# Conversion of 2D Analogue Cadastral Boundary Plans into 3D Digital Information – problems and challenges illustrated by a Swedish case

**Karolina LARSSON, Jesper PAASCH and Jenny PAULSSON, Sweden**

**Key words**: 3D cadastre, legislation, visualization, data collection, RRR.

## SUMMARY

The possibility of forming 3D property units has not existed for a long time in Sweden. The legislation was introduced in 2004 and in 2009 the addition of apartment ownership (condominium) was added. Even though the demand for 3D property formation has not been as high yet as initially expected, there seems to be an increased interest in and demand for it today. The use of 3D property creates a need for 3D registration and visualization of the property units, which can involve difficulties in e.g. representation and storage of 3D real property data, such as the legal boundaries and real property rights connected to the property.
However, even if 3D digital information is used in the real property formation process the 3D properties are still registered using two–dimensional documentation. An ongoing study, which is a part of a project testing 3D data, see Andree et al. (2018a; 2018b) and Tarandi (2017), is focusing on visualization of 3D cadastral boundaries.
This paper discusses problems and challenges concerning the conversion of 2D analogue cadastral boundary plans into 3D digital information and is based on experiences being gained in a research project on visualization of 3D property boundaries in Sweden, see Andree et al. (2018a; 2018b). A newly constructed sports– and event arena in Stockholm where 3D properties are involved is used as a case study in the project to illustrate the process and the problems related to it. Focus lies here on legal issues, although other aspects will be mentioned as well.
The legal foundations for 3D property formation in Sweden are primarily the Swedish Land Code (SFS, 1970:944) and the Real Property Formation Act (SFS, 1970:988). The rights, restrictions and responsibilities, RRRs, are registered in the national Real Property Register, which also includes registration in the two–dimensional digital cadastral index map.
A description of the process of forming 3D property is included in the paper regarding the documents and parties involved. In the present cadastral processes concerning new 3D property formation a CAD drawing containing 3D real property boundaries is often supplied by the developer/entrepreneur. However, the 3D cadastral representation and the documentation in the cadastral dossier is recorded in 2D (El–Mekawy, Paasch and Paulsson, 2014). The CAD file may – or may not - be archived for future use by the Cadastral authority. We therefore sometimes may have to interpret two–dimensional data and convert it to be used in a 3D environment, e.g. BIM. This paper illustrates and exemplifies with some experiences of interpreting the cadastral dossiers for presentation in a 3D digital environment.
Current legislation has to be investigated and interpreted to be able to add or transform into using 3D models as part of cadastral decisions in Sweden. New regulations also may have to be introduced and analysed. In this paper some of the legal issues that need to be addressed

are mentioned, however more work needs to be done in order to get answers to what changes may be needed regarding legislation on this matter.

## SUMMARY (Swedish)

I detta paper diskuteras problem och utmaningar rörande konvertering av 2D analoga registerkartor till 3D digital information och bygger på erfarenheter från ett forskningsprojekt om visualisering av 3D-fastighetsgränser i Sverige. Att kunna konvertera registerkartan till 3D innebär att omvandla befintliga data till 3D, men också att ta fram nya processer för att inkludera 3D digital information i framtida fastighetsbildningsbeslut. En nybyggd sport- och evenemangsarena i Stockholm där 3D-fastigheter ingår används som fallstudie i projektet för att illustrera processen och relaterade problem. Fokus ligger här på juridiska frågor, även om andra aspekter också tas upp.
Studien visade att det skulle vara mer kostnadseffektivt att registrera 3D-gränser och volymer på den nationella registerkartan med hjälp av byggnadsplaner som visar invändiga väggar, balkar och andra detaljer som är föremål för 3D-fastighetsbildning. Nuvarande lagstiftning måste utredas och tolkas för att kunna lägga till eller övergå till att använda 3D-modeller som en del av förrättningsbeslut i Sverige. Nya regler kan också behöva införas och analyseras. I detta paper nämns några av de rättsliga problem som behöver åtgärdas, men mer arbete krävs för att få svar på vilka förändringar som skulle kunna behövas vad gäller lagstiftningen på området.

# Conversion of 2D Analogue Cadastral Boundary Plans into 3D Digital Information – problems and challenges illustrated by a Swedish case

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## 1. INTRODUCTION

The possibility of forming 3D property units and rights, restrictions and responsibilities, RRRs, in Sweden has only existed for 14 years. The concept of 3D property was introduced in the Swedish Land Code in 2004 and in 2009 the addition of apartment (condominium) ownership was added (SFS (1970:944)). Even though the demand for 3D property formation has not been as high yet as initially expected, there seems to be an increased interest today, based on national property formation statistics during the last 8 years, see e.g. Lantmäteriet (2012; 2018). Thus, the increased use of 3D property creates a need for 3D registration and visualization of the property units, which can involve difficulties in e.g. representation and storage of 3D real property data, such as the legal boundaries and real property rights connected to the property.

Digital building plans supplied by the entrepreneurs to the cadastral authorities are often used in the 3D property formation process and used as input for 2D analogue cadastral boundary plans. So, digital information on 3D boundaries exist, but this information is not stored in the national cadastral index map or in other centralised registers. Local cadastral authority offices may store the building plans they use in the formation process, but there is no national tradition or guidelines for doing so and the digital information is not part of the legal documents for property formation decisions.

### 1.1 Problem description

Digital buildings plans are often used in the 3D property formation process. However, even if 3D digital information is used in the real property formation process the 3D properties are still registered using two–dimensional documentation.

Drawings of 3D property units and surrounding building constructions are stored in the cadastral dossier as two–dimensional drawings. It is therefore necessary to interpret two-dimensional data and convert it to be used in a 3D environment, e.g. BIM. This paper illustrates and exemplifies with some experiences of interpreting the cadastral dossiers for presentation in a 3D digital environment.

