E-COLLABORATION BETWEEN THE PRIVATE AND THE CIVIL SECTOR: SUPPORT OF LONG-TERM UTILIZATION AND UPDATE OF OFFICIAL 3D CITY MODELS

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ABSTRACT:
Research on the creation and use of 3D city models has made rapid progress recently. An increasing number of cities and regions now own 3D city models or are planning to use them in the future. Especially planning departments see an enormous potential in the use of 3D city models to visually and algorithmically access environmental and spatial impacts of planning proposals. However, examples for the continuous use in spatial and environmental planning are not documented so far. Within our contribution it is argued that this can especially be attributed to missing concepts for the digital exchange of planning information between the civil sector and the private sector. By conceptualizing digital workflows that enable the utilization of 3D city models and the integration of planning proposals by multiple stakeholders, it will be shown how the collaborative use of official 3D city models can support their regular use as well as their continuous update. References to related research are presented to show that the technology to implement such an e-Collaboration framework is generally available. At the same time our concept also considers national and supranational aims formulated in e-Government programmes to provide governmental services via ICT.

1. INTRODUCTION

Collaboration between multiple stakeholders based on a common data model or within a shared virtual space represents an innovative and promising technology to support planning processes and project management in spatial and environmental planning via information and communication technology (ICT). Within the fields of architecture, construction and engineering (ACE) the idea of collaboration is increasingly supported by the adoption of construction software that enables users to represents a proposed construction as semantic data model rather than as purely graphical model. With respect to building construction such models are called *building information models* (BIM). The BIM approach has significant advantages compared to classical computer aided design (CAD) drawings: One BIM can be used for cost calculations, for structural analysis, for life-cycle management of buildings, and in real-estate management applications. International standards for BIM such as Industry Foundation Classes (IFC) allow the exchange of data between multiple stakeholders and software solutions. It is possible to derive multiple graphical representations from one BIM, such as ground plans, section drawings, structural models, or 3D models in varying levels of detail (LOD).

Analogue to BIM, which can be used to represent buildings through a semantic data model, City Geography Mark-up Language (CityGML, Gröger et al. 2008), a standard of the Open Geospatial Consortium (OGC), can be used to represent cities through a semantic data model. *Semantic 3D city models* (Kolbe 2009) can be used to store virtual 3D city models in different levels of geometric and semantic detail and with multiple appearance models. Since CityGML-based virtual 3D city models are georeferenced and can be visualized in real-time they provide a common data model as well as a geovirtual environment (GeoVE).

Despite the progress made in 3D city modelling during the recent years and the benefits associated with semantic 3D city models for spatial and environmental planning, their utilization by authorities and planning professionals is still in the beginnings and the potentials are by far not fully tapped yet. The hypothesis of our contribution is that not the technology is missing but concepts for the long-term operational use and maintenance of semantic 3D city models. Therefore, it researches requirements for the continuous use of official 3D city models by multiple stakeholders in spatial and environmental planning via ICT. It conceptualizes an e-Collaboration framework, workflows, and processes for the exchange of digital planning information and 3D city model data between the civil and the private sector.

2. RELATED WORK

The presented research focuses on the position of e-Collaboration at the intersection of (1) 3D city models, (2) spatial and environmental planning, and (3) e-Government. Within the following chapters we will introduce the three themes, recapitulate current developments and define the terminology used.

2.1 Virtual 3D City Models

Virtual 3D city models are digital, georeferenced representations of objects, structures, and phenomena of corresponding real cities. Recently, models are extended by semantic concepts such as in the case of CityGML (Gröger et al 2008). In contrast to models that are solely created for visualization purposes, semantic models extend graphical models by storing additional information about type, usage, and role of objects as defined by an underlying ontology (Kolbe 2009). Several of the 3D city models developed recently are attributed to be *official 3D city models* which represent not only a virtual 3D city model but are linked to the land cadastre system and thereby represent the city as it is described by official and legally binding geo-information. The aim behind this approach is to ensure integrity and validity of the city model as it is needed in administrative use.

The progress achieved in 3D city modelling and the resulting increased availability of 3D city models can be attributed to

recent developments in remote sensing technologies and data extraction algorithms. It is now possible to automate the reconstruction of 3D city objects (e.g., Haala and Brenner 1998, Rottensteiner et al. 2005, Becker et al. 2008) and virtual 3D city models respectively to a large degree. Thus the cost for the creation of large and city wide 3D city models have dropped rapidly during the last years. Consequently, many cities start to build up 3D city models as part of their local data infrastructure.

