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Development of process model for Serbian cadastre

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ABSTRACT

Identifying the processes in the cadastre enables understanding the principles on which the cadastre works. Processes in cadastre define the way how the cadastre manages information and what are the prerequisites for the data to be stored in the appropriate data structure. In order to explicitly specify cadastral procedures and workflows to support their automatization, we developed a process model for Serbian cadastre. The main reason for developing the process model is to ensure the framework which will provide possible integration and interoperability with other systems outside traditional cadastral system and between cadastral subsystems themselves. The process model is based on hierarchical decomposition of two basic groups of processes: processes for changing cadastral data and processes for displaying cadastral data. Each group of processes is further decomposed step by step until the workflow of a single process is shown. The developed process model is an abstract model, i.e. it is independent of the implementation. However, in order to instantiate such process model, it is necessary to provide binding of the abstract process model to its underlying implementation. Cadastral registration of spatial units may be beneficial for activities that relay on land administration, such as taxation, spatial planning, obtaining a building permit or legalization of buildings. This relation to the processes under jurisdiction of other organizations justifies the use of cadastral process model and its implementation into SOA environment. Traditionally, cadastral processes include alphanumeric data and 2D spatial data on cadastral maps that contain 2D borders of parcels and buildings. However, recent advancements in 3D technology bring the opportunity to enhance such processes with 3D information. In particular, the aim is to extend current 2D process model to support data maintenance and transactions in the upgrade towards 3D cadastre. Therefore, these 3D data supported workflows are introduced to the process model. For the processes that include 3D information the choice has to be made which specifications will be used and how representations of 3D spatial units will be resolved. In this paper, we first develop an abstract process model of Serbian cadastre. After that, we extend the process model to include 3D information, discuss the options for using the encodings of 3D spatial units (legal spaces) and select buildingSMART openBIM IFC standard for this purpose.

1. Introduction

Identifying the processes in the cadastre enables understanding the principles on which the cadastre works and the needs for its improvement. Identifying the processes in Serbian cadastre is particularly important due to slow procedures in the existing cadastral information system that requires a lot of paperwork and a lot of time spent by the parties themselves. In order to overcome these problems, it is necessary to describe all processes and their workflows and implement them in an architecture that enables their automation, thus increase their efficiency. These processes define the way how the cadastre manages information and what are the prerequisites for the data to be stored in the appropriate data structure. The first step in determining the set of processes is defining business tasks in the cadastre that arise from the needs of different users - internal in the cadastre and external, like right holders, the Government and many other organizations. These needs define business tasks and data sets necessary to successfully perform the task. The next step is to define the process itself, and then implement the process in the appropriate architecture.

A business process is a general notion that is defined as a set of one or more linked activities that collectively realize a business objective within the context of organizational structure that defines functional roles and relationships (Davenport and Short, 1990). Workflow Management Coalition (Hollingsworth, 1995) defines a workflow as the computerised facilitation or automation of a business process, in whole or part. Workflow is concerned with the computerised support for the automation of procedures where documents, information or tasks are passed between participants according to a defined set of rules to

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achieve, or contribute to, an overall business goal. In computer science literature, business process and workflow terms are often used interchangeably.

Conceptual modelling of business processes is deployed on a large scale to facilitate the development of software that supports the business processes, and to permit the analysis and re-engineering or improvement of them (Aguilar-Savén, 2004). Therefore, the main goal of this paper is to provide a conceptual model of processes in Serbian cadastre. This will provide a comprehensive framework for improvements and further automatization of cadastral procedures which will provide possible integration and interoperability with other systems outside traditional land administration domain, which is the ultimate goal of this development. In that context, we established the link with building information modeling which, not only is a source of 3D spatial data for legal spaces in 3D cadastre, but inherently refers to the processes related to the lifecycle of buildings, and to which land administration is tightly related (through registering rights, property taxation, etc.). Although, cadastral system in Serbia is computer based (see Section 2.2), the use of traditional information technologies provides limited capabilities to support automated procedures and cross-domain interoperability. However, the recent developments in Serbian cadastre are showing progress in this direction through the development of individual electronic services (such as handling requests, issuing documents, providing cadastral maps,…), which motivates us to investigate this topic and develop an overall conceptual process model that describes dynamic aspects of cadastral system. Such model will support further development of e-services and interoperability with other organizations and citizens in general.

