Resource-efficient Urban Spatial Development Scenarios 2050. FP 7 Project SUME – Sustainable Urban Metabolism for Europe

Christof Schremmer, Ursula Mollay, Barbara Saringer-Bory

(DI Christof Schremmer, M.C.P., ÖIR-Österreichisches Institut für Raumplanung, Franz-Josefs Kai 27, 1010 Wien, schremmer@oir.at)
(DI Ursula Mollay, MA MSc, ÖIR-Österreichisches Institut für Raumplanung, Franz-Josefs Kai 27, 1010 Wien, mollay@oir.at)
(DI Barbara Saringer-Bory, ÖIR-Österreichisches Institut für Raumplanung, Franz-Josefs Kai 27, 1010 Wien, saringer@oir.at)

1 ABSTRACT

FP 7 project SUME (Sustainable Urban Metabolism for Europe) [1] is focusing on the way how future urban systems can be designed to be consistently less damaging to the environment. With specific relevance to the climate change agenda, the SUME-approach is focusing on the potential to reduce resource flows (land consumption as well as flows of energy and material) by restructuring existing urban systems in a long term vision (until 2050).

SUME analyses the impacts of **urban form** on resource use of urban systems – in a comprehensive understanding of the term. Athens, Munich, Marseille, Newcastle upon Tyne, Porto, Stockholm and Vienna have been analyzed with alternative spatial development scenarios until 2050. These scenarios estimate the potential to transform existing urban building and spatial structures into urban forms with significantly reduced resource consumption. The scenario approach considers both, actual development plans for each of the specific cities (at the level of urban quarters) and, alternatively, a set of selected priorities for pronounced sustainable development. The approach thereby takes into account the great differences between various cities' urban forms at the outset and in their demographic and economic development dynamics.

The concept of metabolism provides with a holistic understanding of the interaction of a society and its environment. In order to support urban development towards a more sustainable future, reasons for and links between environmental pressures caused by human societies are analysed. The methods of social metabolism account for resource use (inputs like energy, materials, land, and others) and the relating outputs to the environment. In the SUME project, spatial development scenarios (as described below) are being linked to a spatially explicit metabolic model, which will be calcualting the energy flows for a number of case study cities for the years 2001 and 2050.

As an important result, the sample of scenarios shows major differences between growing and shrinking cities, between cities with high or low densities and cities which are built in a spatially fragmented or in a continuous way. Different systems of public transport and varying environmental and climatic conditions are also considered. Overall, the SUME-results show realistic quantitative estimates for alternative development paths for urban regions, contribute to a better understanding of how resource efficiency can be improved by effective spatial planning.

2 THE SUME SCENARIO APPROACH

2.1 Purpose of scenario building

The rationale for using the scenario approach comes from the intention to provide a long-term outlook for urban development options. A long-term perspective is needed, since existing urban forms tend to be surprisingly stable, even in phases of accelerated growth: the spatial grid, the main transportation infrastructures and the way residential and economic functions are being localized and formed can be transformed only in decades.

The main intention of the SUME-scenario approach is to show spatial development policy options within a given quantitative development path, derived from actual demographic and economic trends. These projections are taken as input – the scenario approach is not attempting to make prognoses or projections or discuss the impacts of economic disturbances. On the contrary, it is intended to provide realistic estimates for

[1] The FP7-funded project Sustainable Urban Metabolism for Europe (SUME) started in November 2008 and will be carried out over a period of three years (up to October 2011). In total 10 partner institutions from 9 countries and 2 continents (Europe and Asia) work together on four major tasks. The article at hand is referring to scenario building and results achieved in the course of workpackage 1 – Scenarios of urban development in Europe. For further information please visit: www.sume.at

the **future action space** for policy makers and planners: What can be done to improve existing spatial structures – with relevance to the metabolic performance of urban forms ? How much can be done and impacted in a period of 40 – 50 years, compared to the general trends of development? In order to provide such an estimate, for each of the selected cities a trend scenario ('baseline scenario') and a sustainability-oriented SUME-scenario, geared to improve the metabolic performance of the urban regions, are being drafted and analysed in terms of their resource impact.

The scenarios are performed for urban regions, defined as Urban Morphological Zone (UMZ) [2]. Therefore, impact estimates and conclusions are being generated for this general urban level (UMZ as urban region), not for a spatially disaggregated level (i.e. urban districts, quarters, blocks, etc., which is being done in other parts of project SUME).