Parallel to the development of improved data acquisition technologies and object extraction algorithms, open data models such as KML/Collada, X3D, and CityGML have been developed that are used to represent 3D city objects. Our contribution will focus on CityGML-based 3D city models and neglects other solutions; however a discussion on the difference to IFC, X3D and KML can be found in the article by Kolbe (2009) and Yanbing et al. (2006) present an overview on 3D spatial data model approaches developed in recent years.

CityGML is deliberately chosen for several reasons. (1) It is an OGC standard based on Geography Mark-up Language (GML), which enables the use of web feature services for querying 3D city model data and facilitates the integration of 3D city model data with other spatial data sources made available through OGC web services (Döllner and Hagedorn 2007). (2) It defines an expandable, semantic and spatial data model, which makes it possible to adopt it to specific problems (e.g. Czerwinski 2006). (3) An open source database schema (IGG 2009, online) is free available which can be used to store, represent and manage CityGML-based 3D city model on top of Oracle 10g/11g. Along with the database schema a Java-based Import/Export tool is free available as well as a Java class library and API for facilitating work with CityGML (IGG 2009, online). (4) Finally, CityGML is increasingly adopted within research, by city administrations and supported by software vendors in the GIS and CAD domain.

2.2 Spatial and Environmental Planning

Contemporary challenges in spatial and environmental planning such as including social, ecologic, and economic dimensions into planning activities, designing transparent planning processes and enabling participation and collaboration between multiple stakeholders require tools and methods to facilitate communication, support collaboration, monitor land-use change, and assess environmental impacts of development scenarios and planning proposals. Geoinformation Sciences contributes many tools and methods to better solve these challenges, e.g. by making (geo-)information available to stakeholders via Web Services, by the development of land-use models for predicting future developments and analysing the impact of policies, by providing GIS analysis functionalities, or by developing planning support systems (Geertman and Stillwell 2003).

In this context, GeoVE are utilized to visually communicate and explore planning proposals and development scenarios in urban, landscape, and environmental planning (e.g. Bishop and Lange 2005, Buhmann et al. 2005, Counsell et al. 2006, Kibria et al. 2009). While early experiments in this field were often based on manual 3D modelling and Virtual Reality Markup Language (VRML) to create real-time visualizations, other approaches adopted game engines (e.g., Herwig et al. 2005, Stock et al. 2005) which provide sophisticated 3D visualization capabilities, physics engines and possibilities to interact with the GeoVEs created.

However, many of the methods and solutions developed were limited in the past – either with respect to the visual quality, the

interactivity, the information intensity, the required computing power needed or simply because of the effort and costs needed to prepare the GeoVEs. Still these early experiments have shown that interactive 3D models and/or images and animations derived from them can support communication and participation processes between multiple stakeholders (e.g., Danahy 2001; Orland et al. 2001, Schroth 2007). This situation has changed, though. Software like Autodesk LandXplorer 2009 (Autodesk 2009, online), internet-based "digital globes" like Google Earth (Google 2009, online), and Java-based web-clients with support for OGC web services like the xNavigator (GDI3D 2009, online) are used to visualize large 3D city models from heterogeneous data-sources. Actually, we can observe a paradigm change from experimental models towards sophisticated, large and detailed 3d city models which are accessible over the internet (e.g. Kulawik et al. 2009). With the increasing availability of official, city-wide 3D city models as described in the previous section, planning professional now could – at least theoretically – use complex, large, and detailed 3D city models as base models into which planning proposals and development scenarios can be integrated and even published online.

Visual communication of planning proposals or scenarios is only one option for the utilization of 3D city models in spatial and environmental planning, though. Analytical functions which operate on geometric, semantic and topologic properties of 3D city models such as noise emission simulations (Stoter et al. 2008, Czerwinski 2006), simulations of air pollution dispersion (Lin et al. 2009), detection of potentially suitable roofs for solar collectors (Klärle 2008), and shadow-analysis (Lange and Hehl-Lange 2005) are further applications, which can be used to optimize planning proposals or analyse existing city structures. Such analytical functionalities add value to 3D city models as well as to spatial and environmental planning as new knowledge can be produced and spatial concepts can be algorithmically analyzed and optimized.

