A USER REQUIREMENTS STUDY OF DIGITAL 3D MODELS FOR URBAN RENEWAL

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Abstract

Urban renewal is a multifaceted activity that involves numerous actors, software, and types of data. Design communication tools play an important role in this process. Visual information helps to outline, understand, and choose sustainable solutions for problems in the design, while visual tools should be able to diminish professional differences and establish a common language. Recent 3D geo-technologies offer a great variety of new tools that significantly enrich visualisation possibilities and allow for flexible switching between different 3D representations. However, studies have indicated that particular representations create different perceptions in professional compared to non-professional individuals. This paper discusses the specifics of urban renewal processes in the Netherlands and investigates recently developed 3D geo-information technology, and more specifically multiple 3D representations, that can support this task. The concept of LOD, which uses five levels of information, was evaluated as a very promising approach to agree on abstractions and representations in the different renewal phases. The study did not reveal a lack of digital possibilities for visualisation, but instead showed that the simultaneous visualisation of the proposed alternatives should be a priority. This investigation did reveal that different levels of interactivity could be used for the presentation and communication of project alternatives.

Keywords: *Visualisation, Interaction, 3D, LOD, CityGML.*

INTRODUCTION

Urban planning is a complex decision-making process that involves social, spatial, economic, technical, and organisational models with a large number of actors that interact during this process (Bourdakis 1997, Klaasen 2004, Mayer et al 2005). Urban renewal has a growing significance worldwide, particularly in the European Union, because of the large proportion of building stocks that should be updated (Mayer et al 2005, Edwards 2008). Post-war neighbourhoods often fall short of fulfilling current requirements, and consequently are being renovated on a large scale.

Previous studies have indicated that sustainable urban renewal should include participative design strategies (Tjallingii 1995, Conte & Monno 2001, Van Dorst 2005). A participative approach to urban renewal design should allow for consideration of the different perceptions and aims of all stakeholders. Participation should lead to a broader acceptance of the renewal plan, and, therefore, to a better involvement of inhabitants in their respective neighbourhoods. In a strategy of participation, the aims are shared ambition, perception, comprehension, and responsibility (Checkland 1999, De Bruijn & Ten Heuvelhof 2000, De Bruijn et al 2002, Eijk 2002). Several studies have investigated participatory planning and design (Al-Kodmany 2001, Bendixen 2007, Luck 2007, White et al 2007), but were not focused specifically on urban renewal. The level of participation depends on the design process, which can vary from a blueprint planning to an open planning process. The six components for successful interactive spatial planning that have been identified are the following: actors (stakeholders), planning phases, participation level, communication protocol, interface, and visualisation (Hoogerwerf et al 2006). The participation level of actors can be further subdivided into informing, consulting, advising, co-producing, and co-deciding (Dalal & Dent 1993). While the actors, planning phases, and participation level may be relatively specific to the particular country, the remaining factors (communication protocol, interface, and visualisation) are closely related to the employed technology. Visualisation and interface (or interaction) should support the behaviour and

social framework of actor participation (Ewebstein & Whyte, 2007).

Traditionally, municipalities used 2D paper maps, CAD drawings, graphical images, textual/oral information, and physical 3D models to present ideas and alternatives to citizens. Most municipalities have websites for the dissemination of spatial plans, but these are most often 2D maps with static visualisation. Large municipalities have only recently employed systems that allow for the presentation of interactive digital maps to the public in Web Map Services (WMS) (Knapp & Coors 2008). Advances in geo-information and visualisation technology, such as 3D virtual environments, 3D analytical visualisation, and 3D formats for data sharing, offer a large spectrum of new possibilities for the communication of ideas and discussion of design alternatives (Mayer et al 2005, Batty et al 2000, Zlatanova 2000, Bodum 1999, De Vries & Achten 1998). Virtual environments, which include Google Earth and Virtual Earth, have made 3D visualisation known and accessible worldwide. CityGML has been accepted as the standard for representing 3D city models and has been developed from data exchange file format to a data model. Many municipalities have created 3D city models using CityGML or proprietary software (Cebra 2010), but these models are often not actively used for urban planning and renewal.

Due to the aforementioned complexities of this process, our hypothesis was that geo-information technology (3D digital models and appropriate interaction with the models) would promote flexible communication and the exchange of ideas (data and models). The large amounts of static physical models, booklets, other printed materials, animations, and dedicated software for public participation could be replaced with more dynamic and interactive visualisation tools, which are based on 3D multi-resolution models and a set of interaction tools. Therefore, the major questions that were investigated during this study are the following:

- Which computer-generated models (i.e. LOD of CityGML) are suitable for the different phases of urban renewal?
- Which interaction level is sufficient for the different actors to discuss and communicate design alternatives?

