# A BIM-based Approach for Swedish 3D Cadastral Management

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**Key words**: 3D Cadastre, cadastral management, Building Information Modelling, Information Delivery Manual

## SUMMARY

Currently, cadastral management in most countries is 2D-based by using a national land administration system. However, with the development of high-rise buildings and densification of built-up areas, the complexity of ownership spaces in multi-storey buildings pose challenges to the 2D index map. It is difficult to effectively represent, visualize and manage complex cadastral situations by a national land administration system that registers 3D property formation by 2D documentation and presents the legal property boundaries in 2D maps and verbal descriptions. Building Information Modelling (BIM) is a digital representation of a building in the life cycle phases from design through construction to operation and maintenance. BIM can be used as a physical model to integrate with a legal model for 3D cadastre visualization and as an efficient method to extend throughout the whole building development lifecycle for different actors to manage 3D cadastral information sustainably. Therefore, to handle these issues, we present an ongoing research project proposing a BIM-based approach for 3D cadastral management to share, exchange, store, standardize, visualize and manage 3D cadastral information legally and technically through and by all actors in the lifecycle phases. The Information Delivery Manual (IDM) as an international open standard developed by BuildingSMART can capture and specify processes and information flow during the lifecycle of a facility by bringing many different stakeholders together in a project-specific organization. In the project, we will use IDM to manage and improve the 3D cadastre efficiently and collaboratively with a Swedish case study in practice.

# A BIM-based Approach for Swedish 3D Cadastral Management

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## 1. INTRODUCTION

A cadastre is normally a 2D parcel based, and up-to-date land information system containing property unit information (e.g. rights, restrictions and responsibilities) (FIG 1995). To make efficient use of, foremost urban, space, several countries have introduced 3D cadastre. 3D cadastre is an important step towards management of an unbroken digital chain of data that spans a building's lifecycle, from planning, to development, construction, use and facility management, and demolition and recycling. The difference is that a 3D real property is bounded both horizontally and vertically, making it a closed 3D volume. 3D property formation is an effective method for subdividing and separating the ownership of different activities related to the same ground parcel in densely-built areas, e.g. in cities (FIG 2018). The introduction of 3D property in Sweden has been a tool to increase the possibilities of constructing and financing often large and more complex facilities, create more secure and clear ways of constructing e.g. infrastructure objects, as well as facilitate the management of this property (Paulsson 2013).

There have been proposals of using digital object based information to register and visualize 3D cadastre in Sweden. Andrée et al. (2018) has proposed a methodology for using building information models (BIM) and city models for the representation and visualization of 3D cadastre. However, one of the main issues is how the digital information should be shared between the main stakeholders in the 3D cadastre formation and management process; such as Lantmäteriet (the Swedish mapping, cadastral and land registration authority), property developers, AEC (Architecture, Engineering & Construction) companies, and property owners. A second issue is what would motivate the stakeholders to share the information. Lantmäteriet has recommended the Swedish Government to modernize the legal statutes for real property registration to facilitate a smooth transfer from today's handling of information to an information infrastructure of tomorrow. It must in all situations be possible to recreate a decision consisting of digital information structured in a database. This requires good routines for versioning and e-archiving – not only digital documents, but even geodata and BIM-models, which are part of the basis for decisions. (Lantmäteriet 2019).

This paper will present an ongoing research project that aims to develop and evaluate a new approach to manage 3D cadastre. There are currently shortcomings in both registrations and visualization of 3D property units (since it is based on textual descriptions and 2D maps), which need to be resolved. A key issue to resolve these shortcomings is the sharing of digital information. In this project, we aim to develop a process model that describes which information that needs to be sent between the stakeholders and how this information is linked to the information model standards used. The project also aims to study what motivates the stakeholders to share information.

