Combining Three Modelling and Visualization Tools for Collaborative Planning of Urban Transformation

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Abstract

Currently, great efforts are taken to develop new approaches and guidelines for sustainable transformation of urban agglomerations. These new approaches need to facilitate collaborations between science and a variety of public and private stakeholders to come up with socially accepted solutions. In this paper suitable instruments for supporting this task are presented: 1) a 3D zoning plan and urban model kit, 2) a multi-criteria decision analysis, and 3) an integrated land use and transportation model. In combination these tools facilitate integrating disciplinary knowledge and methods for a comprehensive analysis of urban patterns cross disciplines and scales. They can facilitate a change of stakeholders' perspectives and foster informed collaborative planning of urban transformation.

1 Introduction

Collaboration is said to be key for transforming existing landscape patterns into more sustainable ones (STEINITZ 2012). It is widely acknowledged that more socially accepted solutions can evolve from an intense cooperation of science and a variety of public and private stakeholders (PACIONE 2003; HEALEY 2007). However, a major challenge in facilitating this transdisciplinary collaboration is to provide tools and processes "appropriate to the multi-functionality of landscapes" (TRESS et al. 2002: 141). In particular, this requires tools, which allow for analysing landscape change across disciplines and scales in order to support a better understanding of the complex human-environment system (VAN KAMP et al. 2003), and identify undesired developments prior to actual design of development plans (BROWN 2003; STEINITZ 2012).

In this paper we present a set of tools that can facilitate the collaborative design of urban development strategies. The first tool operationalizes legal zoning regulations in interactive 3D visualizations. The second instrument is suitable to make heterogeneous urban quality goals negotiable. The third tool allows for cross-scale simulation and quantitative visualization of urban development scenarios addressing economic, social and environmental aspects of urban quality. On the example of a regional urban development study for the Swiss Limmattal region the concept for implementing the tool set in a collaborative urban planning platform is demonstrated.

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2 Methods

Science and practice have viable indicators available for measuring urban quality with regard to socio-economic aspects (e.g., density measures (DEMPSEY et al. 2012), accessibility (EFTHYMIOU et al. 2013)) and ecological requirements (e.g., available open space or habitat potential for plant and animal species (GRÊT-REGAMEY et al. 2013)). However, such indicators remain to be used in their disciplinary specialist field. They are neither implemented in integrated cross-disciplinary analysis nor cross scales. There is a lack of diagonal understanding of the complex spatial interactions between stakeholders and the different components of urban structure and form (SCHAEFER 2011). Three tools were developed, which combined can facilitate integrating the disciplinary knowledge and methods for a comprehensive mutual analysis: 1) a 3D zoning plan and urban model kit, 2) a multi-criteria decision analysis, and 3) an integrated land use and transportation model.

2.1 3D zoning plan and urban model kit

Planning and building laws strongly influence the urban appearance and possibilities for further development. The rules of these laws are available in abstract form of text documents. As yet spatial implications of the rules have been visualized with laborious and time-consuming physical or digital 3D models, which were produced rather for exhibitions than for supporting iterative analysis and design processes. The first of the developed tools, however, allows for generating 3D visualizations of the possible building massing according to the laws. Implementing Esri's CityEngine System (http://www.esri.com/software/city engine) a procedural, i.e., rule-based "3D zoning plan" was encoded (Figure 1, left image). By importing ArcGIS shapefiles of the current parcels and executing the code, the building masses and development potentials under the current rules are visualized automatically. Changing the rules in the procedural code leads to altered 3D visualizations, which are generated in real-time. The "3D zoning plan" can be extended by an urban model kit with a set of 3D building types such as single and multi-family houses, or office buildings (Figure 1, right image). This kit is useful for designing urban development scenarios on parcel level.

