BIM and 3D property visualisation

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Key words: 3D Real Property, Property Formation, BIM, Cadastre, standardization, Sweden

SUMMARY

The concept of 3D property has only existed a short period of time in Sweden, being introduced in 2004 and expanded in 2009 by the addition of condominium (apartment) ownership. It is therefore a rather new form of land management, and the demand for 3D property formation has not been as high as initially expected. There is however an increased interest in 3D property and ownership apartments today, also as being part of the nation's geospatial infrastructure together with related 3D information for e.g. buildings, utility networks and other features. An effective management of 3D property is depending on, among other things, visualization, representation and storage of 3D real property data, such as legal boundaries and real property rights. There are at present a number of ongoing 3D development and research projects focusing on visualization and standardization of 3D cadastral boundaries. They are part of the national "Smart Built Environment" development and research program, which includes the use of BIM in the (future) 3D property formation process with focus on visualization of 3D real property and condominiums, and specification of requirements and evaluation of 3D digital real property information created and managed in the processes.

This paper presents the preliminary results of the working group on visualization of 3D boundaries in the project "Smart planning, construction and management processes throughout the life cycle". The aim is to test the results produced in the project "Information for planning, real property formation and building permission", working group "BIM for 3D property formation." The purpose of this working group is to set the requirements for and evaluate the test bed for 3D property information. The focus is on visualization of 3D property and ownership apartments. The proposed model for digitization and visualization of 3D property formation will be tested in a test bed environment. A pilot case from the Stockholm area is then used in the test bed to see how it could work in practice.

The expected outcome is recommendations for the exchange of documentation and other digital information in 3D processes, the visualization of legal boundaries for stakeholders, registration of legal 3D objects in the Swedish national real property register and how to communicate 3D models to right holders/stakeholders for 3D property and condominiums and the property market, as well as suggestions for a homogeneous, effective and digital flow of 3D information to be used by actors and other stakeholders in the property formation, planning and building processes.

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1. INTRODUCTION

"Smart Built Environment" is a national strategic innovation program initiated by the government in cooperation with the private urban land development sector and financed by the Swedish research agencies Formas, Vinnova and the Swedish Energy Agency. The aim is to facilitate digitalization of the urban land development process and support new possibilities and business models in the entire sector. The program focuses on object-based information management with industrial processes. A future work model in which stakeholders in property formation collaborates with the support of 3D building models and geographic information during case management can have major effects on both the efficiency of the cadastral agency's performance and the understanding of the real estate decision for all stakeholders in the process. See link to the Smart Built Environment website in the reference list.

The aim of the project "3D testbed for urban land development" is to test how to incorporate legal 3D real property data, e.g. boundaries, with digital building models. The authors have as part of the project cooperated with a similar project," Smart planning for the built environment", which purpose is to improve the urban land development process by describing more streamlined information flows among the involved parties. The aim of the specific component" BIM and 3D-property formation" (SBE, 2017) can be described as a suggestion for an improved work process, quality management and the improved understanding of the importance of the real property formation decision and to simplify the dialogue between the stakeholders and the real property formation agency. This can be done by together developing the processes for the formal real property formation decision by re-using three dimensional building models, visualization of new and changed three dimensional (3D) real property. The information flow has to be model based and to integrate the real property information with BIM.

One of the projects in the Smart Built Environment innovation program is national guidelines for BIM. The guidelines will, among other things, consist of common terms, processes and information that each party has to or may deliver. Today we e.g. talk about different plans and drawings, but with BIM the information deliverables will change both content and form. How to describe it for humans and computers? The guidelines will be part of a digital toolbox to facilitate the exchange of information through the whole lifecycle and build on (inter)national standards for processes, data models and terms. CoClass is an important component in this work and is the core of the management of the terms used in the processes in Sweden, see section 5. Data Models will be based on the IFC standard.

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Martin Andrée, Jesper Paasch, Jenny Paulsson and Stefan Seipel (Sweden)

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2. 3D PROPERTY FORMATION LEGISLATION

