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Towards Design and Development of a BIM-based 3D Property Formation Process

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Key words: 3D property formation, Building Information Modelling, Information Delivery Manual, Level of Information Need, 3D Cadastre

SUMMARY

With the increased interest and demand for 3D property, 3D property formation has shown increased significance. It is important to provide efficient, clear and unambiguous methods to form 3D property units, as well as register 3D property RRRs (rights, restrictions and responsibilities). The 3D property formation process should facilitate solutions to complicated problems within building projects (for example space above and below the ground) and provide secure and lasting rights in complex situations. Therefore, 3D property formation could use the same processes as for the formation of other property units, but adding specific rules and standards concerning the use of 3D models.

Building Information Modelling (BIM) contains rich details of building characteristics such as structures, elements, spaces, schedules, etc. that can form the physical models of the 3D cadastre. The 3D property formation process requires that BIM data are exchanged between actors. To model this exchange, we utilize an open BIM process standard Information Delivery Manual (IDM). IDM helps to clarify the detailed property formation process, facilitates actors' communication, harmonizes different product data models delivered and stored, identifies the results of that activity, as well as improves the management more efficiently and collaboratively. Level of Information Need (LOIN) is a framework that defines the extent and granularity of information, in order to prevent delivery of too much information. The LOIN specifies the granularity of information exchanged in terms of geometrical information, alphanumerical information and documentation, which should be used to specify the information delivery between actors.

In this paper, we use LOIN as a basis to specify information requirements according to the 3D property formation purposes, and design a developed process of the Swedish 3D property formation in IDM. In the study, LOIN fulfills the requirements of forming 3D cadastral property in BIM models and harmonizes all involved actors in the whole process in IDM with a more common and standardized approach. The proposed methodology aims to facilitate a standardized and unambiguous digital 3D property formation process on a national level in order to improve and enhance the digital Swedish Cadastral and Land Administration Systems.

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1. INTRODUCTION

A cadastre contains property unit information (e.g. rights, restrictions and responsibilities) used by countries' legal systems to define the dimensions and location of land parcels described in legal documentation and to record values of land and of landholders. The reason for introducing 3D cadastre can be to enhance 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 these properties (Paulsson, 2013; Andrée et al., 2018). 3D property units can be described as closed 3D volumes bounded both horizontally and vertically. To form property units, the cadastre process requires that the involved actors share information between each other. Much of the cadastral information sharing is still using textual description and non-machine-readable data formats during the formation process.

With the increased interest and demand for 3D properties, the 3D property formation has shown increased significance (Choon and Hussin, 2012; Andrée et al., 2018; Larsson et al., 2020). It is important to provide efficient, clear and unambiguous methods to form 3D property units, as well as register 3D property RRRs (rights, restrictions and responsibilities). It facilitates solutions to complicated problems within building projects (for example space above and below the ground) and provides secure and lasting rights in complex situations (Paulsson, 2013). Therefore, 3D property formation could use the same processes as for the formation of other property units but adding specific rules and standards concerning the use of 3D models (Larsson et al., 2020).

Most documents used in the property formation process are recorded and registered in paper format or frozen digital images (Andrée et al., 2018). In Sweden, the cadastral authorities use 3D CAD drawings containing the 3D real property boundaries in the cadastral formation process, but these drawings are not formally archived in the national real property register (Larsson et al., 2020). Moreover, the organizations and different stakeholders involved in the 3D property formation process reveals it as an unclear and ambiguous process. To overcome these problems several authors have proposed a 3D property formation process based on exchange of 3D digital models, especially Building Information Models (BIM) (see e.g. Olfat et al., 2019; Larsson et al., 2020; Sladić et al., 2020). However, what has been missing is a comprehensive study that describes the information need in the exchange of BIM data between the actors in the property formation process. The aim of this paper is to fill this gap.