Encompassing a great variety of starting conditions in the urban regions included in the study, the scenarios analyse two alternative spatial development perspectives based on the same quantiative framework (demographic and economic development): The spatial development is oraganized either according to an observed typology of building and localization in each of the urabn regions, or, alternatively, spatially (re-)focused on locations with excellent access to public transport and closeness to services and centres of jobs. A gradual stepping-up of urban densities in such priority locations and a higher share of urban development projects in vicinity to attractive lines of public transport are the main elements for the so-called SUME-scenarios

These two scenarios for each city region are seen as the realistic range of options, from a "business as usual"-perspective to an ambitious, sustainability-oriented development policy, considering metabolic interdependencies. The scenario findings in terms of spatial categories, such as land consumption and densities are describing the situation for two alternative future spatial patterns in 2050. . Conclusions concerning effects of developments 'in between' may be derived, but are not in the focus of the work. The spatially explicit metabolism model, to be developed by the team of Social Ecology, Vienna, and Potsdam Institute for Climate Change Research, will be providing quantitative estimates for energy consumption based on a building stock and a transport model component which will use the spatial development scenarios as input (scenario-modeling 'hybrid approach').

Given the general uncertainties in a long-term perspective of nearly 50 years, the objective of the scenario approach is to reduce that complexity by showing the existing limitations that result from urban forms and structures inherited from the past. Cities will be transformed continuously, but what speed of change and what kind of spatial structures will have to be prolonged in the future can be estimated with the scenario methodology developed here.

2.2 Two pathways of future development – two scenarios: BASE and SUME

For capturing the possible range of effects due to urban development policies and planning, two spatial development paths of urban spatial structures have been defined for the analysed cities between 2000 and 2050. Both paths start from the given UMZ as defined for the year 2000, with the population, jobs, buildings and infrastructures given at that point.

Those two scenarios are characterised by the same main drivers for urban development as external factors, most important of which are: change of population and jobs, increase of living space per capita due to moderate economic growth, the extension of a future high-level public transport infrastructure network.

In addition to those external background factors, two different 'storylines' of relevant urban development policies have been defined for the two scenarios:

- BASE scenario as a continuation of current planning policies supporting (or at least not counter-acting) past spatial development trends (densities and configurations of the urban fabric within the UMZ).
- SUME scenario, defined as a path of sustainable spatial development – focusing on the interrelations between urban form and metabolic performance of an urban region, by changing current planning policies towards a clear guidance of urban development on major transport routes, providing

[2] Urban Morphological Zone (UMZ) according to the UN Habitat definition and provided through EEA.

compact and integrated new developments and aim at densification in areas of good accessibility but little use of the given spatial resources.

For each of the selected urban regions (delimited by UMZ) two urban development scenarios are calculated for the time horizon 2050 (BASE and SUME), which then are being compared in terms of their spatial outcome (area use for urbanization, spatial distribution, accessibility of public transport) and which also can be compared to the starting situation around the reference year 2000.

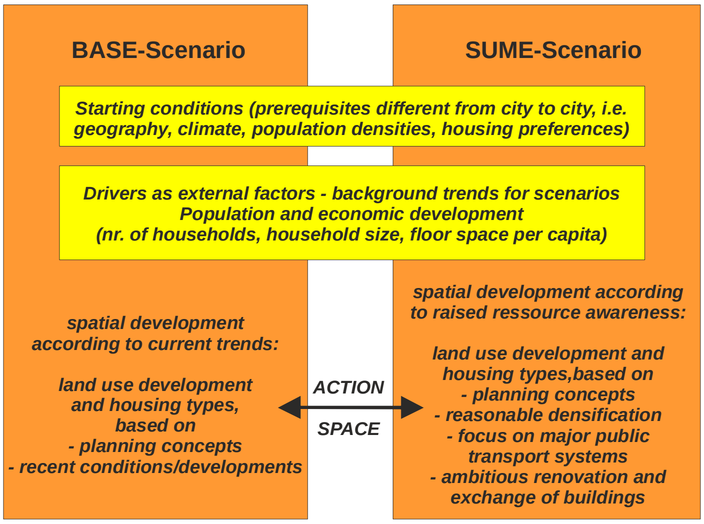

Fig. 1: Overall structure and storyline of BASE versus SUME scenario

The differential of the developmental change in the period 2000 – 2050 between the BASE and the SUME scenarios are the most important result: It describes the action space and the potential influence urban development policies and planning might have in shaping the future.

