1195	-7.0	13	541	-62	-271	12

Table 15b BOF-values of OPTIMA EEF and SOF optima

6.2 Edinburgh

Changes (a)-(f) above were made for Edinburgh with cost changes for decreases in capacity and operating costs split by time of day. Also the introduction of short stay parking charges was new in FATIMA.

The EEF optimum set of measures from OPTIMA included fare reductions of 60% (compared to FATIMA optima of -90% and -35% in peak and off-peak), frequency increases of 85% (compared to 85% and 70% in peak and off-peak), capacity increases of 20% (compared to new 10% limit), road pricing of 1.625 ECU (compared to 1.6 in the peak and off-peak), parking charges short stay were not modelled (compared to a 300% increase), long stay charges were irrelevant and guided bus was implemented as in FATIMA. This set of measures produced a BOF value of 458 compared to 492 for the optimum BOF*.

Filtering the effect of each change was not feasible given the time constraints of the project. However the distinction between peak and off-peak measures and the introduction of short stay parking charges is beneficial in terms of BOF even with a limited capacity increase of 10%.

The best SOF combination from OPTIMA consisted of free fares, 85% increases in frequency, capacity increase of 20%, road pricing charge of 3.3 ECU, no change in short stay parking charges (not modelled) and implementation of the LRT system. This set of measures produced a BOF value of 412.

The FATIMA optimum is a combination of the EEF and SOF optima with slight adjustments for peak and off-peak measures particularly for fare changes and the implementation of guided bus as investment carries a weight of 0.1 in BOF. The introduction of peak and off-peak road pricing compared to all day pricing is of no benefit as the prices are equal in peak and off-peak. This is due to the high weight given to SOF measures which results in trip suppression through fuel reduction benefits in both peak and off-peak rather than benefits due to congestion relief which might suggest higher charges in the peak relative to the off-peak.

6.3 Merseyside

Changes (a) to (f) were made for Merseyside. OPTIMA had already made a distinction between peak and off-peak for public transport frequency, and had distinguished between long stay and short stay parking charges. An important difference in costs between OPTIMA and FATIMA has been that road capacity increases are costed much less in FATIMA. On the other hand, to make quite clear that these increases arise from low cost schemes, the maximum capacity increase in FATIMA is 10% (compared to 20% in OPTIMA).

The EEF optimum from OPTIMA had only a 5% increase in road capacity, due to the high costs of capacity increase. It is therefore not surprising that that the BOF value of the (OPTIMA) EEF optimum (at 651) is below the BOF value of BOF* (687).

On the other hand, the two SOF optima in OPTIMA both had a road capacity increase of 20% (since capital costs are not featured in SOF), which is outside the FATIMA limits. The BOF values for these runs (736 and 734) are higher than the BOF value of BOF* (687). This is an important result since it shows that, if it were possible to achieve road capacity increases of 20% through telematics and traffic management, such increases would be highly desirable.

6.4 Vienna

Changes (a)-(h) were all made for Vienna.

The EEF optimum set of measures from OPTIMA included fare increases of 31% (compared to 77% in FATIMA BOF*), frequency increases of 100% (compared to no change in FATIMA), capacity increases of 10% (compared to -10% in FATIMA), no road pricing (as in FATIMA), parking charges are increased by 226% (compared to 245% short stay and no change long stay in FATIMA) and no infrastructure investment was implemented (as in FATIMA). This set of measures re-run in FATIMA produced a BOF value of -875 compared to 142 for the best run.

The best SOF combination from OPTIMA consisted of a 1% increase in pt fares, 100% increases in pt frequency, capacity increase of 1%, no road pricing, 226% increases in parking charges and implementation of infrastructure high. This set of measures produced a BOF value of -1,195.

The main reason for this difference can be found in changes of the transport model used. The biggest effect is produced by the changes in the valuation of time for commuting trips (access/egress and travel time from 17 ECU/h to 5.6 ECU/h and waiting time from 21.8 ECU/h to 11.1 ECU/h). Also the cost function for investments for road capacity have been changed. The newly introduced distinction between long and short term parking also had significant effects on the optimum results.

6.5 Eisenstadt

Changes (a)-(h) were all made for Eisenstadt.

The EEF and SOF optimum set of measures from OPTIMA included fare reduction of 100% (compared to -50% in FATIMA), frequency increases of 100% (compared to -50% in FATIMA), capacity increases of 10% (compared to -15% in FATIMA), no road pricing (as in FATIMA), parking charges are increases by 149% (compared to -50% long stay and +115% short stay in FATIMA). This set of measures re-run in FATIMA produced a BOF value of -7.0 compared to 3.9 for the current best run.

The main reason for this difference can be found in changes of the transport model used. The biggest effect is produced by the changes in the valuation of time for commuting trips (access/egress and travel time from 17 ECU/h to 5.6 ECU/h and waiting time from 21.8 ECU/h to 11.1 ECU/h). Also the cost function for investments

for road capacity have been changed. The newly introduced distinction between long and short term parking also had significant effects on the optimum results.

6.6 Tromsø

For Tromsø changes (a)-(f) above were made with public transport sector operating and capital cost split by time of day. Tromsø did not make a distinction between long and short term parking.

Common features of the best BOF policy and the best OPTIMA EEF policy are that fares should be reduced, road capacity increased to the maximum and land use development should take the dense direction. Peak period frequency is increased in FATIMA while in OPTIMA it is reduced. The new cost function opportunity to differentiate changes with respect to time periods and the new objective function might explain this. The optimisation both in OPTIMA and FATIMA for Tromsø indicated that RP and PCH are alternative measures. The RP in the optimum BOF* of FATIMA implies roughly 2 times the effect on traffic compared to do-min PCH and lies between the RP from the EEF and the SOF optimum of OPTIMA. Bearing in mind that BOF is a weighted average of these two objectives this is reasonable. The BOF value of the best EEF run from OPTIMA is relatively close to the BOF* run of FATIMA.

6.7 Oslo

For Oslo changes (a)-(f) above were made with public transport sector operating and capital cost split by time of day. Oslo did not make a distinction between long and short term parking.

The best EEF set of measures from OPTIMA included fare reduction of 70% (compared to -5% peak and -15% off-peak in FATIMA), frequency reduction of 26% (compared to -15% peak and no change off-peak in FATIMA), capacity increase of 20% (compared to +10 % in FATIMA), road pricing of 1.2 ECU (compared to 5 ECU in FATIMA in both peak and off-peak), a 100% parking charge reduction (compared to no change in FATIMA) and no infrastructure investment (compared to the medium level in FATIMA). This policy mix was re-run in FATIMA and produced a BOF value of 271 compared to 696 for the best BOF run in FATIMA.

The SOF optimum from OPTIMA had 100% reduction in public transport fares, 20% reduction in pt frequency, road pricing of 7 ECU, capacity increase of 20%, parking charge decrease of 100% and the infrastructure investment was included. Re-run in FATIMA this measure combination produced a BOF value of 541.

Filtering the effect of each change was not feasible given the time constraint of the project. However the new operating and capital cost for the public transport sector, the shadow price of public money for positive PVF and the split between peak and off-peak all contributed significant to the new optimal measure mix and new values of the objective functions. For example, the shadow price of public money pushed the pt fares and parking charge up in FATIMA compared to OPTIMA. And it is of course important that we are now maximising a new objective function in FATIMA, i.e. some mix of EEF (EEFP) and SOF.

6.8 Helsinki

Changes (a)-(h) above were all made for Helsinki MA of which the most important were the improvement in the accuracy of calculating the rule of the half values using the unaggregated matrix of 117 zones, model update to basic year 1995 and using

EVA time values with weighted waiting time instead of lower national values used in OPTIMA. Also the introduction of long and short stay parking charges, frequency and operating costs split by time of day as well as fares and road pricing was new in FATIMA. The public transport overcrowding was handled in the same way as in OPTIMA: introducing larger vehicles as the first measure and giving a waiting time penalty for the people still left out as the second measure.

The SOF optima from OPTIMA had free fares for the whole day compared to a 50% reduction (limited for the new model) in both peak and off-peak in the FATIMA BOF optima. Frequency was unchanged in OPTIMA SOF compared to an increase of 25% and 13% in peak and off-peak in FATIMA. Parking fares were increased by 92% in OPTIMA SOF compared to no change for long stay and for short stay in FATIMA BOF. All other measures stay unchanged both in OPTIMA SOF and FATIMA BOF solution. The OPTIMA SOF set of measures gave a BOF value of -62 compared to 183 for the optimum BOF*.

The EEF optima from OPTIMA had a more opposite set of measures than the SOF optima compared to BOF optima. The public transport fares were increased by 25% and frequency decreased by -30%. Parking charges had zero change and road capacity was increased by 10%. This set of measures led to an increase in car kilometres and thus to a penalty in FATIMA objective functions. The BOF=COF=ROF value is -969, but the EEF optima is ranked much higher regarding COF and ROF than BOF in FATIMA.

The optimal BOF solution is not far away from the OPTIMA SOF solution. Separating peak and off-peak measures and thus also public transport overcrowding calculations make the results more detailed in FATIMA and show exactly where the changes are feasible and beneficial. This applies to both public transport measures and parking. The effect of giving more value to the public transport waiting time can be seen in the change from the reduction of frequency in OPTIMA EEF and no change in OPTIMA SOF to an increase in FATIMA BOF solution.

6.9 Torino

In FATIMA changes (a) to (h) were made except for (f). Concerning (d), the costs of capacity variations were changed: compared to OPTIMA there was a costs reduction for implementing the decrease of capacity, due to the used technology for obtaining it (asphalt instead of paving).

Concerning (e) the upper limit for parking charge was changed; it was decreased from +500% to +100%, considered more realistic by the Torino Municipality.

Concerning (h) there were changes in the mobility data: availability of 1996 motorised (public and private) new matrices instead of 1995 ones, so the re-calibration of modal split was necessary.

The EEF optimum set of measures from OPTIMA included fare reduction of 25% (compared to FATIMA optima +100% in BOF*), no frequency changes (compared to +30%), capacity increase of 10% (same as for BOF*), parking charges increase to the maximum value +500% (compared to +100% which is the limit for FATIMA), while the values for road pricing and the public transport infrastructure are the same as in OPTIMA (no change compared to the do-minimum scenario). This set of measures re-run in FATIMA produced a BOF value of 91 MECU compared to 128 for the best BOF run.

The SOF optimum set of measures from OPTIMA included fare reduction of 50%, frequency decrease of 30%, capacity increase of 10%, parking charges increase to the maximum value, 0 for road pricing and the presence of High public transport infrastructure. This set produces a positive SOF value, but negative value for all the FATIMA objective functions (-271 MECU for BOF, -2271 MECU for COF and ROF).

6.10 Salerno

Changes (a) to (h) (excluding the change (f)) above were made for Salerno.

The EEF optimum set of measures from OPTIMA included fare reduction of 50% (compared to FATIMA optima of +25), frequency increase of 50% (compared to 80% in FATIMA), capacity increase of 10% (compared to no variation in FATIMA), road pricing of 1 ECU (compared to no road pricing policy), parking charges decreases of 50% (compared to a 300% increase), and no public infrastructures as in FATIMA. This set of measures produced a BOF value of 15 M ECU compared to 24 for the optimum BOF* in FATIMA.

The best SOF combination from OPTIMA consisted of free fares, 50% increase in frequency, capacity increase of 10%, road pricing charge of 2 ECU, elimination of parking charge and implementation of the high public infrastructure. This set of measures produced a BOF value of 12.4 M ECU.