Navratil and Frank (2004) organize processes in the cadastre in two groups: processes that change the data in the system and the processes by which data are downloaded or viewed. Processes that change the data can further be divided according to the data group, that is, the processes of changing surveying (spatial and attribute data of spatial units), legal and additional data (such as code lists and office management data). The change of data indicates transactions for entering, modifying or deleting the corresponding data. Processes for data review involve viewing, searching, printing and downloading surveying, legal and other data.

The analysis of business processes in the Serbian cadastre shows that such basic process division is applicable as an initial step in the process hierarchy. A top-down strategy was selected for describing the processes. This strategy increases the decomposition of the process from general to specific, thus creating an insight into the elements of the subsystem. At the highest level, a system overview is defined without the introduction of process details. Each subsequent level introduces more details, or processes, as long as the level specification is not reduced to basic (atomic) processes or activities (Sladić et al., 2018).

The highest level of hierarchy is called the context. In the case of Serbia's cadastral system, this is Level 1 which contains an overview of the entire system. According to the basic division of the process from the beginning, at this level two general processes are defined – one for overview of the data and the other for changes that can be performed on the data. For the process which relates to the changes on the data, Level 2 contains processes that describe how data can be changed. Processes can be grouped into processes for changing surveying data, i.e. changes on real properties, processes for changing rights and restrictions on data and changes of other data such as parties or code lists. For the process which relates to changes on real properties, Level 3 contains basic processes that describe the changes on parcels, buildings and building units like condominium, business space, garages, etc. Level 4 contains processes and activities that specifically describe a process, while Level 5 contains the workflows in the BPMN notation. Process hierarchy for both context processes are described by Radulović (2015).

The standardization of specific processes for all cadastres in the world is impossible due to the large differences in the way in which certain procedures are implemented from one country to another. However, this hierarchical organization and basic division on process groups can be used as a basis and a roadmap for describing the processes in a country. Options for standardisation of processes and transaction in land administration have already been considered given developments as Fit-For-Purpose Land Administration, Apps and blockchain (Lemmen et al., 2018a).

The processes in cadastre can be implemented using the technology of Web services in a Service Oriented Architecture (SOA). There are already a set of web services in use in Serbia, as described by Govedarica et al. (2018). Cadastral Web services are used by the information systems of other public and private organizations such as banks, different government agencies (tax administration, business registry agencies, anti-corruption agency, agriculture subsides), etc. that use cadastral data. They are also used for the work of the eGovernment portal through which online services to clients are executed. The technology of Web services supports automated integration of systems of independent organizations and are in wide use for that purpose.

The motivation for this research is to investigate how processes in Serbian cadastre can be modeled in order to explicitly capture its procedures and workflows to facilitate their further automation. The increasing complexity of modern land use, particularly in the growing urban areas, requires that land administration systems will need a capacity to manage spatial units in three dimensions, and not only in 2D as it is now the case through the means of a cadastral map that contains 2D footprints of parcels and buildings. The advancement of technology for 3D data acquisition and storage supports such need and it is necessary to evaluate how 3D data supported workflows can be introduced to the process model. In this context, the aim is to extend current 2D process model to support data maintenance and transactions in the upgrade towards 3D cadastre, which includes registration and update of 3D spatial units. This requires the analysis of types of transactions defined in the law and associated rulebooks and code lists, and possible overlaps of rights in 3D. Cadastral registration of 3D spatial units may be beneficial for activities that relay on land administration, such as taxation, spatial planning, obtaining a building permit or legalization of buildings. This link with the processes under jurisdiction of other organizations justifies the use of land administration process model and its implementation into SOA environment. Considering the ongoing projects in the world on integration of geospatial information with indoor spatial information and building information modeling, we explore the possibilities of implementation of 3D cadastre related information into the SOA environment.

The possibility of re-using 3D data collected in other areas and stored in formats such as BIM/IFC (Atazadeh et al., 2017a), CityGML (Góźdź et al., 2014), IndoorGML (Alattas et al., 2017), LandXML / InfraGML (Thompson et al., 2017) for the purpose of 3D cadastre has been widely analysed in the literature, since the usability, compatibility and portability of these datasets is considered as a low cost solution to one of the costliest phases of the implementation of 3D cadastres, which is the initial 3D data capture (Dimopoulou et al., 2016). Cadastral data models, such as the Land Administration Domain Model (Lemmen et al., 2015) and its corresponding country profiles (Bydłosz, 2015; Janečka and Souček, 2017; Radulović et al., 2017) have been developed for legal information modelling and management purposes, and although they provide support for 3D spatial units, they do not provide correspondence to the object's physical reality. Building Information Models and 3D topographic city models such as CityGML are used to describe the physical reality, i.e. the physical and functional characteristics of urban structures, but they do not provide information about legal objects (spaces), therefore the integration between physical and legal objects has to be developed (Aien et al., 2013). Since, BIM is process oriented and buildingSMART openBIM standards (buildingSMART, 2019) may provide a basis for representation of legal spaces (Oldfield et al., 2017), we further explore the possibility of using these standards to support cadastral workflows (legalization of the buildings, issuing building permits, support to the property market, valuation and taxation of properties, etc) in Serbia.