2.3 Urban development scenarios using different spatial levels

As a comprehensive approach, the SUME project defines and uses 3 specific layers of urban form which describe most important urban form characteristics of an urban settlement, enabling to describe different issues of the interrelation between urban form and metabolic performance:

(1) The larger urban configuration , to describe the overall shape and expansion of a city (in the SUME project based on the definition and delimitation of UMZ).

(2) The urban diversity pattern (UDP), to describe most important functions within the city and the spatial interrelations between different parts of a city, particularly transportation.

(3) The urban building stock, to describe spatial qualities and technical qualities of the building stock, particularly related to land and energy consumption (not a topic in this article).

These three layers do not necessarily correspond to various spatial scales of analysis, they rather capture different spatial qualities and functions at the overall scale of the city. The following figure 2 gives an impression of how the three layers correspond to each other.

Following the objectives of SUME, the focus of the analysis is laid on cities and urban metabolism from the perspective of a continuously built up urban settlement. Aspects at regional level at the one hand and local neighbourhood level at the other hand will therefore not be taken into account as much as the city level (the urban settlement defined as the entire, continuously built up area, not being limited by the cities' administrative borders).

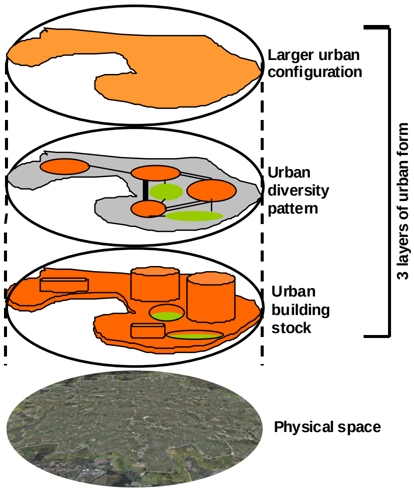

Fig. 2: The three layers of urban form defined by the SUME-project

2.4 Scenario building step by step

The urban development scenarios are based on the given building stock and urban form of selected case cities. A detailed data set is used for each of the urban regions, to be able to analyse the current spatial situation, the building typology and age structure in detail. For each of the case cities an overlay of several information sources has been used to produce a detailed data base for a number of several hundred defined spatial cells within the UMZ:

- Corine landcover data from the year 2000
- Population and workplace data from national census sources for years near 2000
- Apartments, buildings, building types and building age from national census sources for years near 2000
- Main transportation axes of high-level means of mass transport, such as subways and light-rail regional rapid transportation systems from regional and local plans and information given by stake holders.
- Supplementary information with regards to limitations for further development, such as protected zones, historic areas, parks etc.

The combination of these data allows an analysis of the given densities, the mix of uses (residential vs. workplace), the building typology and age structure and the accessibility of main transport lines for each cell of the seven case cities. All these indicators are regarded as descriptors of the given urban form at the outset – the scenario starting year 2000 (or another year close).

2.4.1 Scenario building process

The methodology of scenario building for the SUME project can be characterised as a step-by-step calculation, starting from most likely, anticipated developments to working with spatial development rules based on assumptions for different optional development paths in the BASE and SUME scenarios.

For the future perspectives, population and job development and the projected increases in floor space per capita for residential (and indirectly) other uses are regarded as main drivers of spatial urban development. A number of sources have been used for each of the selected cities to provide the necessary input for scenario building.