In this study, we design and develop a 3D property formation process to provide guidelines of uniform cadastral documents and access to uniform data throughout the process. In the process, we utilize Building Information Modelling (BIM) as a digital representation of a building, containing rich details of building properties such as structures, elements, spaces, schedules, and other aspects of a construction project. The 3D cadastre formation process requires that BIM data are exchanged between actors. To model this exchange, we utilize the Information Delivery Manual (IDM), which is an open BIM process standard, to capture and specify the processes and information flow during the lifecycle of a facility by bringing many different stakeholders together in a project-specific organization (ISO, 2016). Level of Information Need (LOIN) is a framework that defines the extent and granularity of information, in order to prevent delivery of too much information (ISO, 2018). LOIN provides methods for describing information according to exchange information requirements, applicable to the whole life cycle of any built asset (SIST EN 17412-1:2021). In this paper, we use LOIN as a basis to specify information requirements in the 3D property formation process, and design a developed process model of the Swedish 3D property formation with IDM.

2. LITERATURE REVIEW

2.1 BIM

Building Information Model (BIM) is not only a model or tool but also a process and technology of creating, maintaining, using and exchanging building information (Sacks et al., 2018). In the Architecture, Engineering and Construction (AEC) industry, BIM is a digital representation of a building in the life cycle phases, containing rich details of building properties such as structures, elements, spaces, schedules, and other aspects of a construction project. When integrating with cadastre, BIM models provide detailed spatial information about physical components of buildings, which could address the problems with good capabilities as a physical model to generate a 3D cadastral model.

BuildingSMART has developed international open standards for the building industry worldwide (see Figure 1): Industry Foundation Classes (IFC) enable digital storage for interoperability; International Framework for Dictionaries (IFD) to specify the terminology; and Information Delivery Manual (IDM)/Model View Definitions (MVD) identify the process (buildingSMART, 2019).

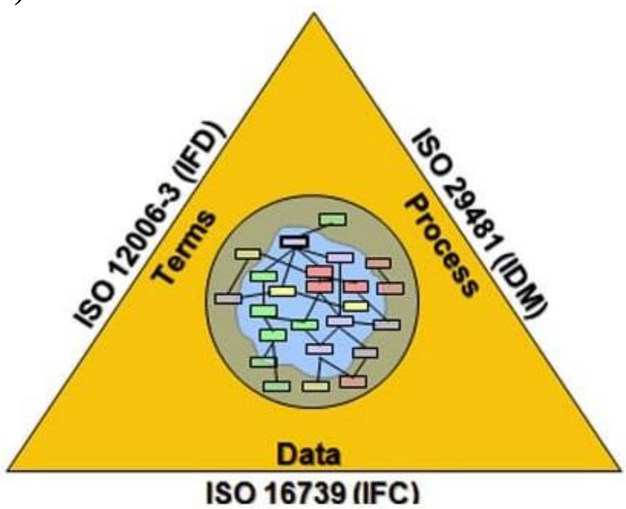

Figure 1. Open BIM standards: IFD, IFC, IDM (buildingSMART, 2019)

IFC is the most spread open international standard in the BIM domain, which is designed to exchange and share information among software applications by many different stakeholders (Borrmann et al. 2018) and supports definition of building elements and the spatial relationship between the elements. Because IFC has powerful capabilities to model detailed physical information and represent 3D property boundaries accurately, BIM/IFC has attracted a wide attention and been used to integrate with 3D cadastre (Sun et al., 2019). For instance, Atazadeh et al. (2017) performed a case study to explore the feasibility of BIM to model the boundaries of ownership spaces inside buildings and identified relevant geometric and semantic IFC entities. In a recent study Asghari et al. (2021) validated cadastral data based on BIM, where they propose a systematic approach to utilize IFC models.

2.2 IDM

Information Delivery Manual (IDM) is a BIM methodology to capture and specify processes and information flow during the lifecycle of a facility by bringing many different stakeholders together in a project-specific organization (ISO, 2016). It clarifies detailed process, helps all actors' communication, harmonizes different product data models delivered and stored, identifies the results of that activity, as well as improves the management more efficiently and collaboratively. IDM can specify information requirements for specific information use cases in a structured manner and is mainly composed of three parts: a process map, exchange requirements, and a model view definition (MVD) (Sacks et al., 2018). Recently, some studies have utilized the IDM process to describe cadastral information exchange between stakeholders following international standards in the 3D property formation process (Oldfield et al., 2017; Sladić et al., 2020).

