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Visualization of Vibrant Cities and Regions – Identification, Design and Development of 3D-GIS Applications and Modules

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1 ABSTRACT

Facing a continuous state of transition and herewith connected financial, societal and ecological challenges such as the climate or demographic change (United Nations 2013), cities try to integrate innovative information and communication technologies in order to optimize administrative processes, legitimize decision making and to involve all relevant local actors into processes of public relevance. In this context 3D-GIS-models offer various not yet exploited potentials for all named levels of interest. This paper presents an overview over existing application fields for 3D-GIS-solutions, further proposing a categorization in order to be able to develop and implement target-oriented solutions.

Moreover, this paper presents the project activities of the Fraunhofer IAO, the city of Cologne and the provider of geo-information-services ESRI, designing and developing end-user oriented applications for the 3D-GIS-tool CityEngine. Therefore various city departments such as the agencies for city planning, traffic and environment were involved in an iterative process in order to identify potential application fields and their benefits within the administrative work as well as their andvantages regarding existing solutions and processes. Aditionally, the particpants decided upon a set of focus applications to be developed within the project.

Therefore, this document will concentrate on the potential benefits of the identified and cooperatively designed application fields, further outlining the first steps of the deleopment phase of the citizen particpiation application.

2 INTRODUCTION

Today, cities are in a continuous state of transition, adapting to financial, societal and ecological changes such as climate or demographic change. Understanding the resulting need for adaption as a chance for a city development towards more sustainability and resilience, most modern cities try to introduce innovative tools and methods to include and address as much relevant actors as possible into planning processes. In that context, 3D-City-models have been identified as a promising technology to build a common understanding between all kinds of actors regarding various thematic fields. Moreover, these models include fully operational GIS functionalities nowadays, opening up even more possible areas of application for public management, decision support as well as citizen participation. Unfortunately, besides pure visualization benefits and usages most of the imaginable application fields are merely ideas or at an experimental status.

Therefore, this paper analyses existing application fields of 3D-City-models and presents an research approach which aims to identify and develop user oriented application fields for this technology. Therefore, the paper is based on an ongoing project of the German research institute Fraunhofer IAO, ESRI Germany and the City of Cologne. Within the framework project City of the Future phase 2, which tries to implement innovative and sustainable projects for city development, this subproject aims to develop modules for the ESRI 3D-City-Engine by identifying use cases with various departments of the Cologne city administration as for example the agencies for city, traffic and environmental planning.

Methodically this paper first outlines the state of the art regarding the benefits of 3D-City-GIS models (chapter 3) as well as existing application fields and research projects addressing the use of 3D-City-models (chapter 4). On this basis, a categorisation of application fields will be proposed in order to be able to design solutions that fit to the end-users needs as good as possible (chapter 4). Subsequently, chapter five addresses the project activities performed by ESRI, the City of Cologne and the Fraunhofer IAO within the Morgenstadt: City insights project. Herein the procedure as well as the results of an iterative design process will be outlined which aims to develop user oriented application fields of 3D-City-GIS-models in close cooperation of end-users, developers and research. The paper concentrates onthe development of solutions adressing specific gaps within the administrative work and will therefore outline specific benefits and

requirements regarding this application fields. Finally, chapter 6 summarizes the papers key insights and draws a first outlook on a possible participation tool for planning processes.

3 POTENTIAL BENEFITS OF 3D-CITY-GIS-MODELS

There are enormous challenges for sustaining city infrastructures, due to financial, societal and ecological changes, nowadays. In the recent scientific discussion 3D-City-modelsare reflected as an effective medium to sustain urban planning, especially, when multidisciplinary experts have to collaborate with the general public and municipal actors in infrastructure projects. Hence, a 3D-City-model should profitably be utilized in urban planning, cartography, architecture and environmental planning (Gröger, Plümer 2009).

3D-City-models can be defined as digital models that "represent spatial and geo-referenced urban data by means of 3D-geovirtual-environments that basically include terrain models, building models, vegetation models as well as models of roads and transportation systems. In general, these models serve to present, explore, analyse and manage urban data. As a characteristic element, virtual 3D-City-models allow for visually integrating heterogeneous geoinformation within a single framework and, therefore, create and manage complex urban information spaces (Döllner, Baumann, Buchholz 2006)."