The digital index map today is in 2D with many existing registered boundaries of properties as well as easements and other rights with poor accuracy. The information seen today is a result of different conversions of older both analogue and digital material as well as more recent digital additions. In areas with a lot of boundaries and RRRs the digital index map is hard or close to impossible to interpret. In addition, representation of existing detailed plans and other regulations can have major errors in regards of actual location compared to what is

shown on the index map as well as differing a lot in age resulting in different accuracy depending on the original legal document.

As of today, there are no regulations or recommendations regarding what information should be submitted or how drawings etc. should be designed within cadastral procedures.

### 1.2 Aim

This paper discusses problems and challenges concerning the conversion of 2D analogue cadastral boundary plans into 3D digital information and is based on experiences being gained in a research project on visualization of 3D property boundaries in Sweden, see Andree et al. (2018a; 2018b). Being able to convert the cadastral index map into 3D includes transforming existing data into 3D, but also finding new processes for including 3D digital information in future property formation decisions. A newly constructed sports– and event arena in Stockholm with 3D property units and RRRs is used as a case study in the project to illustrate the process and the problems related to it. Focus lies here on legal issues, although other aspects will be mentioned as well.

## 2. SMART BUILT ENVIRONMENT PROJECTS

'Smart Built Environment' SBE, is a national strategic innovation program initiated by the Swedish government in cooperation with the private urban land development sector. SBE is financed by Swedish research agencies (Formas, Vinnova and the Swedish Energy Agency) and the participating companies and authorities. SBE focuses on a number of issues, such as new opportunities of digitalisation, sustainable cities and resource management. Several studies and projects are being conducted within the program.[1]

A study within SBE is the finished project 'Information for planning, real property formation and building permission'. The project consisted of five working groups looking at possibilities to better use 3D models and other 3D data throughout the different stages of the planning and building process; idea, detailed planning, property formation, building permits and management. The working group 'BIM for 3D property formation' (hereafter referred to as '3D–BIM working group') found three major fields that need further investigation in order to be able to transfer from analogue 2D maps to a 3D cadastre; the legal matters, the financial aspects and the technical matters in form of data conversion and visualization (Andrée et al., 2018b). Financing for both investigations, implementation and management of a 3D system needs to be solved, but is not discussed in this paper. Legal and technical aspects will however be reviewed further. The project resulted in several new projects within SBE that have or will be started, focusing on the issues that emerged to need further investigation, including legal and technical aspects for the different stages of the planning and building process.

[1] See *http://www.smartbuilt.se/in-english/* Accessed August 18 2018.

Another study within SBE is the ongoing 'Smart planning, construction and management processes throughout the life cycle', which is a part of a project on visualization of 3D data (Andrée et al., 2018a; 2018b) and Tarandi (2017), is focusing on visualization of 3D cadastral boundaries. Findings from the study will be discussed further in this paper.

## 3. SWEDISH 3D PROPERTY SYSTEM

### 3.1 Property formation

The legal foundations for 3D property formation in Sweden are primarily the Swedish Land Code (SFS, 1970:944) and the Real Property Formation Act (SFS, 1970:988).

A traditional 2D property unit is delimited only horizontally with x and y coordinates and contains a volume extending in theory upwards into the sky and down to the centre of the earth, but in practice as much as the property owner can use. In densely–built areas, such as cities, often several different activities compete for the same space with the volume of the 2D property unit, see Figure 1. The instrument of 3D property formation is a good method for subdividing and thus separating the ownership to these different activities.

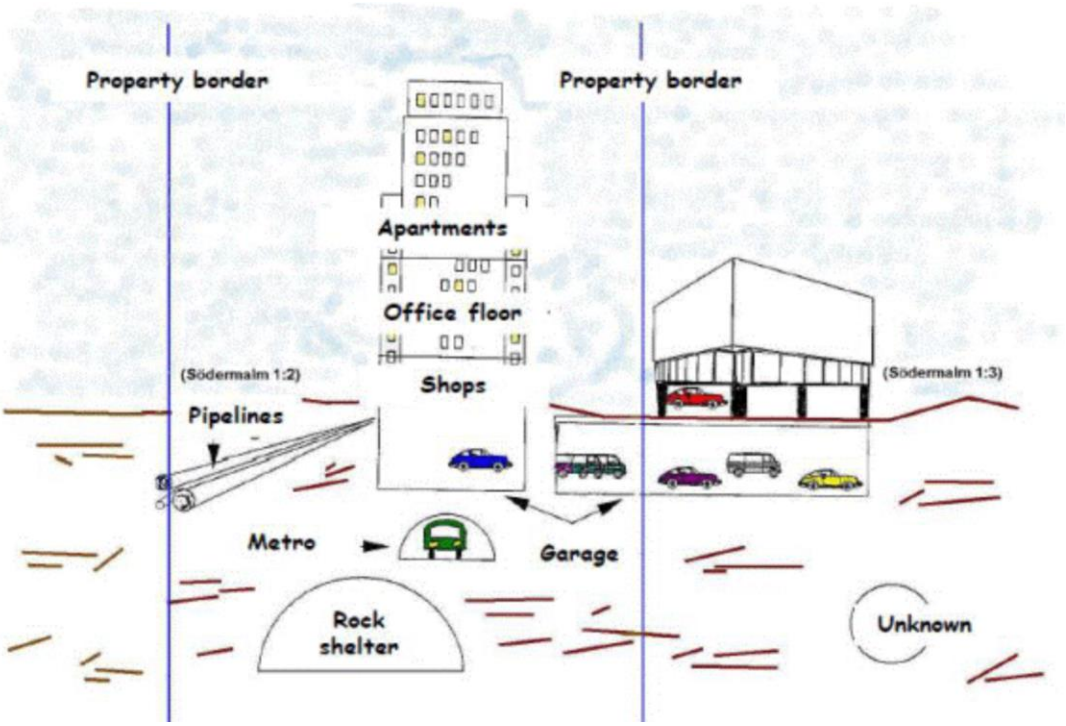


**Figure 1. Description of traditional real properties. Source: Lantmäteriet**

Three–dimensional properties are formed in the same way as the traditional 2D properties. The 3D property is considered as a property unit as all other property units and thus the same rules are applied, although some specific rules have been added for this type of property.