To address these questions, different types of visualisation materials and levels of interaction were discussed with 30 participants from seven different cities. This study included design professional (urban planners, housing companies, and architects) and non-design professionals (municipality). Citizens did not directly participate in the questionnaire, but the municipalities were requested to provide opinions on the level of interaction that would be appropriate for citizens. The largest group of the population was urban planners (17), followed by architects (6), municipality offices (5), and urban design firms (2). Additionally, separate interviews were conducted for nine relatively experienced urban planners (called experts) from two large (Rotterdam and Den Haag) and two small municipalities that had been involved heavily in renewal projects.

The study presented herein is outlined as follows: Section 2 discusses the urban renewal process in Dutch municipalities and defines major actors, Section 3 outlines relevant 3D visualisations and tools for interaction, and Section 4 includes a discussion of the results. The last section focuses on geo-information technology that can be utilised to provide functionality and visual materials.

USE CASE: URBAN RENEWAL IN THE NETHERLANDS

The Dutch system has a high degree of consultation and participation opportunities in comparison to other countries (Newman & Thornley 2006). A municipality typically instates a decision for renewal, but demands may come from housing agencies and even groups of citizens. The goal of a renewal project is to improve living conditions with respect to the following criteria: overall space arrangements (e.g. projection from wind, sun/shadow, or noise), housing, transportation, shopping, school facilities, green areas, water, and energy suppliers. Hence, the process starts with a large investigation of the existing situation, citizen requirements, and problems to be resolved towards sustainable development. In this respect, urban renewal can be viewed as a complex bottom-up process that requires a high degree of interaction and diverse methods for comparing and evaluating renewal variants against the existing situation. The study presented herein investigated the urban renewal situation in the Netherlands:

- We investigated six different large renewal

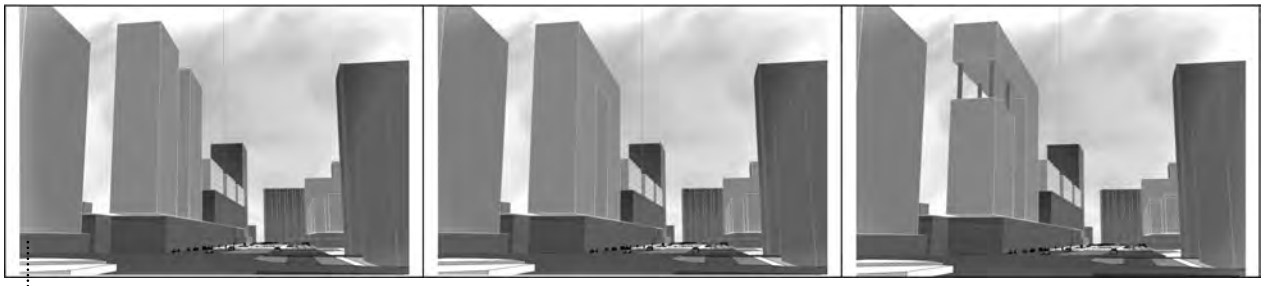

Figure 1. 3D digital models that represent three design solutions of the Poptahof urban renewal project

projects (Poptahof, Schalkwijk, Arnhem Zuid, Hoogvliet, Duindorp, and Bijlmer) in the Netherlands that have followed different approaches to share information with citizens. For example, significant social problems occurred in Poptahof and discussions of the physical environment were frequently postponed. Schalwijk had focused on the introduction of more open water areas, which resulted in the production of many design options for water areas and limited discussions of other important elements in the architectural design. Arnhem Zuid had initiated the clearing of large areas and planners were involved only at very late stages to investigate the social problems. Duindorp is an interesting case because the renewal process was frozen for a long period due to non-acceptance from citizens. Serious miscommunication between planners and citizens contributed to the delay. These investigations revealed several areas for future research. Interaction with citizens is well represented from the beginning of the renewal process. The discussions and negotiations between citizens, the municipality, housing agencies, and architects are intensive and often face-to-face. In some cases, special workshops are organised that allow citizens to propose their own solutions.