To make use of the theoretical advantages, it will be necessary that 3D city model data is made available to planning professionals and that they are enabled to integrate their proposals into existing 3D city models. This would support the use of 3D city models as GeoVE into which planning proposals and development scenarios can be integrated to facilitate visual communication between stakeholders and at the same time their utilization in complex spatial (3D-) analyses to assess spatial and environmental impacts of proposed developments.

2.3 E-Government

E-government is defined as ICT-based services to enable information, collaboration, participation, and transactions between governmental institutions (G2G), government and business (G2B) as well as between government and citizens (G2C). According to the United Nations (UN 2005), e-Government is an important factor for economic growth and international competitiveness. It is also seen as significant contribution to the process of transformation of the government towards a leaner, more cost-effective government (UN 2008). Supranational e-Government initiatives like i2010 in Europe (COM 2005) and national e-Government activities (e.g. the German programme E-Government 2.0 and the e-GIF initiative in the United Kingdom) support the idea of e-Information, e-Participation and e-Collaboration to involve the public in planning processes and increase transparency in spatial and environmental decision-making. Research projects like the Virtual Environmental Planning project (www.veps3d.org) have shown how citizens can get involved in planning

processes via e-Participation platforms based on 2D map services and 3D city models. Although further examples exist, a broad adoption of this technology can still not be observed. Amongst the reasons that hinder a broader utilization of 3D city models are organizational issues of high relevance: In general the exchange of planning information is regulated by law and plans have to be signed by planners and members of the civil administration and archived to ensure their legal validity. In the past this could not be solved through digital processes. Now, technologies and methods to enable authentication, secure data transfer, digital rights management and revision-save storage of data are available. At the same time official 3D city models are increasingly available and can be used to integrate and visualize planning proposals in a broader spatial context. If this knowledge is related to the fact that in contemporary planning practice most plans are produced in digital form (e.g. as CAD plans and models, GIS data, or BIM) the main research questions of this contribution become obvious: *Which digital workflows and processes are needed to integrate digital planning information into official 3D models to enable e-Participation and e-Collaboration under the metaphor of the virtual city on a regular basis? Which technology is needed to implement such concepts and is it available?*

3. CONCEPTUALIZING E-COLLABORATION PROCESSES BASED ON OFFICIAL 3D CITY MODELS

To conceptualize an e-Collaboration framework which supports the regular use of official 3D city models, in a first step, a stakeholder analysis is conducted to identify stakeholder groups, which will benefit from the utilization of 3D city models in planning practice. In a second step, general and stakeholder specific requirements are defined which are a prerequisite for the continuous utilization of 3D city models via ICT by multiple stakeholders. Based on a generalized illustrative example, digital processes are outlined that will have to be implemented to provide completely digital workflows and data exchange. Within this step key technology aspects of the identified processes will be discussed to assess the availability of the technology needed.

3.1 Stakeholder Analysis

Stakeholders in spatial and environmental planning are people and organizations from the civil, private, and public sector, who are involved in local planning decisions (Healey 1997).

The civil sector, i.e. public administration, is responsible for co-ordinating spatial and environmental planning activities within a city or municipality. Usually, the planning department represents the authority responsible for giving planning permission. However the planning department is by far not the only authority interested in spatial planning. It has to co-ordinate plans with environmental, transport, social and economic departments and agencies on local to national and even supranational level. Within this internal coordination processes, the integration of 3D plan representations into semantic 3D city models can be used to visually communicate and assess planning proposals, e.g. visual assessment of important lines-of-sight. Furthermore, the planning department and other authorities can use 3D city models for advanced simulations and analysis functions, e.g., noise emission simulations, shadow analysis, suitability for solar collectors, local wind-field simulations as introduced in section 2.2. In short, the integration of 3D plan representations into virtual 3D city models could support information exchange, spatial

analysis, and communication processes within the administration (Government to Government - G2G).

Members of the general public are diverse stakeholders with varying interests and very heterogeneous map-reading skills and often competing interests (Selle 2000). Since 3D visualizations provide an intuitive way for communicating spatial concepts (cp. section 2.2) one of the most important arguments for the utilization of 3D city models is that they are likely to facilitate understanding and capacity building within this stakeholder group. Therefore, a continuous integration of planning proposals into 3D city models could offer an innovative solution to provide information about planning processes to the public and implement e-Participation and e-Information services (Government to Citizen - G2C) on a regular basis.