A 3D property is bounded both horizontally and vertically and is intended to accommodate a building, other facility or part thereof. The Swedish system, unlike other jurisdictions (see e.g. Paulsson, 2007), contains no specific legal rules for how to draw the cadastral boundaries in relation to the building construction. They will be situated where it is more suitable for each case. Although the boundaries shall follow the construction, there is a possibility to include also a small volume of air to include protruding construction details and for maintenance if deemed appropriate. However, this does not mean that the property can contain space for future building rights, such as adding another floor at a later stage. In such a case e.g. reallotment will have to take place, adding parts of the neighbouring property unit to the 3D property unit. There is a possibility to form 3D property for a not yet constructed building or facility, with the condition that it will be developed within a fixed amount of time. It is also possible to make preliminary decisions for the property formation, e.g. for undeveloped buildings, since it may be necessary to make adjustments when the construction is completed.

There are some conditions to follow when forming the 3D property unit, in addition to the need for a surrounding construction. It should be clear that no other types of property formation or property rights are a more suitable legal solution than forming a 3D property to achieve the desired purpose. There is a requirement to arrange and legally secure the necessary rights for the proper use of the property unit. It must be also be made clear that the measure is warranted with regard to the construction and use of the facility, as well as that the measure is intended to facilitate a more efficient management of the property or to ensure the financing or construction of the facility.

In case the 3D property unit is intended for residential purposes, it must comprise at least three residential apartments. Ownership apartments can only be formed in new production and in reconstruction projects where there has been no housing for the past eight years. In addition to these conditions, 3D property formation must always be carried out in accordance with applicable land use plans.

An application is made to the cadastral surveyor when a 3D property unit is to be formed. The cadastral surveyor will check the application against the legislation (e.g. the Swedish Land Code (SFS, 1970:944) and the Real Property Formation Act (SFS, 1970:988)), planning regulations, building permission, etc. In order to approve the application, there is often a need for the applicant to change certain details in the application. Regarding the location of boundaries, etc., the cadastral surveyor will together with the applicant find the most suitable solution for the specific case. The formation of the 3D property unit require that the horizontal and vertical boundaries are described both in writing and shown on maps and drawings, which also apply to boundaries for rights, restrictions and responsibilities. Today, the documents are mostly in paper format or frozen digital images, as well as the documents that are used as basis for the property formation decision, such as previous property formation decisions, planning regulations and building permissions (see e.g. El–Mekawy, Paasch and Paulsson, 2014). The developer/entrepreneur often provides CAD drawings containing the 3D real property boundaries.

## 3.2 Documentation and process today

When creating 3D property units within current Swedish cadastral legislation and process all boundaries are required to be presented both in a verbal description and shown on maps and drawings. The same applies to boundaries for RRRs. The land surveyor in charge of the cadastral procedure is responsible to check the application against current property formation legislation as well as planning regulations and building permits as applicable. The applicant provides the documents needed for the land surveyor to make the decisions. 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 as well as the detailed planning regulations and granted building applications, that are used as basis for the property formation decision. Decisions are registered in the digital index map and the cadastral dossiers are archived, see examples for ownership apartments in Figure 2.

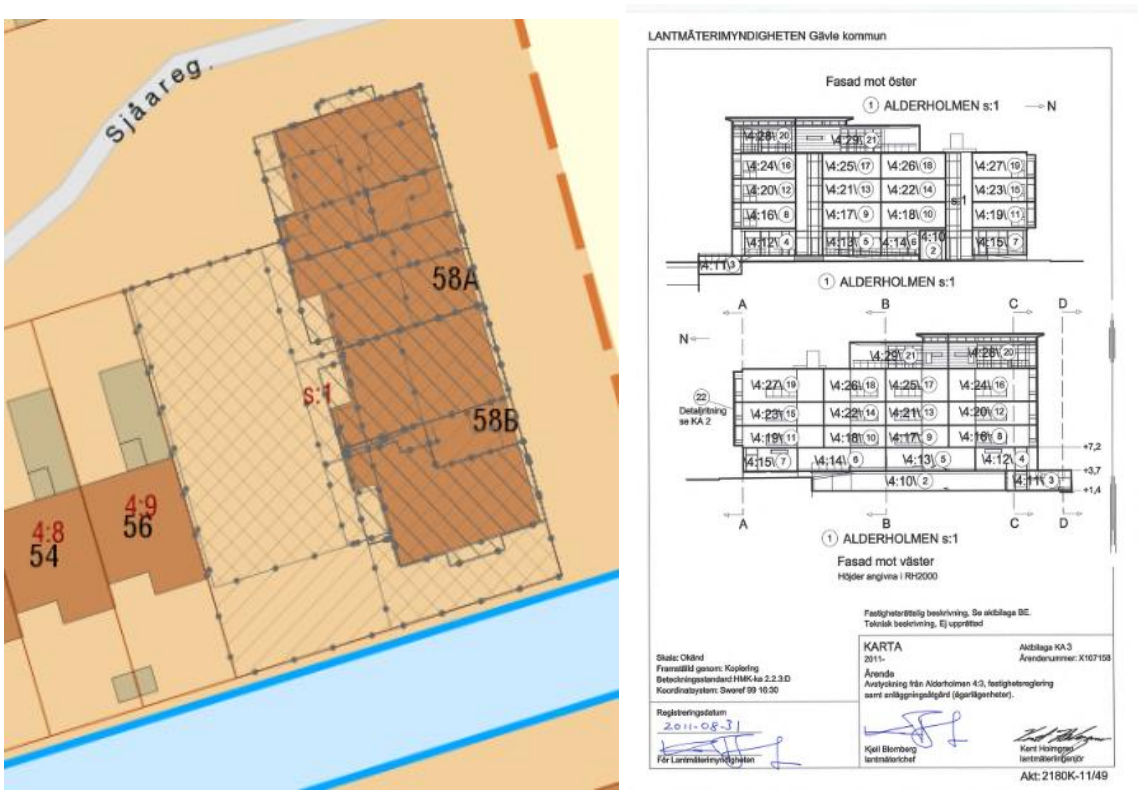


**Figure 2. Picture from the cadastral index map of ownership apartments (left) and cadastral plans of the same properties (right). Source: Lantmäteriet, digital cadastral index map and cadastral dossiers**

## 3.3 Property registration

2D and 3D real properties and numerous RRRs are registered in the national Real Property Register in accordance with the Real Property Register Code (SFS, 2000:224). The content of the register is regulated in the Real Property Register Ordinance (SFS, 2000:308). The register is continuously updated online and is regarded a cornerstone in Swedish land administration. The register consists of a textual part and the digital index map.