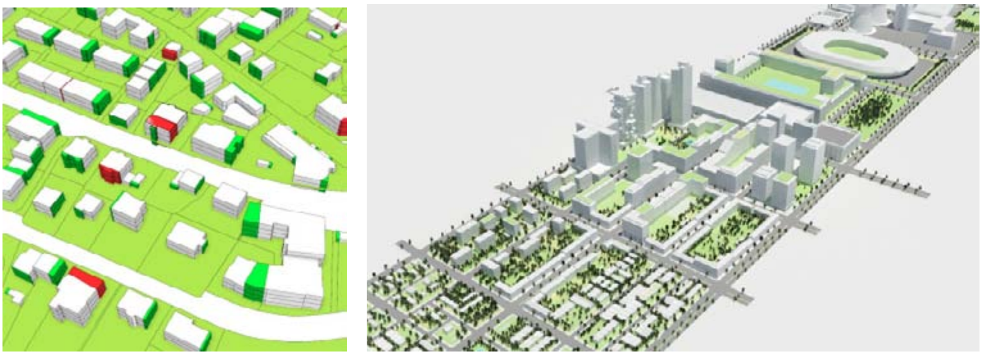

Fig. 1: Left: Procedural 3D visualization of potentials for expansion of existing building masses based on legal zoning regulations. Red building parts are already an overexploitation; green parts present under-utilization and could still be built-up. Right: 3D building examples of the urban model kit.

2.2 GIS-based multi-criteria decision analysis

Increasing the allowed density on parcel level is an effective measure to meet the goal "provision of sufficient housing space". On the contrary, other targets such as "sufficient supply of public open space for recreation" or "optimization of accessibility within the settlement area" can be adversely affected by this measure. The second tool makes these dependencies transparent. It is a multi-criteria modelling and visualization tool, which allows for weighting heterogeneous policy targets against each other consciously (NEUENSCHWANDER et al. 2014). Based on the respective weighting of targets the model calculates possible urban development patterns, which meet the set targets to an optimum (Figure 2).

Political targets are operationalized in this model in form of indicator maps and thus made available as objective factors. For example, the distance to transit axes or to city centres is given as zones with steps of 200 m around these elements. The ecological quality is indicated by the habitat potential of the area for target species. By normalizing the indicator values with a common scale, heterogeneous quality targets are made negotiable and can be defined spatially explicit. These indicator maps are calculated with generic models, which utilize existing official GIS data of the municipalities. The multi-criteria decision-making model, which was realized with the open-source software "R" (http://www.r-project.org), uses a linear goal-programming algorithm. These two factors make the model accessible for practice and transparent due to low model complexity.

The tool supports e.g., the analysis of alternative densification strategies, which are advisable for different quarters, or the impacts of several densification options. The simple and flexible handling of the tool enables importing different zoning plans and immediate provisioning of the results. Quality targets can be modified according to the specific planning questions. However, this can make adaptation of the indicator models necessary.