Finally, the private sector or rather the market includes as diverse stakeholders as architects, engineering companies, project developers, land owners and investors. The main advantages attributed to 3D city models from the private sector are twofold: First, 3D city models provide a "scene" into which a new design can be integrated and interactively visualized and explored, e.g. to facilitate communication between investor and architect or architect and planning department. Second, the integration of plans into 3D city models offers new ways of analyzing and assessing the impact of proposed constructions on the environment and the cityscape as discussed in section 2.2. It is obvious that these usage concepts are very similar to the concepts discussed with respect to the civil sector. Both groups have a professional interest and need access to the 3D data to work with it. Therefore, it will be necessary to enable them to exchange data (3D city model data and 3D plan representations) amongst each other (Business to Business - B2B and Business to Government - B2G).

The different stakeholders compete with each other in respect to their roles and rights regarding 3D city models and 3D plan representations. The main and most important conflict of interest arises between the cadastre and the planning department, potentially involving other departments such as city marketing, too. The cadastre department has the public mandate to maintain geodata with a very high standard and in most cases is responsible for the management of official 3D city models. However, within planning processes official 3D city models will be modified, changed and updated regularly. Therefore, an e-Collaboration framework will have to provide a solution which enables the cadastre department to maintain a valid official 3D city model and at the same time makes it usable, accessible and expandable for other stakeholders. Another conflict that arises is the question who owns 3D plan representations integrated into 3D city models during different stages of planning processes.

3.2 Key requirements for collaborative use

Within section 3.1 stakeholders who benefit from the utilization of official 3D city models in planning processes were identified and it was discussed which usage concepts and roles are associated with the three stakeholder groups. From the stakeholder analysis key requirements for the long-term operational use of official 3D city models by multiple stakeholders in planning processes can be defined:

General requirements:
  – Transparent Access: 3D city models will have to be accessible by authorities, the public, and planning professionals.

- Defined Standards: To ensure integrity and comparability data standards and defined levels-of-detail of 3D plan representations are needed.
- Publishing Tools: Functions to publish 3D city model views to selected stakeholder or stakeholder groups (e.g., general public, involved engineers, authorities) are needed.
- Communication Tools: Communication tools that enable communication between stakeholders based on 3D city model views are necessary.
- Long-term Management: Plan management and versioning functions are needed to ensure the integrity of the databases for the long-term, sustainable use.
- Rights Management: Data owners and stakeholder must be enabled to administer user and access rights.

With respect to the research questions formulated, these general requirements have to be complemented by specific requirements needed to enable the integration of plan representations.

Specific requirements:
- Model Provision: Planning professionals require to get official 3D city data as base data for creating designs and conducting 3D spatial analysis.
- Model Reuse: Planning professionals must be enabled to integrate 3D plan representations into official 3D city models.
- Model Documentation: Authorities must be enabled to store revision save and digitally signed plan versions.
- 3D geo-processing functions: To increase and facilitate the analytical usage of official 3D city models, generic 3D geo-processing functions are needed.

3.4 Example E-Collaboration Use Case

In the following section a generalized illustrative use case for the utilization of 3D city models within planning processes is described. Since planning professionals (PP) are identified to play a central role as they are users of 3d city model data and provider of planning information, it will be necessary to define digital workflows that allow them to request 3D city model data and to integrate 3D plan representations into 3D city models as well as to publish their work to stakeholders involved in planning process. The workflows (Fig. 1 and Fig. 2) needed to accomplish this can be subdivided into processes, which are detailed subsequently.