## 2. BACKGROUND

### 2.1 International 3D cadastral management

There are many international activities related to registration and visualization of 3D cadastre, see e.g. Oosterom (2018). Some examples are: The Netherlands utilizes 3D PDF with legal and boundary descriptions to register as a legal document in the Dutch property register (Stoter et al. 2016). In Australia, Victoria, the municipality has been developing a digital model - ePlan Victoria - to modernize the Australian cadastre to support the digital 3D cadastre that should enable the interested community to identify the location and extent of all RRRs related to land and real property (Atazadeh et al. 2017). In Shenzhen, China, a 3D cadastral management prototype has been developed to visualize 3D property formation (Li et al. 2016). The Danish municipality and a company have started to manage the Danish Cadastre in a digital context. However, those researchers and developers are facing the same issues as in Sweden, and there is no established technique for the registration and visualization of 3D cadastre.

What is lacking in many of the international examples is a good structure for sharing digital information between stakeholders. Oldfield et al. (2017) proposed a collaborative process with IDM in order to look at how data could be obtained from BIMs for input into a 3D cadastre. One research project in Victoria, Australia, has proposed a BIM-driven building subdivision workflow in IFC standard for sharing and exchanging information related to subdivision actors and documents (Olfat et al. 2019).

### 2.2 Swedish 3D cadastral management

In Sweden, *Smart Built Environment*, initiated by the government in cooperation with the private urban land development sector, aims to facilitate digitalization of the urban land development process and support new possibilities and business models in the entire sector. Some related projects within the research platform have been studied.

In a study by El-Mekawy, Paulsson and Paasch (2015), problems and solutions concerning interaction between BIM and the registration and visualization of legal 3D property information were discussed. It described how interaction between BIM and 3D property domains can serve the needs for effective information handling by e.g. using BIM as input in the 3D cadastral formation process.

The Smart Built Environment project DigSam – digital community-building process has among other aspects studied legal aspects of storage of 3D Geodata / BIM models. The study identified legal barriers that slow down digitalization, such as filing issues, quality deficiencies in digital information and lack of cooperation between the different actors (Andreé et al. 2019).

In another study, Sun et al. (2019b) has integrated BIM and city models (in CityGML 3.0 format) with cadastral information stored in LADM. The basic idea was that BIM was used for registration of the 3D property units, while the city models were used for the visualization, i.e. as a base for creating a 3D cadastral index map. One important aspect that was shown in that

study was the possibility to link information in BIM (IFC), city models (CityGML 3.0) and cadastral information system (LADM). That is fundamental for facilitating the stakeholders for sharing information, for example between municipality surveying units (owning the city model), the AEC companies (owning the BIM-model) and the cadastral units in municipalities or on national level (owning the cadastral information). However, that study did not address the issues of how the information should be shared in the process and what would motivate the actors to share the information.

The Smart Planning Project (*Smart Planering för Byggande*) within the Smart Built Environment is 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 study has focused on BIM for 3D property formation and pointed out three major fields in need of further investigation in the process of transferring from analogue 2D maps to a digital 3D cadastre, and these are the legal matters, the financial aspects, and the technical matters in form of data conversion and visualization (Andreé et al. 2019, Larsson et al. 2020). By using a case study, the project identified possibilities and challenges when comparing the current cadastral process (Figure 1) with a possible future process (Figure 2) with a fully digital 3D cadastre for registration where 3D models are part of cadastral decisions and dossiers. It was recommended by the study that there should be a continued development of the work process and recommendations for 3D property formation based on the results of the project.