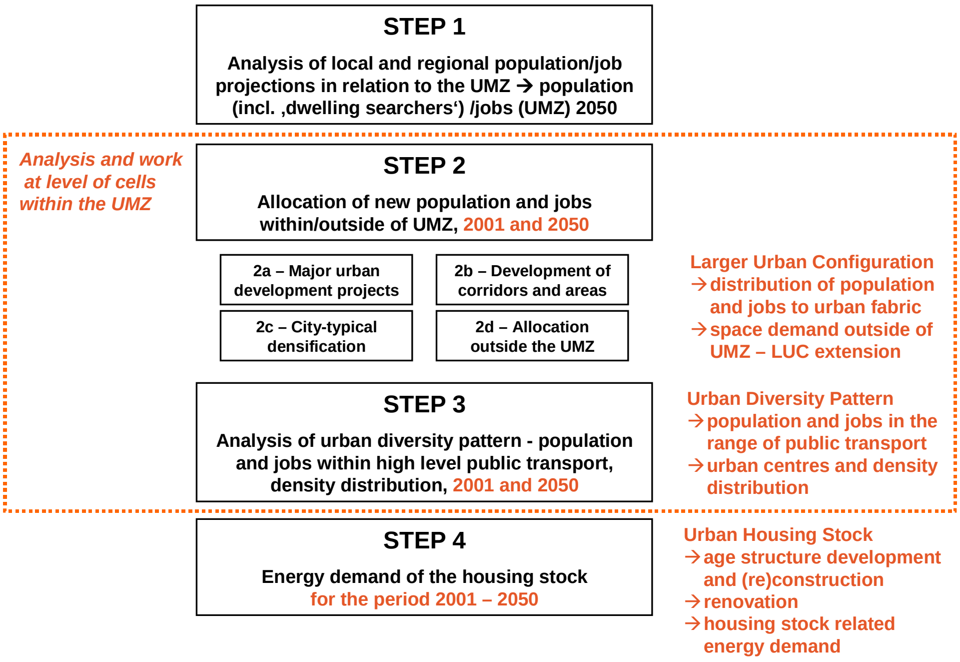

Fig. 3: Working steps for BASE and SUME scenarios

Starting from this quantitative and qualitative framework, a BASE scenario was set up, using the building typology and densities of population and jobs throughout the UMZ as a reference. As general rules for the spatial allocation of population and jobs the following principles have been defined:

- The allocation of population takes known and published large-scale urban development projects with a short- to medium-time frame as a basis (STEP 2a). Such projects usually have at least a 5 – 10 year preparation phase. For such important development projects planning or strategy documents already exist, from which information on location, size and building typology can be obtained. Since these projects will be realized most likely, they also limit the freedom for future decision making in the period until 2050.
- In a following STEP 2b, a planners perspective is used to identify promising locations for major projects (due to future planned extensions of the high-level public transport network, due to strategic planning visions), which are defined as potential additional long-time projects within the UMZ. For these kinds of additional developments examples in terms of city-typical size and densities and the mix of uses are derived from the large scale urban development projects which are in the pipeline and used in STEP 2a.
- Finally, in STEP 2c, for the allocation of residual population and jobs within the total UMZ, the existing building type characteristics in each of the cells are considered as important: Here a general assumption has been appplied that urban development tends to continue the dominant building type in largely built up urban neighbourhoods, leading to a typical density profile. Thus, without a major external impact (e.g. extension of high-level transport lines) characteristic densities of a city-specific housing type are assumed to remain stable. The "urban fabric"[3] portion of each cell then is being "filled up" according to the specific density category.
- The remaining surplus of future population (and jobs) which cannot be accommodated within the UMZ according to the above density rules is to be allocated outside of the UMZ (in the last STEP 2d). Here, no specific spatial allocations were made, but typical densitis of the surrounding area have been used to calculate the resulting land consumption for the category "urban fabric".

The distribution of population and jobs in each of the working steps is not indicating a chronological order. Therefore the working steps are to be seen as a means of making the scenario building operational, but they do not depict different points in time (between 2000 and 2050). Whereas the consideration of defined urban

[3] Corine land use categories 121 and 122, covering between 70 an 80 % of the UMZ area.

large-scale projects suggests a short- to medium-term time frame, other developments may take place in parallel.

BASE and SUME scenario are differentiated – as the result of the development strategies applied in STEPS 2a – 2c – in terms of the size of population spreading beyond the UMZ border, and also in terms of densities applied (for the newly urbanized areas), as well as for the spatial distribution/proximity to the lines of public mass transport (relevant for the transport indicator – UDP-indicator – as described in the following section). A major result of the scenario STEPS 2a – 2d is a quantitative estimate of the share of population which will be settling in urbanized areas outside the UMZ as defined in the year 2000.