Process 1: Registration and authorization of PP and announcement of the planning processes
In a first step it will be necessary that PP authorize and register themselves and announce the type of planning process they are working on. This can be realized through setting up a *P*lanning *I*nformation *M*anagement *S*ystem (PIMS), which supports authorization and registration. Such a system can be implemented based on common ICT technology comparable to a content management system, only that it stores information and data related to a plan. Within this step, basic planning information such as type of plan, responsible planner, land owner, et cetera are collected.
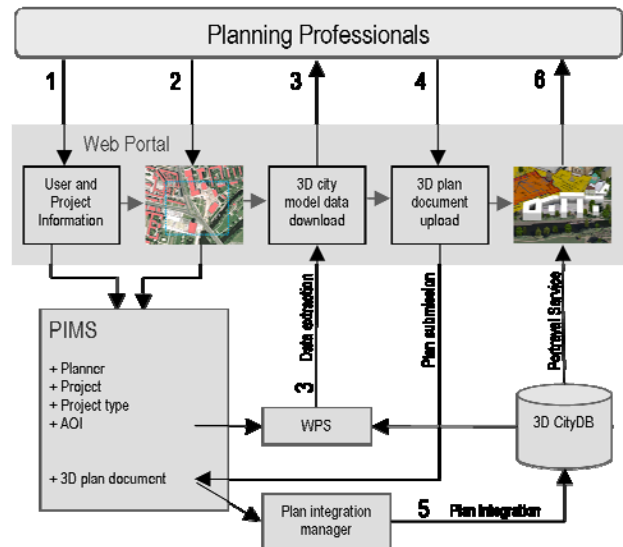

Fig. 1: Workflow diagram for the processes 1 to 6

Process 2: PP request model data for a defined area of interest (AOI).
To implement this process, we can use an input form to get the bounding coordinates of the AOI or a web-map service providing a city map and a function to define an AOI. This process should not be exclusively limited to 3D city model data but can be extended to include further data sources such as cadastre information, environmental information, cultural heritage information, and legal binding spatial and environmental planning information from (local) spatial data infrastructures. The AOI definition should are also stored in the PIMS for documentation purposes and to facilitate the integration of the 3D plan representations later on.

Process 3: Model data is automatically extracted from the 3D city model database and provided to the PP.
Based on the AOI definitions, server-side functions or web processing services (WPS) can be used to extract 3D city model data from official 3D city model databases and serve it to PP. In case of CityGML-based 3D city models it is also be possible to integrate the model data directly into 3D visualization systems using web feature services (WFS) as demonstrated by Döllner & Hagedorn (2008). Kolbe (2008) discusses the possibility to extract (City)GML data using a WFS in combination with a Web 3D Service to create KML based 3D representations. With this approach CityGML data can be transformed into KML which is supported by several software solutions from the ACE domain. Kulawik et al. (2009) use a Java-based converter to process CityGML files and export them to KML and VRML/Shape for visualization purposes and to store the data in a database. Ideally, an expandable import/export manager would have to be implemented which supports the provisioning of city model data in several formats.

Process 4: PP submit planning proposal to PIMS
Based on the acquired data PP create planning proposals as 3D plan representations based on the received 3D city model cut-out. These proposal can then be submitted back to the PIMS. To ensure operability, integrity and validity only agreed exchange formats (e.g., CityGML, IFC, X3D) are accepted and level-of-detail definitions have to be obeyed. The upload can be implemented as file-upload or through transactional WFS.

Process 5: On demand integration of planning proposals into 3D city models

After planning proposals have been submitted to the PIMS, functions to integrate them into the official 3D city model are needed. In the case that planning proposals are submitted in CityGML format, this can be done by combining the official city model with the planning proposal.

However, current 3D modeling software does not support CityGML and submissions most likely might be allowed in other formats as discussed in process 4. Therefore, complex data transformations such as the transformation of IFC data to CityGML as described by Benner et al. (2004) and Isikdag & Zlatanova (2009), the transformation of triangulated multipatches to CityGML as described by Ross et al. (2009) or the transformation of one XML-based data schema into another as described by Henning (2008) can be used. In case that parameterized 2D data, e.g. building polygons with height information, is allowed as data model for representing a plan, the data must be extruded and converted to CityGML. This can be implemented through 3D geo-processing operations for OGC web processing services as discussed by Göbel & Zipf (2008) or comparable server-side geo-processing functions. Another solution is to directly integrate planning proposals provided as 3D model in industry standard formats such as 3ds, obj, or x3d. This possibility is supported by CityGML through the option to include generic city objects. However, this approach will not include semantic object information and further information such as scale, position, and rotation might be needed to automate the on demand integration into the official 3D city models. The on demand integration requires a plan integration manager which handles data conversation and integration.

With the introduced process steps it is possible to implement a workflow that enables PP to acquire and utilize official 3D city model data, submit planning proposals to a plan management system and integrate planning proposals into 3D city models on demand. However the data acquisition, preparation of plans, and their integration into 3D city models are just a first step. To allow participation and collaboration of further stakeholders, it will be necessary to define workflows that facilitate communication between stakeholders based on 3D city model views as illustrated in Fig. 2.