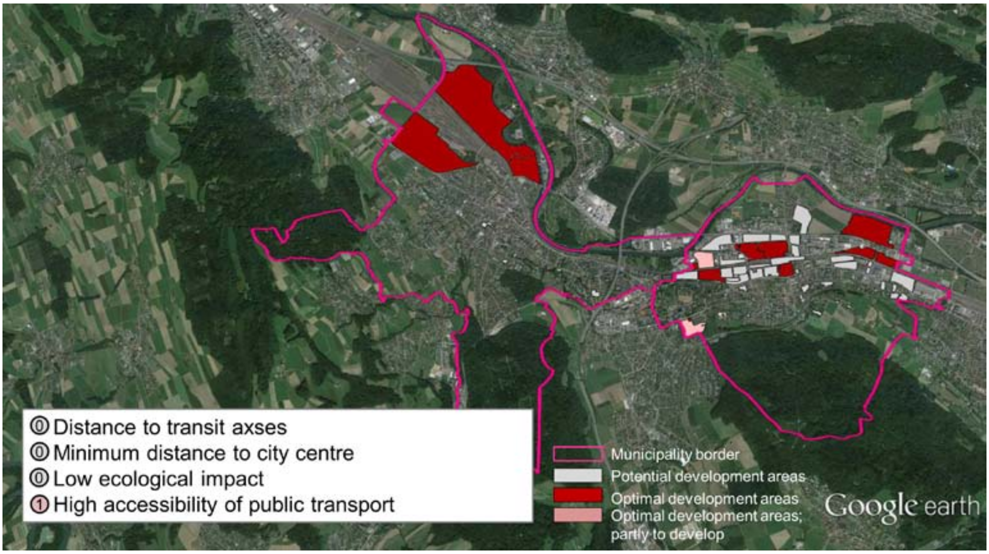

Fig. 2: Optimal development areas resulting from the prioritization of high accessibility of public transport over all other quality targets.

2.3 Integrated land use and transportation model

The third tool supports an approach that allows for cross-scale analysis of urban development scenarios addressing economic, social and environmental aspects of urban quality. It provides practical interfaces for implementing an integrated behavioural and transport modelling system (EFTHYMIOU et al. 2013) in transdisciplinary planning processes facilitating such complex spatial analyses (Figure 3).

Regional scenarios depicting alternative futures were elaborated in a collaborative process with local stakeholders from the case study region. The storylines and pictograms already provided a relevant discussion basis, which helped to look at specific development plans under different framework conditions. However, they did not show where the settlement pressure might go to in the scenarios and which impacts this might have on different urban quality aspects. Thus, the qualitative scenario storylines had to be translated to spatially explicit input data for a modelling system.

To this end, regional zoning plans adapted to each of the scenarios were prepared. This task can be conducted by stakeholders from planning departments at regional or municipality level themselves, since it is one of their core businesses. In the simulation model, location choice models are based on a utility maximization approach, where agents (= households and jobs) choose from a sample of available alternatives (buildings or locations) and select the one that provides maximum utility with regard to its attributes (accessibility, view, exposure, price, etc.). Altering framework conditions at a certain time (e.g., through densification policies or the implementation of a new metro line) affects the agents' choices over time. The simulation results in spatially explicit data on the location and altered attributes of households, jobs and new buildings for a defined year in the future.

Based on this modelling output, indicators can be calculated, which provide evidence on possible urban patterns' potential quality supporting social equity and liveability, e.g., utility of public transport on the regional scale, dwellings per hectare on the district scale, or proportion of open space on the local scale. These results are quantitative, spatially explicit visualizations of policies' effects on the society, environment and local economy.

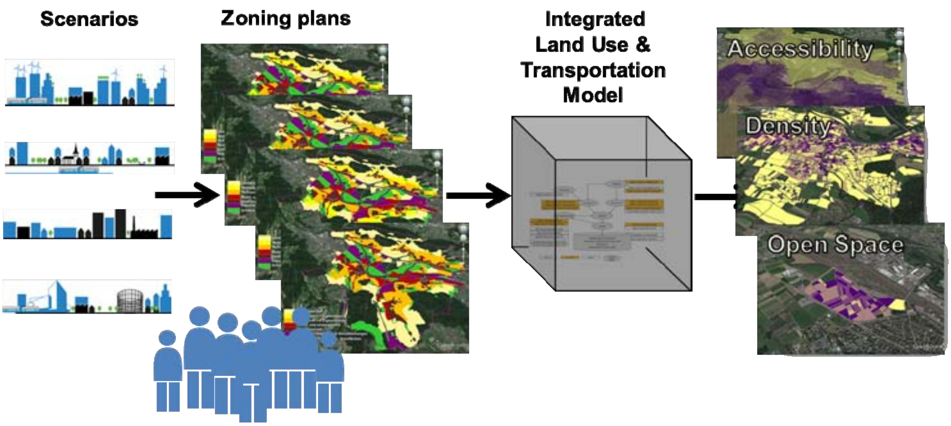

Fig. 3: Workflow for quantitative visualization of qualitative scenarios facilitating the analysis of different urban quality aspects across scale.