- The renewal process typically starts with the preparation of an urban plan (i.e. detailed plan for development), followed by a specialisation urban plan (the volumetric structure of the buildings), and ends with an architectural plan (architectural details of the buildings). Most of the renewal projects are developed for one or several neighbourhoods, which preserves land-use status. Thus, these neighbourhoods are typically compliant with broader master plans.
- There must be a breadth of information available regarding the existing situation. This information ranges from reports to video materials illustrated with maps, photos, and models of the current spatial division, critical problematic areas, and other details of interests.

The urban renewal phases considered during this study were master plan, urban plan, specialisation urban plan, and architectural plan.

VISUALISATION AND INTERACTION TECHNOLOGY

A critical point in the study was the presentation of available technologies to the users. A classification of tools and means was provided, which could be quickly explained and easily understood. On the basis of an extended study of visualisation and interaction taxonomies, a relatively simplified classification was derived for presentation to the users.

Visualisation can be highly realistic or abstract depending on the application and/or the purpose of the visualisation. Numerous classifications can be found in the literature defining the different levels of abstraction (e.g. McCloud, 1993; Verbree et al., 1999; Kolbe at al., 2005). The study presented herein considered photo images and 2D/3D digital models. Photo images are easily perceptible to the viewer and 2D/3D models allow for the relatively straightforward preparation of alternative designs (Figure 1).

The focus of this study was on 2D/3D digital models, which can be either CAD models (representing project alternatives) or GIS models (depicting existing situation). The Level of Detail (LOD) subdivision was adopted to relax the level of abstraction, as presented in CityGML (Kolbe et al 2005). According to CityGML, LOD 0 is a 2D map and the levels are regarded as 3D models. For example, buildings in LOD 1 are block models with flat roofs; buildings in LOD2 are block models with detailed roofs, buildings in LOD3 are represented