2.3 LOIN

The level of information need, LOIN, provides methods for describing information to be shared according to exchange information requirements between actors. In relation to IDM, with the model view and the exchange requirements, LOIN defines the characteristics of the exchanged objects both as the requirements and the realized exchanged information. As a new European standard EN 17412-1, LOIN specifies the granularity of information exchanged in terms of geometrical information, alphanumerical information, and documentation, which should be used to specify the information delivery between actors, see Figure 2.

Each exchange of information must consider each recipient's needs and the purpose for supplying that information. LOIN can be seen as replacing the combination of Level of Detail (LoD) and Level of Information (LoI). In the delivery phase of projects/assets, the appointing party (project client) should consider the method of assignment for LOIN and what is required to meet each information requirement.

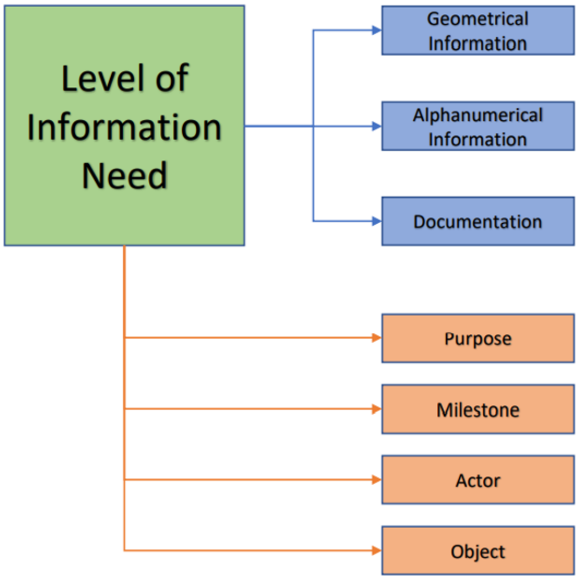

Figure 2. Characteristics of the exchanged object (CEN-CENELEC, 2019).

3. CURRENT PROPERTY FORMATION PROCESSES IN SWEDEN

Swedish real property formation is a responsibility of the national government. The Swedish mapping, cadastral and land registration authority (Lantmäteriet) as a public authority has the overall responsibility for the formation of real property including making decisions on new property units, making changes to existing boundaries, and making decisions concerning joint properties, easements and rights of way. Selected municipalities have their own property formation cadastral and land registration authority after fulfilling certain preconditions in the law and obtaining permission from the Swedish Government. 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.

The increased interest in 3D property formation in Sweden requires an effective formation process. Swensson and Juulsager (2014) has illustrated the Swedish property formation process: application, investigations/consultations, field survey map, meeting decisions, conclusions of procedure, invoice sent and registration. Sun et al. (2019) have formulated general basic requirements for 3D cadastral formation and proposed a framework to integrate 3D cadastre and 3D digital models, both BIM and 3D GIS (see Figure 3). However, no detailed description was presented of the digital data delivery between the actors as well as actions from the actors to obtain an unbroken digital flow of data in the 3D cadastre process. The main difficulties and drawbacks are how the cadastral information should be shared among the different stakeholders in the 3D property formation process.