3 Results

The individual tools were assigned to specific planning questions emerging in collaborative planning processes of urban transformation (Figure 4). In the initial phase, the question is how the urban landscape could be changed (STEINITZ 2012). The interactive, procedural 3D zoning plan can be used to analyse the current situation in order to design first development options based on the results. Depending on the zone, different building types are suitable, which can be visualized with the 3D urban model kit. The scope within the existing planning rules can be explored, and, by altering the rules in the 3D zoning plan, new rules can be tested. Since not all demands can be fulfilled at all locations due to conflicting targets, the multi-criteria decision analysis can help to specify spatially explicit the accepted level of heterogeneous targets. When different visions or scenarios are developed, their impacts are of interest. The quantitative visualization of the scenarios with the integrated land use and transportation model supports a deeper understanding of possible urban quailties cross scale and disciplines, which might evolve from alternative zoning plan revisions. This knowledge is valuable for designing concrete measures, which again have to be iteratively analysed, adapted and evaluated.

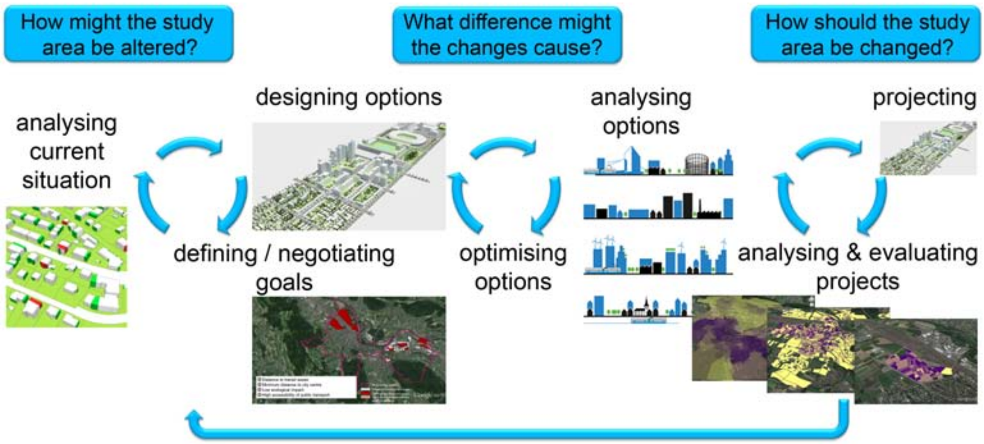

Fig. 4: Possible integration of the tools into a collaborative urban planning process

4 Conclusion and Outlook

There is wide spread consensus that progress towards more sustainable urban patterns is essential for reducing the future resource demands of agglomerations. The demonstrated approach can foster the understanding of complex interactions of different factors across scale. This understanding is required for designing sustainable urban patterns, which provide a long-term sound relationship of the infrastructure, the built, and the un-built environment. With the presented tools and interfaces an effective transdisciplinary collaboration of science and practice is possible. In such collaborative processes supported by scenarios and their in-depth analysis, knowledge from science, practice, and design can be integrated in a way, that we understand how urban landscapes, which we create, work and how they can work better in order to provide high urban quality. Overall, the presented approach has high potential to organize a future oriented mutual sustainability learning and capacity building among stakeholders, planning experts, and scientists.

The whole tool set is required for facilitating the collaboration process effectively. Thereby, the entire process is not a linear course but an iterative progression. The instruments give multi-dimensional qualified inputs for development studies of municipalities and regions: they suit for problem specification and target definition as well as for illustrating the complexity of consequences of certain demands. The targets can also provide a basis for creative design and concept development, which can then be compared with regard to their meaning in the bigger, regional context. The developed tools can provide professional guidance for specific questions and tasks. However, the limits and their specific strengths and weaknesses have to be made aware. In particular, the instruments do not provide urban design solutions off-the-shelf. How the urban patterns should finally look like must be developed collaboratively. Implementing the tools in these processes can facilitate a change of different stakeholder groups' perspectives. In so doing, mutual concepts of urban quality and respective urban patterns can arise, which might not evolve in other manner.

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