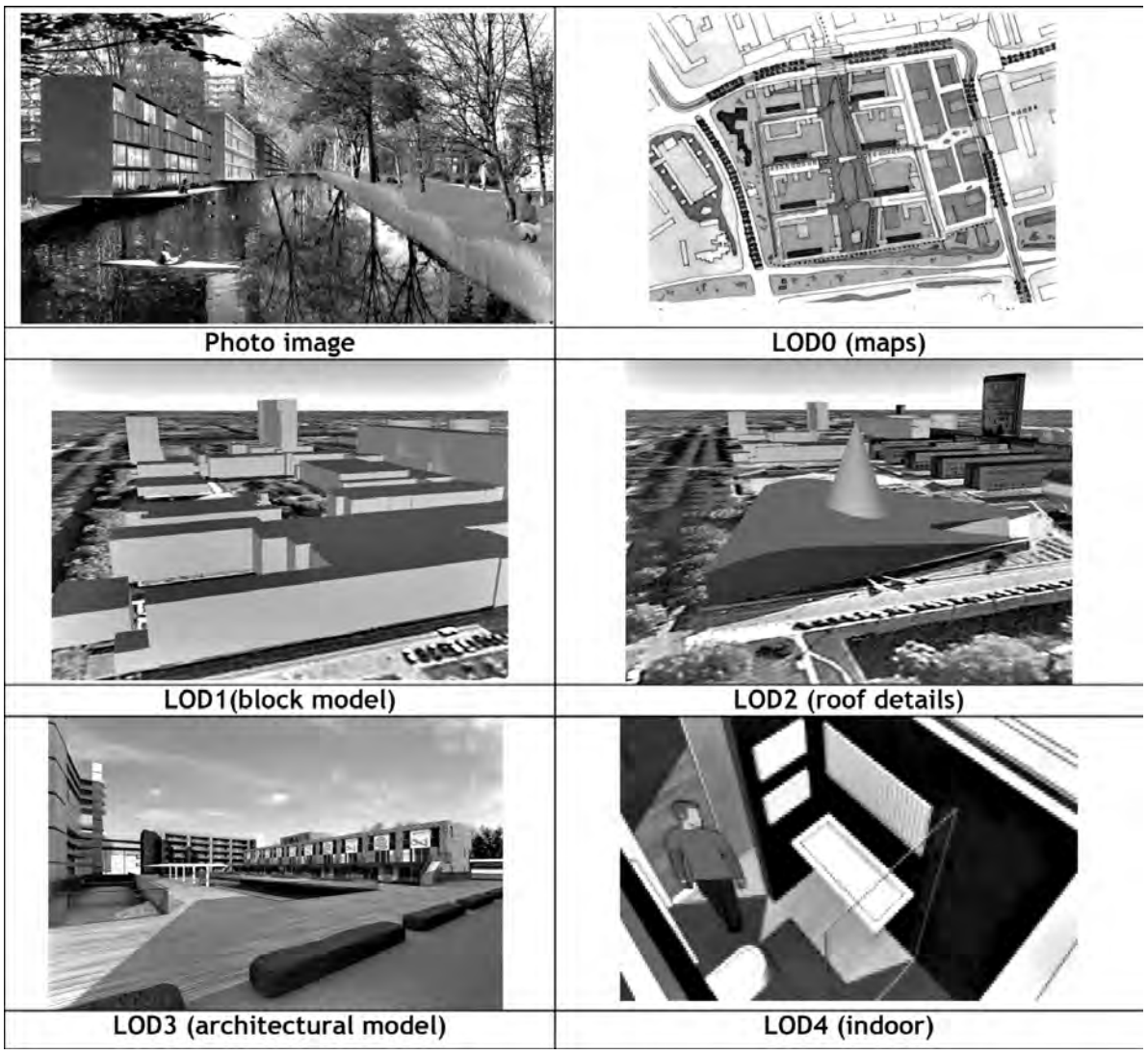

Figure 2. The six representation types used in the study (TUDelft model)

with all details on the façade, and LOD4 describes possible building interiors (Figure 2). CityGML were of particular interest in this study due to the increasing number of available CityGML models and the growing interest of CAD and GIS scientific societies in these respective models (Lapierre & Cote 2008, Isikdag 2006, Emgard & Zlatanova 2008).

An important aspect of using 3D digital models is the level of interaction permitted by a system. A taxonomy of interaction has been described in many previous reports (Kraar 2002, Sneiderman 1998, Sherman & Craig 2003, Wachowicz et al 2002, MacEachren et al 1999). Generally, the level of interaction depends on the hardware, but this study was limited to the use of desktop systems without elaborate hardware equipment. After thorough analysis of previously studied taxonomies (see Kibria 2008), we have defined the following levels of interaction: animation/video (predefined walk through), interaction (navigate, zoom, and manipulate), query (explore attributes of objects, e.g. area of a house or apartment), feedback (the possibility to provide an opinion), and change (edit the shape or a position of a house).

Two questionnaires were prepared to investigate the necessary user requirements. The first questionnaire was aimed at determining the needed visualisation and was organised as a matrix. The surveyed population could indicate whether a specific LOD was appropriate as a given renewal phase, which the participants could indicate with a 'yes' or a 'no'. The second questionnaire was aimed at determining the needed interaction levels and was organised as statements that the participants had to evaluate using a six-level scale (absolutely necessary, necessary, could be, don't know, not necessary and absolutely not necessary). The first three levels were considered validated (i.e. classi-

fied as 'yes') and the last three were not validated (i.e. classified as 'no'). Two 3D models were created to illustrate the concepts of six visual materials. These models were imported in three virtual environments, which were Google Earth, X3D viewer, and LandXplorer (a viewer for CityGML), provided to the user (Kibria et al 2009).

RESULTS ON VISUALISATION

The types of visual materials are illustrated in Figure 2. The results of the interview are shown in Table 1.

Photo images

Photo images have been widely used throughout the entire renewal process. The photos are particularly important at the start of the urban renewal process when the social situation is discussed. Photo images from existing environments are used as illustration material in all reports of the involved institutions. The results of our study demonstrated that 40% of interviewed subjects (on average) found these images appropriate for the presentation of ideas during all phases of renewal.

Discussions with the group of experts revealed interesting observations regarding snapshots of 3D models or architectural drawings. People often focused on less important features while reviewing static images. For instance, the materials used for the buildings will be discussed, while the volume was the principal characteristic under review. As an alternative to the presentation of such images, some municipalities (e.g. in the project Duindorp) planned excursions to other neighbourhoods to demonstrate the presented plans.

LOD0 (2D map)

Design professionals (architects from urban design firms) preferred two-dimensional maps with provisional plans at the process start because these maps do not fix detailed solutions and thereby allow for an extended discussion. However, professionals doubted if two-dimensional plots are really understood by citizens. Therefore, the use of 2D plots in combination with physical models is a preferred option (interviews with experts). Our questionnaire corroborated this tendency. LOD0 is most appropriate for the master plan (76%) and the urban plan (60%). The specialisation urban plan could also be represented as a 2D map (26%), but realistic details are recommended (37% LOD1 and 57% LOD2). This is a clear indication that the 2D representations might be confusing in regards to information on vertical spaces. Although few argue for map visualisation (23%) during the last phase (architectural plan), 3D visualisation is obviously preferable (see below).