A traditional property is a land or water area with its associated property accessories. The property has no limitation upward or downward, which means that it includes all air and all ground down to the center of the earth. In cases where there has been a need to utilize parts of a property such as tunnels and wiring, historically, this has been solved through utility rights or easements. Joint facilities have also been formed in the most appropriate cases.
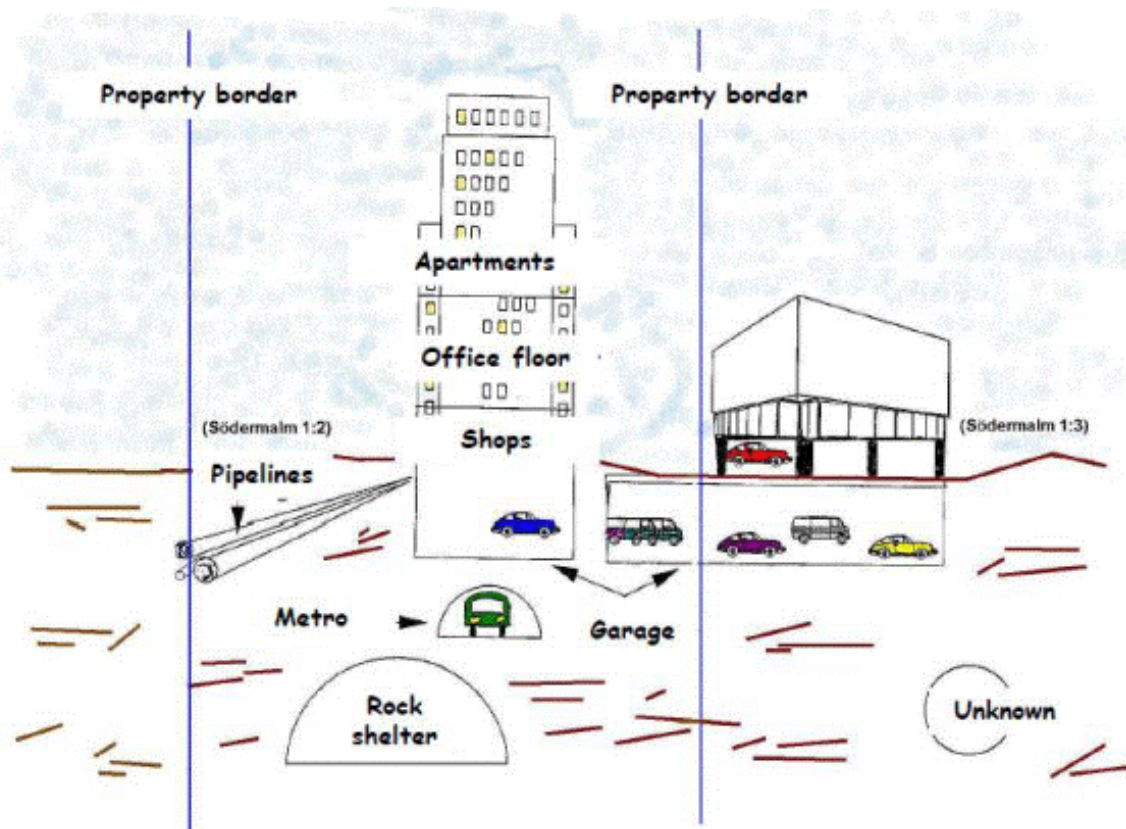

Figure 1. Description of traditional real properties. Source: Lantmäteriet

3D real property can be defined as a real property delimited by borders both vertically and horizontally, see e.g. Paulsson (2007). 3D real property formation was introduced 1 January 2004 and ownership apartments 1 May 2009. The 3D property has to be a closed volume. It is possible to join a 3D property space to a regular 2D real property. A 3D property space is a space included in a property unit other than a three-dimensional property unit and delimited both horizontally and vertically. For example, a 3D property can be a block of residential apartments or a part of a building with office or retail premises. A 3D property can also be a rock shelter or a tunnel for the metro or railroad etc. An ownership apartment is a 3D property which is not intended to consist of anything else than one single residential apartment. Rights to apartments are otherwise granted with tenancy or tenant ownership in Sweden.

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Martin Andrée, Jesper Paasch, Jenny Paulsson and Stefan Seipel (Sweden)

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Istanbul, Turkey, May 6–11, 2018

The rules for forming a 3D property are designed based on three-dimensional real estate utilization for permanent purposes. The right should be independent and the right to use a space can be used for credit security in the same way as other real properties. It should be easy to get acquainted with the right to property utilization and the rules for 3D property formation coincides as far as possible to the structure applicable to traditional property law.

A 3D property is bounded both horizontally and vertically and is intended to accommodate a building, other facility or part thereof. There are no specific rules for how to draw the boundaries in relation to the building or the facility. The property can also include a smaller volume of air for maintenance if deemed appropriate. However, the property cannot contain space for future building rights, such as an additional floor plan for future extensions. On the other hand, 3D real estate can be formed for an undeveloped building or facility, provided that it will be developed within a certain amount of time. It is also possible to make preliminary decisions, which is appropriate for undeveloped buildings, as adjustments may be necessary once the construction is completed.

