A STRATEGIC TRANSPORT MODEL-BASED TOOL TO SUPPORT URBAN DECISION MAKING PROCESSES

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Abstract

The complexity of decision making processes in urban land-use and transport systems raises the demand for an efficient support tool. Such a tool was developed at TUW-IVV in a modular structure: a strategic transport (and land-use) model, a set of policy measures, a set of objective functions and different optimisation methods. The suitability of the TUW-IVV concept has been proved in several EU research projects. Within these projects all modules were continuously improved. Some examples: taking into account user benefits for non motorised modes in cost benefit analysis, considering constant travel time budgets, use of new optimisation methods. The TUW-IVV concept has several advantages: low data requirement, easy to implement as well for small as for big cities, short run time and compatible with more detailed models. Reliable decision support tools are available. But in reality most land-use and transport relevant decisions are made bypassing the planning administration. A future task will be to improve policy maker awareness about supporting tools.

Keywords: Decision making process, strategic transport model, support tool, land-use

1. Introduction - Need to support urban decision making processes

Interaction between transport planning, land-use planning and regional economy is highly complex. As a result even effects caused by the change of a single policy measure can be difficult to understand. Especially as, in reality, most decision making processes have to consider a combination of different policy measures. In addition numerous different protagonists are involved on different administrative and legislative levels. Politicians as well as planners make their decisions under these circumstances (Fig. 1). A tool, which predicts effects caused by different possible actions, is highly welcome in this situation. To asses long term effects of numerous competing possible decisions, extreme accuracy of the predictions is not the crucial matter. Rather characteristics like availability of necessary data, low expenditure to set up the model and a short run time are essential for the suitability as a tool to support urban decision making processes.

Common transport models assess effects on a quite detailed spatial level. Therefore as well quantity as quality of statistical data has to meet high requirements. Also the run time is rather long. Therefore suitability to support strategic decision making processes, as described above, is limited. As it is shown in this paper, strategic models developed at the "Institut für Verkehrsplanung und Verkehrstechnik, Technische Universität Wien (TUW-IVV)" fulfil the described requirements to a higher extent.