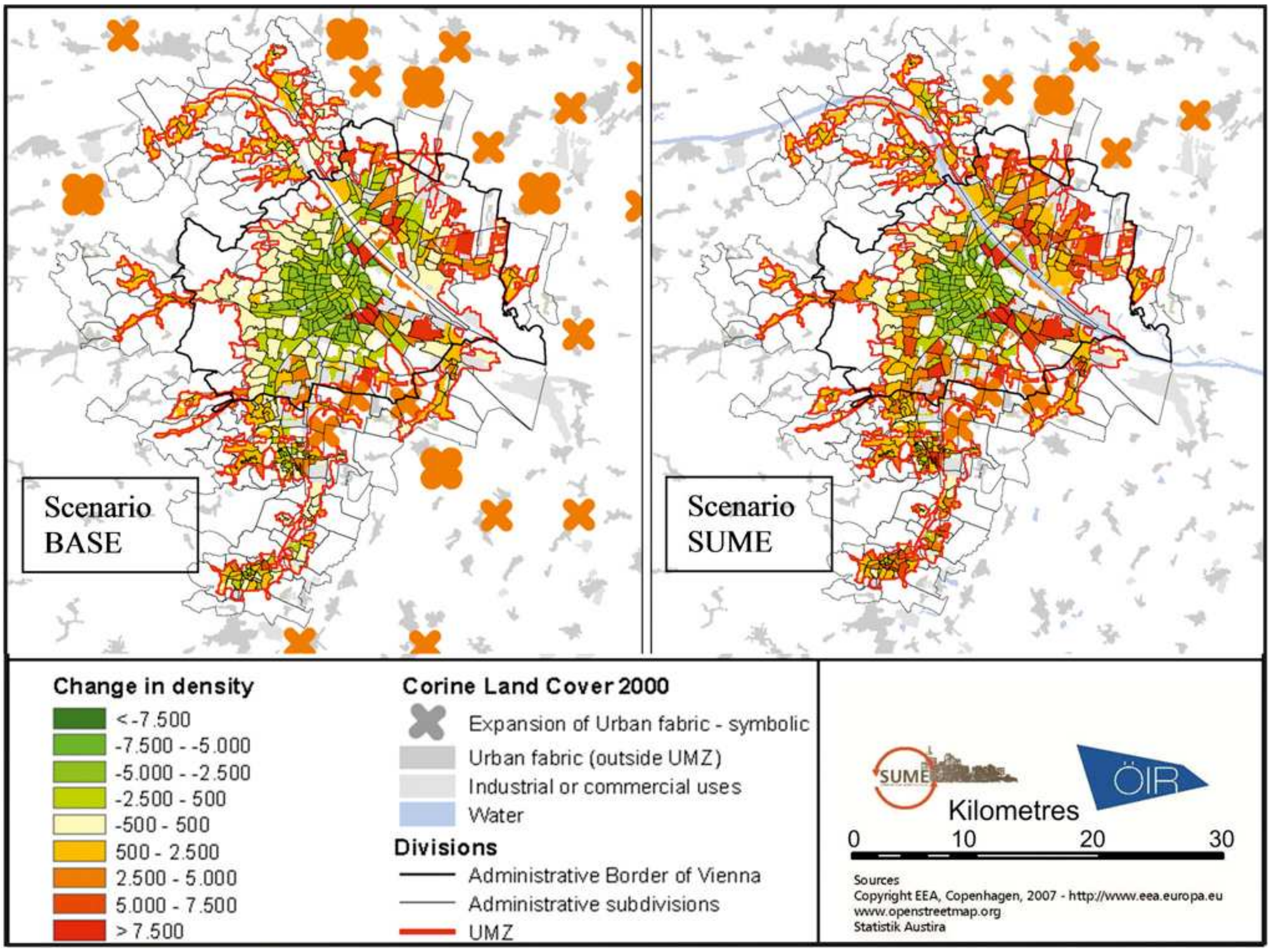

Fig. 4: Population and workplace density in Vienna, Change between situation 2001 and BASE/SUME scenario 2050

Resulting from the spatial allocation of the future population and jobs, comparisons between different cities can be performed for two points in time: the starting year (around 2000, depending on available data) and the year 2050, the time horizon for the two scenarios in each of the urban areas. These spatial allocations (example of Vienna in fig. 4) form the input for the analysis of the so-called "Urban Diversity Pattern" described in the following section.

2.4.2 Spatial Analysis of the urban development scenarios: Urban Diversity Patterns (UDP)

The analysis of the so-called "Urban Diversity Patterns" allows an assessment of the potential impact of urban structues on transportation and the energy consumption needed for transport.

The approach is based on the outcome of the scenario calculation – the overall distribution of population and jobs in cells within the UMZ and the necessary expansion outside of the UMZ until 2050. A qualitative rating of each cells location with respect to central functions, jobs and access to high-level public transportation is performed for existing and future spatial patterns (2000 and 2050), so that a comparison between the status quo and possible future states can be drawn for each of the selected urban areas and alternative scenarios.