The paper is structured as follows. After the introduction, Section 2 provides theoretical background and literature review that support basic assumptions of the paper. Section 3 describes the developed process model in Serbian cadastre. It combines both traditional processes based on the exchange of 2D data, with processes that allow introducing 3D to already existing workflows. Section 4 proposes a method for the implementation of 3D data into these processes based on buildingSMART openBIM standards and discusses advantages and challenges of such approach. Section 5 presents a case study of the process of legalization of buildings. Conclusions and future work are given afterwards.

2. Literature review

2.1. Processes in cadastre

The revision of LADM (Lemmen et al., 2018a) considers the introduction of LADM process models. However, to this moment there are no standardized process models that can be followed in order to develop process model for Serbia. Several researches considered process modelling in cadastre. The focus of the research reported by Zevenbergen et al. (2007) concerning the modelling real property transactions, is the transfer of ownership and other rights in land and buildings. The main objective of the research is to improve the transparency of real property markets and the efficiency of the procedures, to calculate costs of the procedures and to provide basis for the reduction of these costs. On the other hand, our research focuses on the processes in cadastral information system maintained by the central cadastral authority with the main objective to enable their possible automatization through SOA, which in the end leads to the reduction of cost and time necessary to complete a certain procedure, and more transparent and fair workflows. Therefore, this can be considered a more technical objective with narrower scope, but with the similar outcome.

In order to instantiate abstract processes, it is necessary to provide binding of the abstract process model to the underlying implementation. For the processes that include 3D information the choice has to be made which specifications will be used and how representation of 3D spatial unit will be resolved. In addition to the advantages that BIM/IFC might have for representing 3D spatial units, it also comprises the notion of processes. Building Information Modeling is considered as an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure (BIM, 2019). Therefore, BIM includes processes related to the lifecycle of a building and in turn this lifecycle is related to land administration. BIM can be introduced in a workflow for 3D land administration (Ho and Rajabifard, 2016). In this regard, openBIM offers standards that can support processes related to land administration, such as IDM for issuing building permits (Oldfield et al., 2017) or BIM Collaboration Format (BCF) for server-based workflows (van Berlo and Krijnen, 2014). Since Building Information Modelling (BIM) has emerged as a new paradigm to facilitate collaboration among different AEC actors, identifying SOA patterns for BIMs seems justified for facilitating BIM-based software and Web service architecture (Isikdag, 2015).

2.2. Towards 3D cadastre in Serbia

The organization of real estate cadastre and proposed LADM profile for Serbia are described by Radulović et al. (2017). In short, the cadastral information system in Serbia consists of two types of data sets: spatial datasets (digital cadastral map) and alphanumeric data sets in the real estate cadastre database that contain legal data about rights, right holders and attribute data of spatial units. The cadastral maps contain geometry and topology data on real estate and provide 2D spatial visualization of cadastral parcels and buildings. In the real estate cadastre database, other data on real estate are also stored. Cadastral information system is regulated by the Law on State Survey and Cadastre from 2009 – "the Law" (Official Gazette, 2009), Amendments to the Law in 2015, and the Rulebook on Cadastre Survey and Real Estate Cadastre from 2016 (Official Gazette, 2016). The Law defines the real estate cadastre as a basic and public register of real properties and the rights to those properties. Real properties that are recorded in the cadastre are divided into: land (cadastral parcels), ground and underground buildings and separate parts of the buildings (building units) that make one structural unit, such as apartments, business offices, garages, etc. In the real estate cadastre database, data are organized into four sheets inherited from the analogue system (A sheet: data about land parcels; B sheet: data about right holders on land; V sheet: data about buildings and building units and G sheet: data about restrictions on land, buildings and building units). This is not appropriate way to keep the cadastral data since the Law specifies a document called the real estate folio (for parcels, buildings or building units) that contains all related data about one property and in that form should be issued to the parties. In practice this is not yet achieved due to the obsolescence of the existing information system. The new Law from 2018 - The Law on the Procedure for Registration in the Real Estate Cadastre and Utility Network Cadastre (Official Gazette, 2018) introduces the novelty that each property is identified with unique property identification number (UPIN) on the territory of Serbia. According to the Law, for each property the unique identification number is determined individually and recorded. Its purpose is to facilitate data access and management on properties, since the attributes needed to identify a property are administrative municipality code, cadastral municipality code, number and sub-number of the parcel, a number of the part of parcel i.e. sequential number of building on the parcel (1-n) and sequential number of building unit within building (1-n, this number is 0 for the building itself). By introducing UPIN, values of all these attributes are represented by a single code.