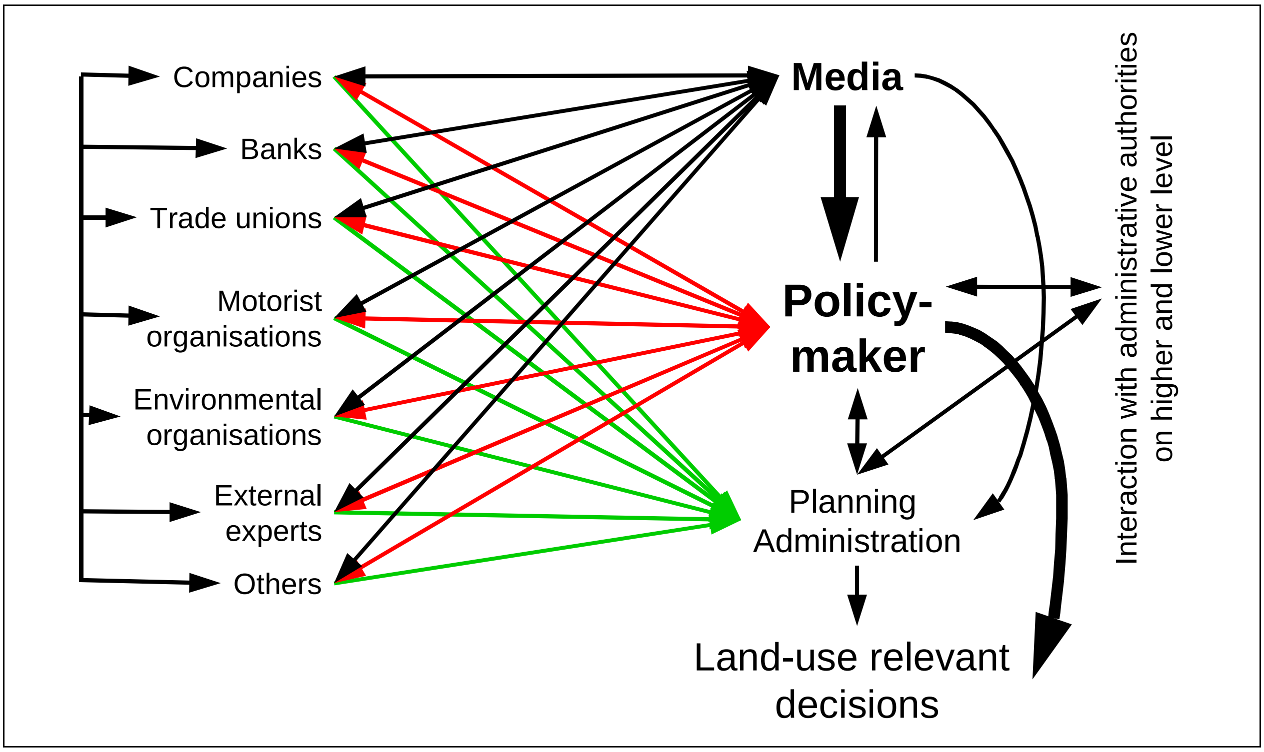

Fig. 1: Interaction between different players involved in urban land-use and transport decision making processes (KNOFLACHER, PFAFFENBICHLER ET. AL., 2000)

2. Basic characteristic of strategic transport models

2.1 Definition strategic transport model

Nowadays conventional transport models are designed using a four stepped algorithm (See Fig. 2). Within strategic decision making processes it is often not necessary to have knowledge about the traffic assignment to certain routes. For such purposes it is sufficient to perform only the basic three steps of the usual model structure. At TUW-IVV such a transport model is named "strategic", while the traditional four step models are named "tactical".

