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Şehir Planlaması İçin Sanal Gerçeklik

Virtual Reality for City Planning

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Öz

Şehir planlama, her türlü planlama gibi, bu sürece dahil olanlar tarafından çok fazla hayal gücü gerektiren gerçek dışı bir şeyle ilgilidir. Bu nedenle, çoğunlukla uzun raporlar ve 2 boyutlu haritalardan oluşan planlama sonuçlarını göstermek için geleneksel araçlar yetersizdir. CBS tabanlı planlama alanındaki araştırmalar genellikle kabartma haritalar, ısı haritaları ve geleneksel 2B grafikler de dahil olmak üzere çok sayıda görselleştirme aracıyla uğraşmış olsa da, şehirlerimizin gelecekteki potansiyel durumlarını görselleştirmek için Sanal Gerçekliğin (VR) fırsatları üzerine olan araştırmalar eksik kalmıştır. Bu tür simülasyonlar, karar vericiler ve kamuoyu gibi paydaşlara "eğer" senaryolarının sonuçlarının gösterilmesini sağlayabilirler. Bu araştırmanın amacı, bir şehir bölgesinin 2B haritasından 3B modele ve son olarak uzman bilgisi olmadan kullanılabilecek bir VR ortamına büyük ölçüde otomatikleştirilmiş bir iş akışı geliştirmekti. Bu yöntem, büyük geliştirme projelerinin yerinde görselleştirilmesiyle kentsel planlamayı yeni bir seviyeye getirecektir. Bu iş akışının gelişimi ayrıntılı olarak açıklanmıştır. Mevcut yaklaşımdaki eksiklikler tartışılmakta ve gelecekteki araştırmalara yönelik talimatlar verilmektedir.

Virtual Reality for City Planning

Abstract

City planning as all kinds of planning is about something unreal requiring much imagination capabilities by those involved in this process. Therefore, the traditional means to show the results of planning consisting mainly of lengthy reports and 2D maps are insufficient. Although research in the field of GIS based planning has dealt with a big number of visualization tools including glyph maps, heat map and traditional 2D graphics, research on the opportunities of Virtual Reality (VR) for simulating potential future states of our cities is missing. Such simulations would include exhibit the results of "what-if" scenarios to stakeholders like decision-makers and the general public. The purpose of this research was to develop a largely automated workflow from a 2D map of a city block to a 3D model and finally to a VR environment that can be used without expert knowledge. This will bring urban planning to a new level by visualization of big development projects on the spot. The development of this workflow has been explained in detail. Deficiencies in the current approach are discussed and directions for future research are given.

1. INTRODUCTION

City planning as all kinds of planning is about something unreal, something about to happen in the future. How this future will look like is left to the imagination of those who are doing the planning and those who will be affected by this planning. Traditionally, the results of this planning have been laid down in the form of lengthy reports and 2D maps. For the preparation of these maps, the use of Geographic Information Systems (GIS) has become standard in developed and developing countries as well since the 90ies [1-4].

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The disadvantage of such a planning is that most people are reluctant to read through hundreds of report pages and have difficulties to read and understand 2D maps in the right way. This applies not only to the general public that thus is excluded from the planning process but also to most decision-makers as well. Not surprisingly, a world-wide poll conducted for the National Geographic Education Foundation/USA revealed that only about 20 percent of the participants could identify hotspots like Afghanistan, Iran and Iraq on a map [5].

Given these circumstances, it is no wonder that in many cases, city planning cannot be considered to be a very efficient process. The classical products of city planning are difficult to understand sometimes even for experts and resemble hieroglyphs for the layman. As KACAR [6] put it "Prepared plans are not being implemented in the way they were intended to, which forms complex and ineffective differences between the plans and their implementation."

With the penetration of GIS into academic institutions around the world, wide-spread use in local governments and virtually all vertical sectors and the availability of the first tools on the internet the foundation for the participation of the general public was led. Thus in 1996, at the meeting of United States National Center for Geographic Information and Analysis (NCGIA) the term "public participation geographic information system" (PPGIS) was contrived for the first time. With this term, a description how GIS can support public participation for various applications with the goal of inclusion and empowerment with emphasis on marginalized populations [7] has been given. This new paradigm is called participatory planning. Participation in this field can be defined as "the process of decision making and problem solving, involving individuals and groups who represent diverse interests, expertise and point of view and who act for the good of all those affected by the decisions they make and the actions that follow" [8].