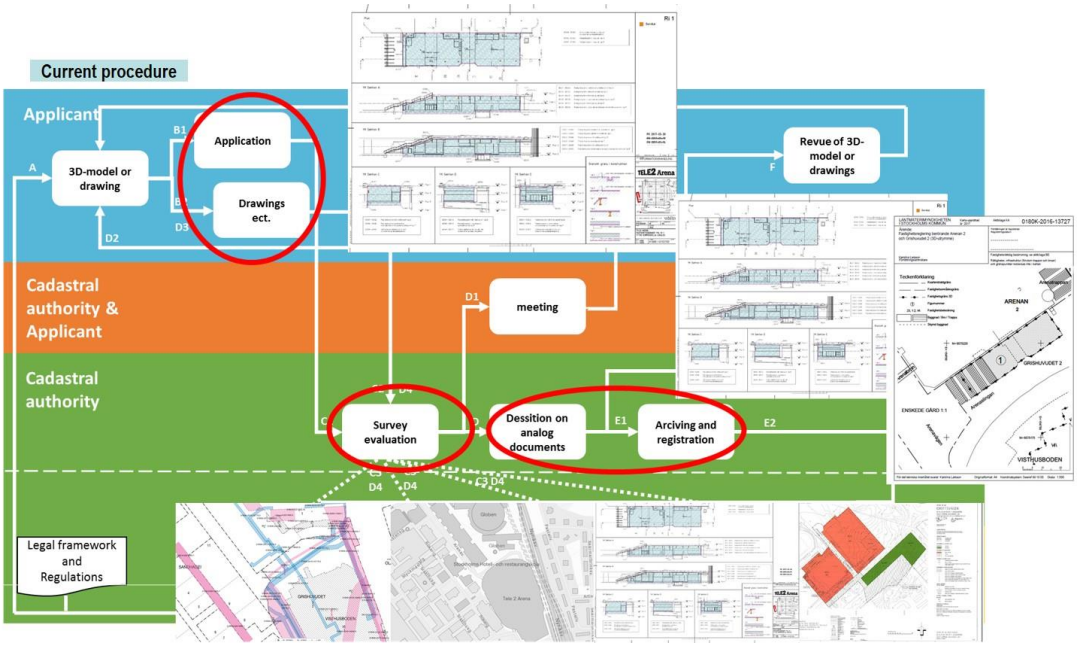


Figure 1. Current 3D real property formation process in Sweden (based on Andrée et al., 2018).

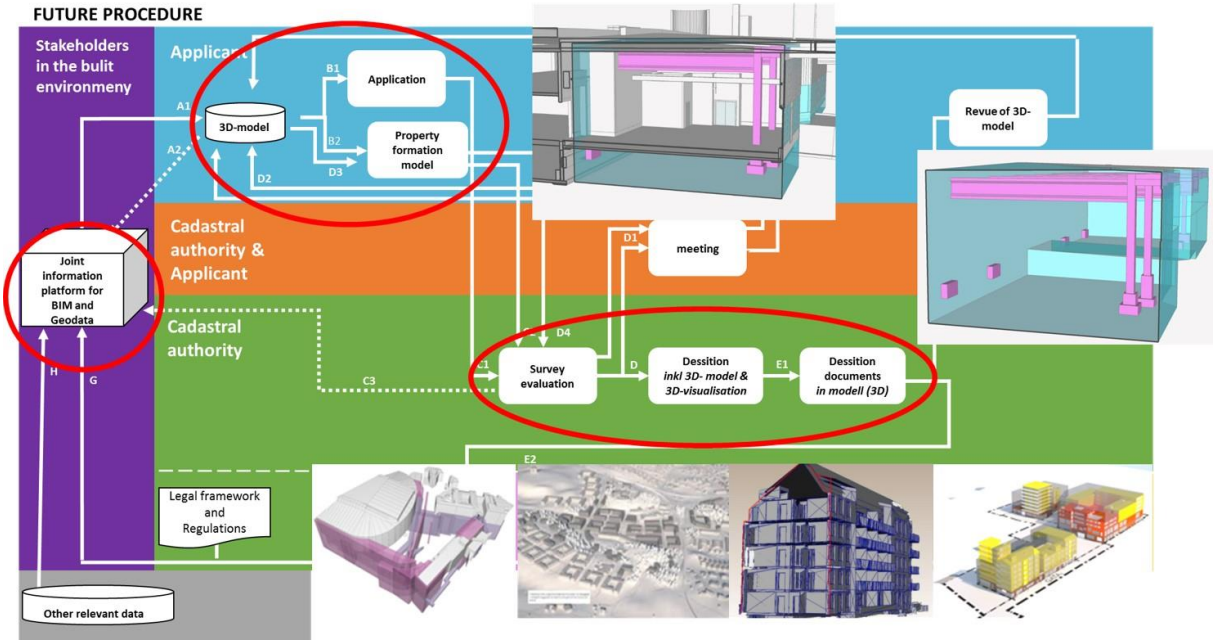


Figure 2. A possible future 3D property formation process (based on Andrée et al. 2018).