Therefore the re-run of the OPTIMA strategies produced BOF positive values, but obviously these values were lower than the FATIMA optimum BOF combination, because of the list of changes showed above. The biggest effect could be produced by the change in the valuation time costs (travel time and waiting time), by the change in some capital and operating costs and by the penalty in time due to the public vehicle overcrowding. In fact in FATIMA the loading of public transport vehicles was taken into account as additional waiting time to be added to the standard waiting time for the public vehicles.

6.11 Summary and conclusions

A number of interesting issues follow from the results given above:

- It would generally be expected that the EEF- and SOF-optima from OPTIMA would have smaller BOF values than the FATIMA BOF-optimum BOF*. This is in fact shown to be the case in all cities except Merseyside, where the OPTIMA SOF-optimum had a higher BOF value than BOF*. The explanation for this apparently odd result is that the range allowed for road capacity increases was lower in FATIMA than in OPTIMA: the OPTIMA SOF-optimum had an increase of 20% in road capacity, which was not allowed in FATIMA. The conclusion from this result is that great care should be taken to find out exactly how much road capacity increase can be gained through traffic management and telematics measures.

- The “benchmark” aspect of BOF is important. It represents the latest “scientific” view of how to assess a set of measures, given a continuing interaction between scientist and politician over how to make such assessments. It is thus useful to assess the optimum results from OPTIMA in the light of the improved assessment methods devised in FATIMA:

    - For Edinburgh and Merseyside, both (OPTIMA) EEF- and SOF-optima scored highly in terms of BOF (i.e. they achieved BOF values within 20% of BOF*).
    - In Vienna and Eisenstadt the OPTIMA optima scored very badly in terms of BOF, gaining high negative results. The main explanation for this is a large reduction in the value of time for commuting trips. This result illustrates the importance of having standard values of time, or at least a standard approach to valuation, agreed across Europe.
    - In Oslo, the EEF-optimum had a BOF-value 60% lower than BOF* whilst the SOF-optimum was 20% lower. One reason for the low score of the EEF-optimum was that a shadow price was not put on positive PVF in OPTIMA and the EEF-optimum has a relatively low level of finance generation. The importance of the shadow price parameter will be examined further in Section 7.
    - In Tromsø, Torino and Salerno, the reverse situation occurs to that described immediately above for Oslo. The EEF-optimum scores, in terms of BOF, approximately 10% less than BOF* in Tromsø, 30% less in Torino and 38% less in Salerno, whilst the SOF-optimum scores 40% less than BOF* in Tromsø, 48% less in Salerno and negative in Torino due to the presence of high infrastructure in the SOF optima.
    - In Helsinki although the SOF optimum had similar measures to the BOF optimum it scored a negative BOF value. The EEF optimum had completely different measures to the BOF optimum and thus had a highly negative BOF value. These results are mainly due to the introduction of external costs, the changes in values of waiting time and the more accurate modelling in FATIMA.

7. SENSITIVITY TESTS

This section reports on a set of sensitivity tests performed by each city to investigate the effects of various key parameters and assumptions and also to provide a direct link to the OPTIMA project optimal runs for EEF and SOF.

Table 16 shows the sensitivity tests performed by each city.

Sensitivity Tests / City	α in BOF	β for VC	λ shadow price	γ External costs	Operating cost tests	Value Capture Tests
Edinburgh	done	-	done	done	-	done
Merseyside	-	done	done	done	done	done
Vienna	done	-	done	done	done	Not possible
Eisenstadt	done	-	-	done	-	done
Oslo	done	-	done	-	-	done
Tromsø	-	-	-	-	-	N/A
Salerno	done	-	done	-	-	Not possible
Torino	-	-	-	-	-	Not possible
Helsinki	-	-	-	-	-	Not possible

N/A =not available, Not possible indicates no value capture under COF*.
Values not needed are indicated by -

Table 16 : sensitivity tests conducted by each city

7.1 The shadow price λ

The shadow price on public money is set at 0.25 for FATIMA and applied to both positive and negative PVFs as opposed to negative values only in OPTIMA. For Edinburgh, Oslo, Vienna and Salerno the optimum strategies for BOF produced relatively large PVFs indicating a possible bias to strategies which generate revenue. The sensitivity test used in these cities was to lower the shadow price to λ=0.0 and investigate whether non-revenue generating strategies become optimum. In Edinburgh and Oslo reducing λ (alone) does not generate a new optimum strategy which indicates that the revenue generation is part of the optimum strategy for other reasons such as increasing the mode switch from car to public transport and reducing fuel consumption and vehicle-km which increases SOF and reduces external costs.

However in Vienna and Salerno a different optimum appears which reduces revenue to operators and provides benefits to users. This means that for some cities, the revenue generation is only part of the best strategies for BOF if the shadow price λ is high enough. In the case for Salerno the sensitivity test suggests that the optimum BOF strategy may in fact have a negative PVF.

Merseyside produces a highly negative PVF for the optimum BOF strategy and the sensitivity test here is to increase the shadow price to λ=0.5 to penalise large negative PVFs and hence produce a more viable strategy. The results were insensitive to this increase in shadow price and it was shown that λ=1.2 would be required to avoid large negative PVFs and result in strategies similar to the COF optimum.

These tests on λ show that the choice of shadow price may be critical in specifying the optimum strategies, and reopens the discussion on whether a shadow price is necessary or desirable. Even if it is agreed that a shadow price should be used, there is the subsequent question as to what level it should be set.

The obvious concern behind setting λ too high is that extreme revenue-generating strategies will appear optimal, and this result at first sight appears undesirable. However, two qualifications should be made here:

(i) All strategies being tested in FATIMA are relative to a do-minimum scenario. If the do-minimum scenario is in heavy deficit, high revenue generating strategies are clearly much more attractive than if the do-minimum scenario was in surplus.

(ii) An important concern with high revenue strategies is that the surplus is somehow "lost" since it is not specified exactly where it has gone. Thus the argument runs that if City A has a BOF-optimum which generates 1000 MECU, this revenue is lost to the transport sector. However, if City B has a BOF-optimum with a 1000 MECU deficit, there is clearly some advantage to at least considering the transfer of the surplus from City A to City B, thus keeping finance within the transport sector and achieving an overall optimum set of city policies. This argument in fact applies whether or not a shadow price is used. However, an important interpretation of λ is that it determines how much surplus finance is available for redistribution: the higher the value of λ, the greater the availability. Clearly, redistribution between cities is potentially politically controversial. However, given the impending access to the EU of lower income states from the CEEC, such issues should be given careful consideration.

7.2 α in BOF

A number of cities performed sensitivity tests on the weight α between EEFP and SOF in BOF. The range of tests was for α=0.0 to 0.25. The current choice for α=0.1 was based upon equality of present and future generations as explained in Minken (1998). The aim of the sensitivity test is to see how robust the ranking of the optimum strategies is to this choice of α.

In Vienna an α value of zero is required before the infrastructure becomes part of the optimum strategy whereas in Edinburgh α=0.015 results in the high infrastructure replacing the medium one as part of the optimum strategy. In Eisenstadt and Salerno the ranking of the runs is insensitive to changes in α whereas in Oslo increasing α has the effect of increasing the road pricing to its maximum charge.

In general, there is an interesting relationship between α and λ which affects the discussion on shadow pricing immediately above. Lower values of α encourage higher infrastructure investment and hence higher public spending, which is also encouraged by lower values of λ. It would be interesting to examine further this relationship in future research.

7.3 β for Value Capture

This test was carried out for the Merseyside model only.

ROF2 results from setting β (the "value capture" parameter) at 0.2 instead of 0.1 in ROF, thus introducing a greater relaxation of the constraints on PVF than ROF.

The ROF2-optimum has a value of 456. Compared to the ROF-optimum, it has: a decrease in peak fares of 80% (rather than 75%); a decrease in off-peak fares of 50% (rather than 40%); an off-peak frequency reduction of 40% (rather than 50%); and no off-peak road pricing (rather than 1 ECU). All other measures were the same. It can thus be seen that the ROF2 is closer to the BOF-optimum than the ROF-optimum, which is in turn closer than the COF-optimum.

Interestingly it can be shown that if a "ROF3" were to be calculated with β set at 0.4, all the expensive policies (such as the BOF-optimum) would be acceptable in terms of spending constraints. This is an important result since it shows that optimal transport policies can be attained if value capture can be set at 40% of user benefits, which is not an impossible scenario.

7.4 The external costs basis γ

Vienna,Eisenstadt, Merseyside and Edinburgh tested increases and/or decreases in the γ values applied to the external costs in EEFP. In both cities the changes made to γ did not significantly change the ranking of the BOF strategies. This is because in general the external cost accounts for approximately 20-30% of EEFP which is then factored by α=0.1 in forming BOF, coupled with the observation that external costs did not vary significantly between strategies in Vienna and Eisenstadt.

In Merseyside, three sets of tests were carried out:

(i) with $\gamma = 0$
(ii) with γ doubled from the values given in Table 1
(iii) with γ multiplied tenfold from the values given in Table 1

It was found that tests (i) and (ii) made no difference to the BOF optimum and the order of ranking of best sets of measures. However, tests (iii) produced some interesting results. Although, the "old" BOF optimum (BOF*) fared reasonably well when γ was given much more importance, a new optimum (BOF**) was formed by a rather different set of measures. BOF** involves: free fares (as in BOF*); a smaller increase in peak frequency than BOF*, road capacity increase of 5%; all-day road pricing charge of 3.5 ecus; no change in long stay parking charges and an increase of 200% in short stay parking charges.

The new BOF value of BOF* (with γ multiplied tenfold) is 1045, of which approximately 40% is due to the "external cost" benefit. The new BOF value of BOF** is 1111, of which approximately 60% is due to the external cost benefit.

In Edinburgh the γ values were doubled. This had the effect of making the previous second best BOF solution now optimum. The only difference between this new optimum and the previous optimum is the increased road pricing charges from 1.6 ECU all day to 3.5 in the peak and 3.2 in the off-peak. The higher charges reduce vehicle-km further which give benefits in external cost reductions. This change in measures for Edinburgh was partly due to the fact that the BOF solution was insensitive to changes in road pricing measures as mentioned previously and so any extra benefits from external cost reduction outweigh the slight disbenefits of increased charges.

7.5 Operating costs

The sensitivity tests on operating costs of public transport are assumed to be applicable to all regimes, the operating cost reductions assumed to be due to improved organisation if publicly owned and/or competition if privately owned and therefore could feature in any regime, whether regulated or deregulated.

Merseyside carried out sensitivity tests on public transport operating costs, examining how a 20% reduction in operating costs would affect the value of BOF. These tests could be seen in two lights. Firstly, they are simply tests to try to ascertain the importance of accuracy in input data. Secondly, they could be seen as representing measures that actually do reduce operating costs.

The 20% reduction in operating costs led to a new BOF-optimum being created which had a 100% increase in peak frequency (compared to 50%) and a 30% reduction in off-peak frequency (compared to 40%), and so is much more friendly to the public transport user.

One effect of reducing operating costs is, ironically, to reduce BOF values (around the BOF optimum). This is explained because BOF* includes an overall reduction in frequency from the do-minimum: if operating costs are reduced, there is not so much to gain by reducing frequency. However, the BOF value (with reduced operating costs) of the new optimum is 678 and thus is not too different from the “old” BOF-value of BOF* (687).

These tests show that if genuine operating cost reductions can be made (which do not reduce quality/safety levels), large increases in peak frequency can be justified.

Vienna also carried out sensitivity tests on operating costs and capital costs of public transport varying between 50% and 100% of the current standard values.