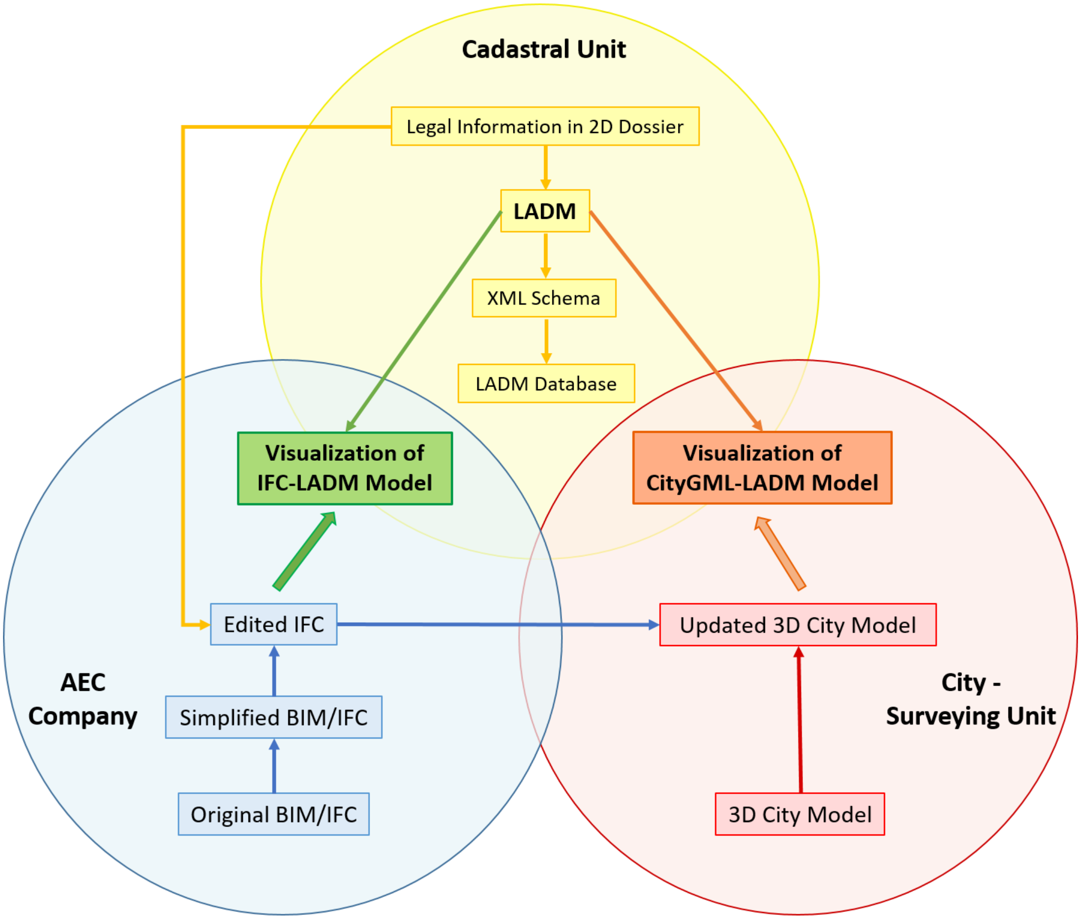

Figure 3. A general framework for integrating 3D cadastre with BIM and GIS (Sun et al., 2019).

4. PROPOSAL OF 3D PROPERTY FORMATION PROCESS

4.1 The real property formation phases

The 3D property formation process can be divided into five phases (Figure 4). Details of data exchange in these phases are given below, but first we provide an overview of the process.

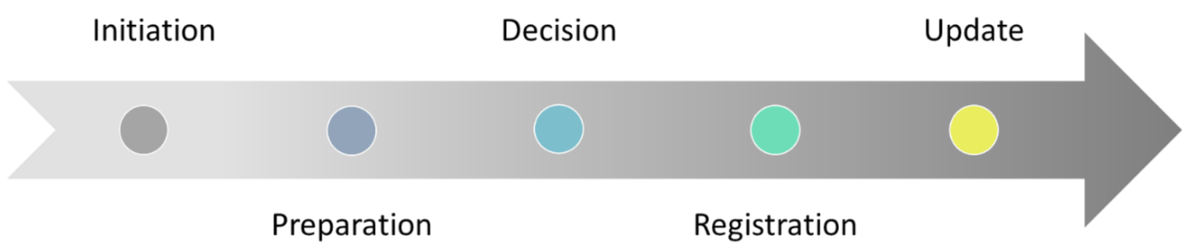

Figure 4. The five phases in the 3D real property formation process.

4.2 Overview of the proposed 3D property formation process

In this paper, we use LOIN as a basis to specify information requirements according to the need of the actors in the 3D property formation process, and describe the data exchange in the process in an IDM process map (Figure 5). We identify four main actors when forming a 3D property: applicants, the cadastral authorities, cadastral surveyors and municipalities. A lane named "Data exchange and store" illustrates which and how the data exchange and store among different actors during the process.

In the study, LOIN are used to harmonize all involved actors in the whole process and support cadastral information exchange in IDM with a more common and standardized approach. To specify how the information is going to be delivered, as shown in Figure 2, the following shall be considered:

- Purposes: for the use of the cadastral information to be delivered in BIM models
- Information delivery milestones: for the delivery of the information, including geometrical information, alphanumerical information, and documentation
- Actors: who are going to request and who are going to deliver the information during the 3D property formation process
- Objects: organized in one or more breakdown structures, for example IFC_Space.

