Are European cities becoming similar?

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1 INTRODUCTION

The paper discusses city specific development patterns to overcome todays transport problems. The results are based on recent and ongoing research activities at TUW-IVV and ITS. At previous CORP-conferences, we presented the basics and the development of a planning support tool to find optimal policy packages in urban transport and land use (Emberger, 1998), (Pfaffenbichler, Emberger, 2001). The core of this planning support tool is a dynamic land use and transport interaction model. This model, which we refer to as Sketch Planning Model (SPM), is embedded into an appraisal and optimisation framework. The SPM and this framework were developed in the recently finished European Union funded research project PROSPECTS[1]. Case studies with this planning support tool were performed within PROSPECTS for the cities Edinburgh, Helsinki, Madrid, Oslo, Stockholm and Vienna. These cities are principally comparable in regards of their status (capitals and major business and education centres), but different in their size, population density, transport system etc. A set of policy instruments like public transport improvements, car traffic restrictions, and infrastructure provision was available to formulate strategies to reduce negative impacts of transport and to increase welfare. The overall objective was a sustainable development of the city. Although the instruments and the goals are similar in all investigated cites, different solutions were adequate. The solutions vary in regard of spatial implementation, implementation time and level of implementation. The paper will highlight some reasons for the different development paths of the cities. As well the comparison of the do nothing scenario as the comparison of the most feasible policy strategies shows that European cities are different, need different solutions for their problems and will stay different in the future.

2 THE SKETCH PLANNING MODEL (SPM)

The SPM is a strategic, interactive land-use and transport (LUTI) model. It was developed as a time-saving alternative to traditional four-step transport models. The SPM process is influenced through the use of several demand and supply-sided instruments whose results can be measured against targets of sustainability. The SPM assumes that land-use is not a constant but is rather part of a dynamic system that is influenced by transport infrastructure. Therefore at the highest level of aggregation the SPM can be divided into two main sub-models: the land-use model and the transport model (Figure 1). The interaction process is shown by the use of time-lagged feedback loops between the transport and land-use sub-models over a period of 30 years.

Two person groups, with and without access to a car are considered in the transport model part. The transport model is broken down by commuting and non-commuting trips, including travel by non-motorised modes. The land-use model considers residential and workplace location preferences based on accessibility, available land, average rents and amount of green space available. A rather high level of spatial aggregation is used in the SPM. In most case studies this means that the municipal districts are chosen as travel analysis zones. The output of the transport model are accessibility measures for each zone while the land-use model yields workplace and residential location preferences per zone.

The interaction between land-use and transport modelling components are influenced through a set of policy instruments. These instruments range from demand-sided measures, such as with public transport fare (increases or decreases), parking or road pricing charges to supply-sided measures such as increased transit service or capacity changes for road or non-motorised transport. These measures, furthermore, could be applied to various spatial levels and/or to time-of-day periods (peak or off-peak).Changes in the transport subsystem due to the application of an instrument cause time lagged changes in the land use system (Knoflacher et. al., 2000). For example new road infrastructure will change the location of housing and workplaces in long term. Changes in the land use system cause as well immediate as time lagged reactions in the transport subsystem. For example a newly established enterprise zone causes an immediate change in travel demand and may initiate the development of a new public transport (PT) service in the long term.

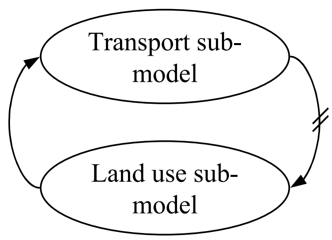

Fig. 1: SPM subsystem diagram on the highest level of aggregation

[1] 5th Framework Program: PROSPECTS (2002), Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems, http://www-ivv.tuwien.ac.at/projects/prospects.html

3 THE APPRAISAL FRAMEWORK

The case studies demonstrate the implementation of the PROSPECTS appraisal approach using the time marching SPM (Shepherd et. al., 2002) and (Minken et. al., 2002). The appraisal framework consists of:

- a set of policy instruments,
- an objective function and
- an optimisation method.

The instruments identified in PROSPECTS cover a wide range of possibilities (May et. al., 2001). The following policy measures are simulated in the SPM (Table 1).