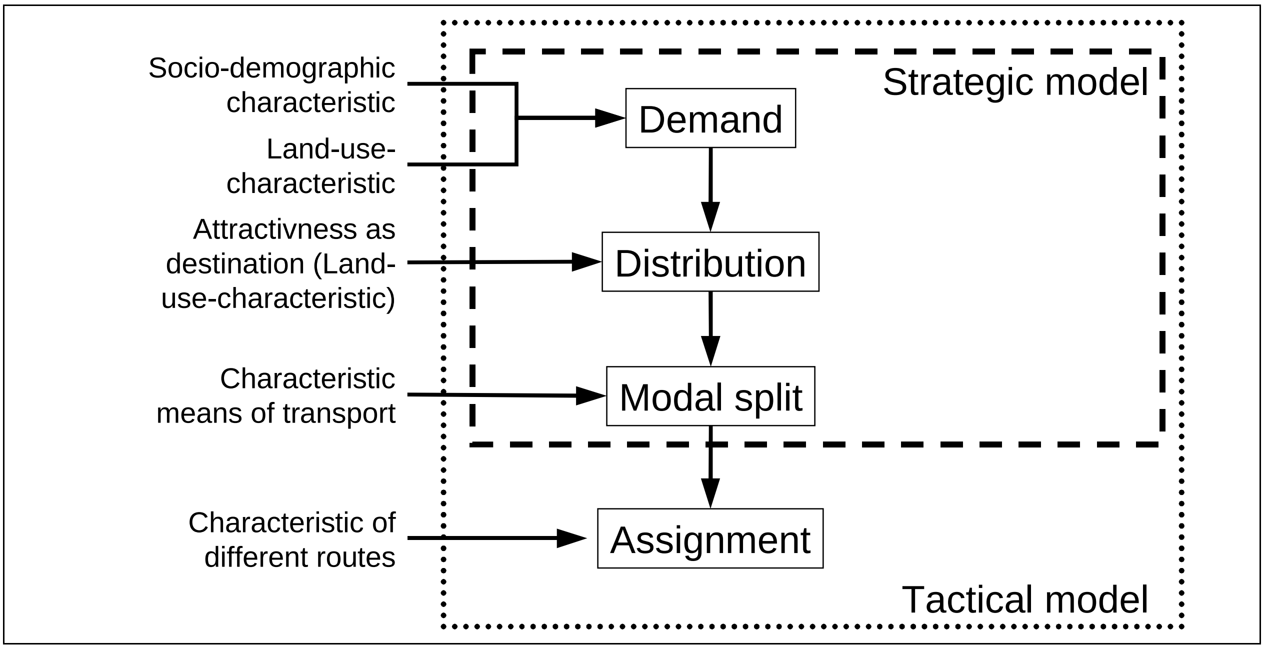

Fig. 2: Distinction between transport models on strategic and tactical level

2.2 Why is it often sensible to use a simple, strategic transport model instead of a more complex, tactical one?

Potential errors in transport modelling emerge from two different sources:

- errors in the underlying statistical data (random error and systematic error) and
- specification errors in the model.

Provided that system behaviour description is enhanced, the specification error decreases asymptotically with increasing model complexity. On the other hand errors, caused by inaccuracy in the underlying data, increase with the degree of complexity. The reason is the repeated application of error multiplying operations. Improving statistical data (e.g. by using a bigger sample) reduces the random error. Adding the two kinds of errors to a total model error (Equation 1) results in a minimum for a certain degree of complexity (Fig. 3). For a higher quality in basic data this minimum is found at higher degrees of complexity. The conclusion from these remarks is that, at least for low quality in basic data, a high model complexity is likely to be counterproductive. As strategic transport models use quite simple analogies and algorithms, they produce useful results especially under circumstances with limited possibilities to gather statistical material.

The connection between complexity and errors is well known at least since the early seventies (e.g. WERMUTH, 1973). In the light of this knowledge it is remarkable that complexity of transport models was increased enormously over last three decades. On the other hand quality of the underlying statistical data could not keep the pace with this rapid development. E.g. important data needed in transport model assumptions are in Austria only available for the census year 1991. Data about certain indicators can only be derived in an indirect way by calculations with other indicators.