The proposed methodology aims to facilitate a standardized and unambiguous digital 3D property formation procedure on a national level in order to improve and enhance digital Swedish Cadastral and Land Administration Systems. The proposed property formation process is based on the results from previous research (Andrée et al., 2018 and Sun et al., 2019), where a possible future process for 3D property formation was described and how to integrate 3D cadastre with BIM. A developed vision for a future process for 3D property formation is described below.

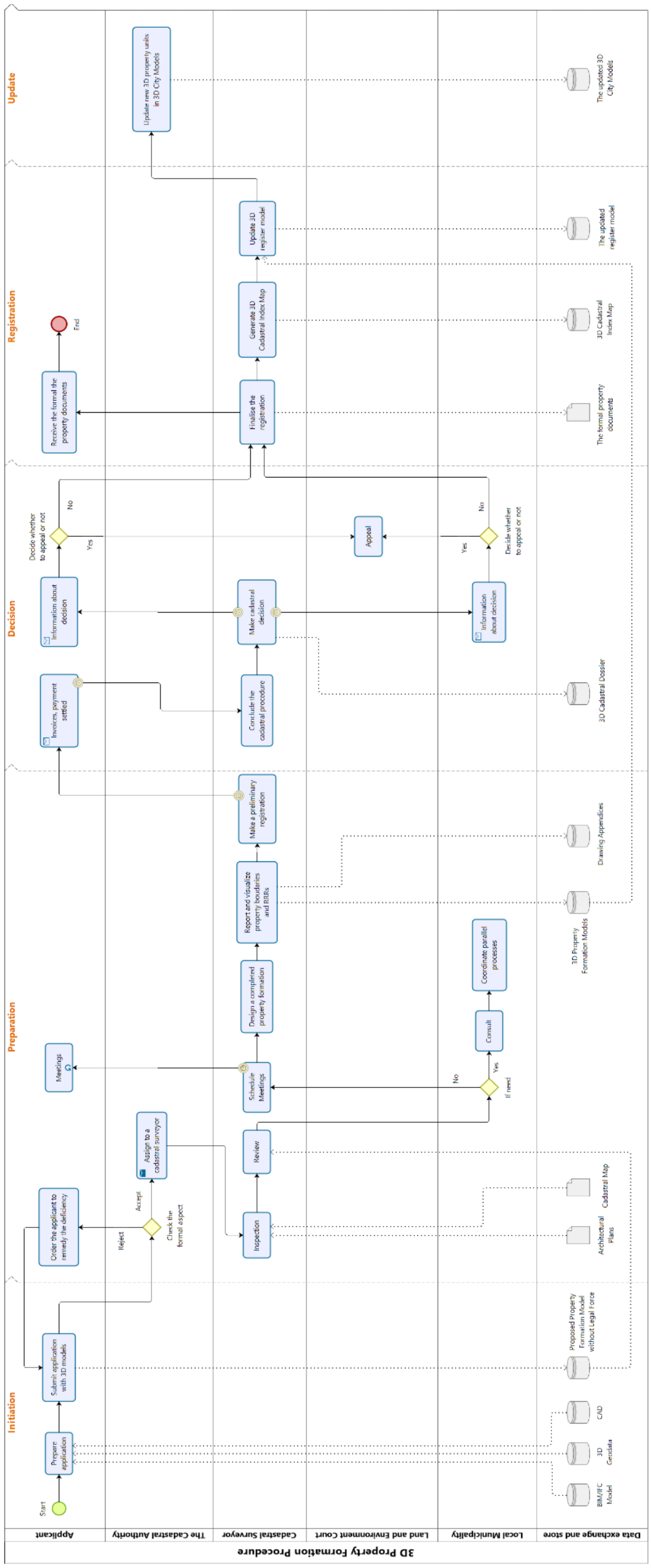

Figure 5. A developed process of Swedish 3D real property formation in IDM.

4.2.1 Initiation phase

The initiation phase is the initial phase of a 3D property formation process where the applicant, typically a property developer, prepares and submits an application to the cadastral authority (Figure 6).