There are different 3D-City-models and 3D-applications that already exist, reaching from prototypes to commercial solutions. In the last years growing efforts were put into the creation of 3D-City-GIS solutions. A 3D-City-GIS is an information management system that is suitable for geospatial and non-geospatial data. According to Fredericque and Lapierre, it is a collection of functionalities that allow for the effective management of data, users and processes related to the city infrastructure by enabling comprehensive and transparent visualisation and navigation. Based on a underlying 3D-City-model it is suitable for the management and geocoordination of information on infrastructure and provides an overview as well as detailed information on existing urban infrastructures. It therefore offers a framework for monitoring and analysing the whole information lifecycle. The main functionalities of a 3D-City-GIS can be characterized as follows (Fredericque, Lapierre 2010):

- "3D modeling and quality control,
- Persist, manage and serve,
- 3D analysis and design."

3D-representations in general and a 3D-City-GIS in particular can increase the value of data, support decision making processes, provide up-to-date information to various stakeholders and enhance an effective communication in complex situations. Providing a simple visualization of future projects and making a more in-depth analysis of existing infrastructures possible, these systems can help to generate a more realistic view of the urban area (Moser, Albrecht, Kosar 2010).

Recently, 3D-City-modelling is becoming more popular in urban planning analysis, noise propagation simulations and flood simulations. But still it is relatively new compared to the 2D-GIS-paradigm. The promising progress of 3D-technologies in the last years has shed light on the main contributions 3D-City-models can make to urban planning, including the validation and evaluation of competing proposals for urban planning projects and the visualization of planned buildings as well as urban areas (Bahu et al. 2014).

Accordingly, the following central benefits of 3D-models – compared to 2D-models – could be highlighted in urban planning processes:

- near-reality visualization on different levels of detail (LOD),
- experience driven and interactive visualization,
- simple navigation in urban areas,
- aggregation of different data sets,
- generation of a common understanding.

Despite these advantages, special challenges like different scales and the necessity to fuse data streams according to different GIS standards need to be faced too.

It can be assumed that visualization is the key factor for a comprehensible presentation of spatial projects. A 3D-visualization can enhance an experience-driven and interactive reflection of projects and accordingly

generate a common understanding. In this context, collaborative 3D-City-GIS can support the involvement of citizens as well as the collaboration of urban planners and citizens in spatial decision making processes. Recently participation possibilities on the internet become more and more relevant. Web participation that can be for example supported through Web-GIS applications allows for intuitive and more accessible citizen participation. At the same time it supports the dynamic interaction of decision makers and the general public offering the opportunity to review planned projects and make comments directly (Bugs et al. 2010).

Overall, it seems that collaborative 3D-City-GIS and Web-GIS-visualization technologies that enhance synchronous and asynchronous communication between all stakeholders can foster a more effective citizen participation in urban planning and especially decision making processes (Klimke, Döllner 2010).Therefore, the project presented in this paper aimedat theidentification of application fields of the 3D-City-GIS-tool CityEngine, mainly trying to strenghten the potential benefits for the end-users (municipal employees) as well as the final target group of citizens (compare chapter 5).

4 ANALYSIS AND CATEGORISATION OF EXISTING APLLICATION FIELDS

These described benefits have partially found their way into first applications developed by private as well as public research projects. Since most of them are not widespread throughout the potential base of end-users it is necessary to provide an overview on these solutions, further offering a categorization approach for the identified solutions.

In the context of the research activities the following general areas of application were identified:

- Energy: Simulation and visualization in 3D-models can be used to evaluate buildings with regard to energy consumption. They enable planners and decision makers to forecast and assess the efficiency of measures.
- Environment: Different environmental media – noise emissions, pollutant emissions etc. – influence the urban climate. 3D-models can support a comprehensible visualisation and simulation of impacts of the above mentioned environmental media.
- Mobility: Traffic is producing noise and pollutant emissions. Therefore, integrated traffic and transport planning and management gain in importance. 3D-models allow for visualizing and simulating traffic, air and emission flows. Accordingly, they can contribute to reduce negative impacts of traffic on the environment and the urban climate.
- Crisis Management: Countries throughout Europe are more frequently subject to a wide range of emergencies, such as forest fires, accidents with hazardous substances or extreme weather events. 3D-visualizations and simulations can support crisis management actors in the preparation of special crisis plans as well as response or reconstruction activities.
- Other Applications: 3D-models gain in importance in various other fields, like facility management and building planning, also.