### 2.3 Standards for legal and physical models

#### 2.3.1 LADM as legal models

The international standard Land Administration Domain Model (LADM) is used for representing the legal cadastral information and for describing 3D properties (ISO 2012). In order to visualize and manage 3D cadastre, the legal model LADM could be integrated with physical models such as Building Information Models and City Models (El–Mekawy et al. 2014, Góźdź et al. 2014, Sun et al. 2019). However, there are several challenges to represent the actual extent of complicated 3D property units, identify the cadastral boundaries accurately, visualize complex buildings detailed and sustainably manage 3D cadastral information.

#### 2.3.2 BIM as physical models

A Building Information Modelling (BIM) is a digital representation of a building in the life cycle phases from design through construction to operation and maintenance (Eastman et al. 2011). BIM can be used as a physical model to integrate with the legal model/cadastral information to identify 3D property and visualize 3D cadastre (El–Mekawy et al. 2014, Atazadeh et al. 2017, Sun et al. 2019). Moreover, BIM is a process and technology of creating, exchanging, using and maintaining building information. In other words, BIM can extend throughout the whole building development lifecycle and provide powerful functions for owners, managers, designers, engineers and contractors, which can act as an efficient method to manage 3D cadastral information sustainably (Olfat et al. 2019, Andrée et al. 2018).

BuildingSMART has developed international open standards for the building industry worldwide, Industry Foundation Classes (IFC), International Framework for Dictionaries (IFD), and Information Delivery Manual (IDM)/Model View Definitions (MVD) (see Figure 3). These open standards for BIM specify the terminology, identify the process, and enable digital storage for interoperability. IFC can exchange and share information among software applications by many different stakeholders (Borrmann et al. 2018).

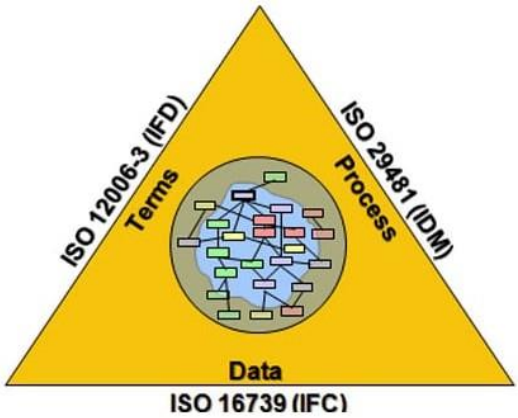


Figure 3. Open BIM standards: IFD, IFC, IDM (buildingSMART, 2019)

### 2.3.3 IDM as process models

IDM is a formal process for actors to know which and when different kinds of information have to be communicated. The IDM standard captures and specifies processes and information flow during the lifecycle of a facility by bringing many different stakeholders together in a project-specific organization (ISO 2010). In other words, it helps all actors know when and which kinds of data need to be delivered and stored, as well as improves the management more efficiently and collaboratively.

For IDM, the *Business Process Modelling Notation* (BPMN) is the preferred notation for process model development that considered and adapted appropriate ideas from a number of prior developments, including UML Activity Diagram (IDM 2007). Olfat et al. (2019) has introduced the current workflow for building subdivisions in Victoria with IDM, including four major phases: design, planning, construction, and registration (Figure 4).