Figure 2 shows the Vienna values of BOF for varying levels of additional pt frequency, under six different assumptions of changes in operating costs from the standard value. The top curve in Figure 2 represents a 50% decrease in operating costs, whilst the bottom curve represents the standard costs. The other policy measures are set constant at the values attained for the best BOF run. It can be seen that if the operating costs are reduced by 50%, the pt frequency is 30% for the optimal BOF solution, compared with 0% with standard operating costs. The BOF value of BOF* increases by about 40% from 142.4 to 197.8. On the other hand, a 20 % reduction in operating costs (shown by the third lowest curve in Figure 2) results in no additional frequency and no increase in BOF.

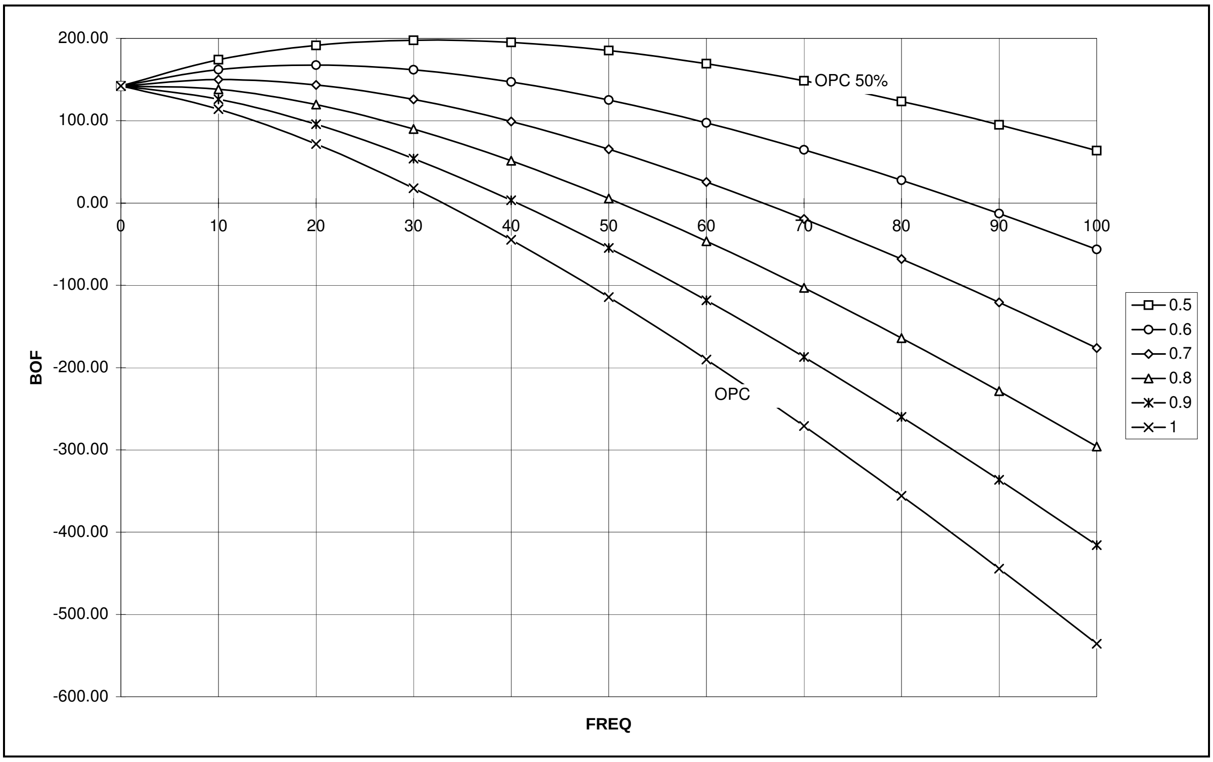

Figure 2: Sensitivity test operating costs for increased public transport frequency BOF

HOF

Figure 3 shows the values of HOF for varying levels of additional pt frequency, under six different assumptions of changes in operating costs from the standard value (as in Figure 2). The other policy measures are set constant at the values attained for the best HOF run. The main effect of the reduction of pt operating costs is that the range for "nearly optimal" HOF values is greatly extended. Thus with a 50% cost reduction, all increases in pt frequency from +10% to +35% deliver nearly optimal HOF values.

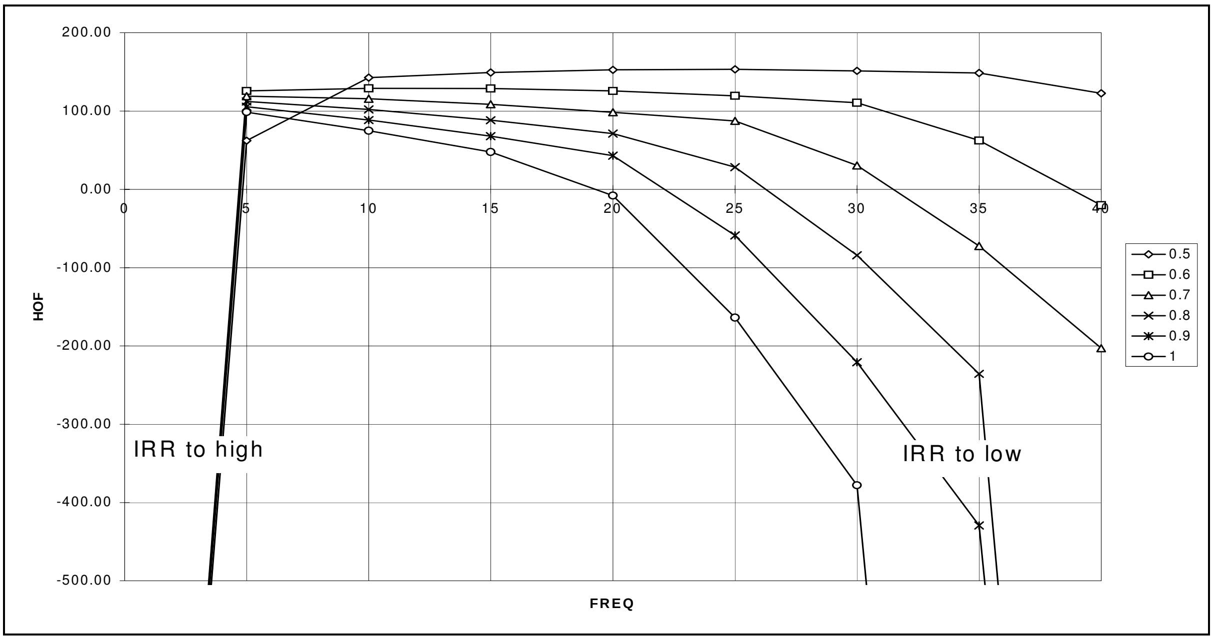

Figure 3: Sensitivity test operating costs for increased public transport frequency HOF

DOF

Figure 4 shows the values of DOF for varying levels of additional pt frequency, under six different assumptions of changes in operating costs from the standard value. Compared to Figures 2 and 3, the units of frequency along the horizontal axis are much more restricted (ranging from a frequency increase of 2% to an increase of 9%). The other policy measures are set constant at the values attained for the best DOF run. It can be seen that the reduction in operating costs leads to a slight increase in DOF-optimal frequency.

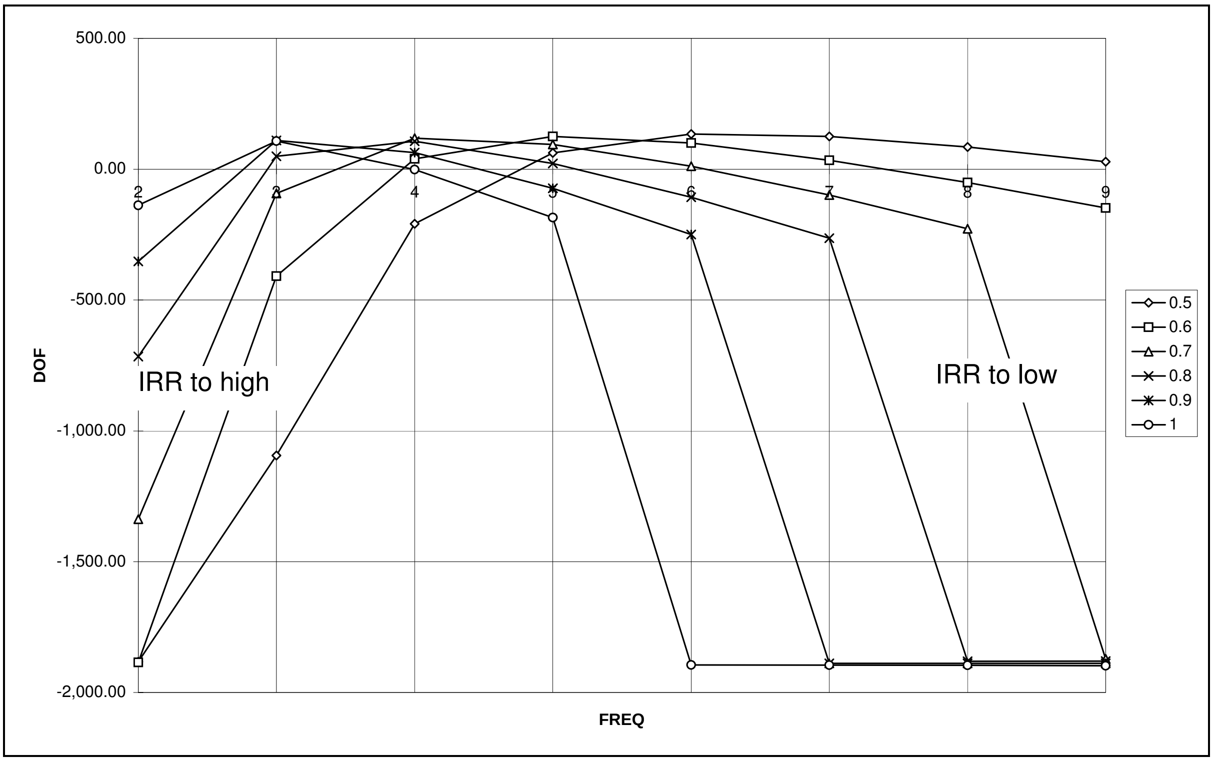

Figure 4: Sensitivity test operating costs for increased public transport frequency DOF

7.6 An alternative approach to Value Capture (AVC)

Further to the main value capture tests (carried out by optimising ROF) most cities carried out tests involving an alternative approach to value capture (AVC). The main difference in AVC is that "extra" value capture finance is directed specifically to the improvement of particular public transport measures (in the original concept of value capture (VC, as implemented in ROF), value capture could be directed at whatever measures would lead to overall social improvement).

The underlying assumption in ROF was that value capture would be raised (through either voluntary agreements or tax) from shop-keepers and other commercial interests who would benefit from the city "being a more attractive place" (as represented by increased user benefits). On the other hand, in AVC, the underlying scenario is of employers paying out for improved public transport schemes specifically to bring their employees to work.

The sensitivity tests for AVC have the following form:

- Take the optimum constrained strategy defined by the optimum COF* set of measures.
- Use the value capture (0.1*user benefits) from this run to invest further in the public transport sector than is done in the optimum COF* measures.
- Perform a transport model run for this improved strategy.
- Evaluate this run by transferring the value capture element from the user benefits to the government sector, which is then used to pay for the improved public transport service.
- Compare the new COF value with that obtained by merely transferring the value

capture element from user benefits to the government sector without service improvements.

- Compare the modal split indicators and percentage change in car-km with COF*

As with VC, there will be no benefit to having AVC if PVF > 0 in the BOF optimum (since there is no financial constraint to restrict optimal transport policies being implemented).

However, if the PVF<0 for optimum BOF* and by definition PVF>0 for COF* i.e. Class 1, then this implies that some form of extra capital would be able to improve the COF* optimum towards that of the BOF* optimum. The AVC test as implemented here has a limited capital element which is directed specifically at the public transport sector and so the extent to which the capital brings about improvements in COF* is limited. Only in Merseyside could improved public transport services financed by AVC bring about benefits greater than those associated with spending the AVC elsewhere.