All identified applications fields were assigned to one of these areas, helping end-users in identifying relevant approaches for their area of expertise. The following table 1 provides an overview over the application fields of 3D-GIS-tools, structured on the basis of the respective application areas.

Application field	Description
Energy	
Energy demand estimation	Energy and heat demands can be presented in 3D-City solutions. Furthermore, they support the calculation of actual and future heat demands and needs for different housing units. In this context an examination of restructuring requirements and potential savings is possible.
Solar potential analysis	With the support of a 3D-model, taking into account complex building geometries and building orientation potentials of solar thermal energy can be assessed. This allows for the evaluation of potential savings on one hand side. On the other hand, requirements for restructuring could be forecasted. In addition to the analysis of solar thermal potentials, 3D-modelscan support the evaluation of the suitability of buildings for the installation of photovoltaic systems.
Geothermic potentials	3D-models support the identification of available geothermal heat sources. The results of their visualization and simulation can be used for the evaluation of requirements of

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	reconstruction projects and the estimation of the energy balance of buildings.
Grid implementation	3D-models promote an integrated planning and analysis of grids allowing for a detailed visualization of network and building plans as well as semantic relations on different floors and levels (infrastructure, buildings, administrative districts etc.).
Environment	
Urban climate analysis	Climatological factors play a major role in development planning and urban planning in general. 3D-models enable planners to evaluate the impact of construction projects on the urban climate. Hence, they can support decision makers with the planning of construction projects.
Emissions evaluation	3D-models allow for the simulation and presentation of CO2 emissions and noise pollution on different levels and floors. They support the visualisation of load values for specific areas and buildings in different colours also.
Mobility	
Terrain model	With the support of 3D-models it is possible to visualize and simulate traffic flows with reference to terrain models. This enables planners to create route suggestions with efficient consumption profiles. The data that is gathered in the 3D-model can be integrated in modern driver assistance systems and support the refinement of route suggestions as well as intelligent interconnections of traffic flows.
Crisis management	
Flooding protection potentials	3D-City-models allow for a forecast of impacts of floods on cities and districts. Furthermore, predicted water levels with reference to the terrain model as well as flooded areas and water flow rates can be visualized and simulated. Simulation and visualization of flooding in a 3D-City-model supports flood warnings given by authorities, citizens' information and disaster management training also.
Earthquake damage evaluation	The evaluation of damages caused by earthquakes requires not only seismic terrain models, but also detailed simulations of impacts of earthquakes on buildings and the closer surroundings. Based on regional risk classifications it is possible to identify potential risks and calculate damages within 3D-solutions. Furthermore, restructuring requirements become obvious.
Gas incidents risk assessment	Dynamic 3D-presentations can predict the impacts of gas incidents. The real-time simulations of the diffusion of gases can be further used to identify requirements for safety technologies, to develop special preparedness plans and to support emergency planning.
Other applications	
Parametric design	3D-solutions can support automated planning taking into account framework conditions, like floor spaces, and special algorithms. They enable planners and decision makers to compare alternative proposals as well as the impact of general planning parameters directly.
Open space identification	In 3D-solutions it is possible to visualize open space in different urban areas and quarters. Accordingly, open spaces for cycle paths or parking space can be identified. The simple visualization of open spaces can in turn support integrated mobility concepts.
Facility management	Building Information Modelling which is focussing on the optimisation of processes in the planning phase of the building, building construction and facility management can be supported by 3D-solutions that provide a common data base for all involved parties. On this basis information sharing and data preparation can be simplified and optimized both.

Table 1: Existing application fields of 3D-GIS

Based on this initial research on existing applications, which are already on the market or in use, a first categorization was developed, dividing two main perspectives on such applications with diverse subcategories. While category A is technical oriented, category B differs the application fields on the basis of objectives and respective target groups as well as user orientation. The following figure 1 provides a first overview of this categorization.