The property shall be assured of the necessary rights for its proper use and it must be clear that the measure is warranted with regard to the construction and use of the facility. It should also be understood that the measure is intended to facilitate a more efficient management of the property or to ensure the financing or construction of the facility.
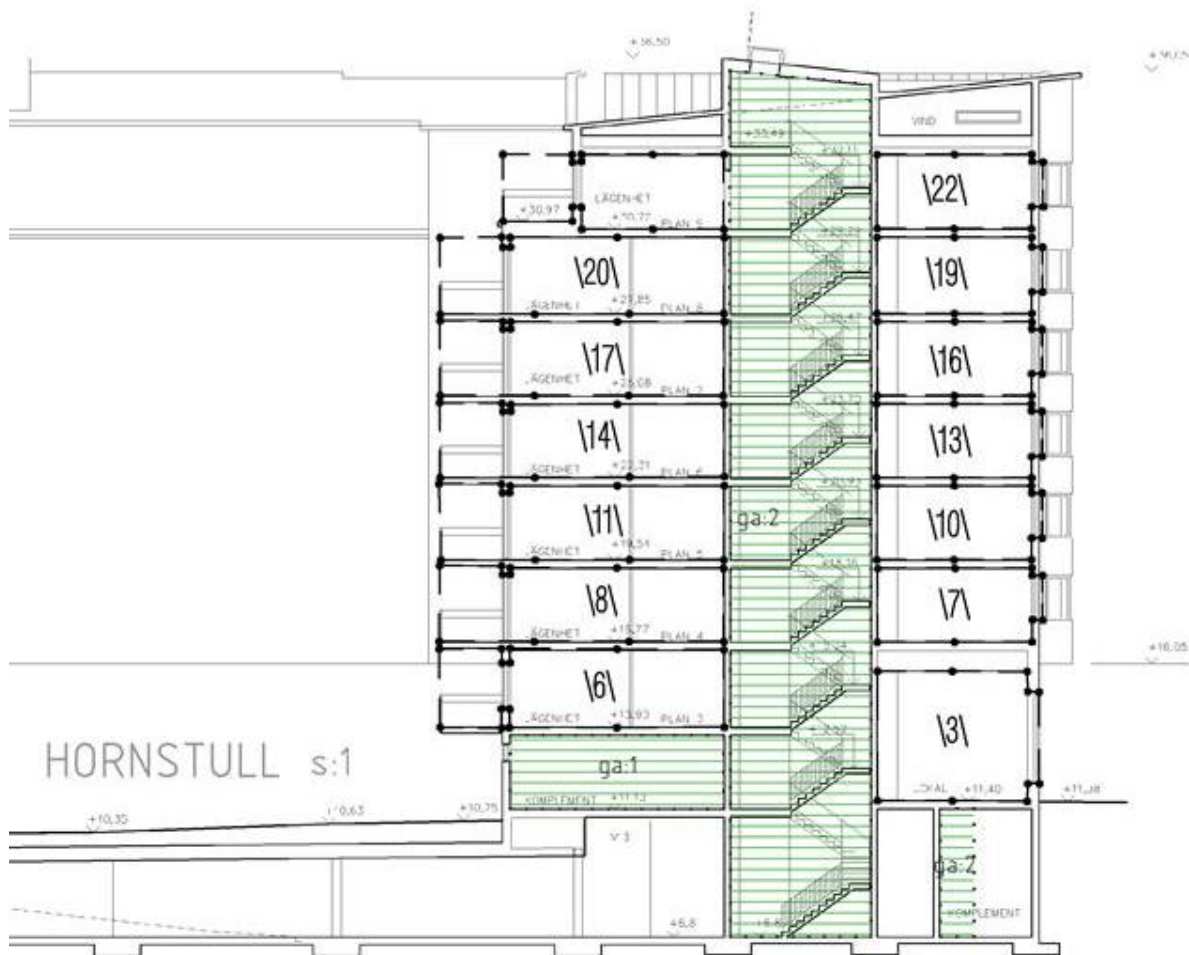
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Figure 2. Ownership apartments in Hornstull. Source: City of Stockholm

There are specific conditions attached to 3D property formation, which include that the formation shall be more useful compared to other types of formation to achieve the desired purpose and the best legal solution.

3. TODAY´S 3D PROPERTY FORMATION PROCESS

The formation of 3D property units require that the horizontal and vertical boundaries are described both in writing and shown on maps and drawings. The same apply to boundaries for rights, restrictions and responsibilities.

The land surveyor is responsible for checking the property formation application against legislation (primarily the Swedish Land Code (SFS, 1970:944) and the Real Property Formation Act (SFS, 1970:988), planning regulations and for example building permission

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Martin Andrée, Jesper Paasch, Jenny Paulsson and Stefan Seipel (Sweden)

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granted for the area in question. Often the process results in the need to change details in the application in order to get it approved. The documents on which the decision is made is today mostly in paper format or frozen digital images. The same applies to earlier property formation decisions and the actual planning regulations and granted building applications used as basis for the property formation decision, see e.g. El-Mekawy, Paasch and Paulsson (2014).