Instrument	Affects:	Type	Spatial	Comment
Public Transport				
New public transport services	TT	discrete	OD	Either built or not
Frequency changes	TT	continuous	all	Percentage change compared to do-min
Fare level	C	continuous	all	Percentage change compared to do-min
Private Car				
New roads	TT	discrete	OD	Either built or not
Road capacity	TT	continuous	all	Percentage change compared to do-min
Road charging	C	continuous	OD	Euro per trip into a defined area
Fuel Price	C	continuous	all	Percentage change compared to do-min
Parking Charges	C	continuous	OD	
Non motorised modes				
Pedestrianised areas	TT	discrete	OD	
Land use				
Land use taxes	C	continuous	by zone	Certain amount per built up space
Protection of certain areas		discrete	by zone	

TT ....Travel time
C...............Costs
OD............Origin-destination pair

Table 1: Policy instruments modelled in the SPM

The policy instruments can in the most general case be applied at any level in any year. For simplification the instruments were optimised for two years: the implementation and a long run year (Figure 2). Between these two years the instruments are linearly interpolated. After the long run year the instruments are kept at a constant level.

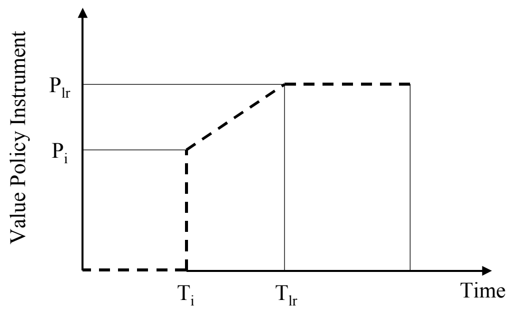

Fig. 2: Policy profile optimised in the task 33 SPM case studies

An automated approach using the AMOEBA routine was applied in the case studies (Minken et. al., 2002). In (Minken et. al., 2002) the following six sub-objectives for the overarching objective of urban sustainability were defined:

- economic efficiency,
- protection of the environment,
- liveable streets and neighbourhoods,
- safety,
- equity and social inclusion and
- contribution to economic growth.

The objective function, which was optimised, incorporates economic efficiency, environmental externalities, safety and equity between present and future generations (Minken et. al., 2002). If the public value of finance (PVF) was negative in the initial optimisation, an additional optimisation of an objective function using quadratic penalties on negative PVF was performed. This scenario simulates a situation in which strategies requiring higher public spending than the do minimum scenario are not acceptable for a city. The traditional rule a half was applied to calculate user benefits (Shepherd et. al., 2002).

4 THE CASE STUDY CITIES

The six case study cities are principally comparable in regards of their status. They are all capitals and major business and education centres. From the geographic point of view they cover Northern, Western, Southern and Middle European cities. As it is shown below the six cities differ significantly in their size, population density, transport system etc. They cover a wide range of European city types.

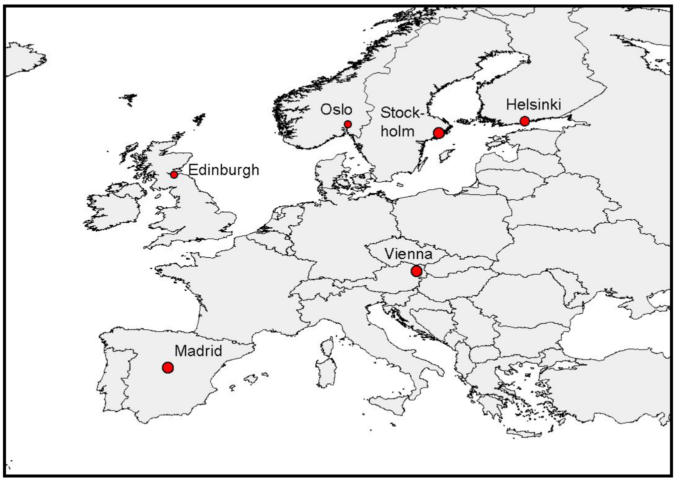

Figure 1: Case study cities

4.1 The initial situation

The following tables compare the initial situation in the six case study cities. The size of the cities in terms of number of residents ranges from about 400,000 in Oslo to about 5 millions in the Madrid metropolitan region. The case studies in Helsinki, Madrid and Stockholm cover the wider metropolitan area while the others focus on the core city. Vienna and Edinburgh are the most compact cities. For the SPM calculations the study areas are subdivided into 15 (Oslo) to 34 (Madrid) zones. The household incomes range from bout 4 (Madrid) to 24 (Helsinki) Euros per hour.