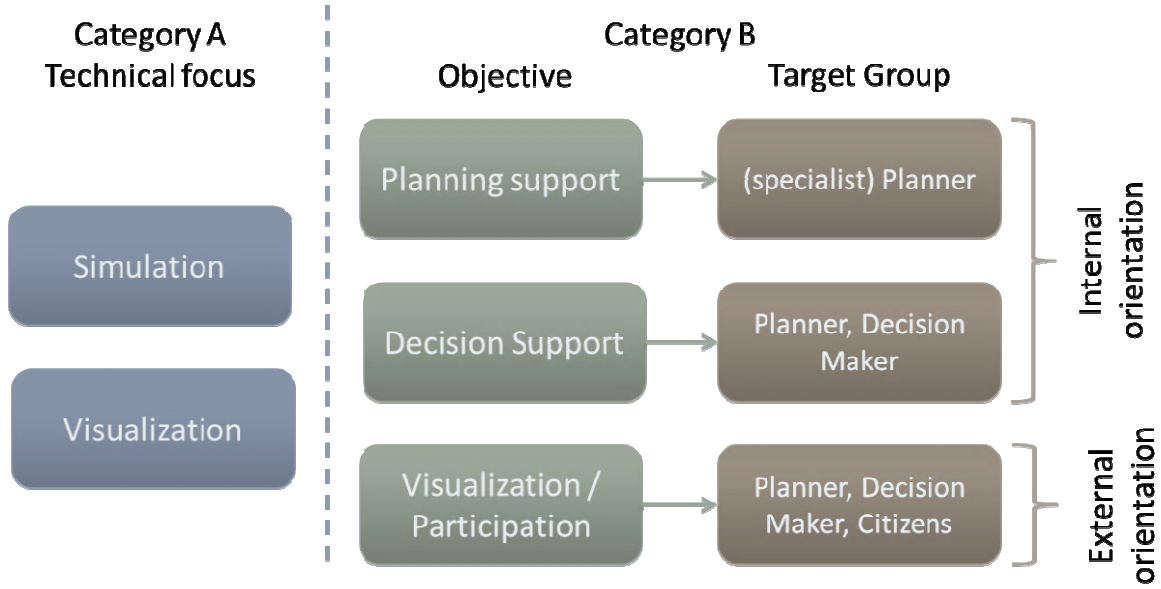

Figure 1: Categorization of application fields of 3D-GIS

The clear distinction and classification of category B is not applicable to the technical category A, since both simulation-tools as well as strict visualization-tools are usable for all target groups and objectives. For instance, a 3D-visualization of planning alternatives can contribute to the formation of opinions within the group of decision makers as well as within the population. On the other side simulations processes are able to support the decision process as well as the planning process.

The sub-categories within category B were defined due to the highly diverse orientation of the identified solutions presented in table 1. The existing specialised and mostly isolated applications of 3D-GIS-tools strongly differ withregard to their main objective, the targeted user group and their internal or external orientation. In particular the necessary level of detail declines from applications supporting planning processes over decision support processes to participation processes according to the background knowledge of the respective user groups. The basic orientation of the applications is also connected to the level of detail presented. While highly condensed information is reserved for internal use, end-users outside the administrative body get access to simplified information, aligned to the limited know-how to be expected.

Finally, in order to be able to design applications that match with the demands, requirements and aims of each target group as good as possible, the sub-categories were defined, helping to focus development and implementation processes on requirements for each sub group.

The following chapter 5 will describe the project activities of ESRI, the Cityof Cologne and the Fraunhofer IAO, developing applications for the 3D-GIS City-Engine referring to the outlined categorization approach and respective requirements and needs identified within the process.

5 THE MORGENSTADT: CITY INSIGHTS PROJECT ACTIVITIES - DEVELOPMENTS OF 3D-GIS APPLICATION FIELDS

The 3D-GIS application field project is part of an interdisciplinary long-term research project called “Morgenstadt: City Insights” (m:ci) initiated by the Fraunhofer Institute and conducted within an network of industry and city partners. In its first phase, the project analysed innovative and sustainable solutions and projects of the city sectors mobility, water infrastructure, production and logistics, governance, buildings, energy, security and ICT in six leading cities around the world in order to identify common characteristics, structures of success stories and key action fields for sustainable city development (Wendt et al. 2014). On the knowledge basis of phase I (2012-2013), the second phase (started in 2014) focusses on the development and implementation of innovative solutions in order to support cities in achieving a sustainable and resilient future. Within this context the City of Cologne, the provider of geo-information-services ESRI and the Fraunhofer IAO initiated a project in order develop application fields for the 3D-GIS-tool City-Engine.