Figure 3. Existing 3D real property formation process. Source: Smart Built Environment

4. REQUIREMENTS TO IMPROVE THE PROCEDURE

There are many different stakeholders that are affected by a property formation procedure and the need for an improved process differs depending on whose perspective is reflected. Applicants in a 3D property formation can vary widely and can range from individuals, small housing associations, to professional builders who manage several 3D property formation procedures per year.

From the applicant's perspective, even when it is a professional actor, it is a challenge to illustrate the desired boundaries, rights and joint facilities in a manageable and understandable way for the required property units.

It is difficult to accurately report a 3D volume only in 2D drawings and it is difficult to read a 2D cadastral index map with properties and rights determined in 3D. This is shown not least in applications with requests to make changes to existing 3D boundaries. Then, the cadastral surveyor first needs to review the existing paper documents to try to understand where

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Martin Andrée, Jesper Paasch, Jenny Paulsson and Stefan Seipel (Sweden)

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Istanbul, Turkey, May 6–11, 2018

existing 3D spaces and boundaries are located, assess the suitability of the desired new boundary drawing, and then in the decision documents clearly explain how they change in the new procedure in relation to the existing 3D boundaries.

There is a need for the applicants to get guidance on how to best describe the property formation application so that the material submitted to the cadastral surveyor becomes as functional and complete as possible. By using materials that are produced in connection with the design and construction of a new building, information is used more efficiently. If there are clear instructions on how boundaries and rights should be defined and illustrated, it creates a more efficient process within property formation.

Additional needs of improvement are:
- Enhance the visibility of the cadastral index map,
- Previous property formations need to be easier to understand,
- More uniform and unambiguous documentation is required,
- Access to unified data throughout the process is needed,
- Re-use of real property information is required, and
- Uniform visualization is required.

A risk with the current lack of requirements (actuality, quality, 3D basis, etc.) is that properties can become unsuitable and disputes arise when the documentation is unclear. If data is produced in varied design and quality, it can be difficult to get consistent decision and registry support, which can complicate interpretation and future management that in turn leads to costly processes for property management.

3D property formation is sometimes today made based on building drawings from the late 19th century with boundaries drawn by hand. An individual assessment of the documentation is made in each case, but that assessment should not be made based on the materials the owner has access to, but on the requirement for a legal and clear decision.

5. 3D PROPERTY FORMATION WITH BIM

The purpose of the project was to investigate how a future real property formation process would be, focusing on the digital base-data common for the whole urban land development procedure.

Depending on the existing conditions, 3D property formation can technically be solved in several ways using different data models of varying content. The questions are however many. For example, whether the cadastral authority shall produce a digital 3D model of the prospected 3D property if it cannot be supplied by the applicant and whether it is possible to use a section of an existing 3D model and decide which parts that have to be visualised.

BIM and 3D Property Visualisation (9367)
Martin Andrée, Jesper Paasch, Jenny Paulsson and Stefan Seipel (Sweden)

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Istanbul, Turkey, May 6–11, 2018

The vision for a future procedure is that the applicant has access to a 3D model of the real property subject for change. If the applicant cannot produce their own 3D model it should be possible to obtain a model from the cadastral authority, under the condition that the authority has produced or otherwise obtained a 3D model of the area in question. These models shall be stored via the cadastral registration model. See e.g. Stoter et al. (2016) on registration of multi-level ownership rights. If the applicant has access to their own 3D model only the section relevant for the 3D property formation shall be submitted. See the process diagram below.
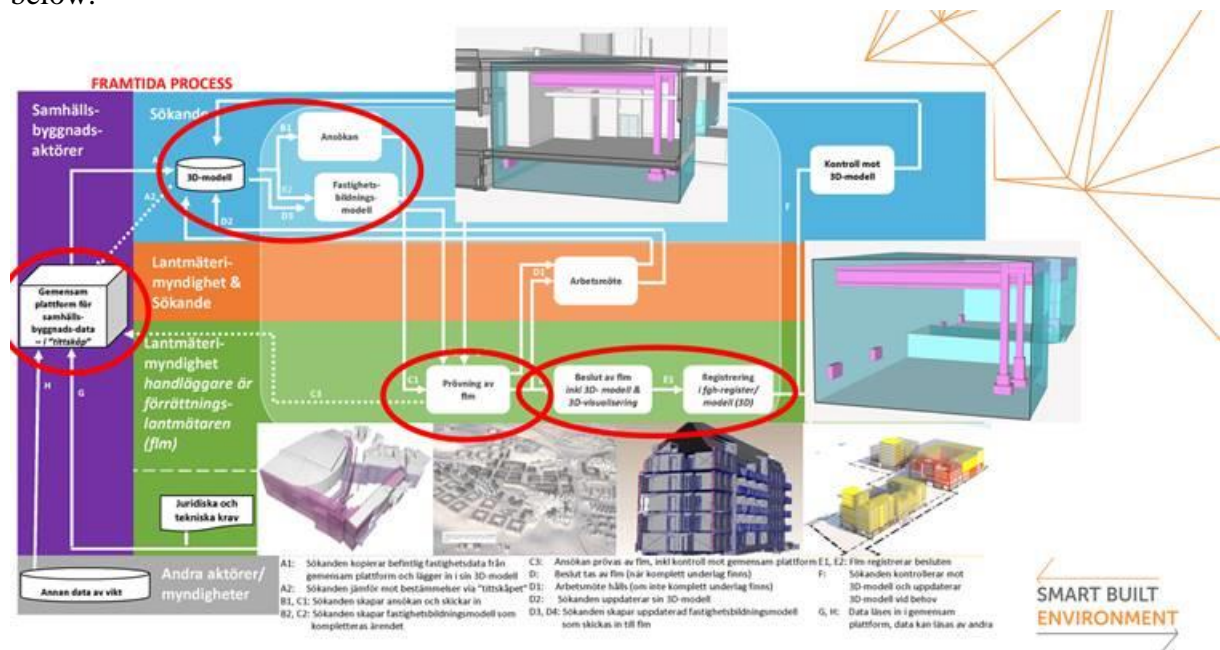