LOD1 (block model)

The block model was recognised by the experts as widely used for creating a volumetric perception and presenting new design within an existing situation. As discussed with the experts, physical (wooden or plastic) block models yield good overviews of existing situations, without focusing on the details. The details are usually known and can be mentally visualized by the actors. For example, the Den Haag municipality featured 'design evenings' with citizens, which involved the observation of physical block shapes that allowed citizens to design their own alternatives.

However, the digital block models seem less appealing. Discussions have revealed that the possibility for overview is mostly lost while viewing the computer screen. The interviewed participants agreed on the inclusion of LOD1 during an early stage for the master plan (73%) and later for the urban plan (57%), but use of LOD1 in the specialisation urban plan (37%) was estimated as could be used. The acceptance percentages or LOD1 slightly decreased if realistic photo textures were applied

	MASTER PLAN	URBAN PLAN	SPECIALISATION PLAN	ARCHITECTURAL PLAN
Photo image	53	46	40	30
LOD0 (maps)	76	60	27	23
LOD1	73	57	37	17
LOD2	23	60	57	57
LOD3	7	13	50	70
LOD4	3	0	0	57

Table 1. Results of the visualisation study (given in % of participants indicating the suitability of the representation for the specific design stage)

to the block models Some confusion is expected if the building volumes are not proportionally correct.

LOD2 (detailed roof)

LOD2 is much more appreciated compared to block models. Evidently, roof information assists in understanding the design. The surveyed population (60%) accepted the use of LOD2 (without texture) in the urban plan. The texture, that provides more information on facades, was viewed as dangerous at this stage. Our interview revealed an interesting observation, i.e., the level of visual detail is understood by the actors as having a relationship with the stage of the project. Abstract forms and hand drawings are tools for the beginning of the project. More details and computer-generated lines depict a finished design. The style of drawing may have an implicit message, which is not necessarily interpreted by professional and non-professional actors in the same way. Therefore, the participants were recalcitrant towards the possibility of using the LOD2 for the master plan (23%), but approved the utilisation of LOD2 (57%) for the specialisation plan. LOD2 models are becoming attractive for the architectural plans (57%), which is not surprising given the combination of textured and realistic images.

LOD 3 (architectural envelope)

LOD 3 was indicated as the necessary abstraction for presenting and discussing the architectural plan (70%). This is the stage when all of the final details are combined and the design ideas should be presented in high quality. This is the only phase that a high level of realistic visualisation is required. Despite the consideration of such visualisation for other phases, the benefit was not apparent during discussions.

The group of experts warned that 3D representations may also be confusing if the viewpoint is not that of the inhabitant walking on the street. For instance, the view of an observer from a building above may be ideal for a marketing aim, but most inhabitants will not be able to draw conclusions regarding the street-level experience. Combining 3D models (or reference images) with realistic elements of the present situation appears to significantly assist in understanding the design. The expert group did agree that interaction (see below) would also play an important role. For example, a computer animation with an existing tram integrated into the design allowed for a greater comprehension by non-professional actors (Poptahof).

LOD4 (indoor)

LOD4 was only appropriate for the last phase of design (architectural plan), although some of the urban designers did not consider this abstraction important for urban renewal (as discussed with the experts). Building interiors may be designed for public buildings, such as shops, cinemas, and restaurants, but this is rarely performed for individual houses. The perception of floor plans by citizens is generally better if room dimensions are given. However, this opinion can easily be altered by the availability of more 3D indoor models. No models investigated in this study had designed indoor space, and therefore, further studies are necessary to derive a strong conclusion.

RESULTS ON INTERACTION

The questionnaire participants assumed that a visual environment was available for all actors during the renewal process and had to define the appropriate functionality for different actors. The different phases of renewal were not the focus of this study because every phase may require animation, navigation, query, sending feedback, or revision. For simplicity, the users were clustered into three groups: housing agencies, municipalities, and fic-

	Housing Agencies	Municipalities	Municipalities for Citizens
Animation	100	87	75
Navigation	83	95	83
Query/Exploration	66	79	79
Feedback	50	66	75
Editing	66	79	25

Table 2. Results on interaction (in % of participants indicating that the interaction should be present)

tive 'citizens'. As discussed with the group of experts, the citizens were not approached directly because variation in their opinion is relatively high. Instead, the municipality provided information (based on experience with citizens) on the functionality type that would be appropriate for citizens.