$$\boxed{e^2 = e_{st}^2 + e_{sp}^2} \tag{1}$$

e .... total model error

e_{st}.. statistical error

e_{sp} .... specification error

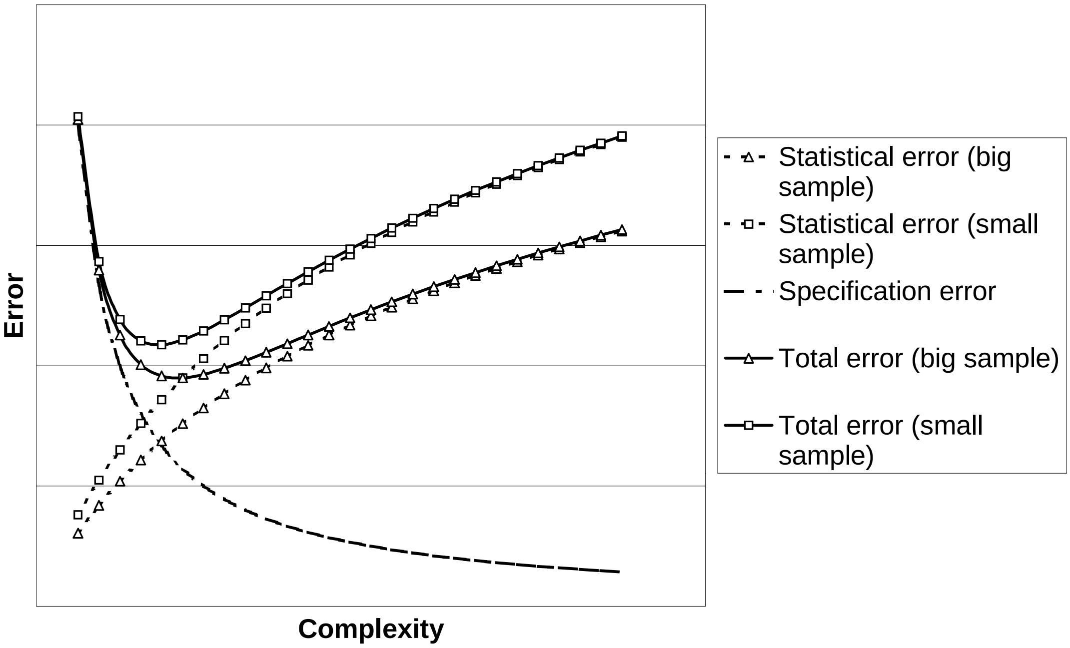

Fig. 3: Transport model error as a function of model complexity and quality of basic data (WERMUTH, 1973)

3. History of transport modelling and cost benefit analysis at TUW-IVV

Strategic transport models, developed by TUW-IVV, were used in a 4th framework EU-research project "Optimisation of Policies for Transport Integration in Metropolitan Areas (OPTIMA)". Computer models have been created for the Austrian cities Eisenstadt and Vienna (OPTIMA, 1997). In a subsequent project named "Financial Assistance for Transport Integration in Metropolitan Areas (FATIMA)" the models were developed further. The changes affected transport modelling itself, as well as introduction of new objectives into cost benefit analysis (FATIMA, 1998). A special focus in this project was on private finance involvement in provision of transport services.

In another project, "Strategic Assessment Methodology for the Interaction of Common Transport Policy Instruments (SAMI)", the same principles as in previous urban transport models were used to build a European transport model. In addition freight transport was considered and the modes air, inland waterways and short sea shipping were introduced (PFAFFENBICHLER, EMBERGER, 2000).

Within the ongoing 5th framework EU research project "Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems (PROSPECTS)" the strategic transport model of Vienna is now extended to an integrated land-use – transport model. The term "Sketch Planning Model" was defined for this kind of model. In a later stage of the project it is planned to use the "Sketch Planning Model" for calculations in a variety of other European cities (Edinburgh, Madrid, Helsinki, Stockholm and Oslo).

4. The modular decision support tool of TUW-IVV

Figure 3 gives a brief overview about decision making processes in reality and how the TUW-IVV tool tries to simulate these processes. In reality, it is the stakeholder who defines targets. The decision maker weights the targets and compares the weighted result with the reality. Based on this comparison, decisions how to act are made. The whole process is built on personal assumptions of how policy measures affect reality.

The TUW-IVV tool simulates system behaviour over time and is designed in a modular way. Module 1, the transport model, simulates the urban transport system. Module 2 describes which policy measures can be changed and how they affect the transport system. Module 3, objective functions, transforms real life targets into mathematical functions based on transport model output. Module 4, the optimisation method, to identify the policy measure combination, which gives the maximum value for a certain objective function.

The TUW-IVV tool is able to substitute the subjective assumptions made by the decision maker to a certain extent. As in general, the decision maker is not a transport expert – the application of the TUW-IVV tool will result in a more objective and rational decision making process.