Figure 4. Proposed 3D real property formation process. Source: Smart Built Environment

In order to specify the level of detail (LOD) and the information content in the model the prerequisites have been to study the CoClass and IFC Standards.

CoClass is an important component in modeling of building objects in Sweden and is the base for a common terminology/language in the building- and real property sector. The IFC standard (ISO, 16739:2013) is used as exchange format and for geometric data. See link to the CoClass website in the reference list.

How could a real property formation model be described in CoClass? The original file is stored at the applicant but an extract is exported using relevant CoClass codes. The illustration below shows an office building where CoClass objects have been selected based on the information needed for the 3D real property formation procedure. Several codes are marked with yellow, which indicate that some parts may be used in the 3D property formation process, but some may however not be relevant depending on where the physical division of the legal real property will be. Our conclusion is that a large number of building parts must be

included in a property formation model, depending on where in the building the legal 3D boundary will be created.
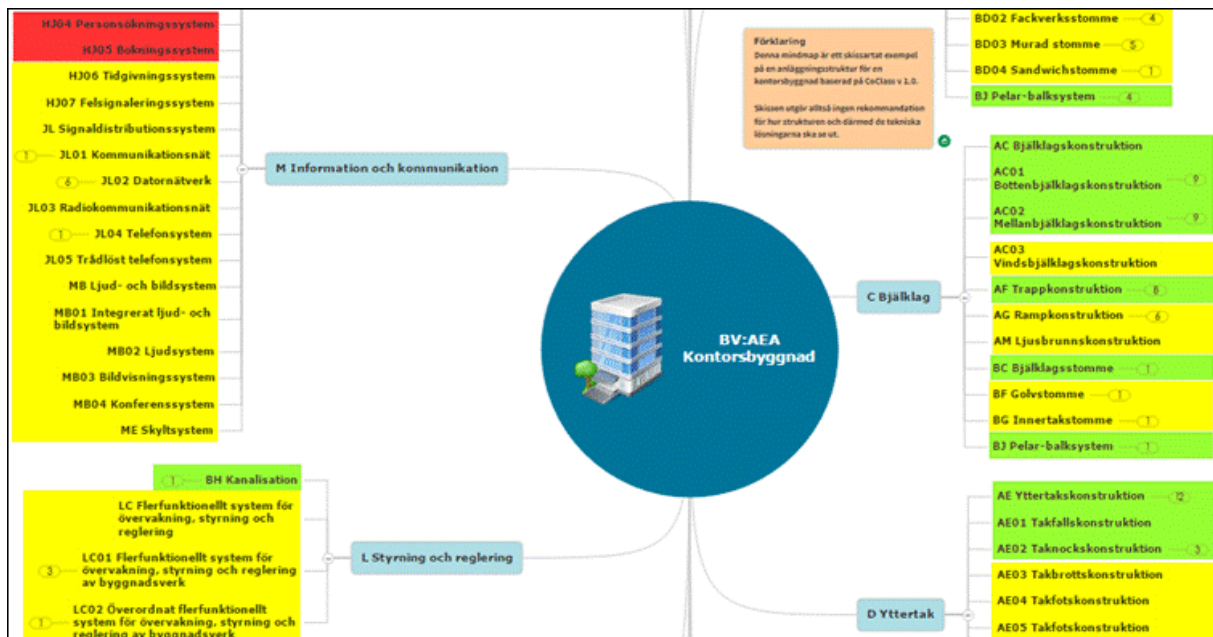

Figure 5. Example in CoClass of how the information structure can be represented in an office building. Information required for property formation is represented in green, objects required based on the specific property formation case is represented in yellow, and non-required objects are represented in red. Source: Smart Built Environment

CoClass also contains codes for different types of boundaries which can be used in 3D property formation. These codes can for example be linked to the physical objects marking the boundary between real properties (volume object, wall object or similar). In our pilot study in the area around Tele2 Arena the pillars carrying the floor structures of the property above could for example have an object property given the code "HBJ" from CoClass which corresponds with "easement" in the CoClass nomenclature. Another example could be a utility easement on another property. A utility easement is a right allowing a real property, or other parties such as power companies, to use a space on another (i.e. a servient) real property for construction and maintenance of a facility, e.g. a telecommunication cable. This right could be coded as "HBL = Utility easement".