Swedish 3D property units are given unique registration numbers independent from the land parcel they are located upon or below in the case of subterranean objects, such as tunnels. The registration of 3D property units in the register is conducted in the same manner as traditional 2D property units. One specific difference in regard to 3D property and RRRs is that the boundaries of 3D property units and RRRs are either defined by x, y and z coordinates or defined by other types of description of the units or RRRs extent in the vertical dimension by referring to surrounding physical construction details on the construction drawing, whereas 2D property units and RRRs are defined by x and y coordinates. Detailed descriptions of boundaries, rights, restrictions and responsibilities are not registered in detail in the register, but a reference is given to the property formation dossier, which has a unique identifier.

The spatial extension is subject to quite rudimentary registration in the digital index map. Only the footprint of the 3D property unit is recorded together with the boundaries, see Figure 3.

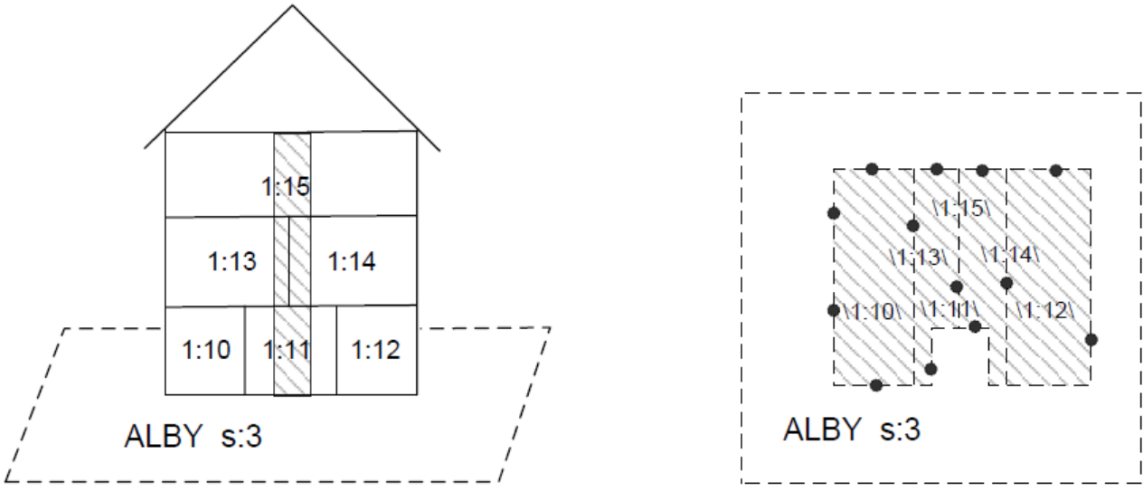


**Figure 3. Cross section of building containing 3D real property units (left) and its visualization on the digital cadastral index map (right) (Lantmäteriet, 2004, ch. 3, p. 33)**

Figure 4 shows an example of the textual registration of heights of 3D property in the register as the 3D property being located between level CA +23.6 meters and level CA +58.5 meters (El–Mekawy, Paasch and Paulsson, 2014, pp. 21–22).

Storlek: Utrymmet i horisontalplan är ca 6 kvm.
Höjd: Höjdläget är mellan CA+26,3 meter och CA+58,5 meter i RH00.
Urholkar: Solna Haga 4:20

**Figure 4. Example of textual 3D height information (in Swedish) in the textual part of the Real Property Register. (Based on El–Mekawy, Paasch and Paulsson, 2014, p. 22)**

The 3D property formation procedures often use existing 3D CAD drawings when provided by the entrepreneur. These CAD files may – or may not – be archived for future use by the cadastral authority. There is no general national system for archiving such files at the

cadastral authorities and different solutions exist. Analogue copies of the building plans may become part of the cadastral dossier showing the building and boundary details.

## 4. CASE STUDY

As part of the 3D–BIM working group a case study was conducted. The case study 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 dossiers of the cadastral authority and with height data provided by the city of Stockholm.

The study used an existing cadastral procedure, that was handled in the traditional manners, but parallel also handled with the basis of a hypothetical digital 3D cadastre and cadastral procedure using 3D models instead of analogue 2D paper drawings. The cadastral procedure was a reallotment transferring a three–dimensional space, containing part of a shopping mall, from one 2D real property unit to another 2D real property unit. Figure 5 below shows the drawings used in the traditional property formation dossier as well as visualization of the 3D model produced within the case study. The 3D model could in future property formation dossiers replace or be combined with the 2D drawings.