The "UDP-indicator" is composed of three sub-indicators, which allow to measure those effects: accessibility of high-level public transport infrastructure (1), centrality (proximity to centre functions) (2) and diversity (mix of economic and residential functions within a cell) (3). Each cell in the UMZ is assessed for each sub-indicator through a rating procedure. The "aggregate UDP-indicator" for each urban area is generated by calculating the population-weighted average of all the cells' UDP indicator. This result is produced for the starting year and the two scenarios for the year 2050.

The assessment of urban form by use of the Urban Diversity Pattern (UDP)-indicator allows to draw conclusions on

- the potential access to attractive means of mass transport for the existing and future urban spatial structure,
- the existing and future potential for the use of different transport modes (based on the share of population with good access to high-level public transport),
- the existing and future impact on transport energy and land use for transport uses.

Especially for conclusions drawn on the use of transport modes it has to be underlined that the UDP-indicator only shows the *potential* of a city. Whether in a city the full potential of low-energy transport modes (foot, bicycle, public transport) will be utilized cannot be estimated directly with this indicator, as e.g. travel behaviour, time intervals or the quality of service of the public transport system are not integrated in the UDP indicator.

The differences in densities, spatial structures (compactenss or fragmentation) and sizes of the 'Urban Morphological Zones (UMZ)' which were analysed in the scenarios (Steps 2a to 2d), effect the distances that have to be travelled each day by its population, workforce etc.. The different densities of jobs and population and their spatial distribution within the UMZ provide an indication of the (future) diversity in a city, which is relevant for (future) transportation modes and distances, relating to the energy consumption for transport purposes.

3 RESULTS FROM THE SCENARIOS

3.1 The SUME case cities

The sample of selected case cities comprises a number of large European cities with varying urban structures in terms of densities and overall urban spatial configurations and facing different population growth/decline perspectives until 2050. This sample allows for comparisons of differences between the cities envisaged developments but also due to varying traditions of urban development cultures and policies.

Database	Vienna	Stockholm	Athens	Oporto	Munich	Marseille	Newcastle
Population development 2000 – 2050							
Population (UMZ) (starting year)	1,805,340	1,280,450	3,436,775	1,271,238	1,663,732	944,785	1,058,070
Projected development until 2050	+ 34.7%	+ 44.3%	+8.9%	- 3.7%	+ 17.7%	+ 20.3%	+ 11.8%
Urban fabric within UMZ (km2) 2000	313	332	221	235	232	137	214
Type of urban spatial configuration	Medium dense, compact form	Low density, policentric form	Very high density, compact form	Low density, fragmented form	High density, compact form	High density, compact form	Low density, fragmented form
Average density: (population plus half of jobs)/(km2 urban fabric)							
Average density	7,251	5,158	18,583	6,691	8,758	8,164	6,038

Table 1: Demographic and spatial characteristics of the SUME case cities

3.2 Future urban form – change in densities and land consumption

The differences between BASE and SUME scenarios show quite differentiated results, offering diverse options for policy-makers considering urban development strategies.

The following description highlights characteristics and most important differences between the case cities of the analysed sample:

Database	Vienna	Stockholm	Athens	Oporto	Munich	Marseille	Newcastle
Population growth out of UMZ (in the delimitation of 2000)							
Scenario BASE	526,000	481,000	306,000	0	409,000	138,000	67,000
Scenario SUME	172,000	247,000	0	0	153,000	0	0
Urban fabric growth out of UMZ in km2							
Scenario BASE	171	155	52	0	95	41	15
Scenario SUME	45	65	0	0	31	0	0
Urban fabric growth out of UMZ in %							
Scenario BASE	55%	47%	24%	0	41%	30%	7%
Scenario SUME	14%	20%	0	0	13%	0	0

Table 2: Scenario results for SUME case cities – population distribution and land consumption