The process of 3D property formation using a 3D model also requires the visualization of existing 2D real properties, 3D real properties, and property rights in order to reveal the relationships between existing properties/rights and those to be planned. In order to explore a new working process for 3D property formation, a 3D model of the cadastral index map for the chosen pilot case has been designed throughout the project.
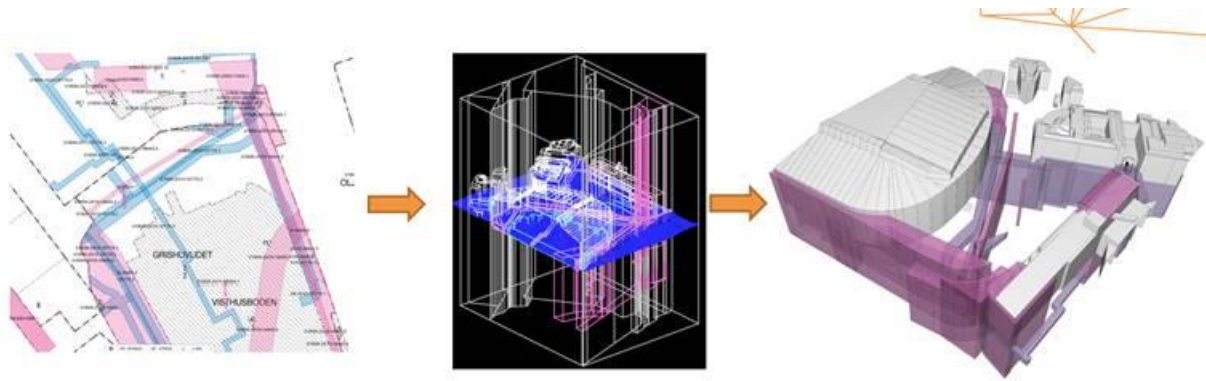
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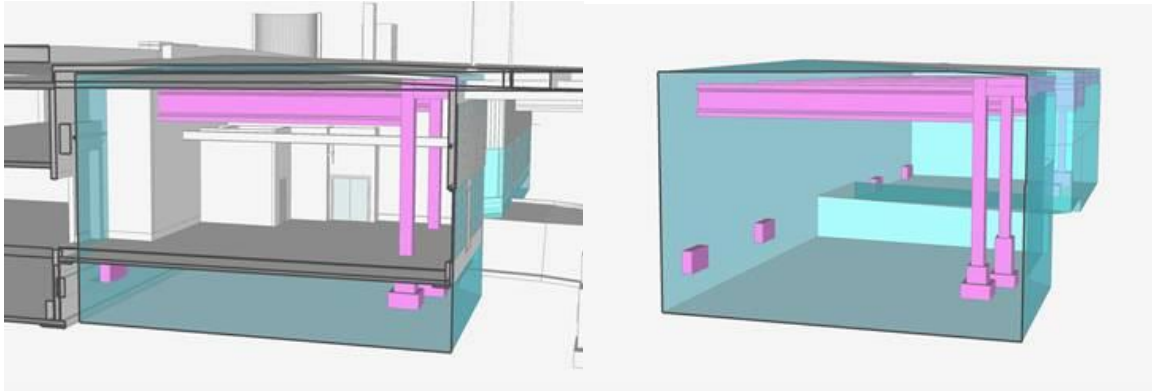Istanbul, Turkey, May 6–11, 2018