Changes in the modal split indicators are shown below in Table 17 for each city based on an AVC test which increased public transport frequency only at a cost equal to the AVC. The changes shown are for (AVC run)-(COF* run).

Modal splits	Edinburgh	M'side	Vienna	Eisen-stadt	Tromsø	Oslo	Helsinki	Torino	Salerno
MS (trips)-car	-0.2%	-0.3%	#	-0.01%	##	-0.04%	#	##	#
MS(trips)-public transport	+0.2%	+0.5%	#	+0.03%	##	+0.15%	#	##	#
MS (trips)-others	n/a	-0.2%	#	-0.02%	##	-0.16%	#	##	#
MS-(distance) car	-0.4%	-0.4%	#	-0.02%	##	-0.06%	#	##	#
MS-(distance)public transport	+0.4%	+0.6%	#	+0.04%	##	+1.34%	#	##	#
MS-(distance) others	n/a	-0.2%	#	-0.02%	##	n/a	#	##	#
Change in Car-km p.a.	-0.4%	-0.4%	#	-0.01%	##	-0.06%	#	##	#

no value capture for Vienna, Helsinki and Salerno COF*
no test carried out in Tromsø and Torino

Table 17: Changes in modal split indicators for value capture tests

As Oslo did not have a positive user benefit in the optimum COF strategy, a slightly different AVC test was chosen for this city. Instead of taking 10% of the total user benefit, 10% of the user benefit from the infrastructure investment was taken. This was calculated by running the COF optimum *without* the investment.

Using AVC, the changes for all cities are small as expected as these indicators are reflected through the COF* measure. It is difficult to say whether the changes in indicators are significant as in Merseyside the changes are of the same magnitude as those for Edinburgh, however as stated above the changes for Edinburgh were not enough to merit the expenditure under the COF measure. (The indicators cannot be compared across city as they are percentage changes from different initial conditions). Indeed for Edinburgh it is possible to get greater changes in car-km and mode splits by simply doubling the road pricing charge without affecting the COF value too much.

8. FEASIBILTY AND ACCEPTABILITY

8.1 The consultation process

After the modelling and optimisation process it clearly becomes important to analyse the feasibility of the proposed strategies and the potential for them to be implemented in reality. At this stage it was therefore important that those involved in policy decisions became involved.

At the end of the strategy analysis process, the FATIMA team consulted the authorities involved in transport decision making and operation in city, in order to obtain a practical view on the results obtained from the modelling and optimisation process.

Each city was provided with a standard questionnaire in order to summarise their comments on the whole project and its final results. The questionnaire consisted of a series of open questions, for most of which it was also possible to give a numerical score that represented the level of agreement or satisfaction with the item referred to.

The questions related to the technical, financial and legislative feasibility of the optimum strategies under each objective function regime and their likely acceptability to the public, politicians and the private sector. There were also general questions on the objective functions and the overall methodology of the project. The completed questionnaires are included as an annex to FATIMA (1998b).

The completed questionnaires provided the basis for analysing the feasibility and acceptability of the various optimum strategies, for each city and objective function, and to identify any potential barriers to their implementation. Responses were received from all cities except Oslo and Tromsø, who had no criticisms of the results.

The sections below summarise, for each city, the results obtained for the different objective functions examined during the project. They present also the main engineering comments and general observations which emerged during the consultation process together with remarks from the respective modellers who took part in the project. The city results are then drawn together under each feasibility and acceptability heading.

As in OPTIMA, it was found during the consultations that there was a degree of overlap between the feasibility, public acceptability, political acceptability and barriers to implementation, with particular issues or problems (e.g. ‘too expensive’) recurring under more than one heading. This is reflected in the structure of this section, in order to help reduce any repetition.

This section is structure as follows: first there follows a series of sub-sections which summarise the results of the consultations with each city in turn, for each of the optimum strategies. In these subsections the focus tends to be on the BOF optimum, with the other optima, where different from BOF, being discussed subsequently. These subsections also contain a summary of the main features of the optimisation results for each city, to avoid the need to refer back.

The final subsections then take the consultation results for all the cities together and analyses them systematically under the various feasibility and acceptability headings. The full city results are reported in FATIMA (1998b).

8.2 Feasibility and acceptability for individual cities

8.2.1 Edinburgh

Edinburgh City Council were interested in the methodology of the FATIMA study in general, the results produced and how they compared with the previous results from OPTIMA. The fact that the model used in OPTIMA and FATIMA was the same as that used in the Edinburgh-area JATES study some years ago enabled the process and results to be more readily understood. The FATIMA results for Edinburgh were also relatively straightforward in that the same optimum strategy emerged for all the objective function regimes, apart from some comparatively small deviations in the Deregulated Objective Function regime.

Edinburgh has BOF*=ROF*=COF* and the HOF* solution has the same set of measures for its optimum. The only changes are for DOF* which has a higher road pricing charge, no increases in frequencies in the off-peak and less of an increase in the peak, lower fare reductions in the peak and no reductions in fare in the off-peak. These optima were considered by the city authority to be reasonable results, against the respective objective functions.

All the Edinburgh optima included medium infrastructure (guided bus), a 10 per cent increase in road capacity, major increases in peak and off-peak public transport frequency (no off-peak increase in the DOF optimum), major fares reductions, especially in the peak (no change in off peak fares in the DOF optimum), peak and off-peak road pricing of 1.6 ecu (3.2 ecu for the DOF optimum) and 300 per cent increases in both long and short term parking. This was considered to be a reasonable optimum policy, provided that the revenue raised from motorists in road pricing and parking charges can be seen to be invested in a more frequent and much cheaper public transport system. In this respect, the DOF optimum was less satisfactory as it has higher charges on motorists but less improvement to public transport.

The comments made below in this section mainly relate to main points made by the City of Edinburgh, particularly from the completed FATIMA questionnaire: however, the optimal strategies for Edinburgh from OPTIMA were in many respects similar to those from FATIMA, so comments made in an earlier, similar questionnaire about the OPTIMA strategies have been included here where it is believed that they are also pertinent to the FATIMA results.

It was considered that the optima were without any serious technical barriers to implementation, other than the difficulty of installing new infrastructure (such as guided bus) in the historic urban environment of Edinburgh, and it was felt that this could be overcome provided the facility exists for new infrastructure to be ‘tailored’ into the historic setting.

Financially, the optima are broadly neutral in terms of feasibility. Obtaining sufficient capital to finance schemes at their outset could pose difficulties together with recovery time for the initial investment. The problems could perhaps be overcome by borrowing against expected future receipts from the system.

It is unlikely that there would be any major legislative barriers, though it is too early to be sure as, for example, it may prove that the proposed charging systems may be legally challenged. There is also a need for legislation to enable road pricing to be implemented, though this is unlikely to be a serious barrier: however, there is also a need for changes to the regulatory regime for public transport to enable fares and frequency policies to be implemented and this is likely to be a much larger constraint in the current political and commercial climate.

Politically, any policy involving highway construction is unacceptable to Edinburgh and it was assumed that the highway capacity increase of 10 per cent could be achieved without this. If this proved not to be the case then these optima (or this component of the optima) would become unacceptable. (Note that the highway capacity increase in FATIMA was limited to 10 per cent, compared to 20 per cent in OPTIMA).

The public as a whole are likely to be fairly content with the optima as they are likely to give faster travel times for most travellers, improve the quality of public transport and improve the journeys for essential traffic. Against this would need to be weighed the negative opinions of some road users (principally car travellers) because of the extra costs which would accrue to them, and the ‘subsidy’ which would be required for public transport services. The single exception to the likely acceptance of the optima to the public is the DOF optimum strategy, in which the combination of the increased parking charges with a road pricing charge much higher than in the other optimum strategies would be unacceptable. Also, the DOF optimum (with the higher road pricing charge) would be politically unacceptable.

It is difficult to predict the acceptability of the optimum strategies to the private sector, though one benefit to this group could be that the strategies would allow the improvement of travel times for essential traffic. It is also difficult to predict political acceptability, with the improvements to the public transport system being offset by the financial disbenefits to private motoring (especially the higher road pricing charge in the DOF optimum) which would be opposed by the motoring lobby. However, operators are likely to support the optima because of the shorter travel times and the expectation of fairer competition with private transport.

Quality is of importance to Edinburgh. It was felt that, though the optimum strategies should enhance quality through shorter travel times and improved infrastructure, quality issues should have been given explicit emphasis in the project. Edinburgh City Council suggested that the maintenance of quality in the system could be enhanced by ‘quality partnerships’, public/private funding for some public transport routes and better marketing by public transport operators.

In terms of acceptability in general, the main constraints on the optimum strategies are that there could be no road construction, and road pricing would have to have been shown to be successful elsewhere before implementation in Edinburgh.

Regarding information from the process, Edinburgh would have liked more disaggregation of results (city centre and non central policies) and, given their emphasis on walking, cycling and the environment, more data on motorised/non-motorised modal split and on environmental indicators.

8.2.2 Merseyside

Merseyside were interested in FATIMA and its results and the development of the process from the earlier OPTIMA project.

The comments made below in this section mainly relate to main points made by Merseyside in the completed FATIMA questionnaire: however, the optimal strategies for Merseyside from OPTIMA were in some cases similar to those from FATIMA, so comments made in an earlier, similar questionnaire about the OPTIMA optimum strategies have been included here where it is believed that they are also pertinent to the FATIMA results.

Generally speaking, the optimum strategies identified under each objective function were regarded as being reasonable, with the possible exception of the inclusion of road capacity increases in a strategy (BOF) which is at least partly designed to provide a sustainable transport system for future generations.

All the Merseyside optimum strategies are different from one another, except the HOF and COF optima which are identical (the PVF is large enough to provide the subsidy required to give a return of 15 per cent to public transport operators).

The BOF optimum is:

- to increase capacity (+10%);
- to increase peak frequency(+50%);
- to decrease off-peak frequency (-40%);
- all-day free fares;
- no road pricing;
- cheaper long stay parking (-100%);
- more expensive short stay parking (+100%);
- medium infrastructure (SMART bus).

The COF and HOF optima are the same as each other and similar to BOF, but the pro-public transport measures are less strong than in BOF. Road pricing and greater increase in short stay parking charges are included, to pay for the public transport system and at the same time maintain a positive PVF.

The ROF optimum is between BOF and COF/HOF, though closer the latter: ROF has a larger decrease in peak fares and a smaller increase in short-stay parking charges than COF/HOF.

The DOF optimum is similar to that for COF/HOF but with lower increases in peak frequencies and small fare reductions and with a smaller increase in short-stay parking charges.

In terms of the social objective function (BOF), the ROF optimum is 40% lower, but has a PVF of only - 152 Mecus, making it far more affordable than the BOF optimum (PVF = -2120 Mecus) – affordability is a major issue in Merseyside, as discussed below. The lowest optimum in terms of BOF is DOF, which is a further 19 per cent below the ROF optimum.

Regarding the optima in general, Merseyside considered that any policy involving very large increases in short term parking charges together with free public transport fares, though in the right direction, would be too extreme: though fares should be reduced, they should not be free and short term parking charge increases should not exceed, say, 50 per cent (the reasons are discussed below, under public acceptability). Merseyside suggested that better optimum strategies would include:

- Parking charges in town centres to be increased sufficiently to reduce car dependency but not enough seriously to affect trade;
- Public transport charges should be reduced and public transport frequency at peak periods should be increased to compete with the convenience of a car.

In order to achieve the latter, either public transport needs to be subsidised by Central Government or an increase in fuel tax could be hypothecated to subsidise the public transport system.