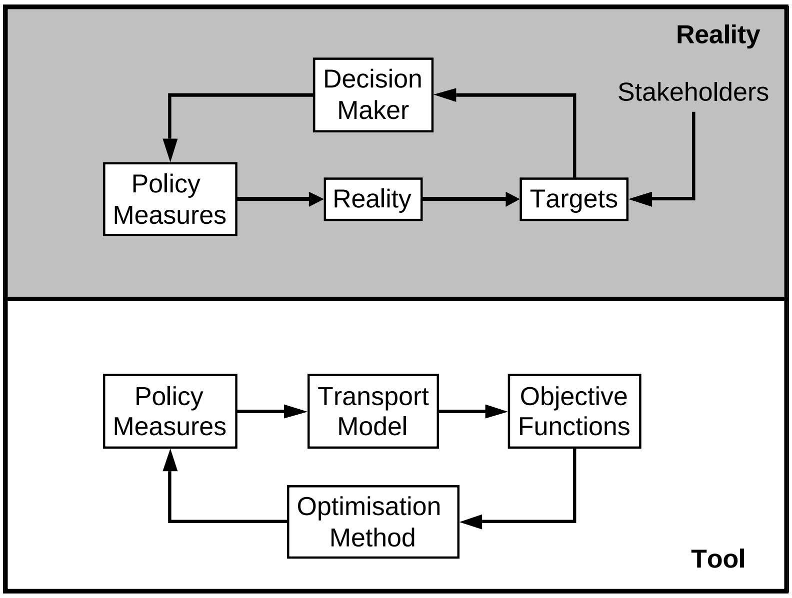

Fig. 4: Decision making process in reality and its transformation into the TUW-IVV tool

In the following sections the four modules will be described in a more detailed way.

4.1 Module 1: Transport model

For the use in a strategic transport model the study area has to be subdivided into a relative small number of zones. Vienna is represented in the TUW-IVV models by 23 cells, which are equal to it’s administrative districts. For the land-use model additionally the surrounding NUTS 3[1] regions “Wiener Umland - Südteil” and “Wiener Umland Nordteil” are taken into account.

The underlying principle for the strategic transport models created at TUW-IVV is the analogy to the law of gravity or to Kirchhoff’s law. The model uses simultaneous trip distribution and mode choice algorithms. The demand for trips from a source is assumed or calculated externally.

$$\boxed{F = \gamma * \frac{m_1 * m_2}{r^2}} \tag{2}$$

F	Force of gravity
γ	Proportional constant
m_1	Mass 1
m_2	Mass 2
r	Distance between masses 1 and 2

The number of trips for each source - destination combination, mode and purpose is calculated as shown in the following equation:

$$\boxed{T_{ijmp} = T_{ip} * \frac{VW_{mp} * A_{jp} / GC_{ijmp}}{\sum_{jm} VW_{mp} * A_{jp} / GC_{ijmp}}} \tag{3}$$

T_{ijmp}	Trips from source i to destination j using mode m for purpose p
T_{ip}	Potential of trips in source i for purpose p
VW_{mp}	Calibration factor for mode m and purpose p derived from surveys of the reality
A_{jp}	Attractiveness of destination j for purpose p
GC_{ijmp}	Generalised costs for a trip from source i to destination j using mode m for purpose p

The force between two masses in the law of gravity is equivalent to the trips made between two zones. The masses are equivalent to demand in the source and attractiveness of destination. The square of the distance between two masses is equivalent to the resistance between source and destination. Travel resistance is represented in this transport model by generalised costs. The proportional constant is equivalent to the calibration factor.

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[1] Nomenclature des unités territoriales stastiques.

In the projects OPTIMA and FATIMA only passenger transport and the purposes “commuting” and “non working” were considered. The following modes were taken into account: Pedestrian, bike, private car and public transport. In SAMI also freight transport was considered. In urban context freight transport is carried out mainly by the mode road. It is therefore not necessary to consider mode choice for freight transport in urban models.

4.2 Module 2: Policy measures

The following policy measures were simulated in the TUW-IVV strategic model for urban transport: infrastructure investments, changes in frequency and fare changes for public transport and road capacity, road pricing and parking charges for private car.

Policy measures are influencing generalised costs either by changes in travel time or costs or both. The interaction of some policy measures with travel time and costs could be seen in Fig. 5.