Figure 6. 3D model of the cadastral index map. Source: Smart Built Environment

This model comprises existing 2D and 3D real properties, as well as property rights. The chosen pilot case includes a variety of property rights and several 3D real properties. Their spatial extent is, according to the existing data provided by the city administration of Stockholm, represented in form of polygons in the 2D planar cadastral index map. Those polygons have then been combined with height information from the cadastral case folders of the cadastral authority and with height data provided by the city of Stockholm. Some information such as e.g. legal rights without specified location are represented in form of text within the conventional maps as they do not have any spatial extent within the 2D plane. Within the 3D model, those objects are modelled as cylinders with some radius from the center of the text label.
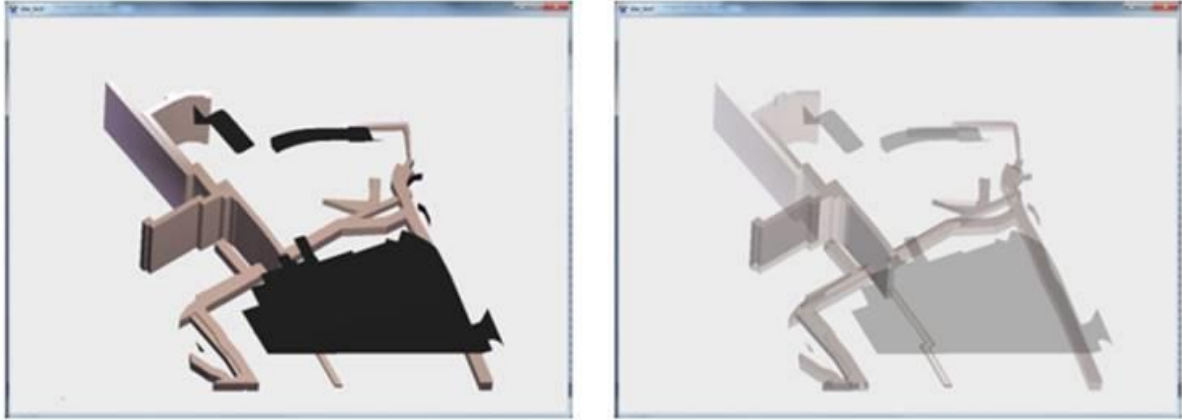
The input data used to model 3D boundaries for a new 3D property and new easements are imported from 3D models of the (planned) building and completed with sectional drawings as well as the textual descriptions of the boundaries from the cadastral case folders. Whenever the boundaries of a property are modelled in 3D from an existing BIM model, it is important to state the precision to which the boundary shall be true with various architectural details, such as glass windows. The boundary can, for instance, be exactly aligned with the window frame and window glass, or be more simplified with more tolerance to allow for different construction details in the final building. Obviously, an exactly specified property boundary increases the risk of disagreement with the actual building, if building details are implemented differently or added compared to plan. In the process of modelling the 3D property in our pilot case, for instance, a disagreement between the 3D model (BIM) as well as the drawings and text documents was encountered, which previously had not been identified.

BIM and 3D Property Visualisation (9367)
Martin Andrée, Jesper Paasch, Jenny Paulsson and Stefan Seipel (Sweden)

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Istanbul, Turkey, May 6–11, 2018

Figure 7. A cross-sectional view of the visualization from the pilot study, wherein 3D property boundaries are identified as turquoise surfaces and property rights are shown in pink color. The picture to the left shows the property formation model including the building information, boundaries and property rights. The picture to the right shows the cadastral registry model containing boundaries and property rights only. Source: Smart Built Environment

The visualizations of the 3D model of the cadastral index map have in our pilot study initially been produced with the same graphical modelling tools that were used for the design of the visualization models (compare Figure 7). These tools offer a limited set of rendering styles that are most commonly used in CAD and BIM.

For continued studies and research, the project has implemented an experimental visualization application to render the models of 3D properties and rights. This visualization application is a developer tool that allows to programmatically change the visual appearance of the graphical models and hence it offers flexibility for future explorative research. This prototype application is also the basis for user tests and controlled experiments to study the effects of different graphical representations of the same visualization model, as well as to investigate human perceptual limits when it comes to the interpretation of complex visual situations, e.g. involving multiple occluding structures and transparent structures. Figure 8.1 presents a situation from the pilot case, which shows the same model rendered in two different styles. It illustrates that spatial appearance of 3D structural features in the visualization model is reduced in situations with multiple overlapping transparently rendered structures, which is otherwise useful to avoid that small but relevant objects are overlooked due to occlusion. Stylistic rendering techniques and image post processing, such as edge-filtering and edge-rendering, are intended to improve the visual appearance of complex geometric relationships when a transparent rendering style is chosen. In this way, both the depth complexity in a visual scene as well as spatial structure of the rendered objects can be conveyed in a visualization at the same time (see Figure 8.2).