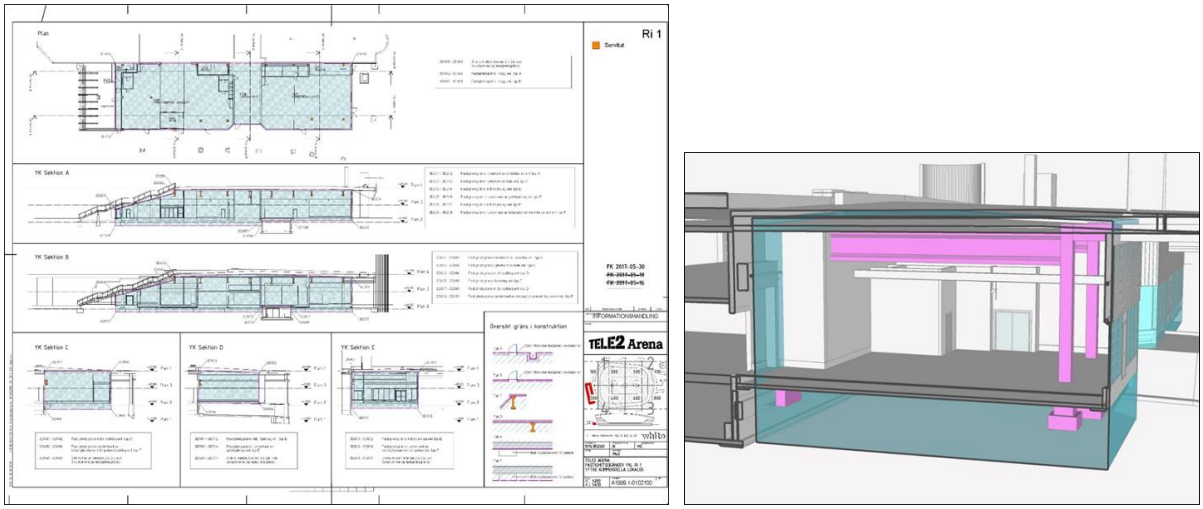


**Figure 5. Drawings as part of the actual property formation dossier (left) and possible future 3D information as part of property formation dossier (right) (Based on Andrée et al., 2018b)**

The case study showed both possibilities and challenges when comparing the process being used today with a possible future process including 3D cadastre for registration and 3D models as part of cadastral decisions and dossiers.

A major advantage of using 3D models as part of the cadastral dossiers and cadastre is of course that the information can be reused, without, as in present conditions, having to transform 2D drawings to new 3D models. Provided that the information is reliable, a 3D

registry index map can provide a clearer picture of land use within a particular area, which makes it easier for planning and management. This requires, however, that new information entered is correct, but also that older information is interpreted in a sufficiently correct way for the understanding to be sufficient. In addition to this, it has to be determined how information in the 3D registry index map and cadastral dossiers should be interpreted, for example, what accuracy different objects should have. When this has been decided it is important to make sure that all users understand that different objects in the 3D cadastre can have different accuracy, this is a major part of the need for good visualization.

The case study also discovered that the description of where a boundary is located might need to be revised. As of today, the boundary is described in a verbal description combined with drawings, often in scale 1:100-1:1000. For the reallotment in the case study one boundary was described as 'exterior of construction, windows are part of the 3D space' and the boundary was shown in a 2D drawing in scale 1:400. This did not show detailed information of mm precision, however, when creating the 3D model, the boundary line had to be placed somewhere more accurate, making the question as to where the boundary of the window should be placed more exactly (outside of glass, some air left outside the glass making a straight line between the window casings, etc.). The fact that incorrect data of current conditions had been used by the architect was discovered late in the process, this had probably been noticed much earlier if a digital 3D model and cadastre had been used. Visualization is discussed further down, including descriptive figures from the case study.

## 5. POSSIBLE FUTURE 3D CADASTRE

### 5.1 Legal and organizational aspects

The 3D–BIM working group did not look at the legal aspects of managing property formation using 3D models etc., but established that a review of existing Swedish property formation legislation is needed before it can be determined whether changes to current laws and regulations are necessary or not to enable further use of 3D digital data in the cadastral procedures. A new project within SBE will look deeper into the legal aspects of 3D digital information as part of authority decisions regarding property formation, planning and building permits. The 3D–BIM working group highlighted the need to investigate how to handle some legal aspects of using 3D digital data in the cadastral process.

In order to make cadastral decisions based on 3D digital information it needs to be determined what is the original data file, where it should be saved and who should have access to it. The system needs to ensure the quality and accuracy of the data as well as that the data cannot be manipulated. 3D data also tends to be big data, resulting in the need of finding a functional way to store the data.

Current cadastral legislation needs to be examined to determine whether a digital data file could have the same status as a paper document, or if changes need to me made to enable the use of 3D digital information. Another legal issue is that of copyright of 3D models, since

when you are submitting documents to an authority it normally becomes public. The status of digital data in this aspect needs to be investigated.

Contents from the digital index map in Sweden is more and more being published by third parties, without information to the users about accuracy etc. The need to get that information through to the users will be even more important if a 3D cadastre is used. It needs to be decided how to interpret a 3D model as part of a cadastral dossier and also how to interpret and visualize information in a 3D cadastre. Connected to this is the issue of how to interpret detailed planning regulations if they are transformed into 3D models. Today with 2D analogue detailed plans and cadastral maps there is a interpretation allowance depending on the scale of the document, will that disappear with 3D models, or can that still be included? If it disappears, what effects would that have? Either way it has to be described how to interpret the models and the users need to comprehend it. Of course, visualization will be of great importance for this.

Another aspect of transforming a 2D system, that might be more diffuse, to a 3D system, that could be more detailed, is that of classified information. Today, some drawings or a full cadastral dossier can be classified as confidential (i.e. not visible for all parties), and only part of the information may then be shown in the cadastral index map. Therefore, it needs to be determined how to handle this information within a future 3D cadastre that has the capacity of showing more details than a 2D cadastre. If the majority of the cadastre contains more detailed information the full content may be expected to have the same accuracy. This also applies to existing decisions of e.g. 3D properties and RRRs, as they never can be represented with the same accuracy as new decisions which are based on a reliable 3D model. How to resolve this needs to be investigated.

### 5.2 Possible future documentation and process

The 3D–BIM working group presents a vision for a future procedure where the applicant has access to a 3D model of the real property subject for change as well as regulations for the area in 3D data format. 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 should be stored via the 3D cadastre. If the applicant has a 3D model with more content than of cadastral information, only the section relevant for the 3D property formation should be submitted. In order to have a uniform and functional 3D cadastre a level of detail (LOD) and the information content for the 3D model need to be specified. The 3D–BIM working group prerequisites for this was to study the CoClass (a Swedish classification system)[2] and IFC (ISO, 16739:2013) standards.