Animation

Animation was one of the most well accepted tools (75-100%) for presenting a particular design to a group of people. The expected quality of animation increases with more advanced phases. The experts group confirmed that animations are the best tools for presenting projects to citizens. Video recordings are performed mostly during the beginning of the renewal project to demonstrate the existing design problems. An interesting result was that the system should be able to animate and simulate a scenario. Animations have been developed to illustrate the development of green areas, traffic, sun movement (to be able to estimate the shadowing), noise distribution, and many other characteristics. Animations may also be 2D, e.g., to illustrate the growth of a city in the last five years. The animations created for our study were in the walking-though and flying-over categories created for and presented in Google Earth (see Figure 3).

Navigation

All the participants agreed the desktop navigation possibilities of walk-though, fly-over, and examine should be available. Most of these options worked with visualisation environments, such as Google Earth or Virtual Reality browsers. This level of interaction was classified as compulsory for all actors when 3D digital models were utilised. Almost all of the surveyed population agreed that the system should have multiple linked windows to visualise co-coordinated views of different data and dimensionality (83-95%). If necessary, the user should be able to turn off the coordinated windows and view only the 3D scene and/or the 2D map/plan.

As the urban renewal involves comparing existing and new situations, the study participants agreed that the system should be able to visualise existing situations and designs in different representation for specialists. The municipalities also viewed the navigation as more critical for the specialists than for the citizens and disagreed with the sharing of information with citizens at all phases. Urban planners in Delft, Den Haag, and Rotterdam

Figure 3. Animation prepared for Google Earth

thought that there was no benefit to consulting citizens during every phase.

Query/Exploration

The two groups, i.e., municipality and housing agencies, considered a model query as a necessary property, which allows users to 'click/query' objects. Evidently, this option is more important for the municipalities (79%). The discussions during the workshop revealed that while further questioning and information request is important, direct user manipulation of the 3D scene is not vital.

The participants agreed that the system should have a dynamic spatial query to determine such values as streets, specific areas, and locations by a given postcode, similar to Google Earth (66-79%). This was classified as a functionality that was absolutely necessary. The same is valid for the elaboration of 3D models through hyperlinks and linked windows. The general conclusion is that municipalities are prepared to provide a large set of exploration possibilities to both specialists and citizens.

Feedback

Feedback is considered important when specialists discuss and present designs to citizens, but real-time discussions or the collection of opinions and off-line analysis is preferred. Computerised feedback for citizens was viewed as beneficial by 75% of the interviewed specialists. Many officials at the municipalities and housing agencies regarded tools, such as interactive chatting, as low priority.

Although certain tools, such as interactive chatting and videoconferencing, increase collabo-

ration and design interaction, this option is still not accepted. The specialists indicated various reasons, which included that 'chatting is relatively slow' (better to talk via phone), 'videoconferencing might be unreliable' (better to discuss face-to-face), or the high quality video-conferencing system is expensive. However, nearly all participants agreed that the system should have functionalities for email feedback or electronic voting (absolutely necessary).

Editing

The editing of provided information could be permitted only for specialists (66-79%). However, 75% of the municipality population disagreed with allowing citizens to move and delete 2D/3D objects and their attributes. Agreement was reached on the system having functionalities to locally modify views, colours, and transparency, without changing the municipality database.

Interesting results were obtained on the editing of information by specialists (see Kibria 2008 for more details). While the majority of municipality participants were interested in allowing housing companies (53%) to add 3D models to the system (assuming that the system is managed by the municipalities), only a minority (33%) of the housing agencies were interested in sharing 3D data with the municipality. These agencies preferred to provide their data via services. In both cases, the municipality (67%) and the housing agencies (83%) strongly disagreed on whether such data should be copied and saved. Both groups demanded to have the functionality to hide and filter information (80%).

In general, housing agencies and the municipality did not differ much in overall opinions regarding required functionality. The system should be more elaborate for design specialist, and provide basic navigation and exploration tools for the citizens. Data sharing is a very sensitive issue for design-professionals who do not want to share the entirety of their design models with the municipality. However, these individuals understood the benefits of comparing and sharing.

OUTLOOK

In this paper, we reported our investigation on the use of 3D models and interaction tools for the urban renewal design process in the Netherlands. The presented case studies, interviews, questionnaires, and discussions confirmed the assumption that computer-generated models could be a flexible solution to avoid misinterpretations during the urban renewal process. After learning the provided taxonomy and tools, the participants posed many questions regarding system architecture for model organisation. Such architecture (outside of the scope of this paper) can be designed on the basis of GIS, CAD, DBMS, and VR software packages. The 3D models (existing and design) can be organised in a DBMS system that could be accessed by GIS, CAD, or VR software depending on the users and tasks to be performed.