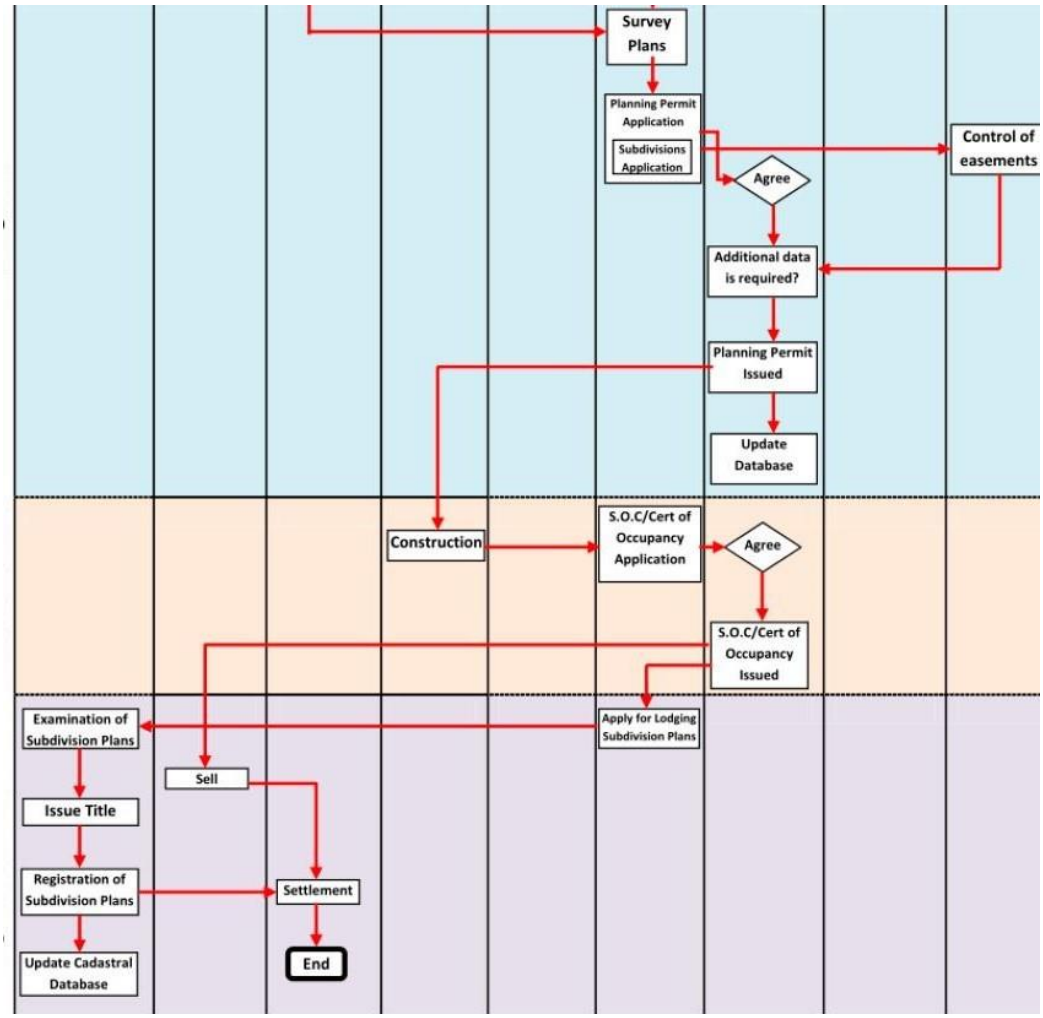


Figure 4: Current building subdivision workflow in Victoria (Olfat et al. 2019).

## 3. REQUIREMENTS FOR SWEDISH 3D CADASTRAL MANAGEMENT

Generally, the requirements for Swedish 3D cadastral management depend on legal and technical perspectives. Sun et al. (2019b) has proposed six topics, illustrated by a Swedish case study:

a. Organizational perspectives
b. Legal perspectives
c. Coordinate reference system and height system
d. Data standards
e. Geometry
f. Users and user requirements

By conforming to these requirements, 3D cadastral management should be possible working in a sharing and sustainable environment with independent and standard data, including cadastral

dossiers, geodata and BIM data. In addition, the motivation for all actors involved in the 3D cadastral process must be considered in order to reduce possible risks between private sector actors and public sector actors. For example, in a typically digital information flow between phases in the planning and building process in Sweden (see Figure 5), how to manage the 3D property formation process? How to increase the total market value? How to monitor progress in exchange of cadastral information between private sector actors and public sector actors?