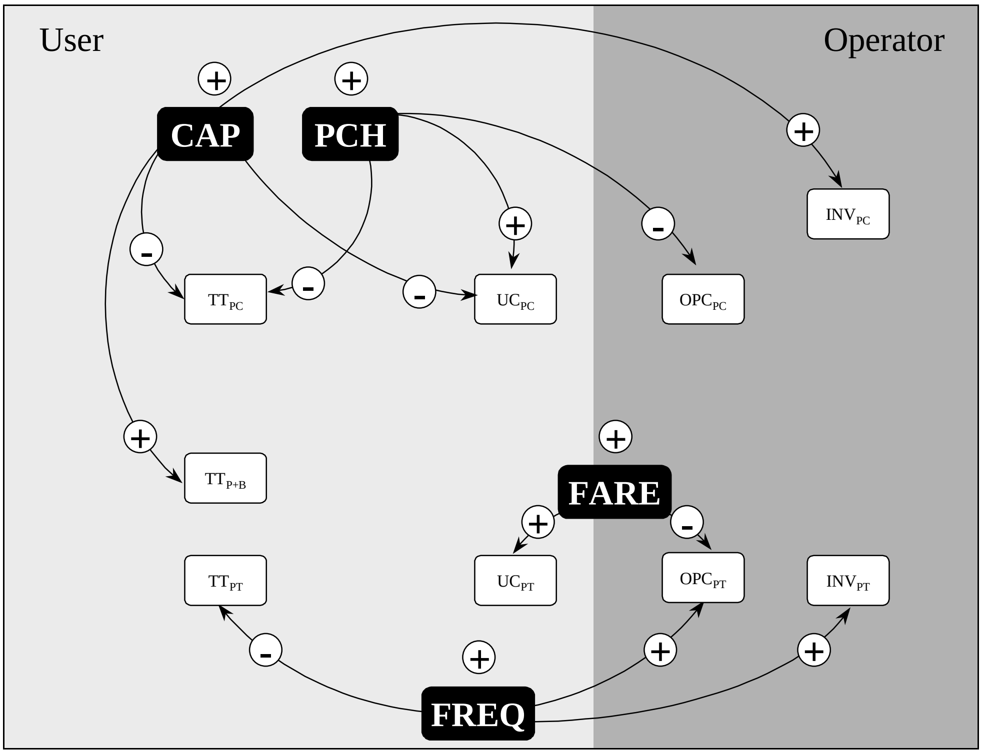

Fig. 5: Effects of policy measures on traveltime and costs for users and operators

Legend:

Modes:	Time & costs:	Policy measures:
PC.................Private car	TT.................Travel time	CAP..............Road capacity
PT.................Public transport	UC................User costs	PCH..............Parking charges
P&B..............Pedestrian & bike	OPC..............Operating costs	FREQ ....Public transport frequency
	INV...............Investment costs	FARE ....Public transport fare

Policy measures are written white on black ground in Fig. 5. Time and costs for the different modes and protagonists are written black on white ground. As an example how to read Fig. 5: If road capacity CAP is increased (indicated by “+”), investment costs INV$_{PC}$ for operators will increase (“+”), travel time private car TT$_{PC}$ will decrease (“-“), while travel time non motorised TT$_{P\&B}$ will increase (“+“).The latter is due to increased separation effects of the road network.

4.3 Module 3: Objective functions

The targets of different players involved in decision making processes, were transformed into mathematical expressions called objective functions. The basis for such calculations is a cost-benefit analysis. In OPTIMA two objective functions were used, one purely economic and one taking sustainability aspects into account. In FATIMA the effects of externalities and different scenarios of private finance involvement in public transport were also considered. This led to a set of five different objective functions (Table 1).