The concept of LOD (not know by the participants) was evaluated as a very promising approach to agree on abstractions and representations during the different renewal phases. Consensus was reached among the participants that the best abstraction was a map representation for the master plan, LOD2 (non-textured) for the Urban plan and Specialisation Urban plan, and LOD3 (with photo-realistic textures) and LOD4 (for public buildings) for the Architectural-quality plan. LOD1 might be of interest when reviewing non-important existing situations or for analysis (mobile coverage, sun-shadow analysis, and wind analysis). The discussions did not reveal a lack of digital possibilities for visualisation, but often included that the proposed alternatives should be simultaneously visualised.

Our investigation revealed that the tested levels of interactivity could be utilised for the presentation and communication of project alternatives. The municipalities were convinced that the citizens should not extend beyond providing a feedback, which is a feature of most public participation systems. Animations, navigations, and possibilities to explore the design proposal via additional information from web links are the best tools. The municipalities were allowed to consider higher functional and interaction possibilities for design specialists. However, a system that can manipulate all of the data to allow multi-view visualisations and even editing may be beneficial. Several of the municipalities have begun using types of investigation systems, such as GIS, CAD, DBMS, and other Virtual Environments, that are able to provide this functionality.

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REFERENCES

AL-KODMANY, K. 2001 *Visualization Tools and Methods for Participatory Planning and Design*, Journal of Urban Technology, **8** (2) 1-37.

BATTY, M, CHAPMAN D, EVANS S, HAKLAY M, KUEPPERS S, SHIODE N, SMITH A, TORRENS P M. 2000, *Visualizing the City: Communicating Urban Design to Planners and Decision-makers*, CASA Working Papers (26), CASA, London, UK

BENDIXEN, M, KOCH C. 2007, *Negotiating Visualizations in Briefing and Design*, Building Research & Information, **35**(1) 42-53.

BODUM, L. 1999, Future Directions for Hypermedia in Urban Planning, in: Spatial Multimedia and Virtual Reality (eds) Y Camara, J Raper, Taylor & Francis, London, pp 21-34

BOURDAKIS, V. 1997, *Virtual Reality: A Communication Tool for Urban Planning*, in: CAAD-Towards New Design Conventions, (eds) A Asanowicz A Jakimowitz, Technical University of Bialystok, pp 45-59

CEBRA, 2010, Cebra BV available at http://www.cebra.eu/ (last accessed April 2010)

CHECKLAND, P B. 1999, *Systems thinking, systems practice*. Soft Systems Methodology: a 30-year retrospective, John Wiley, Chichester

CONTE, E, MONNO V. 2001, *Integrating expert and common knowledge for sustainable housing management*, in Towards Sustainable Buildings, (eds) N Maiellaro, Kluwer, Dordrecht, pp 11-28

DALAL, B, DENT D. 1993, *Sustainable Development Strategies: A Resource Book*, Environmental Planning Issues No. 1, Barry Dalal-Clayton, 14 p.

DE BRUIJN, J, TEN HEUVELHOF E. 2000, *Networks and Decision-making*, Lemma, Utrecht

DE BRUIJN, J, TEN HEUVELHOF E, IN'T VELD R. 2002, *Process Management, Why Project Management Fails* in Complex Decision-making Processes, Kluwer, Dordrecht

DE VRIES, B, ACHTEN H H. 1998, *What offers Virtual Reality to the designer*, Proceedings of the Int. Conf. on Integrated Design & Process Technology, Berlin, Germany, July 6-9.

EDWARDS, C. 2008, *Participative urban renewal? Disability, community and partnership in New Labour's policy*, in: Environment and Planning A, **40**, 1664-1680

EIJK, P. 2002, *Changing water management in urban renewal in the Netherlands; ecological modernization through a participative strategy*, in: Global Solution for Urban Drainage, Conf. 8 13 2002, Portland USA

EMGARD, L, ZLATANOVA S. 2008, *Implementation alternatives for an integrated 3D information model*, in: Advances in 3D Geoinformation Systems, LNGC, Springer-Verlag, Heidelberg, pp. 313-329

EWENSTEIN, B, WHYTE J.K. 2007, *Visual representations as 'artefacts of knowing*, Building Research & Information, **35** .81-89.

HOOGERWERF, ET AL. 2006, *Three-Dimensional Geo-visualization for Spatial Planning: Towards a Conceptual Framework*, Published by Wageningen University.