Technically, all the optima will experience problems due to the implementation of road pricing, except the BOF optimum, which is the only optimum strategy with no road pricing component.

The question of affordability of optimum strategies was a prime concern of Merseyside in the OPTIMA project, and the need to develop objective functions in FATIMA to take affordability specifically into account was suggested by Merseyside towards the end of the OPTIMA project. Affordability continues to be crucial, causing the FATIMA BOF option to be unacceptable as it stands, because of the large negative PVF. Regarding specific financial issues relating to the optimum strategies, the following problems exist, particularly for the BOF optimum:

- Parking charges can be controlled only in Local Authority-owned car parks:
- Free peak and off peak fares would be resisted by the Local Authorities;
- Substantially reduced fares would place an unacceptable financial burden on the Local Authorities;
- Increasing short term parking charges might encourage shoppers to visit out-of-town locations where parking is free: local Chambers of Commerce and their members would resist this.

These problems are sufficient to make the BOF optimum unacceptable financially: only considerable additional funding from Central Government could overcome these problems. As was found in the OPTIMA project, the questions of finance and funding, though important everywhere, are particularly crucial to policy formulation in Merseyside.

In terms of legislation, the main difficulties expected for the various optimum strategies included the need for legislation for road pricing (all optima except BOF) and the need to review the regulatory system for public transport.

Politically, the optimum policies would tend to polarise voters: non car owners would benefit greatly and give support to the political party promoting such a strategy, but car owners would probably vote against the party because of the significant increase in motoring costs. What would be completely unacceptable politically would be to raise local taxes to support free public transport. There was also some concern about the political (and public) acceptability of introducing road pricing, especially in a relatively uncongested city such as Merseyside.

The public would find all the optima to be barely acceptable – they would be broadly neutral on the BOF and ROF optima, but would generally be somewhat less happy with the COF, DOF and HOF optima. The problems are as follows:

- Free long term parking in town centres would encourage commuter traffic to the detriment of shoppers (but if located at rail and bus stations would have the benefit of encouraging park and ride);
- Increasing short term parking charges would discourage shoppers.

The particular element of the strategy that might be unacceptable to the public is the supplementing of free public transport, which could exert unacceptable financial burden on council tax payers.

For the private sector, the optima would be broadly neutral as, though the increases in short term car parking charges would discourage shoppers, this would be offset by free peak and particularly off peak fares. The only benefit to the p.t. operators is that bus journey times would reduce significantly if fare collection ceased. The optimum strategies would also be wholly unacceptable to taxi operators, who would suffer severe loss of revenue.

In respect of ensuring transport service quality, it is possible that free or much reduced peak and off peak fares would remove the incentive for bus operators to compete on quality. As a means to help overcome this, Merseyside suggested that there should be ‘quality partnerships’ between the Passenger Transport Executive (the local authority public transport body) and the bus operators.

Regarding the analytical process as a whole, Merseyside considered that the supply of parking should be included in the policy options, as well as parking charges, and that greater attention should be given to the benefits of walking and cycling.

8.2.3 Vienna

For Vienna the BOF* solution is also the ROF* and COF* solution. It includes reduced capacity, increased short stay parking charges, no change in long stay parking charges, no changes to public transport frequencies, but an increase in fares of 77%. The increase in fares gives a high public PVF and is generated by the shadow price effect on revenue generation. The high PVF could be used to reduce the subsidy given to the public transport system in the do-minimum.

The DOF* solution is similar to BOF*, but it includes small increases in frequencies with much smaller increases in fares as the private sector is limited to a 15% return.

The HOF* solution is identical to DOF* in terms of measures and the subsidy is used to increase the private sector return from 14% under DOF* to 15% under HOF*. No improvements in services are implemented with subsidy as the value of revenue generation outweighs the benefits to users of improved services. The DOF* solution is 24% worse in terms of social objectives than BOF*.

The person interviewed in Vienna was also involved in the OPTIMA consultation process. He pointed out that the inclusion of more external transport related costs, like accidents, air and noise pollution, in the objective functions and regimes was an important step in the right direction.

With reference to BOF, COF and ROF regimes, the consultant sees no technical problems in implementing the proposed combination of measures.

Financially, two of the key measures are pricing measures (fares and parking charges), which are inexpensive to realise. The reduction in road capacity is seen not to be cost intensive.

From the public and political point of view there might be troubles due to the fact that the suggested optima generate disbenefits to public transport users and car users. On the other hand, from the strategic point of view the proposed policy combination will move the modal split share towards the target set out by the local authority in the early 1990's.

Generally, Vienna were familiar with the optimisation method and therefore no questions or problems arose about this issue. However, it was pointed out that a wide range of scientific disciplines, like social science, economic impact analysis and so on, should be involved in the formulation of the objective functions.

8.2.4 Eisenstadt

The Eisenstadt authorities interviewed were interested in the final results from FATIMA for their city.

The BOF* solution for Eisenstadt is to reduce capacity, reduce frequencies and fares, reduce long stay parking charges whilst increasing short stay charges.

For Eisenstadt BOF*=COF*=ROF*. HOF* is similar but has a lower reduction in capacity, smaller reductions in frequencies, greater fare reductions and greater reductions in parking charges for long stay. This has the effect of transferring users from the walk and bicycle mode to public transport, so the subsidy removes users from the slow modes. The HOF* solution is 19% worse in terms of social objectives than BOF*.

Eisenstadt is a special case in that it has no feasible DOF* solution.

From the technical point of view there exist no problems at all and from the financial side any problems are only minor in nature.

From the public and political point of view there would be some problems with all the suggested optima, especially the public transport related measures. The public transport system is very underdeveloped compared to the other cities. The main reasons for that are on one hand the high number of cars per capita and on the other hand the structure of the city itself. Due to the poor public transport system, price increasing measures for car users automatically increases the number of trips made by foot or by bicycle. Generally this effect is desired, but to attract trips to the public transport system a lot of investment would be needed and no private investor would be capable of investing the large sums needed. However, improved quality in the public transport is the only way to cause a desirable trip shift to public transport. Such a shift is also necessary to make the public transport system economically interesting for private investors.

8.2.5 Helsinki

There has been a local follow-up group for project FATIMA throughout the project in Helsinki MA. The group comprised representatives of the Ministry of Transportation and Communications, Transport Planning Office in Helsinki Metropolitan Area Council, the City Planning Office of Helsinki, The City Planning Centre of Espoo and the Planning Office of the City of Vantaa. The consultation process in Helsinki MA, in general, has been successful and the response has been positive, as all the authorities involved have shown interest in the project. Two of the above mentioned authorities returned the interview form; the head of Transport Planning Office in Helsinki Metropolitan Area Council reported the collaborative opinion of his office and the other answer came from the representative of Espoo. In addition to these activities, a half-day seminar of the final results of the study was arranged for the follow-up group.

The BOF* solution for Helsinki increases public transport frequencies in both peak (+25%) and off-peak (+13%) periods and reduces fares by 50% both in the peak and off-peak (which is the lower limit for Helsinki due to modelling constraints). Parking charges are not changed. No capacity changes, road pricing or infrastructure measures are implemented. This set of measures yields a highly negative PVF.

In the COF* solution there are only some small changes in the optimum measures. The public transport frequency is reduced in the off-peak (-10%) thus saving on the operating costs. However, for to keep the passengers also fares are slightly reduced both in the peak and off-peak (-10% and -7%). For cars there is a modest increase in long stay parking charges (+20%), and no change in any other measure.

For Helsinki ROF* equals COF* including a very small value capture element that does not change the ROF* function. The COF* solution is 75% worse in terms of sustainable objectives than BOF*. (which was financially infeasible – see below).

DOF* and HOF* were not calculated for Helsinki.

In the discussion at the half-day seminar of the follow-up group severe doubts about implementation of the strategies emerged. Regarding the BOF* strategy the Transport Planning Office in Helsinki MA Council pointed out that although it would attract more people to use public transport, the strategy is financially impossible to implement because, as a whole, the fare revenue decreases and there is a need for more subsidy. The second best solution is a nearly similar strategy with a smaller reduction in fares resulting in a slightly worse BOF-value. This strategy is somewhat better in financial terms but also here all financial savings are on the users' side and more subsidies are needed.

From the legislative point of view there are no problems in the implementation of the BOF* strategy. It is, however, financially unviable (as discussed above) except with increased taxes (as discussed below). Also, some technical problems may arise from the implementation of the strategy because of the need for a new fleet of buses and trains due to the increase in frequency.

From the political point of view, the Left and the Greens are likely to back the BOF* strategy because it improves the quality of public transport and enhances the image of the public transport as a part of the sustainable development of the area. However, the parties on the right would line up against it.

From the public point of view, The BOF* strategy would be welcomed as it is in favour of both public transport users and car drivers who will have more space due to people's transfer from car to public transport. On the other hand, especially because the level of subsidy is already very high, the municipalities in Helsinki MA could not in the present economic situation afford a higher subsidy, and thus the only way to finance the strategy would be to increase municipal taxes. Car users would not accept a tax increase for this reason.

Though no technical or legislative problems in implementation of the COF*=ROF* strategy were found, this optimum nevertheless aroused suspicion as it is against present policy in two respects: firstly the fares are cheaper in the peak than off-peak period of the day (intuitively Helsinki felt it should be the other way around) and secondly the off-peak frequency level should not be made worse compared to the present. The decrease in public transport fares is obviously in favour for public transport users but the off-peak frequency reduction is against them. The increase in parking fees, although small, will not easily be accepted by car users or by the private sector entrepreneurs in the city centre although it would make it easier to find a parking place. Politically, the Left and the Greens should support the strategy.

The COF*=ROF* solution may also cause some problems especially from the political point of view. In fact it may be difficult to get a political decision to decrease public transport fares and to find a real justification in increasing parking charges. From the legislative point of view some difficulties could arise from changing parking charges in general, as neither the state nor the municipalities can determine the charges for the private parking operators, only for places under their control which represent the minority of the supply. The reduction of the PT frequency could cause problems of public acceptability, even if it is suggested only for the off-peak period and opposition to the increase of long-term parking charges could arise among drivers. In general the strategy may improve the performance of the transport system but because the changes are very small the effect is minor.

As an alternative for both optimal strategies the Transport Planning Office in Helsinki Metropolitan Area Council proposed a strategy consisting of a congestion charge or tax, an increase in parking fees and only small improvements in public transport fares and frequencies, if any.

8.2.6 Torino

With reference to the consultation process, the responses were, in general, positive as all the interviewed people (the technicians of the City Council and the technicians of the Transport Company-Transport Planning Sector) showed interest and curiosity in the FATIMA project and in the final results of the study.

The BOF* (= COF* = ROF*) solution for Torino foresees a strong increase of both private and public (increased frequency) supply, no change in public transport infrastructure, road pricing and the highest permitted increase of both public transport fares and parking charges (100% in both cases). The scenario reduces user benefits overall and the combination of high fares and high parking charges leads to a strong increase in revenue that should at least balance capital and operating costs. This yields a positive and quite high PVF (710 million ECU).

The HOF* solution is identical to DOF* and it is quite similar to BOF* (= COF* = ROF*) . In particular, it suggests an improvement in both the public and private supply (increase in the private capacity of 10% and increase in the public transport frequency of about 30%), an increase in public transport fare by 70% and in the parking charge by 100%. The DOF*=HOF* solution is 16.5% worse in terms of social objectives than BOF* solution.