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The project concentrated on the city district Köln Mühlheim-Süd which is currently in a state of transition. The transformation of the district was already initiated, proclaiming a planning competition and receiving a set of structural concepts. Based on the winning proposal the project partner ESRI implemented a 3D-model within the CityEngine as well as a model of the current situation. Therefore, all participants were able to discuss and develop ideas for possible applications of a 3D-GIS-tool on a common basis.

5.1 Project procedure& general application fields

From the very beginning of the project it was intended to develop applications in constant cooperation between all partners in order to be able to meet all demands and requirements of the aimed target groups. In respect to the categorization, outlined in figure 1, solutions can have different target groups, as for example participation applications mainly target citizens, collecting their opinions on planned projects. Nevertheless, is the planning department another central target group of such an application, offering a tool to interact with the population and all other concerned actors. Therefore a three step process was conducted leading to a defined set of first applications to be developed in a first development process phase:

I. Identification of relevant application fields for the Cityof Cologne,

II. Specification of a first set of possible applications,

III. Prioritization of application fields.

Within the first step workshops were organized in order to detect potential application fields of use for various departments of the Cityof Cologne such as the transport, environment or city planning department. As a result of this first set of workshops eight potential application fields were identified.

(1) Flooding Simulation, including visualization and simulation of high water levels and backwater for crisis management activities as well as population training.

(2) Energy demand estimation tool in order to simulate energy demands of planning alternatives on the basis of active and passive parameters such as solar radiation, construction arrangements or applied building materials.

(3) 3D-visualization and analysis of unused urban spaces in order identify spaces of potential use (e.g. for ecological projects, food or bike paths etc.)

(4) Visualization of noise emissions on the detail level of house floors as well as balancing of planning alternatives on the same level.

(5) City climate simulation to assess the potential impact of planned projects on the cities climate, including comparing functionalities for planning alternatives.

(6) Comparing visualization of the traffic situation (real situation as well as scenarios) for various uses, such as the optimization of energy consumption or the evaluation of different usage scenarios.

(7) Traffic emission simulation of different planning alternatives as well as integration of such information into traffic management systems.

(8) Planning of traffic infrastructure on the basis of a 3D-GIS-tool, helping to control relevant sight axis respecting all road users.

In the second step, these first ideas of the city employees were also categorized and iteratively refined, starting with the named overall themes and developing specific modules for respective target groups. The following table 2 presents the output of this step.

Objective & Target Group	Benefit of 3D-GIS
Flooding simulation	
Planning support for (specialist) planners	Simulations for water back-up or back-pressing during floods for crisis management experts.
Decision support for decision makers and planners	Visualization of water flows and levels in order to support decisions regarding: • The implementation of risk reduction infrastructure, • Planning proposal alternatives within threatened areas.
Visualization and participation	Visualization of water flows and levels during floods in order raise