City	Population	Area (km²)	Density (#/km²)	# SPM zones	Household income (€/h)
Edinburgh	1,071,768	53*	-	25	15.0
Helsinki	920,732	742	1,241	22	24.0
Madrid	5,022,289	8,011	627	34	4.2
Oslo	396,974#	454	874	15	18.0
Stockholm	1,682,595	5,866	287	25	9.5
Vienna	1,550,123	415	3,735	23	11.3

* Floor space, therefore not directly comparable with other values
# Residents over 12 years

Table 2: The initial situation in the case study cities

The Edinburgh public transport system is bus based. The public transport systems of the other cities include metro and tramway lines. Madrid and Vienna have the densest metro network. Edinburgh and Oslo have the lowest share of non motorised trips while Stockholm and Madrid have the highest (Table 3). Madrid has the highest share in public transport while Stockholm has the lowest. The share of car trips is the highest in Edinburgh and Stockholm and the lowest in Madrid.

City	Commuting			Non working		
	Non motorised	Public Transport	Private car	Non motorised	Public Transport	Private car
Edinburgh	18%	34%	48%	24%	20%	56%
Helsinki	27%	30%	43%	30%	24%	46%
Madrid	11%	36%	53%	37%	34%	29%
Oslo	14%	33%	53%	10%	15%	75%
Stockholm	37%	26%	37%	38%	13%	49%
Vienna	26%	37%	37%	28%	25%	47%

Table 3: Mode split in the base year

4.2 The do nothing scenario

The do-nothing scenario is defined as a scenario where no major changes in the transport sector are implemented. The only change in the transport system is an endogenously calculated improvement of the road network if the flat and/or workplace development is over a certain threshold in a zone. Of course not everything could be considered as endogenous variable in the SPM modelling suite. Therefore the following exogenous assumptions about growth rates concerning population and workplace development have to be made (Table 4). These growth rates are defined separately for each individual city. They affect the endogenously calculated future land use development of the cities. The defined growth rates have to be seen as potential growth rates, i.e. how many people/workplaces are willing to move into the city. The endogenously defined supply with flats/premises does not necessarily meet this demand. Over demand is aggregated over iterations and increases rents and stimulates new developments. The growth rates lead to a movement of residents towards the outer districts of the cities. As an example Figure 3 shows the change in the number of residents between the base year and year 10 in the Vienna do nothing scenario. More people residing in the outer districts lead to an increase of car usage in all investigated cities (Figure 2). These trends occur in all six case study cities although with a different intensity. E.g. due to the already very high share of car use increases are very small in Oslo. The car ownership is assumed as being constant by the SPM. Car availability and captive riders limit the share of care use in the case of Oslo.

	Yearly growth rate		
City	Population	WP service	WP production
Edinburgh	0.6%	0.8%	0.8%
Helsinki	0.8%	0.8%	0.8%
Madrid	0.6%	2.0%	3.0%
Oslo	1.0%	1.0%	1.0%
Stockholm	0.6%	0.8%	0.8%
Vienna	0.1%	0.7%	0.7%