- Vienna has a large share of cells within the UMZ with lower densities and therefore has substantial options for densification in the existing urban fabric. In the Vienna case, the SUME strategy, focusing on existing and projected transport axes allows for a major reduction of land consumption. It shows the greatest potential impact, due to both key elements, the starting situation with low density urbanized fringes and the strong growth perspective, offering a wide variety of devlopment strategies.
- The situation in Stockholm is in some ways similar to the Viennese, but the potential of reducing land consumption with a SUME strategy is not as pronouncesd : Due to its topographical situation densification is limited as well as the possibilities to reduce the UMZ-expansion.
- The SUME scenario for Munich also shows a strong potential to reduce the future expansion of the UMZ. This reduction is not to be achieved easily, however, since Munich already has reached a comparatively dense, compact settlement pattern. The potential to reduce land consumption lies mainly in the density and compactness of new developments in the fringe areas within the UMZ, re-densification of already urbanized areas is of comparatively less potential. This leads to a similar expansion of the UMZ in the SUME scenario as in Vienna, although the relative population growth is only half.
- In Athens, starting with a density more than double of Munich, the SUME scenario shows the potential to accommodate the city's growth within the UMZ, if the comparatively high densities are being applied in the outer sections of the city. The question remains to be answered, however, if such densities in the outer parts of the UMZ are advisable and adequate in terms of quality of life conditions.
- Marseille shows a similar density and growth rate as Munich . Density values in Marseille are comparingly high throughout the whole urbanized area, thus the incorporation of the total additional population within the existing urban fabric (as in the SUME scenario) seems possible, but might lead to new challenges related to the quality of life.
- The Oporto perspective does not offer much opportunity to differntiate spatial development strategies and to reduce land consumption, since due to the stable or even shrinking population already in the BASE scenario there is no expansion of the UMZ needed. The specific problem of Oporto is the low density/scattered settlement pattern, which cannot be substantially improved in a situation without growth, aggravated by the weak public transport network, offering little options to use attractive non-motorized means of transport (see also UDP-indicator results).
- The action space in Newcastle is a little bigger, but largely determined by the identification of options for additional high level public transport within the UMZ. Moderate population growth can

be directed into focussed development and densification nearby public transport stops in the SUME-scenario. Due to this effort it is possible to minimise additional land consumption.

3.3 Urban diversity patterns – functional distribution and options for public transport

The analysis of urban diversity patterns assesses the existing spatial structures, determining access to public transport and workplaces. Comparing with the spatial structures of the scenario year 2050, changes in in the functional distributions and access options for public transport, derived from a development according to the BASE and SUME-scenario are being analysed. The UDP-index is based on the outcome of the spatial population and workplace distribution of the scenarios as described above.

With the great differences in densities, fragmentation of the UMZ and the transport system, given in the urban areas compared, it seems no wonder there are also great differences between the cities in the sub-indicators and the aggregate UDP-indicator:

- With its highly scattered settlement pattern and low densities, Oporto shows by far the lowest values in all three indicators; this holds for both, the outset and the scenario end-states, since there is little potential for improvement, even in a consequently applied SUME scenario.
- Stockholm's UDP-value of the starting year is relatively good considering the low densities and an urban form allocating large parts of the population far away from the city main center. In contrast to Oporto, the development of the city was more controlled and concentrated in a polycentric urban form. Due to its specific urban form and topographical situation, Stockholm's dynamic development leads to an allocation of additional population in the outskirts of the UMZ, where the UDP-indicators show low values. Even in the SUME-scenario there is comparatively little potential for improvements.