Objective & Target Group	Benefit of 3D-GIS
functionalities for all involved local actors	awareness within the population.
Energydemandestimationtool	
Planning support for (specialist) planners	Definition of specifications in land-use or development plans based on simulations of expected energy demands (e.g. regarding building orientation or structure).
Decision support for decision makers and planners	Visualization of demands of alternative planning proposals
Visualization and participation functionalities for all involved local actors	Visualization of before-after comparison for participation processes.
3D-visualisation andanalysisofunused urban spaces	
Planning support for (specialist) planners	None - specialist planners can accomplish this task sufficiently with 2D-solutions (workshop result/statement).
Decision support for decision makers and planners	Visualization of alternative locations for different purposes in order to support location decisions.
Visualization and participation functionalities for all involved local actors	Visualization for participation processes in the context of location decisions.
Visualizationofnoiseemissions	
Planning support for (specialist) planners	Simulation and visualization of emmissions up to house floor levels. At the moment 2D-solutions are required by law and 3D-visualisations are elaborated afterwards with extra tools. A 3D-GIS-apllication could cover all needs.
Decision support for decision makers and planners	Visualizionof alternative planning proposals
Visualization and participation functionalities for all involved local actors	Visualization for participation processes in the context if alternative planning proposals and sensitization of the population.
City climatesimulation	
Planning support for (specialist) planners	Definition of specifications in land-use or development plans based on impact simulations of different building settings.
Decision support for decision makers and planners	Visualizion of alternative planning proposals.
Visualization and participation functionalities for all involved local actors	Visualization for participation processes in the context if alternative planning proposals.
Visualizationofthetrafficsituation	
Planning support for (specialist) planners	Simulations in order to support urban traffic planning.
Decision support for decision makers and planners	Visualizion of alternative planning proposals.
Visualization and participation functionalities for all involved local actors	Visualization for participation processes and utilization of simulation data for: • Traffic guidance systems, • Local traffic calendar (providing information on critical traffic situations as well as alternative routes).
Traffic emissionsimulation	
Planning support for (specialist) planners	Simulations in order to support street environment design
Decision support for decision makers and planners	Visualizion of alternative planning proposals.

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Objective & Target Group	Benefit of 3D-GIS
Visualization and participation functionalities for all involved local actors	Visualization for participation processes in the context if alternative planning proposals and sensitization of the population.
Planningoftrafficinfrastructure	
Planning support for (specialist) planners	Visualization of sight axis for the planning of traffic infrastructures, street display and advertisement installations.
Decision support for decision makers and planners	None
Visualization and participation functionalities for all involved local actors	None

Table 2: Identifiedapplicationfieldsandtargetorientedbenefits

On this basis further workshops were organized in order to synchronize the identified first set of application fields and requirements with the thematic experts in each field.Within this process certain potential application fields have been identified as not necessarily urgent due to already existing sufficient 2D-solutions, while others were ruled out because of non-existent but required data sets. On the other side, various applications have been identified as realizable and therefore specified in more detail.

This phase provided two main outcomesthat are relevant for the next project phases:

I. Expert modules are not feasible at the moment due to a lack of available information and existing national regulations, demanding for certain output standards not anticipating 3D-solutions.

II. The first set of applications should focus on the assistance of processes of the planning department, including supporting information of the other involved departments, since the majority of the applications of the other departments is targeting participation and decision making processes to be prepared and organized by the city planning department.

The key outcomes referring to the benefits to be expected by a citzen participation apllication will be outlined in chapter 5.2.

The third and last step aimed at prioritizing the remaining applications and developing a strategy for the implementation process. Therefore, a further workshop with the planning department was organized, cooperatively developing solutions tackling the different levels of category B. As a main output of this workshop it was decided to perform the development process bottom-up, starting with the level of citizen participation, followed by decision support applications and concluding in solutions supporting the planning-design phase.

This specific order was a result of two main considerations:

- The quality of the required input data increases with each level. Sufficient data is only for the level of citizen participation already available. The determination of additional information for the other two levels will take more time and could require new survey/ data exchange methods or techniques. During the implementation phase of level 1, additional research on such methods can be executed.
- The solutions of the two upper levels of planning and decision support will strongly benefit from a well implemented participation level, profiting from the technical basic infrastructure, an already experienced group of actors and colleagues and a set of lessons learned.

In summary, by addressing the participation processes of level 1 the project first targets the low-hanging fruits, building the fundament for more detailed steps at the same time.

5.2 Participatory planning processes

Respecting these results, the analysis of needs within participatory planning processes was intensified within the project phase, specifically searching for open questions the planning department liked to address with the help of a 3D-GIS-Particpation tool. In that context, a further workshop revealed the following basic needs of the planning department on such a tool:

- Easy understandable visualization of planning proposals, also in comparison to the existing situation.