Table 4: Growth rates in the do nothing scenarios

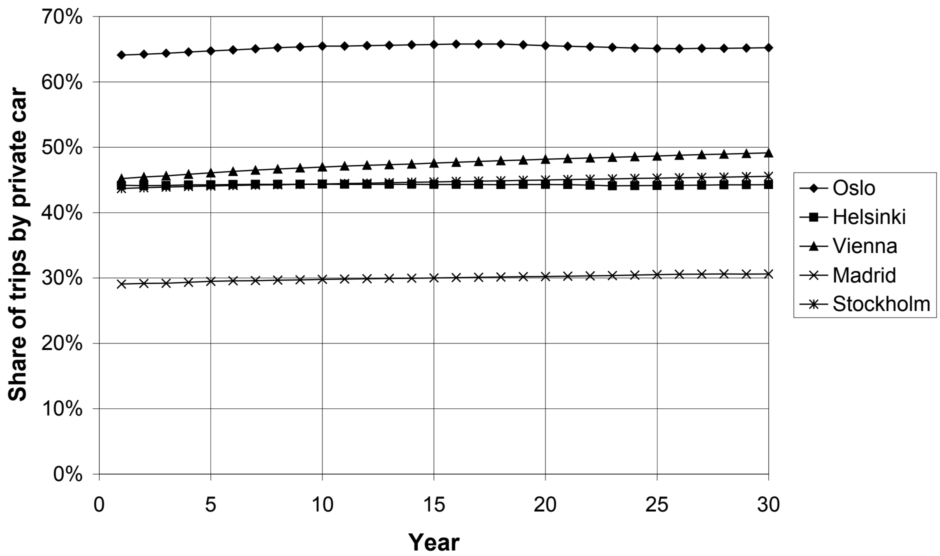

Figure 2: Development of the share of private car trips in the do nothing scenario

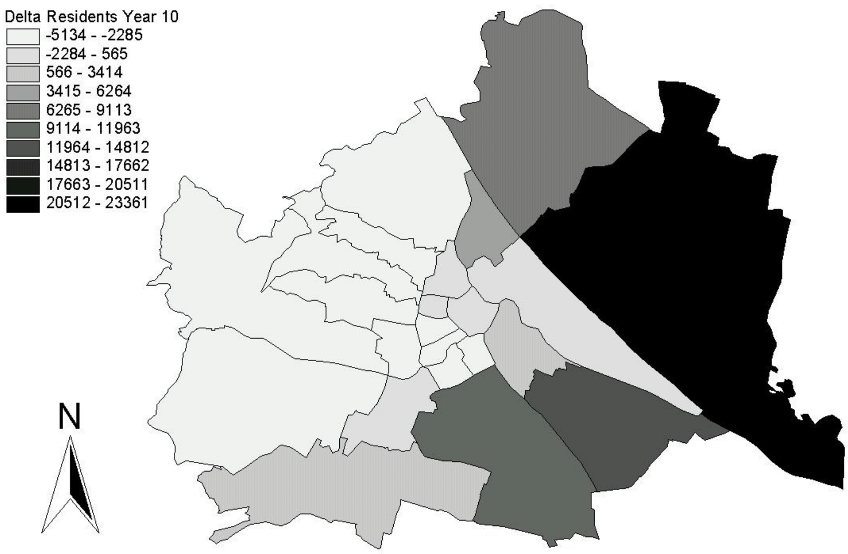

Figure 3: Delta residents in the Vienna do nothing scenario in year 10

5 OPTIMAL STRATEGIES

From the instruments modelled in the SPM (Table 1) a common set to be tested in each city was selected. The policy instruments studied in all six case studies were public transport fare, public transport frequency and fuel tax changes. In some of the cities road pricing and parking charging schemes were tested in addition to the common set of policy instruments. Table 5 shows the allowed range of the instruments. Table 6 to

NM........... Non Motorised
PT............. Public Transport
PC............. Private Car

Table 8 show the results of the unconstrained optimisation of the common set of instruments.

Instrument	Lower boundary	Upper boundary
Fares	-50%	+100%
Frequency	-50%	+100%
Fuel tax	0%	200%

Table 5: Boundaries common set of instruments

Most of the optimisation results suggest significant decreases in PT fares. In the cities Edinburgh, Stockholm and Vienna the optimal policy strategy suggests to reduce the fares in peak and off peak periods to the lower boundary. In Madrid the optimal combination consists of a major fare increase for peak in the early years and tends then to decrease this high fare level to a zero change in the year 2016. For the off peak fare level the optimal solution seems to be a minor change of the fare level in the implementation year and then to reduce the fare in the long run year towards the lower threshold value. In Helsinki fares are suggested to be decreased in the peak period and increased in the off peak period. The Oslo result proposes a slight increase of peak fares in the implementation year and a significant decrease in the long run year. For off peak slight fare decreases are suggested.