Process 6: PP explore integration results
This step is necessary to enable PP to visually assess the integration results and detect possible integration or design errors prior to publishing proposals to further stakeholders. This process requires a web-enabled 3D city model viewer which might be implemented as Web 3D Service (Kulawik et al. 2009), Web Perspective View Service or even based on clients like Google Earth. If PP are not satisfied at this point they can redesign the proposal and restart with process 4, else they can publish their planning proposals to other stakeholders.
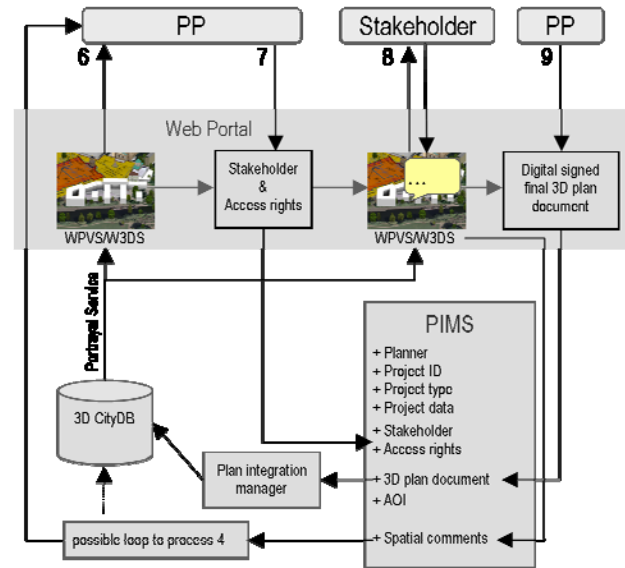

Fig. 2: Workflow diagram for the processes 6 to 9

Process 7: PP publish the planning proposal to stakeholders
Within this process PP must be enabled to define users and/or user groups that can access planning proposals. Furthermore, access rights might be necessary to differentiate between stakeholders, e.g. some stakeholders might be enabled to comment, while others are allowed to view the planning proposal and further groups might be allowed to download and use the source data for analysis or design supplements.

Process 8: Stakeholder comment on the planning proposal
By giving PP the possibility to publish planning proposals to other stakeholders the proposals can be explored and discussed or even be used for collaborative. In addition to a web-based viewer, visualization-based tools for spatial communication must be implemented, e.g., options to add spatial comments to city models or to draw on top of city model views (images). This process might result in the decision to re-work the plan or parts of it due to legal requirements or design needs identified by stakeholders. Thus process 4 to 8 are likely to be cyclic processes in practice.

Process 9: PP transfer planning proposal to administration
At a certain point plans are final and have to be submitted to planning authorities to enable them to examine if proposals fit building and planning regulations and can be approved. In contrast to the processes discussed prior this process is final. Therefore, the ownerships and the user rights connected with planning proposals have to be transferred from the PP to the responsible planning authorities, planning proposals have to be digitally signed and stored in a revision-save form. The planning authorities as responsible bodies for approving or rejecting planning proposals might restart at process 7 to include further stakeholders such as other departments or the public in the planning process.

Process 10: Registration of the approved planning proposal as temporary plan object in the official 3D city model
Upon approval of planning proposals the planning authority transfers them to the cadastre department which registers it as *temporary city object* in the official 3D city model. This ensures that approved plans are integrated at an early point of time into the data infrastructure and can be accessed by stakeholders through e-Information services. After the plan is implemented, i.e. the construction work is finished, the

temporary plan object can be used to update the official 3D city model database by changing its status from temporary to existing. However, it will be necessary to compare the digital representation with the real situation prior to the final acceptance of plan objects.

3.2.1 Excursus: The role of CityGML

In paragraph 2.1, the reasons for concentrating on CityGML as interchange format were explained. The use case shows why CityGML is very powerful as interchange format for official 3D city models: (1) Since it has become a standard in 2008 CityGML is increasingly adopted by scientists working in the field of 3D geo-information and several studies have shown that it is possible to convert CityGML into formats, which are better suited for 3D-visualization such as KML and VRML. (2) The database schema is not only compatible to Oracle 10g/11i, but it also provides a structure, which make it easier to standardize planning proposal submissions. (3) The expandable and semantic data model can store semantic information allowing new forms of analyses. Most important, the Application Domain Extensions (*ADE*) enable the various stakeholders to adopt CityGML for their specific purposes. The CityGML noise ADE, used in North Rhine-Westphalia, Germany, provides a good example (Czerwinski 2006) for the use of ADE.