All the optimum strategies require an increase of the road capacity by 10%. This, in a city like Torino, can be achieved first of all increasing the traffic control by the improvement or the extension of intelligent transport systems and secondly reducing the on-street parking zones, widening some cross-roads. To implement this measure, costs have been overestimated (about 48 Million ECU) in order to have an economical margin to build some new parking where the increase of the road capacity is obtained by eliminating on-street parking. There are no additional operating costs (with respect to the do minimum) as the municipality budget for road maintenance is a fixed sum per year. Obviously the increase of road capacity would lead to a general benefit for road practicability, but would at the same time give a disbenefit to the users of the on-street parking and for pedestrians (capacity increase partly obtained by reducing the width of pavements).

In general, the city authorities agreed that probably the suggested optimum strategies include some measures (in particular, strong increases in PT fares and parking charges) that would be too heavy a burden on the users, both public and private. So an alternative strategy was suggested, broadly in the same direction as the optima, but with a more gentle increment of measures. In particular, an approach was suggested with a smaller increase in fares and in which the additional income deriving from the increased parking charge could be used to fund the frequency increase.

From a technical point of view, the variation of charges can be implemented without problems, since the implementation and operation costs are zero. However, the 10% increase of road capacity could be technically problematic, if implemented by reducing the pavement width or eliminating parking place on streets, but might be possible by improving or extending intelligent traffic systems, such as intelligent traffic lights, so that the traffic movement may be facilitated without changing road characteristics. Technical problems could also arise from the increase in public transport frequency which might need improvements in production and maintenance facilities. But it was pointed out that these problems should be soluable.

From a political point of view difficulties in acceptability would arise as politicians who accept a strong increase of PT fares and parking charge would become unpopular. Other political problems could arise because the public transport fare is suggested by the Transport Company, but the final decision is taken by the municipality (who also decide parking charges).

The increase in PT fares and parking charges would not be acceptable to the public. These increases might be acceptable in other European cities where the gross domestic product is higher, but not in Italy where the average salary is not sufficiently high to support similar costs. Moreover shopkeepers will be probably against the increase of parking charge because this could reduce the number of customers.

It was also suggested that the additional income deriving from the optimum strategy implementation should be used to improve the global quality of transport and especially of the public transport (in terms of cleanliness, air conditioning, etc).

With regard to the DOF and HOF objective functions, doubts were expressed about the privatisation of some public services. It was asserted that for every kind of service, a certain quality level must be maintained. As in general operating costs are quite high, an adequate service level can be kept only by a public company that can count on the help of the State.

Finally it was affirmed that for the city of Torino a new public infrastructure system is necessary and its capital costs should not be part of the cost benefit analysis. In this way it might be possible to find better optima that don’t weigh so heavily on transport service users.

Regarding the FATIMA method, it was suggested that it would be useful to try to find a formulation of the objective functions that takes into account some “quality indicators”, such as cleanliness, comfort and so on.

8.2.7 Salerno

With reference to the consultation process, in general the responses were positive as all the interviewed Salerno authorities, both the technicians of the Transport Company and the politicians of the city council, showed interest and curiosity in the FATIMA project and in the final results of the study. They already knew the optimisation method and the measures examined, as they had followed with interest the previous project OPTIMA. They found the FATIMA optimum strategies sensible in terms of the defined objective functions.

For the city of Salerno, the BOF* solution (=HOF* solution) requires no new infrastructure, no changes in capacity and no road pricing, but a large increase in frequency (+80%), a 25% increase in fares and a 300% increase in parking charges. The increased revenue yields a positive PVF.

The best runs for COF and ROF, like in the BOF case, all require an improvement of the quality of the public transport (but with a lower increase in frequency than BOF: 50%), an increase in fares of 25%, no change to capacity and an increase in central parking charges of 300%.

The best run for DOF includes an increase in public transport frequency of 50%, the maximum increase in fares (100%), no variation in network capacity, and the implementation of a low road pricing policy (1 ECU), coupled with the maximum increase of the parking charge (300%).

The DOF* solution is 36% worse in terms of social objectives than BOF* and HOF*, while the COF* solution is 4.5% worse.

Overall, it can be seen that all optima for Salerno require improvement in the public transport supply and an increase in costs for the user of the private network. The latter can be achieved either by the implementation of road pricing or by an increase in the parking charge, or both.

Technically, there would be difficulty in increasing the public transport frequency by the required percentages (50%-80%) as this would imply the redesign of all the lines and perhaps also need many modifications to the public network. Moreover, in order to increase the public transport supply in this way, financial problems could arise, as it would be necessary to find funds to buy new buses and trams and for new employees.

In order to pursue measures that require tariff increases, political approval is needed. But it was agreed that there is a balance between, on the one hand, the tariff increases and the improvement of the public transport service (involving more financial and management burdens) and on the other, greater income. Politically, it was felt that road pricing policy for the city centre (suggested in the DOF optimum strategy) is not yet suitable for Salerno.

The public regard the long waiting times caused by crowded buses and low frequency as being a problem in Salerno. The improvement of the supply of the public transport can lead to an increase of fare that would probably be accepted by the users because of the high benefits of the new public transport.

Both politically and publicly, the increase in road capacity is not favourable for two reasons. First of all it requires quite high capital costs that would weigh on cost-benefit analysis and secondly it increases the private modal split increasing fuel consumption at the same time.

Other comments made during the consultations were, that although the BOF function safeguards important aspects such as environmental sustainability, it was judged not to reflect reality, as it did not consider budget bonds. The COF function, however, as it takes into account financial restrictions, was considered to be closer to the present Italian situation.

Finally, it was agreed that the involvement of some private businessmen or private companies in financing or managing services that at the moment are under the control of the government would be a good thing. However the private sector will be interested in such investments only if they can obtain a big economic advantage.

8.3 Overall feasibility

8.3.1 Financial feasibility

As in OPTIMA, the financial feasibility of the optimum strategies was the most frequent concern of the city authorities. However, financing the whole package was considered to be an overwhelming concern only for Merseyside, and to a lesser extent for Salerno and Helsinki. Specific financial concerns expressed included the difficulty of obtaining enough capital to finance schemes at the outset (Edinburgh), the need for an unacceptable increased public transport subsidy for the BOF solution (Helsinki) (which could be slightly eased in the alternative, sub-optimal, solutions) and the need to finance extra buses and staff (Salerno).

8.3.2 Technical feasibility

Overall, the optimum strategies were viewed as being broadly feasible by nearly all the authorities – certainly more feasible than in OPTIMA. One reason for this is the reduction in the range of some of the policy measures, making certain components of the optima, particularly the highway capacity increases, more technically achievable. Specific concerns which remained included the difficulty of designing new infrastructure to fit in with a historic setting (guided bus in Edinburgh), the introduction of road pricing (Merseyside), the methods of providing extra road capacity and increasing public transport frequency (Torino) and the need to redesign public transport routes (Salerno).

8.3.3 Legislative feasibility

With the exception of Salerno and Vienna, which were broadly neutral in this respect, there were no major legislative barriers to the acceptability of any of the optima. Edinburgh (and Merseyside) pointed out the need for legislation for road pricing, but did not consider this to be a major barrier. In these two cities, however, there would be a need for changes to the regulatory framework for public transport to enable fares and frequency changes to be implemented. The difficulty of controlling parking charges other than in local authority car parks was also mentioned by Merseyside),

8.4 Overall acceptability

In FATIMA, the consultation process was extended beyond that applied in OPTIMA, to include private sector acceptability and acceptability to the public transport operator, rather than just public and political acceptability. A question was also asked concerning the contribution of the optimum strategies towards transport sector service quality. The results of all these consultations are set out in the sub-sections which follow.

8.4.1 Public acceptability

In gauging public response to the optimal strategies, it is important to stress that the views in this section are based on the views of city officials, rather than on a poll of the public as a whole.

In only one of the cities (Edinburgh) was the optimal solution considered to be publicly acceptable; in three others (Merseyside, Helsinki and Salerno) public reaction would be broadly neutral (balanced between perceived benefits and disbenefits); while in three (Vienna, Eisenstadt and Torino) the optima would on the whole be unacceptable.

Particular problems of public acceptability resulted from the need for (increased) subsidy to public transport which would need to be funded from local taxes (Merseyside and Helsinki). In this respect, Helsinki pointed out that the alternative to increased subsidy could be the re-allocation away from other spending sectors. Increases in charges to motorists, in the form of road pricing and parking charges, were also of general public concern. For Torino, the combination of increased fares and parking charges becomes unacceptable to all sectors of the public. In the case of Eisenstadt, reduction of public transport frequency, with consequent longer waiting times, was the main cause of public unacceptability to the minority who use public transport.

8.4.2 Political acceptability

In three cities (Edinburgh, Helsinki and Salerno) the optima were regarded as being broadly politically neutral, with benefits roughly balancing disbenefits, while in the remaining four (Merseyside, Vienna, Eisenstadt and Torino), the optima were on balance not acceptable. The political problems were in the main similar to those cited for public acceptability, with burdens upon local taxes being of major concern as well as increases in charges to motorists, in the form of road pricing and parking charges. In Eisenstadt, the reduction in public transport services, especially in service frequency, is seen by politicians as being a key problem.

8.4.3 Private sector acceptability

With the exception of Torino, the optima were considered to be broadly neutral from the point of view of private sector acceptability. In almost all cases this was due to a perception that increases in parking charges, especially short term, would cause a loss of custom to retail businesses, particularly by encouraging shoppers to choose new destinations away from the city centres. A related point was that higher charges on travellers leaves them less money for consumer purchases (Helsinki). An interesting point from Salerno was the suggested possibility that this disadvantage might be overcome by reimbursing customers the cost of parking or of shuttle bus access to the centre. The neutral result for private sector acceptability came about because the disbenefits listed above are seen as being offset by other improvements to the transport system. This was not the case in Torino, however, where the anticipated loss of shoppers made the strategy unacceptable to the private sector.

8.4.4 Operator acceptability

There was wide divergence among cities on the acceptability of the optima to the operators. In three of the cities (Edinburgh, Salerno and Torino) the optima were acceptable to the operators. The main reasons given or this were the encouragement of faster and more reliable travel times (Edinburgh) and higher incomes from fares (Salerno and Torino), reducing the need to find alternative sources of finance. In the cases of Merseyside and Eisenstadt, the optima were deemed to be unacceptable because of loss of revenue to the taxi service (Merseyside) and the low public transport revenue (Eisenstadt). In Helsinki, opinions were divided, with the Espoo Planning Centre considering the optimum to be acceptable to the operator but the Helsinki Transport Planning Office taking the opposite view. Vienna offered no opinion on this aspect of acceptability. A point made by Merseyside was that in optima with free fares, the removal of fare collection procedures would reduce bus journey times significantly.

8.4.5 Quality issues

The authorities were asked whether, under each optimal strategy, it would be possible to assure the quality of the public and private transport service. Two cities (Edinburgh and Helsinki) believed that it would, four cities were broadly neutral (Merseyside, Vienna, Salerno and Torino), while one (Eisenstadt) emphatically said no. Those who answered positively gave reasons which included better quality as a result of faster and more reliable journey times and improved infrastructure. Those who were neutral pointed out that a problem with reduced or free fares is that they would reduce the incentive of the operator to compete on quality (Merseyside). It was also pointed out that quality would only improve if traffic flow is made more smooth by increases in speed (Salerno) or by using the increased revenues to improve the physical conditions of public transport (comfort, cleanliness, air conditioning, etc.) (Torino).

8.5 Comments on the methodology

Of those interviewees who expressed any opinion on the methodology, most were generally happy with the approach. There were one or two suggestions for improvement, however.

Regarding information from the process, Edinburgh would have liked more disaggregation of results (city centre and non central policies) and, given their emphasis on walking, cycling and the environment, more data on motorised/non-motorised modal split and on environmental indicators.