The results for PT frequency depend very much on the operating costs for additional frequency. In general there is a tendency to increase off peak frequency. The highest increases are proposed in Edinburgh and Helsinki, the lowest in Madrid, Oslo and Stockholm. Vienna lies in the middle of the proposed range. The Edinburgh urban PT system is completely based on busses and although Helsinki has an underground and tramway lines, its PT system relies mainly on busses. Significant frequency increases for the peak period are only proposed in Edinburgh. The main reason is the relative low cost for improvements of the bus based PT system. In the other cities except Madrid only slight changes are suggested. The Madrid result suggests to nearly cut in halve the PT service in peak. As the SPM currently has no overcrowding model this result has to be questioned.

Fuel tax increases are proposed in all case study cities. The highest increases are suggested for Edinburgh and Helsinki, the lowest for Vienna.

Policy surfaces were created to analyst the robustness of the optimisation results (May et. al., 2001). The optimal strategies are quite flat around the optimum. I.e. it is possible to get nearly optimal objective function values with a rather wide range of instrument values. This robustness offers leeway to make implementation of a strategy easier.

City	Fare				Frequency				Fuel tax	
	peak		off peak		peak		off peak			
	2006	2016	2006	2016	2006	2016	2006	2016	2006	2016
Edinburgh	-50%	-50%	-50%	-50%	87%	100%	100%	100%	200%	57%
Helsinki	-42%	-50%	35%	82%	10%	-26%	100%	100%	194%	106%
Madrid	80%	-1%	2%	-40%	-45%	-47%	5%	24%	117%	48%
Oslo	15%	-45%	-6%	-18%	-7%	-24%	-4%	28%	87%	35%
Stockholm	-49%	-49%	-42%	-49%	10%	9%	3%	18%	34%	37%
Vienna	-48%	-50%	-50%	-49%	-7%	-25%	57%	54%	23%	3%

Table 6: Policy instruments unconstrained optimisation results

Table 7 shows which groups are the beneficiaries of the proposed strategies and which groups are financing them. Private car (PC) users are in all case studies paying more than in the do nothing scenario. In all cities except Helsinki PT users benefit from the suggested strategy. With the exception of Helsinki and Madrid PT operators loose money compared to the do nothing scenario. In all cities except in Vienna revenues are generated on the road operators side. Benefits from reducing external costs are achieved in each city. Vienna is the only city in which the public value of finance (PVF) is negative. I.e. public authorities have higher costs than in the do nothing scenario. Therefore an additional constrained optimisation was performed for Vienna. The basic characteristic of the suggested strategy stays the same. Additional revenues to finance the constrained strategy are raised by higher fuel tax increases, a slight off peak fare increase in the implementation year and lower frequency increases in off peak. The constrained objective function value is about 20% lower than the unconstrained one.

City	User benefits			Operators		External costs	PVF	EEF	OF
	NM	PT	PC	PT	PC				
Edinburgh	-116.2	2,932.8	-3,235.2	-1,718.1	2,775.7	346.7	1,017.7	945.9	190.2
Helsinki	-7.4	-866.7	-2,313.2	1,792.4	2,108.9	128.3	3,901.3	844.4	149.9
Madrid	-4.4	1,036.4	-3,916.3	2,440.7	2,932.0	891.0	5,372.7	3,292.8	627.9
Oslo	0.7	262.7	-600.3	-135.2	525.5	19.8	390.3	69.6	18.6
Stockholm	-129.3	1,101.8	-1,340.8	-804.9	1,236.5	168.4	431.6	225.0	49.6
Vienna	-17.6	3,316.0	-145.1	-2,347.0	-284.9	224.8	-2,631.9	725.1	161.6

NM........... Non Motorised
PT............. Public Transport
PC............. Private Car
PVF .... Public Value of Finance
EEF .... Economic Efficiency Objective Function
OF .... Objective Function

Table 7: Appraisal result unconstrained optimisation (mio. €)

Table 8 and Figure 4 show the effects of the suggested strategies in the transport system. The proposed strategies lead to an increased share of PT use. The share of non motorised and car trips is decreasing.