Table 1: Summary of the FATIMA objective functions

Objective function	**Acronym**	**Description**
Economic Efficiency Function that considers environmental costs	EEFP	A measure of net present benefits to travellers, operators and government. A shadow price on the net outlay and generation of public funds (compared to the do-minimum strategy) is included, as is a shadow price on the local environment and safety.
Sustainability Objective Function	SOF	A measure of net present benefits to travellers, operators and government in a future target year. It imposes a very high shadow price on fuel and has the constraint that fuel consumption is less than for the do-minimum strategy.
Benchmark Objective Function	BOF	An idealised economic function which balances the interests of the current generation with those of future generations. BOF is a weighted sum of EEFP and SOF.
Constrained Objective Function	COF	An extension of BOF, but which assumes that public finance is constrained to the do-minimum level.
Regulated Objective Function	ROF	An extension of COF, which recognises that extra (private) finance can be input to the transport system through value capture.
Deregulated Objective Function	DOF	An extension of COF which assumes that full control of public transport is handed to the private sector, with no public subsidy.
Half-regulated Objective Function	HOF	An extension of DOF but which permits subsidy to privately-run public transport to be made, but only if the present value of finance is positive.

4.4 Module 4: Optimisation method

The goal of the tool is to find optimal policy measure combinations with regard to different targets. For n policy measures the objective function gives an n-dimensional surface. Different methods can be used to find the optimum of such a multi-dimensional surface. In OPTIMA and FATIMA a statistics-based method was used (OPTIMA, 1997), (EMBERGER, 1998). For an initial set of policy measure packages the transport model calculates objective function values. Using the objective function values for these initial runs, a statistical regression is carried out, which aims to explain the (objective function) results in the form of an equation. The variables in this equation are the values of the measures. This equation has a quadratic form: i.e. it has linear terms and squared terms in it. The curve defined by the equation will have a maximum value. This maximum value of the curve gives an estimate of what set of transport measures give the highest value of the objective function, i.e. an estimate of the optimum set of measures.

The transport model is run again to test the estimate of the optimum package, and other packages that are close to the estimated optimum. For a number of reasons, the estimate of the optimum is unlikely to be the optimum. Thus, using the results of the new transport model runs as well as the initial runs, a new regression estimate is made, leading to a new estimated optimum. Further transport models runs are then carried out to calculate the objective function for this new estimated optimum. This procedure (involving transport model runs and statistical regressions) carries on iteratively until a convergence criterion is fulfilled.

Some objective functions used in the project FATIMA have discontinuities. For these objective functions the regression model based method fails. This was one of the reasons that in SAMI another method based on an operations research routine called AMOEBA was used (PRESS, FLANNERY ET. AL., 1990). This method is able to cope better with discontinuities in the form of hard constraints. A disadvantage of AMOEBA is that it is not possible to use nominal scaled variables.

The short run time of the TUW-IVV model allows, at least for a limited number of policy measures, a simple method to overcome problems with discontinuities: a grid scan of the whole multi-dimensional policy surface. The derived data can be used to draw 3-dimensional sections through the n-dimensional policy space (see Fig. 6). For two policy measures each, it is possible to visualise the form of the objective function. Such figures can be used to find the sensitive measures and estimate elasticities. This method is useful to sort out non-sensitive measures and to limit the range of the remaining measures for an intensified analysis. If seen necessary the detailed analysis could also include the use of more detailed and complex models.