### 5.3 Data collection and visualization

The registration of boundaries in the digital cadastral index map does not allow any detailed visualization of legal boundaries, as shown above. The index map is only used for overview illustrations of the cadastral boundaries and has no legal force. Data has therefore to be collected from the cadastral formation dossiers, consisting of 2D analogue cadastral boundary

[2] See https://coclass.byggtjanst.se/en/about#about-coclass Accessed August 18 2018.

plans and text–based descriptions. This information may not be easy to collect through digitalization due to difficulties to interpret some the plans and/or the describing text, for example that the RRR volume covers the existing room and the hallway. To interpret the analogue cadastral boundary plans in an effective way it is necessary to have access to detailed building plans and textual descriptions, which was not always the case in the study.

Some legal information, such as RRRs, without a specified location are represented in form of text on the conventional cadastral maps as they do not have any known spatial extent within the 2D plane. Within the 3D model, those objects are modelled as cylinders with some radius from the centre of the text label

The boundaries were in the case study of the 3D–BIM working group digitized partly with assistance of digital building plans showing outdoor and, however less frequent, indoor features. The result is a 3D digital index map of varying degrees of detail. Figure 6.1 shows RRRs and building footprints on the analogue cadastral index map, Figure 6.2 shows RRRs in 3D in relation to outside building features and Figure 6.3 shows RRRs in 3D with and without internal building features.