City	Commuting			Non working		
	NM	PT	PC	NM	PT	PC
Edinburgh	14.3%	43.2%	42.5%	20.0%	29.2%	50.8%
Helsinki	27.9%	28.7%	43.3%	25.9%	30.0%	44.1%
Madrid	24.7%	36.8%	38.5%	35.4%	39.5%	25.1%
Oslo	21.6%	31.2%	47.3%	11.5%	17.6%	70.8%
Stockholm	31.4%	31.1%	37.4%	33.7%	18.0%	48.4%
Vienna	19.7%	40.8%	39.6%	21.8%	34.4%	43.8%

NM............Non Motorised
PT ....Public Transport
PC ....Private Car

Table 8: Comparison mode split year 2021 unconstrained optimisation result

Although there is a common trend towards more PT use, the transport systems do not necessarily become more similar. In Figure 4 the white coloured points indicate the situation in the base year. The grey points show where the cities would go in the do nothing scenario. The black points show where they would go if they apply the suggested strategies. Helsinki (H) and Vienna (V) are very similar in their initial situation. Applying the proposed strategies increases the difference.

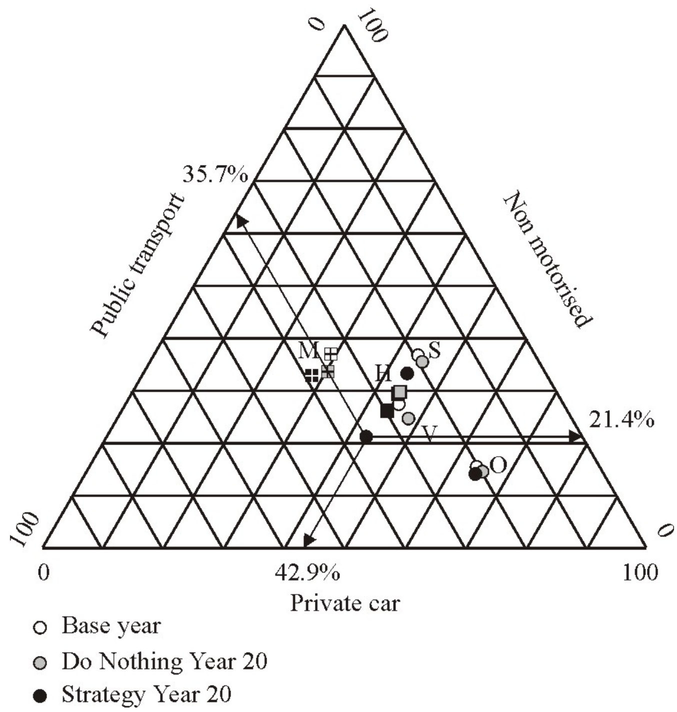

Figure 4: Mode split development different scenarios and strategies

6 SUMMARY AND CONCLUSIONS

6.1 Summary

In the project PROSPECTS a strategic appraisal framework was developed. This framework was used to perform a case study in six European capital cities. In some aspects, like their status, the cities have similarities while they are significantly different in other aspects like number of residents, density, transport system etc. In a do nothing scenario the cities show some common trends. The most important are:

- increase in car use and
- migration into the outer districts.

Albeit this common behaviour differences in their transport and land use system remain.

Strategies to achieve the overall objective of sustainability were developed for each city. The suggested policy instruments show some similarities, e.g. increases in fuel tax and decreases in fare. Nevertheless there are significant differences in the proposed instrument values. The major difference lies in the suggested frequency changes which are very much depending on the actual PT system (bus – metro based) and the costs for additional services. The pattern of transport system use stays significantly different or even gets more different.

6.2 Future SPM tests and improvements

The tested instruments are more or less evenly distributed over the whole study area. Therefore their effect on the land use pattern is relatively small. Other instruments, which are spatially more varied like road charging cordons or discrete infrastructure projects, have more significant effects. Land use charges were not tested yet, but proposed for future case studies.