In this context, Ballal described a web based Geodesign software called "GeodesignHub" that he had developed in cooperation with Carl Steinitz [9]. He mentioned the challenges of 2D and 3D visualization technologies when applied to large geographies or on regional planning problems. According to him, this is due to the uncertainty of impacts given the long time scales, multiple factors affecting the site and competitive interests and actors involved and the unsatisfactory process of creation of design, which is largely disjointed from that of analysis and visualization. In this thesis, he described an effective bridge between GIS analysis and the creativity of design into a seamless process. Using simple digital sketching and a rational design analysis process based on GIS technology a digital workflow that enables collaboration has been developed.

Since its invention in 2015, GoedesignHub has been successfully used in many planning efforts throughout the world including Turkey [10-14] where it served regional planning, urban planning and site planning at larger scales as well.

Most recent research results in neuroscience help to shed light on the question how the spatial component of man's environment can be displayed more effective. In 2014, J. O'Keefe, M.-B. Moser and E. Moser won the Nobel prize for Medicine for their research on how the brain manages to orientate itself in its environment. In one of their related researches, it was hypothesized that the brain uses to a large extent the same neuronal algorithms for navigating in the physical world as in mental space [14].

While these and other findings explain the situation and may even help to train people who require superior map skills it does not help the majority of people who despite their "spatial deficiencies" want to participate in spatially related decision-mapping. With the latter we do not only mean more daily live related questions like where to spend the next vacation or how to find a special restaurant in a city of 20 million but also, complex subjects like regional planning. Virtual Reality coupled with the relatively new planning approach of Geodesign and the visualization software CityEngine of ESRI [15] might help to spatially enable different members of the society who care about what is going on in their near and distant environment.

The use of Virtual Reality (VR) tools brings urban planning and architectural design to a new level. It allows a reality like experience of the results of planning efforts in real time. Moreover, interactive tools of VR offer even the opportunity to see the results of changes to this planning immediately. Ivan Sutherland, one of the pioneers of VR, stated already in 1965 “make that (virtual) world in the window look real, sound real, feel real, and respond realistically to the viewer’s actions” [16]. For the purpose of this paper we use the definition of VR from Schweber & Schweber [17]. “Virtual reality lets you navigate and view a world of three dimensions in real time, with six degrees of freedom.” and “In essence, virtual reality is clone of physical reality.”

For visualization of compound spatial information such as 3D city models immersive 3D virtual environments have been created. Such an immersion is directly related to user experience, which Witmer & Singer [18] described in the following way: A ‘psychological state characterized by perceiving and experiencing oneself to be enveloped by, included in, and interacting with an environment’

Engel & Döllner [19] described requirements and concepts of a system that enables the visualization of 3D city models in an environment with a high degree of immersion and its application for e-planning. According to this concept, stakeholders including citizens and policy-makers, can navigate in a virtual 3D city model and assess different scenarios for urban projects in-situ. In their study, they suggested hardware and requirements for 3D rendering that have to be met in order to achieve fully immersion. As an example, for such a system they show the Elbe Dom facility that is part of the Fraunhofer Institute (IFF) in Magdeburg, Germany. It is made up of a multiuser cylindrical projection system with 360° angle, 6.5m in height and a diameter of 16m suitable for interactive visualizations at a large scale.

Studies of Hermund & Klint [20] and Hermund et al. [21] indicated that similarities exist when the perception of architectural space how it is experienced in physical space conditions is compared with its experience in virtual reality. Based on these earlier studies, Hermund et al. [22] discussed the opportunities of representation architectural models in new ways such as using virtual reality. This was investigated in terms of neurology and perception. They identified the extent, to which architectural space can be communicated through a direct use of Building Information Models (BIM) subjectively and objectively when it is combined with Virtual Reality. By analyzing eye tracking of 60 test persons they found out that the representation of virtual reality models is less demanding than three- dimensional models shown on two-dimensional computer screens when the brain’s cognitive load is measured.

Mullins [23] compared differences in spatial perception of architectural application in a classical (physical) environment, CAVE and at Aalborg University’s ‘Panorama’ theatre, a facility of the Virtual Reality Media Lab. The results of his study showed that the perception of depth in a physical environment on the on-side and in a virtual environment like in CAVE and Panorama on the other side are quantifiably different. These differences can be attributed to previous contextual experience of the user. Especially, spatial ability seemed to be an important contributing factor. These results indicated significantly better overall accuracy of response in the CAVE than in the Panorama VR environment, which was attributed to the relatively higher degree of immersion and movement possible in the first VR environment.