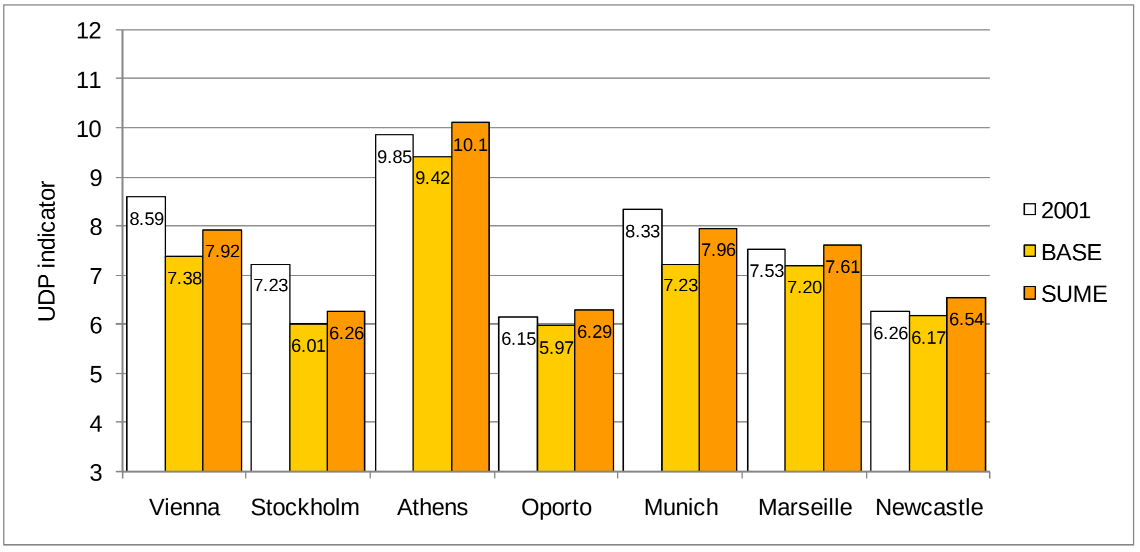

Fig. 5: Scenario results for the (aggregate) UDP-indicator

- On the other hand, Munich and Vienna show remarkably similar, high indicator values; in both growing cities it is clearly visible that the expansion of the urban area with the BASE scenario results in a major deterioration of the transport situation, since a large share of the population growth would have to be allocated outside the UMZ, resulting in a worsened access to transport lines and centres of work and services. Both cases also show, that a SUME scenario has a great impact, keeping the reduction of the UDP-indicator to a minimum (for a larger total population)
- Resulting from the high densities and the central location of a large share of work places, Athens has by far the highest UDP-indicator values; as said before, the SUME scenario keeps densities rather high even in the outer sections of the urban area, and in context with the proposed extensions of the Athens subway system, this even leads to a slight improvement of the UDP indicator. This is only an indication of what could be reached in the future, if the metro system would be expanded beyond the lines included in the scenarios.

- Marseille shows a similar result in terms of having the potential to improve the starting situation, even in a population growth perspective. This result could be achieved due to the effects of an overall densification within the existing limits of the UMZ together with focussed development along high level public transport, together with the realisation of current plans to expand the public transport system.
- The low level of public transport access in Newcastle is the main reason for only minor reduction of the UDP-index between th existing situation and a BASE scenario. Considerable room for maneuvre is shown by minor investment in public transport within the UMZ, resulting in a considerable improvement of the UDP-indicator in a potential SUME scenario.

4 CONCLUSIONS

The 2050 scenarios show considerable **action space** for **urban development: Land consumption and access to high-level transport and concentrations of workplaces can steered in different directions**.

Urban planning with a focus on compact development and careful use of space and infrastructure would result in **a dramatic reduction of land consumption** until 2050. The sample of seven analysed European case cities shows the potential for a reduction of consumed land by a total of 73% . If SUME measures were applied, some cities could avoid additional expension of the UMZ altogether (e.g. Newcastle, Oporto and Marseille).

In terms of **distribution of densities, functional mix and options for public transport**, a trend development – as intended to represented in the BASE scenarios – in a growing city situation leads to a deterioration of the spatial preconditions for providing attractive transport systems. Densities in the accessed areas of transport lines tend to be low, a lot of growth is happening in spaces between axes or out of reach. Both factors raise the distance to stops of transport lines and indirectly reduce the level of service, contributing to a less attractive transport system.

Growing cities have the option to counter this automatism through a clear spatial focus for their development strategies, as captured with the SUME scenarios. The case of Oporto presents opportunities for improvement even in a shrinking city, Newcastle shows great potential for improving the access through a minor expansion of the transport system. if a rigorously focussed development near public transport routes can be achieved . Specific topographical situations, as in the case of Stockholm, may have an additional influence on the potential of improvement through SUME-scenario-type policies. On the other hand, the Athens case also shows the limits to a further densification strategy – here, densities are already high enough to provide for attractive urban transport systems; the answer here could be the expansion and improvement of the (modern metro) transport system while maintaining the given (or even lowering) densities.

Different policy sets, spatial development and transport policies, can be synergetic and thus become more resource relevant, particularly if there is substantial growth in an urban area. In addition there is also great space for improvements, in case the past spatial development has been less consistently sustainable (as in the Vienna case).

Overall, the comparison of urban development scenarios and the analysis of related distribution of densities and functions throughout the cities, shows the a great potential of urban planning to impact urban form – and thus to reduce ressource consumption – over time. As the most important requirement for such options – as represented in the SUME-scenarios – a consistent set of policies has to be applied.

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