Regarding the analytical process as a whole, Merseyside considered that the supply of parking should be included in the policy options, as well as parking charges, and that greater attention should be given to the benefits of walking and cycling.

The Torino City Engineer suggested a formulation of the objective functions should be found that specifically takes into account some “quality indicators”, such as cleanliness, comfort, air condition and so on.

There were also some comments which followed from the earlier OPTIMA consultations. For Merseyside, the question of affordability of optimum strategies had been a prime concern in the OPTIMA project, and the development of objective functions in FATIMA to take affordability specifically into account was therefore welcomed. The person interviewed in Vienna was also involved in the OPTIMA consultation process and he pointed out that the inclusion of more external transport related costs, like accidents, air and noise pollution, in the FATIMA objective functions and regimes is an important step in the right direction. For Helsinki, all the major concerns expressed during OPTIMA, particularly combining EEF and SOF, including external costs and considering peak and off-peak separately, had been taken care of in FATIMA.

8.6 Applicability to other member states

8.6.1 General

As in OPTIMA, it was part of the FATIMA project to consult with other cities in the EU in countries other than those covered in the modelling process. Stockholm again agreed to give their opinion on the results and opinions were sought from Berlin (which was preferred to the OPTIMA German city, Idstein, which is considerably smaller than most of the OPTIMA/FATIMA cities).

The purpose was to gain professional outsiders' impartial opinions of the FATIMA project and the method it employed and particularly of the practicability of the FATIMA optimum policies more generally in European cities. The FATIMA project with its preliminary results was therefore presented to the two cities concerned.

Key data for the two cities are as follows:

	Stockholm	Berlin
Population ('000)	1600	3459
Area (ha)	345500	89167
Density (person/ha)	4.63	38.8
% pedestrian trips	13	-
% cycling trips	8	-
% car trips	31	70
% public transport trips	47	30

8.6.2 Stockholm

The FATIMA method and results were presented to researchers at the Division of Traffic and Transport Planning of the Department of Infrastructure and Planning at the Royal Institute of Technology (KTH) Stockholm. The representative of the researchers and developers of transport planning methods at KTH in Stockholm was very interested in the FATIMA project, its strategic approach and the methods developed.

Comments on the results: The Stockholm respondent preferred not to comment on the results. This was because Oslo was the only study city known to the respondent and the Oslo results had just changed, giving insufficient time to allow considered comments to be made. It was not considered sensible to offer opinions on the other study cities because the respondent did not know them well enough. A number of comments were made about the FATIMA method, however.

Comments on the method:. The formulation of the objective functions to represent the targets of the whole transportation system was seen to be a significant step forward in the field. However, it was felt that, in practice, the objective functions might still need some development and more detailed definition, depending on the city and country to which they were applied.

The objective functions and the social economic calculations were considered to cover most issues of importance, as the cost-benefit analysis included basic external costs, the requirements of sustainability, revenue generation and privatisation. However, it was considered that there were some further impacts that were not assessed, such as the effect on income, land use and car ownership, which become important when the changes are non-marginal. In addition to the sensitivity studies it was felt that some more research or discussion could usefully take place on the balance of the two basic objectives, the economically efficient transport system and the sustainable transport system.

There was also some doubt about the general applicability of the unified measures in the project to cities which were vastly different in size, characteristics and present transport system. The level of congestion for instance affects the set of measures and policies that are feasible. The FATIMA results of the test cities indicated this, in that the response to the measures in the small cities differed from that of the larger cities. For the method to be more generally applicable, a different set of measures could be chosen, e.g. traffic calming and the use of speed control as policy measures.

It was noted that the FATIMA consortium was already aware that the assumptions and simplifications made in the project have practical consequences and that within the project's resources it was not possible to assess these consequences further. The differences between the strategic and tactical models, and the benefits and disbenefits of each were discussed; from this a doubt was expressed that some of the models used produced results which were rather too uncertain. It was pointed out that Stockholm (like the other Nordic cities) only has tactical models in operation.

In principle they would not have any objection to testing the FATIMA method for Stockholm but would like to make some changes to the objective functions and measures tested. The structure of the Stockholm area differs from the cities tested which would make differences in the practical applicability of the measures as well as their effects on land use. There are 24 municipalities in the Stockholm Region of which around ten form the actual Stockholm Metropolitan Area. There is no special council for the metropolitan area, as is the case for Helsinki MA, but the planning function is carried out by the authorities of each municipality including the City of Stockholm and the authorities of the Stockholm Region. This raised the question of whether the measures should be applied at the municipality level or at the regional level. It might thus also be difficult to convince the individual municipality authorities of the optimal set of measures and the benefits they would gain.

8.6.3 Berlin

The FATIMA method and results were presented to the head of the Department for transport Models and databases of the Berlin City Council.

Comments on the results:

a). The BOF, COF and ROF regime:

Berlin suggested that the Vienna optimum was not appropriate for Berlin and suggested an alternative set of measures for the BOF, COF and ROF regimes. Rather than specifying actual values they suggested a scale of change from the do-minimum, which is compared with the Vienna optimum below.

Measure	Berlin	Vienna
public transport infrastructure	++	0
public transport	+	0
public transport	0/+	++
road capacity	0/+	--
road pricing	+	0
long term parking charge	+	0
short term parking charge	++	++

The comments which follow relate to this combination of measures.

It was considered that the starting point for technical feasibility is in political consensus, with technical feasibility essentially being a question of the availability of funds. However, the costs of such an optimum strategy were considered to be too high for the city authority, especially as it appears unlikely that the modal share of public transport would fall short of the level required by the authority. There appeared to be no way in which this financial problem could be overcome.

From the legislative point of view, there is a German law which requires fares to be high enough to ensure the public transport enterprise remains profitable. If this is not the case under the optimum strategy, there is a possibility that the difference could be made up by the state in the form of a subsidy.

For the public, the private sector and the pubic transport operator, the optimum would be generally unacceptable. Despite the reduction of car traffic causing a reduction in noise and air pollution, the public would object to the parallel reduction in personal mobility. It is also likely that road pricing would be unacceptable. (In this respect, increases in parking fees are likely to be a more acceptable way of placing an additional financial burden of car travel). The private sector could be expected to fear that the significant increase in short term parking charges could persuade shoppers to change destination to locations outside the city centre while the public transport operator may expect a reduction in earnings due to a smaller than expected shift in modal split towards public transport.

Politically, though there may be political disbenefits (road pricing, no new car-related infrastructure, higher parking charges), provided the cost of public transport can be reduced (perhaps by competition) and the level of public transport service at least maintained, the optimum may be regarded as neutral in political terms.

Berlin considered that the only improvement which could be made to this optimum strategy would be the introduction of additional measures to increase the modal share of environmentally friendly transport modes, but pointed out that this would need a consensus on a European scale.

It is difficult to know how to interpret these comments, since the respondent has proposed an alternative strategy which he then considers to be unacceptable on several grounds.

b). The Vienna DOF and HOF regime if applied to Berlin.

Overall, this optimum would be generally feasible from the technical, financial and legislative points of view. The only (minor) financial problem foreseen would be the need for more rolling stock, which could be overcome by the selection of suitable financial instruments.

The public transport operator would benefit from higher profits from a shift to public transport modes (though there would be an increase in risk), while the private sector would benefit from new orders for rolling stock.

From the public and political points of view, the optimum would be broadly neutral: the public would weigh the benefits of better public transport supply against the possibility of reduced public transport service quality resulting from lower profits.

Comments on the method: Unlike Stockholm, who chose to concentrate comments on the methods of FATIMA, Berlin chose to concentrate on the results. However, regarding the method, Berlin did make a number of points, the first of which was that the objective functions are very theoretical. They also pointed out that the information available from the FATIMA analyses was insufficient to answer fully the various questions asked in the consultation process.

The attempt to quantify the effects of policy measures in combination was welcomed, but the difficulty, in research terms, of doing this effectively, was acknowledged.

Finally, it was suggested that qualitative methods may have a role to play in that they may more adequately address some of the assessment problems.

8.6.4 Implications of the Stockholm and Berlin consulatations

The main implications came from the comments made by Stockholm on the method. The issues are:

- the objective functions would need to be developed further to reflect the needs of other cities;
- a wider range of impacts may need to be modelled when changes are non-marginal (i.e. when there is a major change in the costs of travel);
- a wider range of policy measures could be tested;
- consideration needs to be given as to whether to apply the methods at a local, city or regional level.

All these issues could be incorporated within the FATIMA method.

8.7 Summary of the consultations

In OPTIMA, the major barrier to implementation in a number of cities was the availability of finance, particularly for the sustainability optimum strategies. The introduction of a new benchmark objective function in FATIMA has generated strategies which overcame this problem for the majority of cities However, finance is still seen as a barrier by some city authorities and the alternative objective functions provide means of overcoming this, albeit with lower social benefits.

Legislation will be needed to enable road pricing to be implemented and for parking charges to be controlled. In Italy and the UK there is also a need for legislation to permit the recommended public transport strategies to be implemented.

Public and political acceptability will be a significant barrier to measures which increase costs (especially motoring costs) or reduce service levels. The successful implementation of such measures, demonstrating their overall effectiveness within a package of policies, could help overcome this, as could effective marketing.

Most of the suggestions made in OPTIMA for improving the methodology were included in FATIMA, but there were some further concerns that the methodology should ideally be capable of addressing directly the issue of transport system quality.

9. POLICY CONCLUSIONS AND RECOMMENDATIONS

9.1 The effects of constraints on public finance

A particularly important result from FATIMA is that in six of the nine cities (Edinburgh, Vienna, Eisenstadt, Oslo, Torino and Salerno) an optimal strategy could be identified which required no net additional financial support (in addition to the do-minimum support) over the 30 year evaluation period. In all of these cases (Classes 3 and 4 in Section 5.8) the revenue from users more than covers the cost of any changes in infrastructure and operation. Even so, city authorities may be constrained, since typically they have to raise finance for investment initially, and only obtain repayment from users later. This represents one of the situations in which private finance may be used. In these situations the private sector can be reimbursed either directly by the users or indirectly from the city authority using revenues from users. In the former case, it is important that the charges on the user are consistent with the overall optimal strategy. With the exception of private sector operation of public transport (see 9.3 below) it has been assumed implicitly in the model tests that the private sector would require the same rate of return as the public sector. Where this is not the case, the optimal strategy may well be constrained, resulting in lower social benefits.

In the other three cities (Merseyside, Tromsø and Helsinki), the optimal strategy would require a higher level of financial support than the do-minimum (Classes 1 and 2 in Section 5.8). That it is not to say that such strategies are unacceptable; the shadow price assigned to the financial outlay indicates that use of public finance is justifiable when compared with its use in other sectors. However, city authorities may be constrained by national governments not to increase their financial outlay (and hence the tax burden). Where such restrictions apply solely to the initial investment, private sector finance can be used, but part of the cost will have to be met by increased taxation (or reduced expenditure in non-transport sectors) in future years. The comments in the preceding paragraph then apply. Where restrictions apply throughout the (30 year) evaluation period, an alternative strategy is required, represented here by the Constrained Objective Function (COF). As noted in Section 5, these strategies impose higher costs on the user, make reduced investment, and have smaller benefits to society. An alternative which in principle can avoid these constraints is to raise additional finance from the (secondary) beneficiaries of the strategy, through value capture.

9.2 The role of value capture

Value capture in Project FATIMA was represented by a percentage (typically 10%) of the user benefits and was raised where it could relieve the restrictions on availability of public finance. In practice value capture was only relevant in Class 1 cities, where there are substantial user benefits even under a constrained public finance regime. In these circumstances value capture can help towards financing the socially optimal strategy (as represented by the Benchmark Objective Function). In Class 2 cities, there are no substantial user benefits under a constrained public finance regime and so there is limited scope for value capture. In Class 3 cities there is no significant financial constraint, and availability of additional finance will not lead to an enhanced strategy. In Class 4 cities there are typically no significant user benefits to be captured. Thus value capture appears to have a very limited role in financing optimal strategies.