Although research in the field of GIS based planning has dealt with a big number of visualization tools including glyph maps, heat map and traditional 2D graphics, research on the opportunities of Virtual Reality (VR) for simulating potential future states of our cities is missing. Such simulations would include exhibit the results of “what-if” scenarios to stakeholders like decision-makers and the general public [24].

Kersten et. al. [25] described a complete VR workflow covering the steps of data recording, 3D modeling, texture generation, implementation in a game engine and visualization by means of VR systems. Their research dealt mainly with the generation of 3D models for cultural heritage objects like the Selimiye mosque in Turkey and Solomon's temple in Israel. They presented a workflow that results in the creation of models featuring a high degree of precision. Şenol et al. [26] set up a workflow consisting of the usage of GeodesignHub, CityEngine and Unity software to create future scenarios for a district of Şanlıurfa/Turkey and display it in a VR environment.

The purpose of this research was to develop a largely automated workflow for planning of a city block from a 2D map to a 3D model and finally to a VR environment that can be used without expert knowledge. This will bring urban planning to a new level by visualizing the design of big development projects and how they might impact their environment on the spot.

2. METHODOLOGY

To use software like GeodesignHub, ESRI's City Engine and Unity for planning purposes, a high level of software knowledge and a considerable amount of time is required. In order to overcome these drawbacks a custom-made solution based on the API provided by GeodesignHub was developed. By means of a user-friendly graphical user interface (GUI) a largely automatic workflow has been created from Geodesignhub to City Engine and Unity3D, which facilitates the selection of parameters and the flow of information from one system to the other.

The workflow consists of these three steps: 1) In GeodesignHub, the user has to select a system (like agriculture or low-density housing). Then, he selects a username and a new development project in form of a polygon. For this project, he must define several parameters like the type of neighborhood and average amount of floors. 2) The selected polygon is automatically transferred to CityEngine where it is modeled according to the selected parameters. 3) In the last step, the user can easily transfer the modeled project to the Unity game engine. It is automatically applied to the virtual reality environment in Unity. By using VR glasses or other VR means, the user can experience the planned development project as it was real.

Prior to passing through the workflow as described in more detail below, a GIS database using ArcGIS and QGIS had been created and works started on building evaluation models. These models basically consisted of suitability maps created by means of multi-criteria analysis (MCA) within the GIS. The MCA was implemented according to rules described in MS Excel sheets, which reflect the views of subject-matter experts. Such a sheet for the system "Mixed Use" is shown in figure 1. This system is characterized by new settlements with apartment houses exceeding 5 stores, retail stores and small workshops. Criteria were related to land cover classes and conservation types.

Mixed Use (High Density Housing + Services)				MIXED
System 8			Contact / Expert Name	
Description of Evaluation: New settments with houses exceeding 5 stors including small retails tores and workshops. Criteria: Land cover class, conservation types.				
Feasable	Suitable	Capable	Not Appropriate	Existing
land cover class = 'field' OR 'steppe', conservation type = none	land cover class = 'new almond' OR 'new olive' OR 'new pistachio' OR 'pomegranate', conservation type = none	land cover class = 'old almond' OR 'old olive' OR 'vineyard', conservation type = none	land cover class = 'garden' OR 'quarry' OR 'reforestation area' OR 'wasteland' OR 'landscaping' OR 'roads', conservation type = 'archeologic' OR 'flora' OR 'geologic'	land cover class = 'hospital' OR 'housing' OR 'other building' OR 'teaching facilities'

Figure 1*. Criteria and evaluation classes for the system "Mixed Use".*

The Geodesign project was set up for 10 different systems: Green Infrastructure (biodiversity and conservation), Water Infrastructure, Grey Infrastructure (transportation, communication), Energy (production, distribution), Agriculture, Industry Infrastructure (e.g. manufacturing, distribution commerce, mining, etc.), Housing (Lower Density), Mixed Use (High Density Housing + Services), Institutional (schools, hospitals) and Archelogy/Tourism (figure 2). Due to time constraints, in this research the whole workflow was implemented for the system named "Mixed Use" only. The evaluation maps were imported into GeodesignHub (GDH), an online decision support system. In any case, these preparation works had to be carried out by experienced users of GIS in cooperation with subject-matter experts.