The overall objective of sustainability was not fully met by the current design of the objective function. The carbon dioxide emissions start to raise again in the longer run years. One surprising aspect before the background of sustainability was that non motorised trips were suppressed in al scenarios and strategies. As they are emission free it was expected that they are an important part of a sustainable strategy. The reason might be that no monetary effects are associated with this mode. Therefore it is underrepresented in the current appraisal framework. One of sub-objectives of sustainability is “Liveable streets and neighbourhoods“. This sub-objective was not yet considered in the SPM appraisal framework. The non motorised modes would very likely benefit from the consideration of this sub-objective. On the agreagation level of the SPM it is difficult to consider “Liveable streets and neighbourhoods“. Possibilties might be the consideration of vulernable road user accidents or the car speed level. Further research is needed in this field.

During the case studies it turned out that the understanding of input parameters on such an aggregated level is rather heterogenous. This issue requires future work to establish a common understanding of model parameters. Furthermore SPM results would significantly benefit from including a car ownership and PT overcrowding model.

6.3 Final conclusionss

The case studies performed in PROSPECTS show that European cities follow some similar trends. Albeit these similarities there are a lot of differences. Although cities have sustainability as a similar overall objective, different strategies are needed to achieve the best result. Therefore the project PROSPECTS developed a set of three guidebooks to give European cities the specific guidance they need in their particular situation:

- Decision makers guidebook (May et. al., 2002),
- Methodological guidebook (Minken et. al., 2002),
- Policy guidebook.

As well the comparison of the do nothing scenario as the comparison of the most feasible policy strategies shows that European cities are different, need different solutions for their problems and will stay different in the future.

7 REFERENCES

Emberger G.: Vorstellung einer Methode zum Lösen komplexer Optimierungsprobleme, Proceedings CORP 1998; Ed.: Manfred Schrenk; Institut für EDV gestützte Methoden in Architektur und Raumplanung; Wien; 1998.

Knoflacher H., Pfaffenbichler P. C., Gielge J.: Analysing the driving forces behind decision-making processes for the (new)location of businesses. In: Proceedings "2nd International Conference on Decision Making in Urban and Civil Engineering", Ed.: J.-C. Mangin, M. Miramond, 1, INSA Lyon (Fr), ESIGC Chambery (Fr), ENTPE Vaulx-en-Velin (Fr), ETS Montreal (Ca), Lyon, 20-22 November 2000, pp. 563-574.

May A. D., Jarvi T., Minken H., Ramjerdi F., Matthews B., Monzon A.: Cities Decision-Making Requirements, Deliverable 1, PROSPECTS (Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems), Proposal Nr. EVK4-1999-00013, 2001, www.ivv.tuwien.ac.at/projects/prospects/Deliverables/pr_del_1.pdf

May A. D., Shepherd S. P., Minken H., Markussen T., Emberger G., Pfaffenbichler P.: The use of response surfaces in specifying transport strategies, Transport Policy, Vol. 8, 2001, pp. 267-278.

May A. D. et. al.: Decision makers guidebook, PROSPECTS (Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems), Proposal Nr. EVK4-1999-00013, 2002, http://www-ivv.tuwien.ac.at/projects/prospects.html

Minken H, Jonsson D., Shepherd S., May A. D., Jarvi T., Karlstrom A:, Timms P., Pearman A., Pfaffenbichler P. C., Monzon A.: Methodological Guidebook, Deliverable 14, PROSPECTS (Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems), Proposal Nr. EVK4-1999-00013, 2002, http://www-ivv.tuwien.ac.at/projects/prospects.html

Pfaffenbichler P. C., Emberger G.: Ein strategisches Flächennutzungs-/Verkehrsmodell als Werkzeug raumrelevanter Planungen, Proceedings CORP 2001, Ed.: Manfred Schrenk; Institut für EDV gestützte Methoden in Architektur und Raumplanung; Wien; 2001, pp. 195-199.

Shepherd S., Pfaffenbichler P., Page M., Sumalee A., Vold A., Samstaadt H., Jonsson D., Karlstrom A., Järvi T., Vieira P., Simmonds D.: Forecasting and Analysis, Deliverable 8, PROSPECTS (Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems), Proposal Nr. EVK4-1999-00013, 2002, http://www-ivv.tuwien.ac.at/projects/prospects.html