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Martin Andrée, Jesper Paasch, Jenny Paulsson and Stefan Seipel (Sweden)

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Istanbul, Turkey, May 6–11, 2018

Figure 8.1 Visualizations of the legal objects related to a property with solid style rendering (left) and transparent surfaces (right). Source: Smart Built Environment
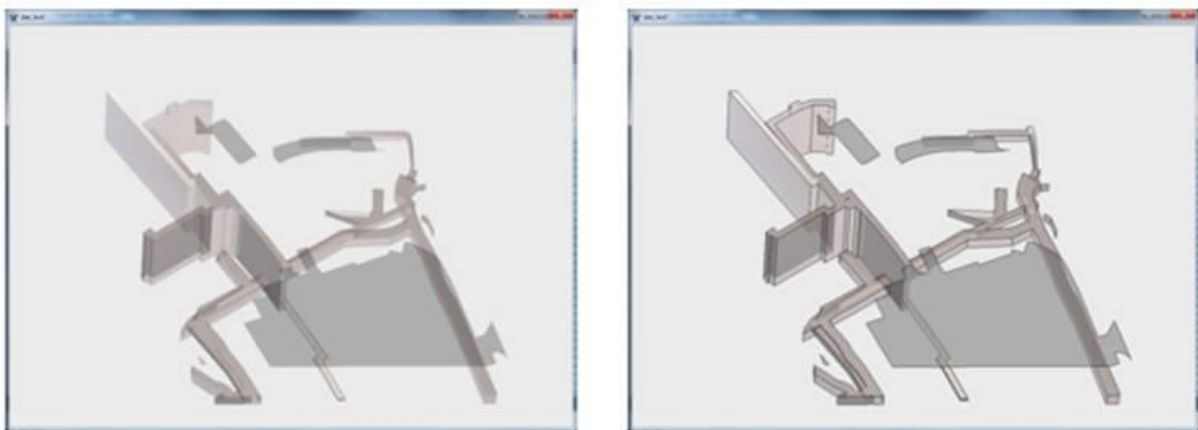
Figure 8.2 Visualizations of the legal objects related to a property with transparent surfaces only (left) and with edge-enhanced transparent rendering for enhanced visual appearance structural detail (right). Source: Smart Built Environment

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Martin Andrée, Jesper Paasch, Jenny Paulsson and Stefan Seipel (Sweden)

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Istanbul, Turkey, May 6–11, 2018

6. CONCLUSIONS

We have studied the questions raised by the project and developed a hypothesis for future work and investigations. The questions require more detailed knowledge on multiple levels. Our hypothesis is based on the establishment of a working model where actors and stakeholders in the digitalization of the urban land development process cooperate. A future model where the public authorities cooperate in conjunction with BIM and geographic information in the real property formation processes can achieve great effects in regard to the effectiveness of the involved real property formation authorities' decision making and may help to increase the involved parties' understanding of the real property formation decisions. We recommend that the national and municipal property formation authorities continue to develop the processes and recommendations for 3D property formation shown in this project. There is a demand in today's real property formation process to be able to work in a BIM based process, even if the documentation on which the decisions are based in a transition period still will have to be based on 2D drawings.

Further research will involve carrying out practical tests according to specifications identified from the project, focusing on visualization of 3D property. The proposed model for digitization and visualization of 3D property formation will then be tested in a test bed environment, using a pilot case from the Stockholm area to see how it could work in practice.

BIM and 3D Property Visualisation (9367)
Martin Andrée, Jesper Paasch, Jenny Paulsson and Stefan Seipel (Sweden)

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Istanbul, Turkey, May 6–11, 2018

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http://www.smartbuilt.se/in-english/

BIOGRAPHICAL NOTES

Martin Andrée is a senior advisor in cadastral procedures at the Swedish Land Survey and has 16 years of experience in business development within the Swedish Land Survey. He holds a MSc in GIS and has experience from both local and national government and international development work. He is a national delegate to FIG Commission 10.

Jesper M. Paasch is a senior lecturer/associate professor in land management at the University of Gävle, Sweden, and coordinator of research in geographic information at Lantmäteriet, the Swedish mapping, cadastral and land registration authority. He has been

BIM and 3D Property Visualisation (9367)
Martin Andrée, Jesper Paasch, Jenny Paulsson and Stefan Seipel (Sweden)

FIG Congress 2018
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Istanbul, Turkey, May 6–11, 2018

working with standardization, cadastre and geographic information at Lantmäteriet for almost three decades. He is a national delegate to FIG Commission 3 and member of the FIG Joint Commission 3 and 7 Working Group on „3D-Cadastres".

Jenny Paulsson is an Associate Professor at the Department of Real Estate and Construction Management of the KTH Royal Institute of Technology, Stockholm, Sweden. She holds a MSc degree in Surveying and a PhD degree in Real Estate Planning, both from the KTH Royal Institute of Technology. Her PhD thesis concerned 3D property rights. She is a member of the FIG joint commission 3 and 7 working group on „3D-Cadastres".

Stefan Seipel is a professor of computer graphics and visualization at Uppsala University and University of Gävle, where he is heading the research group in geospatial information science. His present research is in developing and evaluating interactive and visual technologies for efficient presentation of geo-spatial data.

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BIM and 3D Property Visualisation (9367)
Martin Andrée, Jesper Paasch, Jenny Paulsson and Stefan Seipel (Sweden)

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Istanbul, Turkey, May 6–11, 2018

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