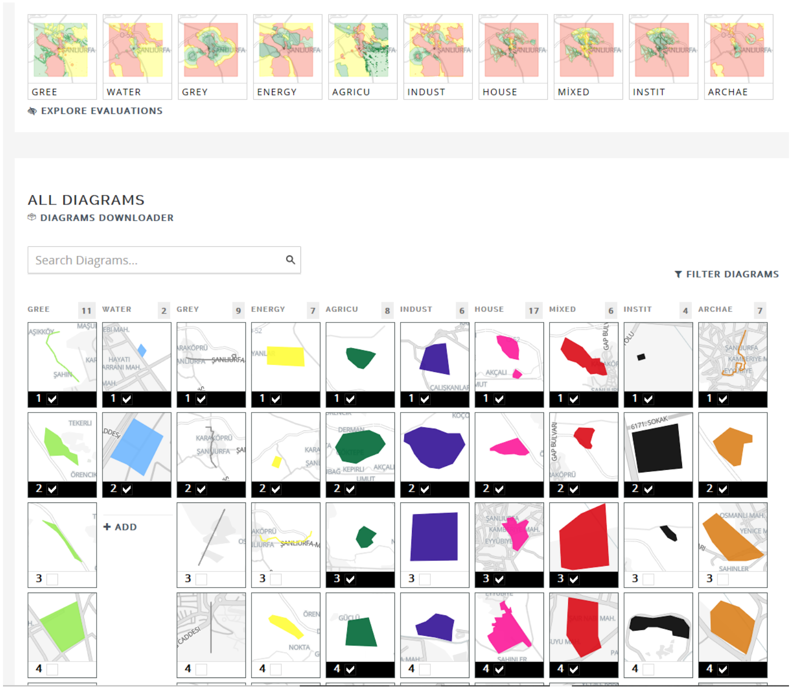

Figure 2. *Part of the GUI of GeodesignHub with evaluation maps for all 10 systems displayed at the top and several projects ideas for each of these systems in the bottom.*

After these preliminary works had been finished the first step of the workflow could start. The evaluation maps served as a background, on which the area of new projects within the system "Mixed Use" could be drawn using the user-friendly tools of GDH (dark red polygon in figure 3). Then, the impact of such new projects like construction of new apartment buildings. could be investigated not only on its own system (mixed use) but, also on any of the 9 other systems e.g. green infrastructure. Using this instant feedback, suggested projects could be edited using 2D maps until an optimal solution had been found. All the details of this step using GDH will not be explained further here. They can be found in Rivero et al. [27].

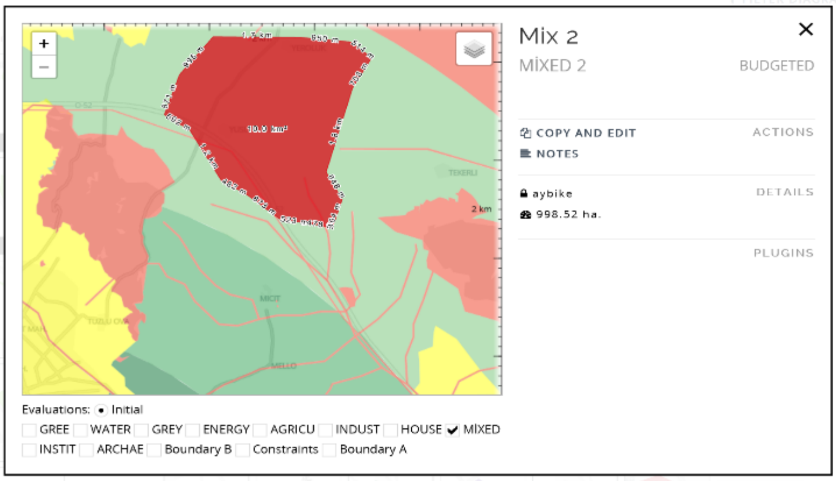

Figure 3. *2D map showing a newly drawn project against the background of an evaluation map.*

During the second step, one selected project had to be imported into CityEngine where its 3D model was created. While this could have be done manually, we programmed it in a way that the user had only to select a certain project and define its characteristics. Then, the respective geometric data together with its attribute data were transferred into CityEngine and the 3D modeling process automatically initiated.

To implement this step, the API offered by GDH was used. For this, more information can be found under the following link: https://www.geodesignhub.com/api/ Using Python's "Spyder" module, a simple user interface was created that included options to select the three following parameters: a) Prevailing house type (villa, townhouse, high-rise apartment building, retail/apartment building, workshop), b) Number of floors (1-2, 3-5, 6-10, 11-20, >20), and c) District type (housing only, housing with schools and parks, mixed use, commercial, institutional) (figure 4). The selected parameters are imported into CityEngine by means of a Python script. During the last years, the use of this programming language for GIS application like the one described here has increased especially, after Python 2.0 has been introduced. Since then, Python has not only been supported by commercial products like those of Esri including CityEngine but also open source platforms, for example QGIS (also used in this research). The use of Python by large companies like ESRI is due to the fact that it is an easy language that many users have fully accepted [28].