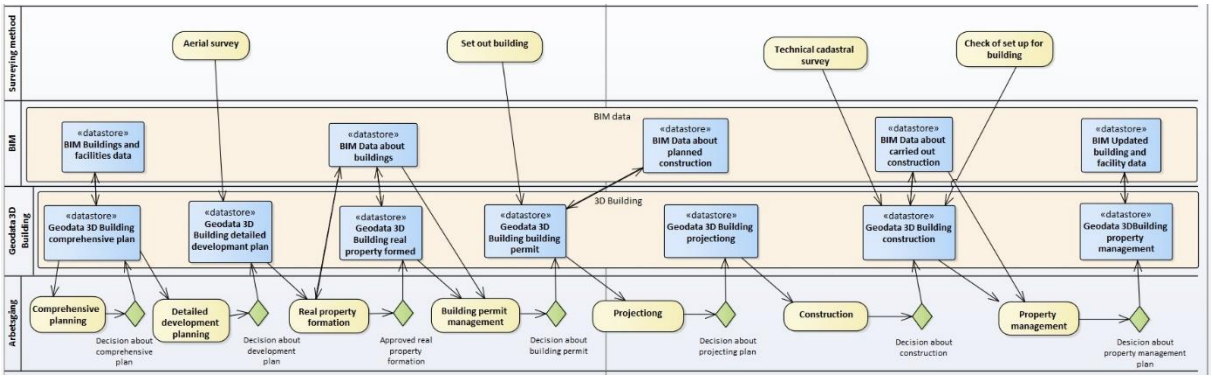


Figure 5. Digital information flow between phases (Sun et al. 2018).

## 4. TEST CASE

### 4.1 Test Data

Multihuset is a newly built multistore building in Malmö, Sweden. In Multihuset, there are two property units Bryggan 1 and Bryggan 2 divided by the property boundaries through the building. Figure 6 shows the index map of Multihuset (left) and its IFC model with the specified property boundaries (right).

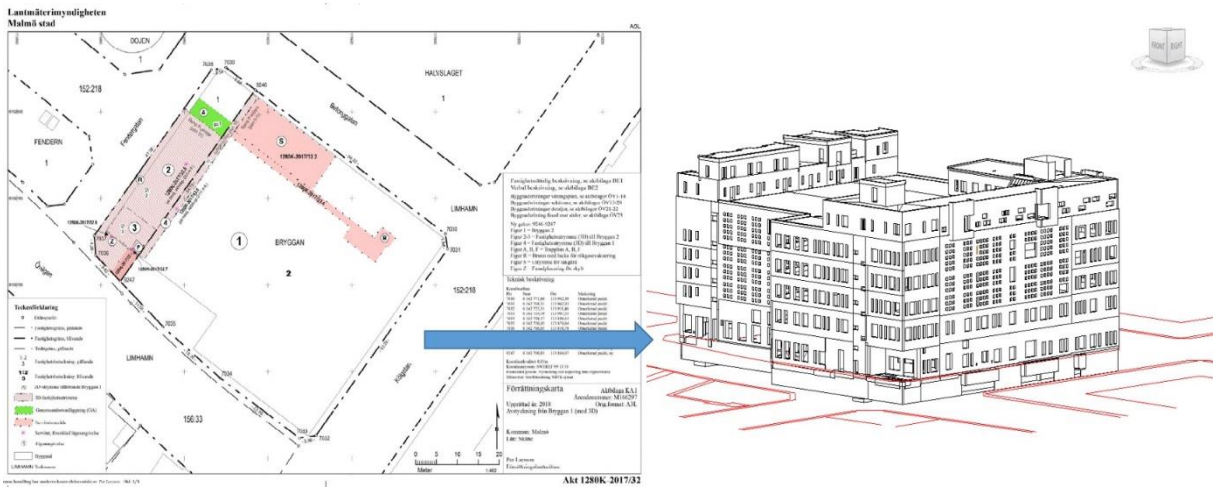


Figure 6. The index map of Multihuset, Malmö, Sweden (Source: Malmö stad, left) and its IFC model with specified property boundaries (IFC model source: NCC Company, right).

### 4.2 Test IDM Process

According to the proposed method and current Swedish digital information workflow, we have introduced a test IDM process for Swedish 3D cadastral management in lifecycle phases that include plan phase, real property formation phase, building permit phase, design phase, construction phase and property management phase. See Figure 6 below.