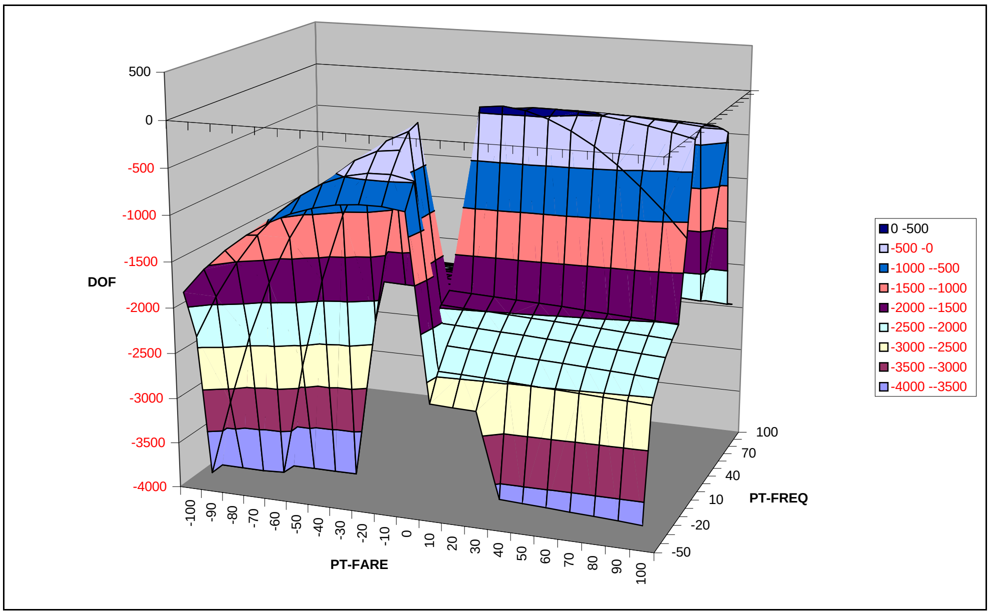

Fig. 6: “Deregulated Objective Function DOF” as a function of public transport and fare, project FATIMA

5. Future development on tools to support decision making processes

The previous research proved the ability of the model to handle small cities as well as big cities. This is an important pre-requisite for common use as a tool to support urban decision making processes. In the 5th framework research project called PROSPECTS TUW-IVV will develop a so-called “Sketch-Planning-Model”. Therefore a land-use model will be added to the transport model module. This also includes the simulation of new policy measures and new targets in the objective functions. The inclusion of a land-use part into the tool will be an important extension to its usability and usefulness. One of the aims will be to perform a pre-analysis for tests with more detailed land-use – transport models.

6. Conclusions and future needs

6.1 The TUW-IVV modular decision support tool

- In several research projects the modular concept of the TUW-IVV decision support tool has proved its usefulness and advantages.
- It has been proved that the TUW-IVV concept works as well for small cities as for big cities. Therefore it could be supposed to be generally applicable to all types of cities.
- Especially the fact that the model does not require very high quality in underlying data could be seen as an advantage compared to more detailed and complex models.
- Under conditions with low data quality it is likely that the resulting error of the strategic model is lower or at least not higher as in more detailed models.
- With the TUW-IVV model suite a useful decision support tool exists. The tool is already validated in numerous European research projects. The model will also be further improved within ongoing and future national and international research.

6.2 Needs to encourage the use of decision support tools

Decision making processes in reality involve numerous different players and interests (Fig. 1). The planning administration is the main addressee to use the presented decision support tools. But it could be seen that only a relative small part of land-use relevant decisions is planned directly by the administration (thin arrow from “Planning administration” to “Land-use relevant decisions” in Fig. 1). Most of the real life decisions are made bypassing planners and administration. This is indicated in Fig. 1 by the thick arrow from “Policy maker” to “Land-use relevant decisions”. To objectivise decision making, one of the main future tasks should be to improve policy maker awareness about supporting tools and to encourage them to use these techniques.

Nevertheless a serious reservation has to be made. It is important to bear in mind that modelling results are never equal to reality. Models are only pictures of reality, always based on the experiences of the persons behind them. Decision support tools cannot relieve policy makers from being responsible to make decisions! There is always need to put weight on different aspects in the decision making process. A risk in using decision support tools is that personal judgement and prioritisation is hidden behind pseudo objective procedures.

Decision support tools can offer help to get a better understanding how the highly complex system of land-use, transport and economy reacts. Even behind the most sophisticated and complex models there is always personal judgement. Therefore as a final conclusion a periodical validation of effects caused by decisions must be one of the main tasks for the future.

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