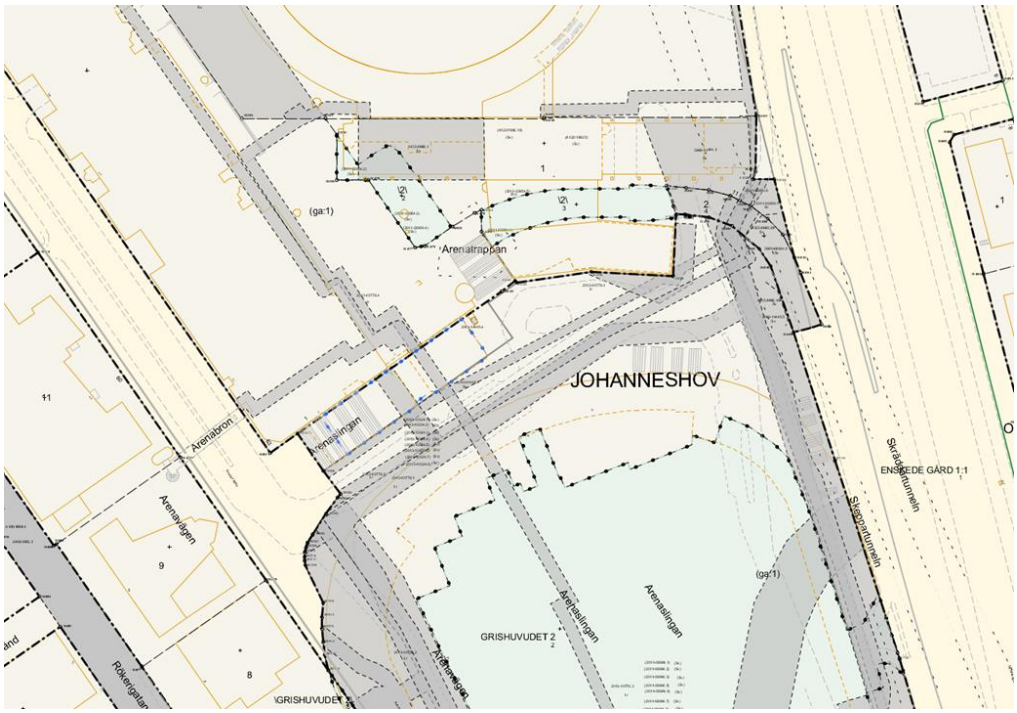


**Figure 6.1. Visualization on 2D analogue cadastral index map. Source: City of Stockholm, Cadastral Index Map**

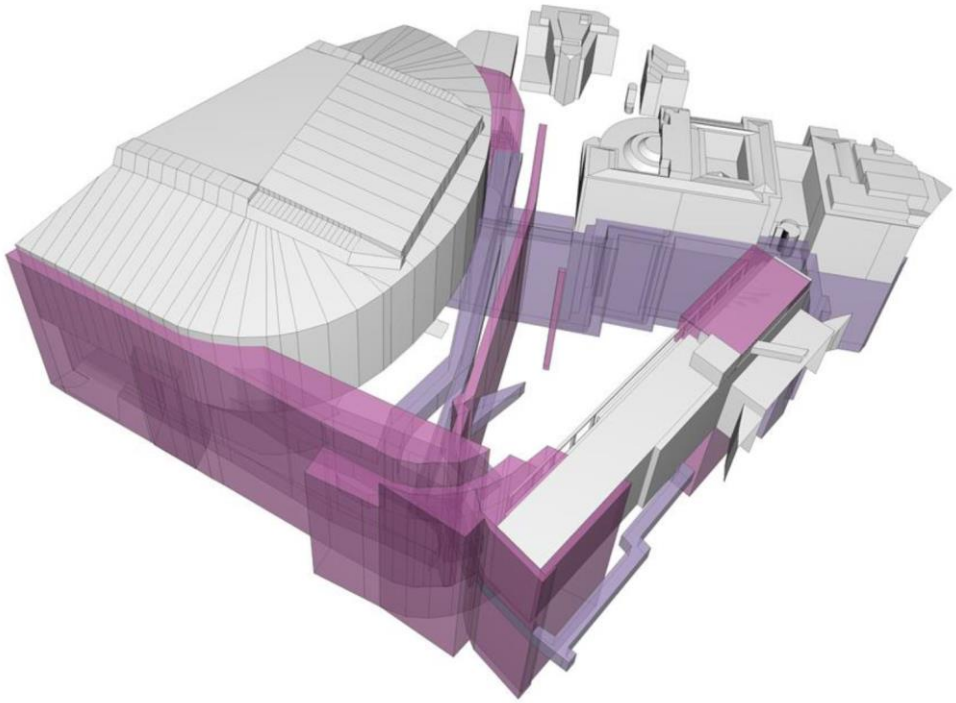

**Figure 6.2. 3D model of the RRRs and external building details (Andrée et al., 2018b, p. 44)**

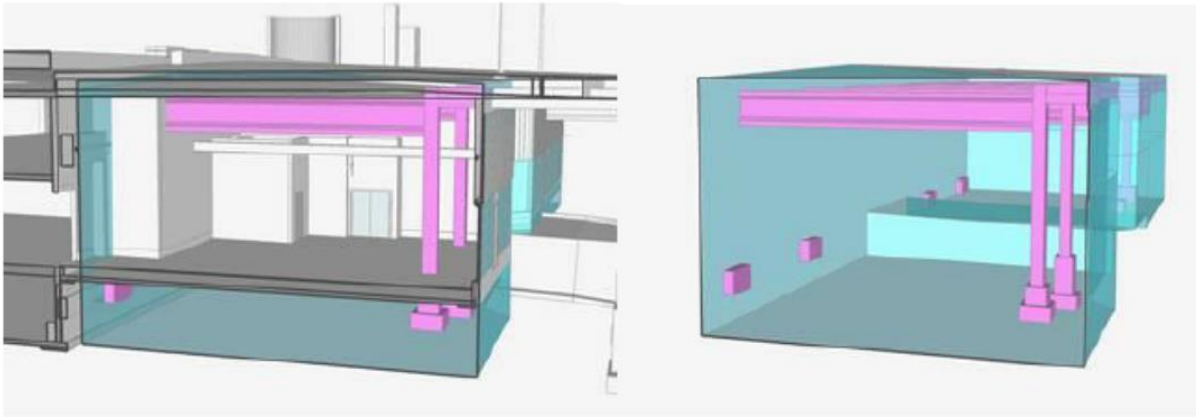

**Figure 6.3. Left: 3D property boundaries (in turquoise colour) and property rights (pink colour) and internal construction details (Andrée et al., 2018b, p. 46). Right: 3D property boundaries (in turquoise colour) and property rights (pink colour) without internal construction details (Andrée et al., 2018b, p. 46)**

Cadastral information has traditionally been displayed in 2D and visualization of 3D cadastral systems is still an emerging field, see Pouliot et al. (2018). This study has so far not been focusing on the legal aspects of visualization regarding interpretation of 3D information, even if they have been subject for discussions. The visualization has been challenging. Legal RRRs often, but not always, have the same outline as a construction detail, e.g. a wall. The boundary can be located inside or outside the wall and even pass through it. Therefore, both solid style rendering and transparent surfaces have been used for visualization, see Figures 7.1 and 7.2.

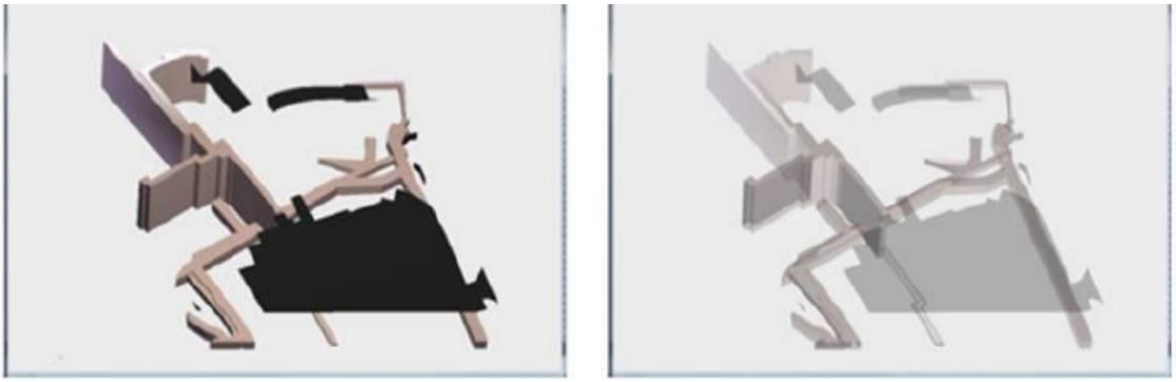

**Figure 7.1 Visualizations of legal RRR objects related to building details using solid style rendering (left) and transparent surfaces (right) (Andrée et al., 2018b, p. 47)**

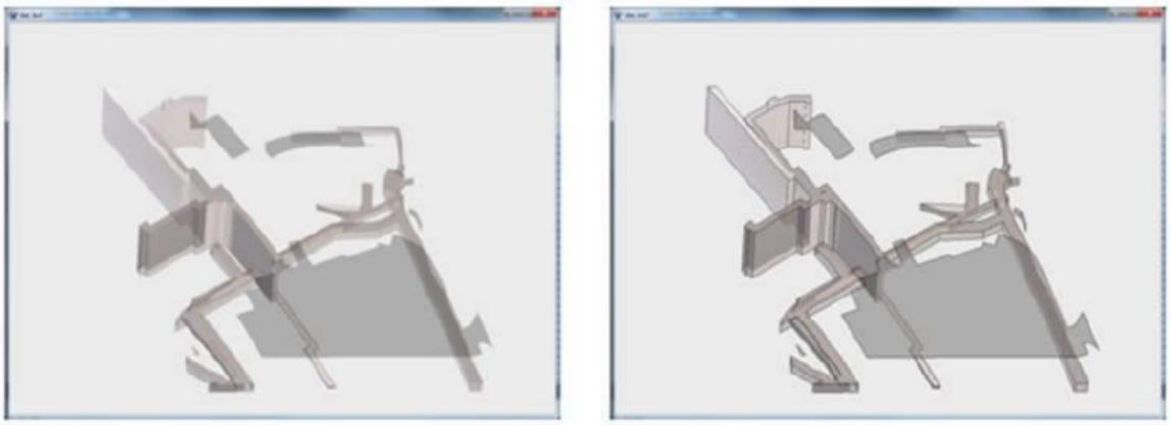

**Figure 7.2 Visualizations of legal RRR objects related to building details using transparent surfaces (left) and edge–enhanced transparent rendering for enhanced visual appearance (right) (Andrée et al., 2018b, p. 47)**