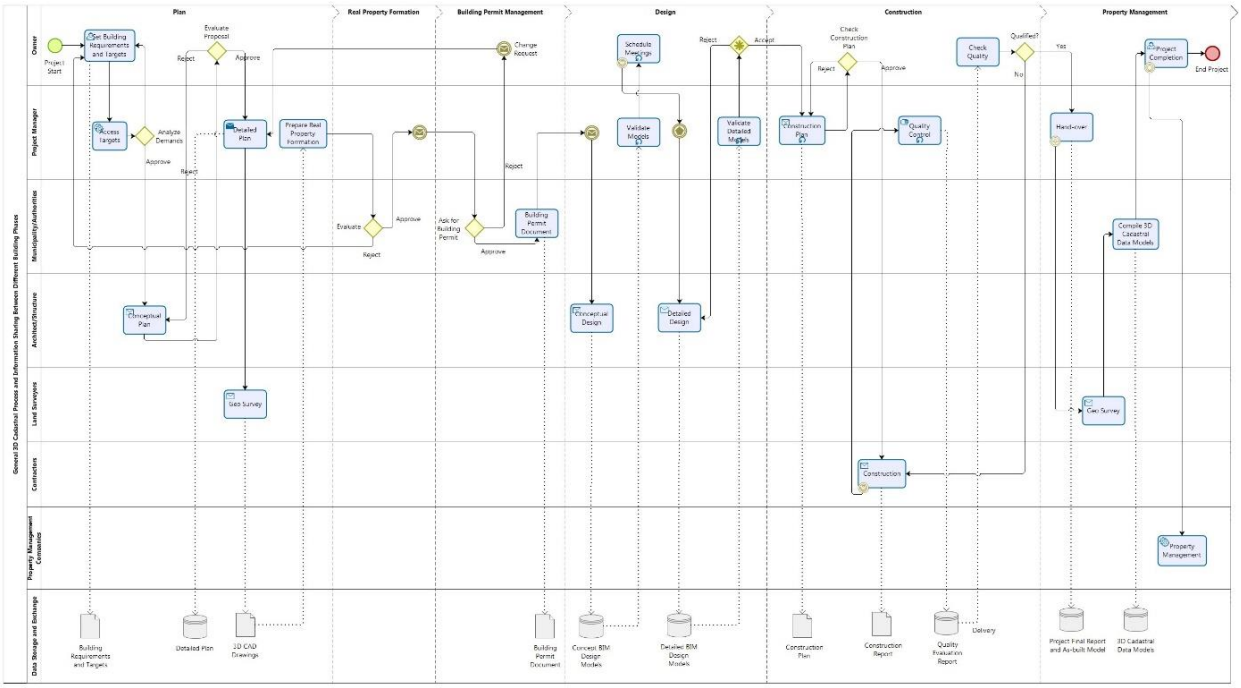


Figure 7. Test IDM Process for Swedish 3D cadastral management in lifecycle phases.

Through the IDM process, we aim to improve:

- Process description of cadastral information exchange between stakeholders;
- Standards: ensuring that definitions, specifications and descriptions in the information exchange are following international standards;
- The geometry description of 3D property units using BIM;
- The visualization of the 3D cadastral information (using e.g. 3D cadastral index maps);
- Knowledge about what motivates the actors to share cadastral information. Especially, what could be done to better motivate the stakeholders to share information for a common good.

## 5. CONCLUSIONS

In this paper, we have provided an overview of current 3D cadastral management internationally and in Sweden. We have presented an ongoing research project proposing a BIM-based approach for 3D cadastral management to share, exchange, store, standardize, visualize and manage 3D cadastral information legally and technically through and by all actors in the lifecycle phases. In accordance with previous projects,a detailed IDM process has been proposed for the test case study in all lifecycle phases including the plan phase, real property formation phase, building permit phase, design phase, construction phase and property management phase. The IDM process has also includes information about when and how BIM data and cadastral information is shared between different actors. Further research in the presented project will apply the proposed IDM process to a pilot case to test the practicality.

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## BIOGRAPHICAL NOTES

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