However, there are of course limitations to CityGML: Although it is acknowledged by the Open Geospatial Consortium OGC, only a couple of software products support CityGML export or import yet. Furthermore, is has been argued that CityGML might be limited in its performance when storing large datasets with very high levels-of-detail. However, more precedents are necessary to test the boundaries of CityGML in official 3d city models in the context of spatial and environmental planning.

4. DISCUSSION

The presented simplified digital workflows show how the continuous utilization of 3D city models by planning professionals can be implemented based on a service-oriented architecture and existing international standards. The provision of 3D city model data as well as the continuous and automated integration of plan representations into 3D city models which becomes possible by the proposed digital transaction of planning information between planning professionals and authorities, will make it possible to establish communication and participation processes via ICT. References to related work show that the city modeling technology and methods for such an e-Collaboration framework are already available. However, the implementation of the concept will require to set-up several data provisioning, processing and integration services, which are integrated into one planning information management systems. This planning information management system makes the services available to multiple stakeholders through a central interface as described by Wang et al. (2007) and stores and manages plan documents and planning information. Thereby, one of the key challenges seems to be the sophisticated user and rights management which is necessary to ensure the integrity and validity of the system.

Moreover, business process within municipalities will have to be adopted to the new technology and employees will have to be trained. We think that an implementation is still likely to repay the effort and investment needed as it will enable planning professionals to work with high-quality 3D city model data and at the same time offers a solution to the problem of updating and maintaining official 3D city models. Even more the quality and level-of-detail of an official 3D city model

could be enhanced continuously during its lifetime. This could especially be the case if planning proposals are submitted as semantic models to the system.

The proposed digital processes are not restricted to a specific planning domain or planning scale, but might be used as well in urban planning as in open-space planning or traffic planning. In urban design competitions for example, the use of 3D city models as shared base model could facilitate the objective assessment of all contributions as described by Lange et al. (2004). They conclude that the technology is already in place, but there is still strong skepticism to overcome, particularly among architectural associations. Therefore, additional research is needed to evaluate the benefits and limitations of using 3D city models as basis for urban design competitions. In the same direction points recent research by Kibria et al. (2009), who observed that our knowledge about the appropriate degree of realism and level of detail of planning proposals from varying disciplines and on different scales is very limited, although obviously the LOD increases during planning processes. Strongly related to this uncertainty with respect to the appropriate LOD is the question which real world objects should be modeled. The references made to 3D city modeling within this contribution refer in almost all cases to buildings. The integration of streets, railways, open space, parks, vegetation, technical infrastructure and other objects is seldom researched so far on city level, although they represent important objects. To put it even stronger: If in the future these objects are included in 3D city models and in plan documents based on a ontology as in case of CityGML, it would become possible to report on the land-use changes induced by plans. This means that a continuously updated 3D city model could be used to create regular reports on important planning and land-use indicators such as imperviousness of a plan, urban density, increase/decrease of settlement area or the percentage of urban green in a defined area. Furthermore, the integration of all these smaller objects which coin the spatial structure of a city as it is perceived from a human perspective would enable valid visual or algorithmic assessments of important lines-of-sights which is presently not possible. Finally, the integration of other objects besides buildings will be needed to foster consultation of agencies responsible for economic, transport, environmental and other relevant issues. Such inner-institutional consultations are mandatory for planning departments in most countries and the processes are not digitally implemented yet. The provisioning of an expandable and semantic official 3D city model might provide a starting point to develop innovative tools and functionalities for implementing such e-Consultation processes within the administration.

5. CONCLUSIONS

Within our contribution we conceptualized an e-Collaboration framework based on digital workflows and processes that enable multiple stakeholders to utilize 3D city models in spatial and environmental planning and to collaborate based on 3D city models via ICT. It is argued that such e-Government functions will support the long-term utilization of official 3D city models as well as their continuous update. By referencing related studies it was possible to show that the implementation of the proposed concept based on CityGML, OGC Web Services, and current ICT technology can be done. However, it was also identified that current 3D city model research is in most cases restricted to buildings and that solutions and tools that enable semantic and geometric modelling of other objects in CityGML are still missing.

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