ISIKDAG, U. 2006, *Towards the Iimplementation of Building Information Models in Geospatial Context*, PhD Thesis, University of Salford, UK

KLAASEN, I T. 2004, *Knowledge-based Design: Developing Urban & Regional Design Into a Science*, PhD Thesis, Delft University Press, Delft

KIBRIA, M S. 2008, *Functionalities of Geo-virtual Environments to Visualize Urban Projects*, GIMA MSc Thesis (Utrecht Univ., TU Delft, Wageningen Univ., ITC), The Netherlands, 124 p. available at: http://www.gdmc.nl/publications (last accessed April 2010)

KIBRIA, M S, ZLATANOVA S, ITARD L, DORST M VAN. 2009, *GeoVEs as Tools to Communicate in Urban Projects: Requirements for Functionality and Visualization*, in 3D Geo-information Sciences, (eds) J Lee, S Zlatanova, Springer-Verlag, Heidelberg, pp. 379-395

KNAPP, S, AND COORS V. 2008, *The Use of eParticipation Systems in Public Participation: The Veps Example*, in: Urban and Regional Data Management UDMS Annual 2007, (eds) V Coors, M Rumor, E Fendel, S Zlatanova, Taylor & Francis, Leiden, The Netherlands, pp. 93-104

KOLBE, T H, GRÖGER G, PLÜMER L. 2005, CityGML: *Interoperable Access to 3D City Models*, in Geoinformation for Disaster Management, (eds) P van Oosterom, S Zlatanova, E M Fendel, Springer-Verlag, Heidelberg, pp 883-899

KRAAK, M-J. 2002, *Visual Exploration of Virtual Environments*, in Virtual Reality in Geography, (eds) Fisher Unwin, Taylor and Francis Inc, New York

LAPIERRE, A, COTE P. 2008, *Using Open Web Services for Urban Data Management: a Testbed Resulting From an OGC Initiative Offering Standard CAD/GIS/BIM Services*, in: Urban and Regional Data Management; UDMS Annual 2007, (eds) V Coors, M Rumor, E Fendel, S Zlatanova,Taylor and Francis, London, pp. 381-393

LUCK, R. 2007, *Using Artefacts to Mediate Understanding in Design Conversations*, Building Research & Information, **35**(1) 28-41

MCCLOUD, S. 1993, *Understanding comics: the invisible art,* (Kitchen Sink Press.

MACEACHREN, A M , EDSALL R, HAUG D, BAXTER R, OTTO G, MASTERS R, FUHRMAN S, QIAN L. 1999, *Exploring the Potential of Virtual Environments for Geographic Visualization*, Project report, available at http://www.geovista.psu.edu/publications/NPIVM99/ammNPIVM.pdf

MAYER, I, BUEREN E VAN, BOTS P, VOORT H VAN DER. 2005, *Collaborative Decision Making for Sustainable Urban Renewal Projects: a Simulation – Gaming Approach*, Environment and Planning B: Planning and Design **32** 403-423

NEWMAN, P, THORNLEY A. 2000, *Urban Planning in Europe*, Rutledge, London

SHERMAN, W R, CRAIG A B. 2003, *Understanding Virtual Reality: Interface, Application & Design*, Morgan Kaufmann Publishers, imprint of Elsevier Science, California, USA

SNEIDERMAN, B. 1998, *Designing the User Interface: Strategies for Effective Human-computer Interaction*, Reading MA., Addison Wesley Longman, Inc.

TJALLINGII, S. 1995, *Ecopolis, Strategies for Ecologically Sound Urban Development*, Backhuys Publishers.

VAN DORST, M. 2005, *Een Duurzaam Leefbare Woonomgeving*, PhD Thesis, TUDelft, Delft www.eburon.nl

VERBREE, E, VAN MAREN, G, GERMS R, JANSEN F, KRAAK M.-J. 1999, *Interaction in Virtual World Views – Linking 3D GIS with VR*, International Journal of Geographical Information Science, **13** (4) 385-96

WACHOWICZ, M, BULENS J, RIP F, KRAMER H, LAMMEREN R VAN, LIGTENBERGET A. 2002, *GeoVR Construction and Use: The seven factors*, in Proceedings of 5th AGILE conference on Geographic Information Science., 4p.

WHYTE, J K, EWENSTEIN B, HALES M, TIDD J. 2007, *Visual Practices and the Objects used in Design*, Building Research & Information, **35** (1) 18-27

ZLATANOVA, S. 2000, *Toward a 3D GIS for Local Governing: a Web-Oriented Approach*, in: Proceedings of the 22nd Urban and Regional Data Management Symposium, pp. VI33-VI40

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