- Inclusion of environment information (e.g. traffic volume, noise emissions or lightning) in order to allow a realistic assessment of the situation by the key audience.
- Obtainment of geo-referenced suggestions and objections directly within the tool in order to optimize participation processes.
- Usability and maintenance of the 3D-GIS-model should not exceed efforts of usual 2D-GIS-applications. Further, the 3D-GIS-model should allow easy adaptions and changes between iterative participation workshops within a short period of time.
- Compatibility to existing visualization and analysis tools as well as to data interfaces should be well established (e.g. existing 3D-traffic-simulation for specific road sections). This would not only simplify specific implementation steps of phase 1, rather these data sets could support the development process of the participation and planning tools of the next phases as well.
- Further, the citizen perspective on requirements for such a tool was analysed, building on the experience of the involved experts and a comprehensive analysis of already performed participation processes:
- Adaptable level of abstraction is necessary, since the model to be used in the participation process needs to be understandable, but should not give the impression of an already finished planning result. Citizens are very sceptical regarding their influence on highly detailed models. Therefore the model needs to suggest a certain level of incompleteness.
- Freely scalable visualization (zooming functionality) is necessary due to the need of citizens to check the impact of planning proposals on the personal situation.
- The visualization needs to provide a pedestrians perspective, since citizens mostly see and understand urban spaces from this perspective. Therefore, a great number of specific questions often raised by citizens can be examined herewith, including topic areas such as barrier liberty or the design of public space or the street environment.

Based on this two sets of requirements, it is possible to develop a first version of a CityEngine participation-tool which benefits the city administration as well as the citizens. This tool is currently in development, providing a before/after comparison of the planning area with sliders and direct interaction functionalities for citizens (e.g. comments, zooming etc.). Since the project is still ongoing, further planned steps will be outlined in the following chapter, basing this foresight on a summary and lessons learned from already completed project steps.

6 CONCLUSION& OUTLOOK

Nowadays, the enormous challenges for sustaining city infrastructures have increased the need for new Information and Communication Technologies on the one and collaboration processes in urban planning and development on the other hand. In this context 3D-City-models have become more popular in the recent years. The transition from 2D- to 3D-models can help to increase the value of data, improve decision making processes and capabilities, simplify the access to relevant information and enhance a more effective communication between different stakeholders in complex situations.

Since decision making in urban planning is always a multi-stage process, collaboration among urban planners, decision makers and citizens is strongly required. In this paper it was outlined that high benefits can be expected of 3D-solutions especially with regard to citizens' participation. 3D-City-GIS provides a more intuitive and accessible medium for citizen participation allowing for near-reality as well as experience driven and interactive visualisation. This comprehensible visualisation is the key factor for collaborative and group-based decisionmaking processes.

Recently, 3D-GIS participation possibilities in the Internet have been identified as promising means to foster effective and efficient collaboration in urban planning in general and citizen participation in particular(Bugs et al. 2010). These technologies are meant to ease the understanding of complex urban planning projects for non-professional participants and offer a low participation barrier. A Web-based GIS can create a virtual meeting space, where citizens can explore different plans and comment on them. This allows for

synchronous and asynchronous communication both. The realisation of such a collaborative 3D-City-GIS approach is able to support citizen participation in multi-stakeholder decision making processes.

Despite all benefits of 3D-City-models, the implementation of 3D-City-GIS-systems in organisations and especially public administrations cannot be seen as a simple process, because of the various organisational aspects that have to be considered. Furthermore, the integration of 3D-City-GIS-systems requires a broad acceptance of the involved organisations and public administrations. Accordingly, the implementation is always an evolutionary process, which has to be critically accompanied by the scientific community, developers and the end-user organisations.

On the basis of the outlined application fields as well as functional and non-functional requirements elaborated above ESRI, the Cityof Cologne and the Fraunhofer IAO are developing a 3D-CityEngine participation-tool within the Morgenstadt: City insights project. This tool enables for before/after comparison of the planning area with sliders as well as direct interaction (e.g. comments, zooming etc.) with citizens. To further explore the benefits of 3D-GIS-systems in citizen participation we plan to implement the ESRI CityEngine-participation tool after its finalisation in an actual participation process. The implementation of the tool in a participation process will allow for the evaluation of the usefulness of the tool and will give hints in view of potential (modification) needs for the tool adaption. After consolidating the effectiveness and efficiency of the citizen participation tool, we intend to transfer the 3D-City-GIS-model to the decision support and planning support level also.

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