The initiation phase starts prior to the application for property development, when a digital 3D model (BIM or similar) has been developed by the applicant. The 3D model contains, among other things, existing property boundaries (2D and 3D) and rights in the affected area retrieved from the cadastral authority, desired new property boundaries and associated rights, as well as physical BIM details, such as walls and load-bearing structures, for existing and planned buildings that are affected by the planned 3D property formation. The applicant can, in addition to entering new own data, access data for his/her 3D model from a register model (register map in 3D, responsible cadastral authority), geodata model (responsible municipality), plan model (current planning regulations in 3D, responsible municipality) and / or building permit model (current building permit in 3D, responsible municipality) and digital models of e.g. existing building structures used in previous cadastral processes. These are accessed through a proposed common platform for built environment data, which can be used by all the actors in the process and where the platform mainly functions as a peephole where the applicant can compare his/her data with other actors' / authorities' data, but from where certain data can also be downloaded / copied for use in the applicant's 3D model.

In connection with the application, the applicant produces supplementary documentation. The application is prepared by the applicant, sent to the surveying authority and supplemented early in the process with a digital property formation model. The submitted model is a suggestion for property formation and has no legal force. It may be changed – in cooperation with the applicant – by the cadastral surveyor during the preparation phase. It is important that the property formation model states both existing and proposed changed, revoked and new boundaries and rights, respectively. This is to be able to see in retrospect what changes took place with the cadastral procedure.

4.2.2 Preparation phase

The preparation phase starts with a technician at the cadastral agency checking the formal aspects of the submitted application, e.g. that the application is signed by the applicant. If not accepted, the application is returned to the applicant for revision and resubmission. If accepted, the application is then assigned to a cadastral surveyor who is in charge of the entire property formation and registration process (Figure 6).

The surveyor inspects the applicant's architectural plans and the necessary cadastral map(s) on footprint level, for example property boundaries and easements, to see the overall extent of the legally affected area subject to property formation.

The cadastral surveyor reviews the suggested property boundaries and the need for rights, restrictions and responsibilities (RRR) in 3D by using the information in the 2D/3D cadastral dossier stored in the Real Property Register. He/she also makes inquiries about existing RRRs. If needed, the cadastral surveyor will consult with the local municipality (typically regarding water supply, sewerage, and/or development plan issues) and/or regional or governmental agencies, such as the national Transport Administration (typically regarding road access). Ongoing parallel processes for building permits and detailed plans are coordinated through consultation and/or other contact with the relevant stakeholders.

Work meetings and other contacts are held continuously with the applicant. The applicant may then, if necessary, update his/her 3D model with correct reporting of suggested rights and new demarcations. The real property formation model, which is created by the cadastral surveyor, contains all spatial cadastral information in 3D. Prior to the cadastral decision, a completed design of the property formation is ready. The phase ends when the cadastral surveyor makes a preliminary registration of his/her decision in the Real Property Register.