9.3 Private sector operation of public transport

Private operation of public transport is possible in a regulated regime (as represented by the Benchmark Objective Function (BOF)) or in a deregulated regime (as represented by the Deregulated, and Half Regulated, Objective Functions (DOF and HOF)).

In the former case it is often argued that the operating costs are reduced if public transport is operated privately. We have been unable to find any convincing evidence that this is the case, but we have conducted sensitivity tests to assess the impact. These suggest that operating cost savings would have relatively small impacts on the overall social benefit, or the specification of the optimal strategy. There may be benefits to be gained or adverse effects from private sector operation, as listed in Section 5.3, but they need to be more convincingly demonstrated. As noted in Section 5.3, changes in operating costs as a result of private operation were not modelled in the main optimisation work, although they were considered in subsequent sensitivity tests.

In the case of a deregulated regime, private sector operation carries the additional disbenefit that the city authority has no control on the strategy adopted by the private sector, and the resulting strategy may as a result be substantially sub-optimal. This essentially results from the loss of the concept of an integrated “package” of measures; whilst some measures are set in order to maximise social benefit, others are set in order to maximise the separate and possibly contradictory objective of private sector profit. It is not then surprising that the overall optimal combination of measures in a deregulated regime is inferior, in terms of net social benfit, to the optimal combination of measures in a regime where the public authority has full control over all measures. In fact it was found in the optimisation work that even the best performing DOF solutions produced lower social benefits than the BOF optima. However, DOF solutions did have the advantage of substantially reducing the initial capital outlay by the city authority.

The problematic nature of complete deregulation led to the consideration of HOF (the half-regulated regime) which allowed for subsidy to be paid to the private operator whilst still keeping an essentially deregulated regime. Since there are a large number of mechanisms for providing subsidy, the half-regulated regime was less clearly defined than either the fully deregulated regime or the fully regulated regime. In spite of this imprecision, though, the FATIMA results showed that whilst the HOF-optimal solutions were always preferable to DOF-optimal solutions (over a 30 year time horizon), they were never superior to Constrained Objective Function (COF) optima. Thus, over a 30 year period, all deregulated regimes (both HOF and DOF) were inferior to the constrained regulated regime.

9.4 Recommendations for the design of optimal transport strategies

The following recommendations can be made for policy makers on the design of optimal transport strategies:

1. Strategies should be based on combinations of measures, and should draw fully on the synergy between successful measures.

2. The key elements of a successful strategy should be public transport measures and car user charges. In most cases, the public transport measures should include increased service levels and/or reductions in fares. However, the degree of such changes will clearly depend on the service and fare levels in the base case. Car user charges can be applied through road pricing or parking charges.

3. There should generally be a distinction between peak and off-peak implementation of public transport and car user charge measures.

4. Low cost road capacity improvements should generally be included in a successful strategy. However, it should be emphasised that such improvements should come from measures that genuinely improve traffic efficiency, given a fixed level of infrastructure. Such measures would typically include: traffic signal coordination and optimisation; telematics measures; and other traffic management measures. Low cost road capacity improvements should not be introduced if they have a negative effect on plans for city centre pedestrianisation, traffic calming in residential neighbourhoods, or enhancements to pedestrian mobility or safety.

5. Large-scale public transport infrastructure projects would typically not be part of an optimal strategy. However, medium-scale and small-scale infrastructure projects, such as guided bus or improvements to the public transport vehicle fleet, may be beneficial.

6. In some circumstances, optimal policies (in terms of net social benefit) may include both car user charges and increased fares for public transport users

(without a corresponding increase in service levels). The implications of this require careful consideration, since they suggest that transport policy can be used to subsidise other areas of public policy."

9.5 Recommendations for the involvement of the private sector

The following recommendations for policy-makers can be extracted from the discussion above:

1. In many cities it will be possible, following the methodology outlined in Section 9.6, to identify strategies which are optimal, and whose costs over a 30 year evaluation period are met in full by payments from users. Care will needed to ensure that the pattern of charges on users is politically acceptable and legally feasible.

2. Even in the circumstances in (1), city authorities may not be able to raise the finance required for initial investment in the strategy. In such situations, the private sector may be able to finance the strategy, and be repaid either directly by users or by the city authorities using payments by users. In either case, the user charges should be consistent with the strategy: fares or charges imposed at higher than optimal levels to satisfy the private sector can significantly reduce the performance of the strategy. Furthermore, where the private sector requires a higher rate of return than the public sector discount rate, this may result in a more constrained, and less beneficial, strategy. The implications of this for involving the private sector need to be carefully assessed.

3. Where the financial costs of the strategy exceed the revenues, it may still be acceptable for city authorities to finance them. The optimal strategies in FATIMA have been generated on the basis that the opportunity cost of using finance for them is fully justified. Where city authorities cannot raise the initial finance, it may be appropriate to involve the private sector, as in (2). However, the private sector will need to be reimbursed in part from future tax revenue, or from future revenue generated by reducing public expenditure on other sectors.

4. Where public finance is limited, the optimisation procedures used in FATIMA can identify the appropriate modification to the strategy to achieve the optimal performance within the financial constraint. Such strategies will usually have smaller social benefits than those without such constraints.

5. In the situation in (4), value capture may offer an opportunity for raising additional finance to help support the transport system. Such finance, which would not involve (later) repayments by transport users or the city authority, should be distinguished from the private finance arrangements in (2), which do involve such repayments. However, within the range of conditions tested, value capture appears not to offer the potential for significantly improving the overall strategy.

6. Whether or not the private sector is involved in financing a strategy, there may be interest in private sector operation of the public transport service. Such involvement may possibly increase managerial efficiency which would enhance

the performance of an overall strategy or alternatively it may lead to a reduction in net social welfare: evidence on the scale of these benefits or losses is unclear.

7. Private sector operation has been implemented through deregulation, in which operators are free to determine service levels and fares, and through franchising, where the city authority specifies them. If a city authority decides that private operation is beneficial, it should use, where legally possible, a franchising model in which it specifies the objectives and the optimal service levels and fares.

8. If a deregulation model is required (in order to comply with national law), private operators should not be given complete freedom to determine the operating conditions which meet their profitability target, even if the level of profitability is itself constrained as a result. There are typically a number of combinations (e.g. of fares and frequency) which achieve a given level of profitability, and not all will be equally effective in terms of public policy objectives.

9.6 Methodological recommendations

The key steps for strategy/policy formulation, in the order they should occur, are given below. Of these steps, the most problematic in terms of practical transport policy-making are steps 1 and 2, and they should be given special attention by policy-makers:

1. identify the policy objective(s) clearly;

2. where a set of policy objectives is identified, indicate what the appropriate trade-off is between them (assuming, usually correctly, that they are to some extent in conflict);

3. identify the set of policy measures which are to be considered, and which can be expected to have a strategic impact (in particular, list those which meet the latter requirement);

4. specify the range(s) within which the measures in point 3 can be applied, and the factors which limit that range (financial, political, legislative etc.);

5. specify any other overall constraints (e.g. financial) on the specification of optimal strategies;

6. employ a transport model which enables the full range of measures in point 3 to be assessed against all the objectives (from point 1), taking into account of all the user responses (mode, time of day, destination, frequency, route) of strategic relevance, and all the supply interactions (congestion, overcrowding, queuing) of strategic relevance;

7. follow the optimisation procedure (as set out in Sections 1.5 of this report) to identify the optimum, taking into account constraints where appropriate;

8. check that this optimum is feasible and acceptable and modify if necessary;

9. decide whether it is appropriate to use private finance or private sector operation, or both. If so, decide how best to employ them within the context of a socially optimum strategy.

9.7 Recommendations for further research

The general approach taken in OPTIMA was well accepted, particularly by the city authorities involved in the consultation procedure. However, the approach could be further refined in a number of directions, as given below:

1. The objective functions have no measure of equity in them. Issues of equity arise in two different aspects, amongst others. Firstly, there is the issue of intrazonal equity, concerning the relative differences in benefits received by different socio-economic groups living in the same neighbourhood. Secondly, there is the issue of interzonal equity, which concerns the differences in benefit received by inhabitants of different neighbourhoods. It is recommended that both issues of equity be considered in future research into the construction of objective functions.

2. The choice of measures to be used for forming optimal packages did not include land use measures. As explained in the OPTIMA Final Report, this was due to the lack of availability of appropriate models for representing combined land-use / transportation policies. However, as such models are currently being developed, the possibility should arise for including land use measures in future optimisation work.

3. Research should be carried out into making a comprehensive assessment of the consequences of private sector operation of public transport, both under regulated and deregulated regimes. Such an assessment should not be limited to financial costs of operation, but should also take into account potential "external" effects of private operation such as: redundancies (and hence increasing social costs due to increased levels of unemployment); changes in employees' wages; changes in safety levels and changes in other environmental benefits or costs.

4. The policy measures considered by FATIMA were, for each city, relative to a "do-minimum" strategy specified by the respective city authority. Typically, the measures involved with such strategies are those to which an authority has made a full commitment. It follows that the recommendations given make an implicit critique of a city's committed policies. However, it could be argued that such an approach might misrepresent a city's intentions since it might be planning "likely" policies to which it has not made a full commitment. Such policies were not considered explicitly in the FATIMA optimisation work. It is thus recommended that, in future optimisation work, a method be devised which takes account of potential city policies to which there has not yet been full commitment.

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ANNEX 1: LIST OF ABBREVIATIONS

BOF	Benchmark Objective Function
BOF*	Set of measures with highest BOF value (BOF optimum)
COF	Constrained Objective Function
COF*	Set of measures with highest COF value (COF optimum)
DOF	Deregulated objective Function
DOF*	Set of measures with highest DOF value (DOF optimum)
EC	External Costs
EEF	Economic Efficiency Function without external costs (used in OPTIMA)
EEFP	Economic Efficiency Function with external costs
HOF	Half-regulated Objective Function
HOF*	Set of measures with highest HOF value (HOF optimum)
IH	High public transport infrastructure
IM	Medium public transport infrastructure
IRR	Internal Rate of Return
MA	Metropolitan Authority
MS	Mode Split
NPV	Net Present Value
PVF	Present Value of Finance
PVF*	Present Value of Finance for public authority when public transport is deregulated
ROF	Regulated Objective Function
ROF*	Set of measures with highest ROF value (ROF optimum)
SOF	Sustainability Objective Function
VC	Value Capture
α	parameter used to calculate BOF (default value 0.1)
β	parameter used to calculate VC (default value 0.1)
γ	parameter used to calculate external costs in EEFP (given in Table 1)
λ	shadow price parameter used to calculate EEFP (default value 0.25)

ANNEX 2: DESCRIPTIONS OF THE CITIES

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

A2.1 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.

A2.2 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.

A2.3 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 A2.1 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.

A2.4 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 A2.2 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.

A2.5 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 A2.3 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	18450	28.53
Espoo	191 247	172 629	31190	6.15
Kauniainen	8 298	7 889	590	14.07
Vantaa	166 480	154 933	24080	6.94
Total	891 056	827 851	74310	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.

A2.6 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 A2.4 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.

A2.7 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 A2.5 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.

A2.8 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 A2.6 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.

A2.9 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 A2.7 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.

ANNEX 3: SUMMARY OF THE OPTIMA PROJECT

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.

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 A.3.1 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 A.3.1: 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).

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 A.3.2 : Summary of beneficial measures

From the results in Table A.3.2 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.

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