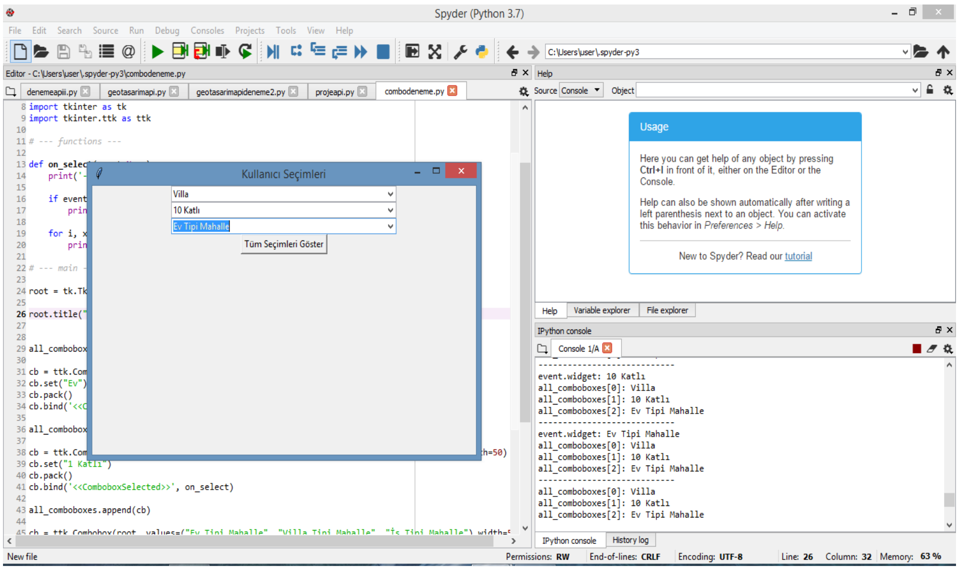

Figure 4. *GUI programmed with Python for selecting parameters of newly created project.*

Within CityEngine, the imported parameters are interpreted as “rules” that are included in a rule file. During the modeling process a 3D model is created based on the rule file. For this study, the 3D models are created on-the-fly within seconds. The amount of different 3D models that can be created by CityEngine depend on the number of rules that have been created before. According to the likelihood to be applicable in our region given its special geographic conditions, only a limited number of rules had been created and stored within CityEngine. The respective rule is loaded depending on the combination of selected 3 parameters. At the moment, due to the limited parameters that can be defined the created 3D model is a relatively simple one corresponding only to CityGML's LOD2 specifications [29]. Such a Level of Detail (LOD) is suitable for the scale of city blocks, city districts and projects. Differentiated roof structures and prototypes of city furniture and vegetation types cannot be shown. However, at this level the real situation on the ground cannot be mirrored: in essence it is not real but generalized. Figure 5 shows the city block and its surrounding created and rendered with CityEngine.

During the third step, the 3D model created within CityEngine was rendered using the game engine Unity. Unity is widely used in the VR community due to its broad palette of editing tools usable through plug-ins and support of many asset formats. Its usage is for free for anyone as long as not a revenue has been generated. By using Unity's Holotoolkit library a new project selecting the most appropriate parameters for our model had been prepared. This library provides the necessary connection between the model and the VR glasses that have been selected to consume the model.

Figure 5. *3D model created automatically in CityEngine.*

After the last step had been completed the project was ready to be consumed by any of the different VR devices available on the market. In our case, we used the PC based LENOVO Mixed Reality headset. The user has just to wear the VR glasses of this system and adjust it according to his eyes. Now, he finds himself within the selected project and can move around it using joysticks. Such an experience can be made by anyone with a minimum amount of instruction (figure 6).

Figure 6. *Presentation of a VR scene during a workshop organized in cooperation with the Municipality of Metropolitan Area of Şanlıurfa.*

3. RESULTS

We used a participatory GIS for entering and editing of spatially referenced data. These data consist of proposed projects to be included in the plan for a respective area in the form of polygons. By means of a simple user interface for any selected polygon certain parameters can be defined.