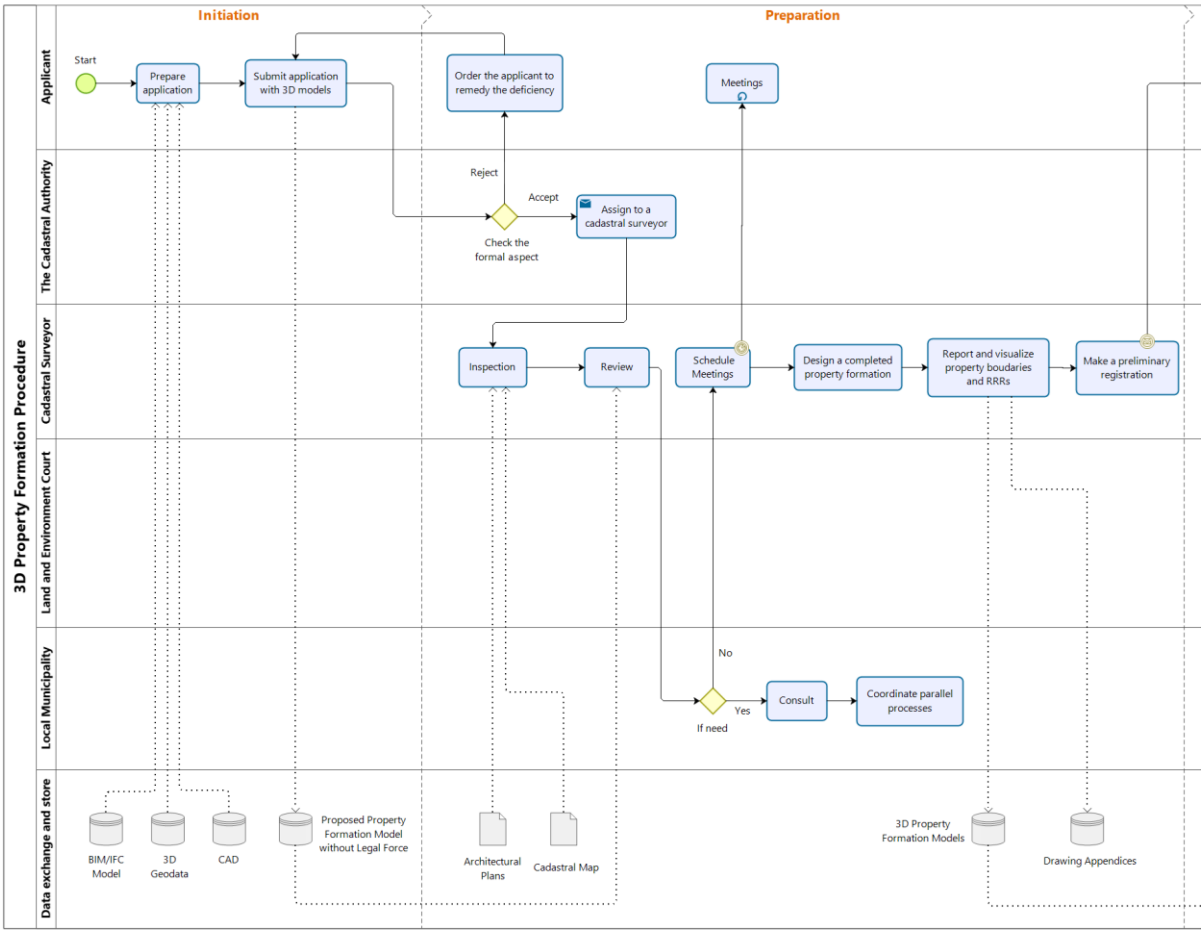

Figure 6. The proposed initiation and preparation phase in the IDM.

4.2.3 Decision phase

After the payment is settled, the cadastral surveyor will conclude the cadastral procedure and make a final decision (Figure 7). Both the applicant and the municipality will receive the decision information and decide whether to appeal or not to the Land and Environment Court.

The cadastral decision is confirmed by the cadastral surveyor. In addition to the map, description and minutes, the decision also includes a property formation model, 3D visualization and appendices (paper/pdf) which are stored in the 3D cadastral dossier.

4.2.4 Registration phase

The cadastral surveyor will finalise the registration of the new real property unit in the Real Property Register national cadastre after the mandatory appeal period has ended and no appeals have been made. The new or altered 2D and 3D real properties are registered in the agencies archive and shown in the 3D cadastral index map. Finally, the applicant will receive the formal property documents and the property formation process ends. The cadastral dossier is stored in the agency's digital archive. The property formation model is used to update the register model, which can handle 3D. In the register model, only property boundaries and rights are included, not construction elements etc.

4.2.5 Update phase

The cadastral surveyor will update the new 3D property units in the 3D city model after registration.