When cadastral boundaries are modelled in 3D from an existing BIM model, it is important to state the precision to which the boundary shall be true with a multitude number of architectural details, such as glass windows. A boundary can, for example, be exactly aligned with the window´s frame and glass, or be more simplified with more tolerance to allow for different construction details in the final building. A property boundary which is exactly specified will of course increase the risk of disagreement with the actual building, due to that building details may be implemented differently or added compared to building plan.

Apart from 3D boundaries, also RRRs can have limitations in heights that need to be interpreted if a full 3D cadastre is implemented.

## 6. PROBLEMS AND CHALLENGES

Even if 3D digital information is used in the real property formation process the 3D properties are still registered using two–dimensional documentation. This creates problems and challenges concerning the conversion of 2D analogue cadastral boundary plans into 3D digital information.

As mentioned, the cadastral process concerning new 3D property formation usually includes that the developer/entrepreneur supplies a CAD file containing 3D real property boundaries. However, the 3D cadastral representation and connected documentation in the cadastral dossier is still recorded in 2D (El–Mekawy, Paasch and Paulsson, 2014). It is not certain that the CAD file will be archived for future use by the cadastral authority, which means that it might be necessary to interpret the 2D data and convert it when it is to be used in a three-dimensional environment such as BIM.

The applicant can find it to be a challenge to illustrate the intended boundaries, rights, joint facilities, etc. in a comprehensible way for the involved property units. It can for example be difficult to accurately present a 3D volume only by using 2D drawings. At the same time, it is difficult to read and interpret a cadastral index map in 2D when the included properties and rights are determined in 3D. It will be even more difficult interpreting and converting the data when the 3D property formation is based on building drawings from the late 19th century where the boundaries are drawn by hand.

Since there are no standard requirements on how to present the data, concerning actuality, quality, 3D basis, etc., unclear documentation can lead to properties becoming unsuitable and disputes may arise. Data produced in varied design and quality can create difficulties in obtaining consistent decision and registry support. This can complicate both interpretation and future management, and leads to costly processes for property management.

The present registration of boundaries in the digital cadastral index map only involves overview illustrations of the boundaries and does not allow any detailed visualization of these boundaries. When collecting data from the 2D analogue cadastral boundary plans and text–based descriptions, it may be difficult to interpret some of these plans and/or the describing text. There are different ways of interpreting the information which has to be made equally clear to interpret from a 3D digital image.

Another difficulty involves the problems with that the digital index map containing many existing registered boundaries of properties as well as easements and other rights with poor accuracy. It will be difficult to discern and interpret all included information in such cases. There may also be major errors and various accuracy in regard of actual location in existing detailed plans and other regulations compared to what is shown in the index map, also depending on the original legal document.

The connection to the legal decisions and cadastral procedure is another challenge. One step is to convert all necessary parts of the cadastral map into 3D, but other steps are how to make all

decisions connected to and visible in the 3D digital information. There is a considerable amount of text related to the cadastral decision that is not present on the drawing and will not be possible to transfer to a digital image by digitalization and automatization.

In addition to the more technical and legal aspects, also economic issues have to be solved. The number of 3D real property units has been increasing ca 9 –13 % annually during the last three years and a total of 2270 units were registered in the Real Property Register on June 30 (Lantmäteriet, 2018). The costs for digitizing already existing 3D property units are therefore also expected to increase in the future if not new and more efficient ways of registration are implemented.

## 7. RECOMMENDATIONS

The study showed that it is not cost effective to register 3D boundaries after the property formation process is finished and the legal information is registered in 2D cadastral maps based on building plans and described in text. Sweden does not yet have a fully 3D digital cadastre, but if such a cadastre is to be developed it is recommended that 3D registration in a 3D cadastral index map is done in connection with the property formation process. Until then, the digital CAD files often used in the 3D property formation process today by the cadastral authorities are to be stored and used instead of 2D plans in order to avoid loss of legal information which may be difficult to interpret afterwards. The identification of the boundaries has in this study shown to be cost consuming.

A precondition for the above–mentioned recommendations is a political will and need in society to create a full 3D cadastre. This seems not to be the case in the near future since the existing technical and infological solutions are working well. However, the continuous digitalization of society, and for example the evolving concepts of smart cities, are in our view indications for the coming need for a better cadastre to meet the needs in a more digitized society. A society where the cadastre still plays a major role in land administration.

If a cost-effective digitalisation of existing 3D RRRs should be achieved the work has to be started sooner rather than later since the number of 3D units is constantly increasing.

## 8. CONCLUSIONS

This study has revealed some problems and challenges related to the conversion of 2D analogue cadastral boundary plans into 3D digital information.

The study indicated that it would be more cost–effective to register 3D boundaries and volumes in the national cadastral index map using indoor building plans showing internal walls, beams and other details being subject for 3D property formation.

Current legislation has to be investigated and interpreted to be able to add or transform into using 3D models as part of cadastral decisions in Sweden. New regulations also may have to be introduced and analysed. In this paper some of the legal issues that need to be addressed are mentioned, however more work needs to be done in order to get answers to what changes may be needed regarding legislation on this matter.

### 8.1 Future research

Further research in this matter is already ongoing in a project that will involve practical tests according to specifications identified and focusing on visualization of 3D property. A model for digitization and visualization of 3D property formation will be tested in a test bed environment, where the described case study will be used in order to see how it could work in practice. Additional cases should also be tested further on to capture different types of property situations and make sure that they can be included in the proposed recommendations.

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