In a second step, these definitions are forwarded to ERSI's CityEngine, a 3D modeling software based on parametric modeling. This software interprets these definitions according to predefined rules and creates automatically 3D objects like apartment buildings, office buildings or shopping malls. Although in this research only a very limited number of parameters were defined this list could be extended if required by the purpose of the respective planning study. CityEngine virtually accepts an unlimited amount of parameters, for which of course the rule files have to be set up by an experienced user of the software. Depending on the complexity of the rule file one set-up might take up to 3 hours for one rule.

In this research, a system with only three parameters each having five categories offering a total of 125 different options has been developed. For a system with five parameters each offering five categories the total would rise to 3125 different. Naturally, a lot of these 3125 options would be irrelevant because for different reasons, they just do not exist given a special geographic location. Still, the amount would be so high that it has to be questioned whether such a system could work. It has to be kept in mind that the whole system has been designed for a certain user group (general public and non-expert decision-makers) lacking the required expertise to drill down into the finest details of a planning study.

So far, the system has been set-up only for the development of one city block that poses a severe limitation for the development of more comprehensive plans. Furthermore, such a city block can currently consist only of the same building type like apartment, office, shopping mall, etc. In order to be realistic, a city block should contain different building types for example apartment buildings and schools. Here, the limitations are imposed by the simplicity of the used GIS software that does not allow for a further subdivision of a project, which could define the footprints of different buildings types present in the city block. And, without clear footprints the CityEngine cannot produce 3D models because as a GIS, its whole modeling procedures starts from such polygons.

Another limitation lies in the lacking capability to create rules on the fly. Instead the rules have to be created beforehand and stored within CityEngine from where they are loaded depending on the selected parameters. As hundreds of different combinations can be chosen even with three parameters the creation of models for only a limited selection of parameters is feasible at the moment.

In a third step, the 3D models created by CityEngine are forwarded to Unity, a game rendering machine that create the environment to be used in a Virtual Reality application. Virtual Reality consists of two components: While it is relatively easy to create a virtual environment (any digital game that has been developed even 50 years ago was virtual), to present this environment in a way that a human being interprets it as real is something totally different. It requires that the 3D models used to be of high complexity showing so many details that it can be felt to be “real”. As discussed before, a lot of input parameters should be available if such a high-fidelity model should be produced, something that might not be possible during this kind of planning process. Certainly, there is a trade-off between practicability of the planning process and high-fidelity of the virtual environment to be created. However, if all stakeholders involved in the planning process including those setting-up the system are aware of this situation a compromise that is reasonable for the special purpose of the respective study could be found.

4. DISCUSSION AND CONCLUSION

Until recently, access to advanced visualization techniques was restricted to laboratories of big companies and a selected amount of universities and research facilities. Ever increasing performance of computers coupled with decreasing prices has widened this access to a much wider user group. If the required experience and knowledge exists, the workflow described in this paper could even be implemented in a home office.

The advantages of using advanced visualization techniques including VR in combination with a public participation geographic information system for urban and regional planning can be summarized as follows: 1) Enabling the design of urban mega projects in real time with a visualization that addresses the needs of non-experts 2) Powerful communication among all stakeholders comprising city planners, academics, decision-makers and the general public. 3) Time saving of the lengthy planning process by applying a largely streamlined workflow, 4) Integration of all aspects of city life in the aiming at the development of a resilient and sustainable city that makes the most efficient use of available funding; and 5) Realization of a participatory planning approach that goes much beyond a level where only posting and processing of comments is supported.

Implementing VR in urban planning is still challenging due to different reasons. While costs for VR hardware have dropped and VR related software tools have become much more user-friendly other obstacles continue to exist. Especially, the simulation and visualization of complex urban settings require the integration of different software including at least Geographic Information Systems (GIS), Computer-Aided Design (CAD), multimedia data, simulation models and gaming engines.

Therefore, we conclude that future works on this subject should focus on finding answers to three questions: 1) How can a higher level of detail for visualization be achieved without making the workflow to complicated? 2) In which way could the amount of software packages that cover the whole workflow be reduced? Currently, the usage of a GIS, sophisticated 3D modeling software and a gaming engine is the minimum requirement, which is not only in need of considerable financial but also of related human resources. 3) Currently, even if the workflow described in this research can be implemented the involvement of the general public is limited to certain aspects of the planning process. Here, the question is how non-experts and the general public can be involved more effectively in the planning process.

Answering these questions would be of benefit especially for urban designers and city planners who work in SMEs, smaller municipalities and universities could benefit from integrated planning systems including VR visualization in their design or planning practices.

CONFLICT OF INTEREST

There is no conflict of interest in publishing this paper.

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