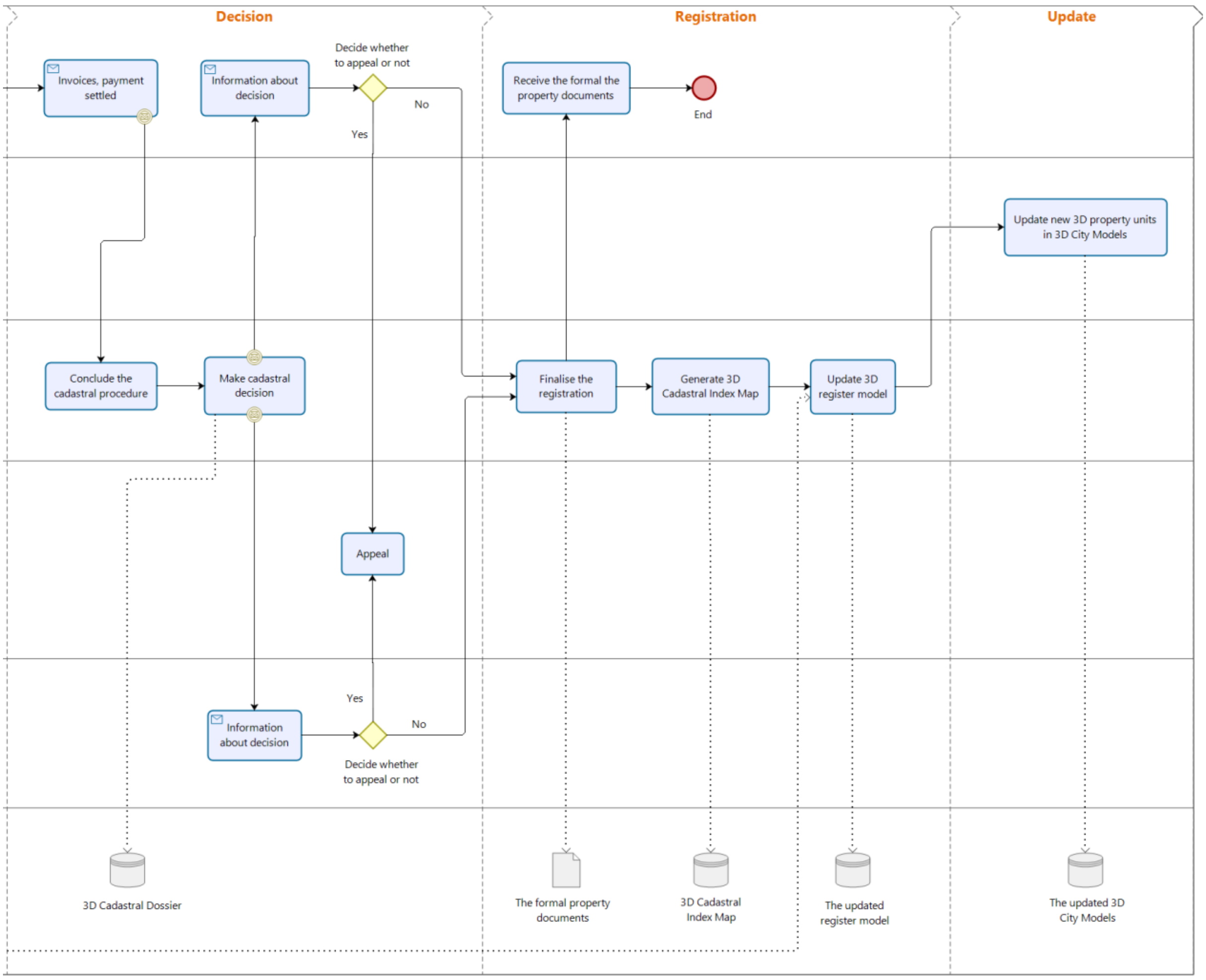

Figure 7. The proposed decision, registration and update phase in the IDM.

5. CONCLUSIONS

Traditional cadastral systems register property and share cadastral information in 2D. From a technical aspect, 3D property registration can represent and form legal objects in a 3D reality world in order to investigate complex spatial structures and avoid ambiguous property boundaries. However, within the 3D property formation process, this faces practical difficulties. For instance, when and which cadastral data should be exchanged and stored by which organizations/ actors. Therefore, in this study, we presented and designed a BIM-based 3D property formation process. LOIN has been used to specify information requirements according to the 3D property formation purposes, and IDM as the international standard process of BIM has been used to design a developed process of Swedish 3D real property formation including four actors and clear data exchange flow. The proposed methodology facilitated a standardized and unambiguous 3D formation process and enhanced a holistic cadastral management in 3D for sustainable development in economic, social and environmental aspects. In this paper, even though the BIM-based approach has been developed from organizational and technical aspects, more detailed data and steps still need to be further investigated. Therefore, practical case study will be considered in further studies.

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