The recent developments in 3D data technology have also been followed in Serbia, with a great interest. There have been many projects in the field of 3D data acquisition and modeling for the purpose of utility network cadastre using e.g. LiDAR (Light Detection And Ranging) technology for 3D surveying of powerlines (Popović et al., 2017a) or underground utility network infrastructure (Ristić et al., 2017). Also, there have been attempts to convert point clouds from LiDAR surveying into the city models in CityGML format and to use that data for the purpose of 3D real estate cadastre (Popović et al., 2017b), but this data is only available for buildings and not for separate building units that are registered in cadastre. However, there are no many researches that include BIM in Serbian cadastral workflows, although we have witnessed the increased usage of BIM technology in Serbia in recent years. Despite the fact that surveying and construction companies are traditionally oriented toward Computer-Aided Design (CAD) applications, there is a wide initiative that comes from the private sector to promote the usage of BIM technology.

Cadastral offices also archive construction documents as part of geodetic reports (e.g. crossections or 2D floor plans of buildings called sketches). A number of studies in the countries with the similar land administration background (Drobež et al., 2017; Vučić et al., 2017), identified these technical documents and other data collected in cadastral procedures, as a source for creating a 3D spatial units for the purpose of 3D cadastre. The collected data can be used to convert into 3D formats such as IndoorGML (Tekavec and Lisec, 2018) or CityGML (Radulović et al., 2011). Furthermore, Mađer et al. (2018) recognized the possibility of collecting the 3D data in cadastral resurvey from the legalization reports. In legalization reports, a geodetic situational draft is made to display position and elevation data on all visible natural and built features of the land surface in the construction area (e.g. buildings and other structures, traffic infrastructure, vegetation, water, utility lines with associated facilities, etc.). In addition to geodetic situational drafts, legalization reports also contain technical documents of the building usually developed using CAD or BIM tools. This workflow will be used as a case study in Section 5.

2.3. Registration of 3D spatial units

Taxonomy of spatial units in a mixed 2D and 3D cadastral database is presented by Thompson et al. (2015). It includes several types of spatial units starting from the 2D spatial units to the general 3D spatial units, with the growing complexity. These are: 2D spatial unit, building format spatial unit, semi-open spatial unit, polygonal slice spatial unit, single-valued stepped spatial unit, multi-valued stepped spatial unit and general 3D spatial unit. Cadastre in Serbia is based on 2D spatial units by law. In this research, we mainly focus on building format spatial units, which is by the level of complexity the next after 2D spatial units, and is considered the most feasible solution in the near future, while the more complex cases of 3D spatial units will be left for the future work. Building format spatial unit is defined by the extents of an existing or planned structure. This spatial unit is legally defined by the structure of the building that contains the unit. It may be defined to the outside of walls in the case of the building, or to the middle of walls in the case of building units (such as apartments). Building format spatial units are sufficient to cover the legal spaces defined in V sheet of the cadastral database (related to buildings and building units and their rights), while the more complex 3D spatial units might be necessary for the legal spaces in A sheet (land parcels) and situations of overlapping rights.

One possible solution is to keep representations of spatial units in the 2D cadastral maps, while the full 3D definition of the 3D spatial units is kept in another format (such as BIM) that can be obtained from a document archive by the means of unique property identification number. This number can be used to perform mapping of a single property (a single legal space) to a physical model in a 3D data source. In the case of Swedish cadastre (El-Mekawy et al., 2014), a unique reference number is referring to the legal cadastral formation document case file. Linking a 3D spatial unit with its source was also used by Stoter et al. (2017) within a legal document in 3D pdf format.

2.4. Using technical models to represent 3D spatial units

For the proper representation of 3D cadastre, 3D legal spaces modelled with LADM may be linked to 3D physical objects. These legal spaces and their boundaries may follow physical objects, but they are not necessarily coincident. LADM focuses on legal space rather than on physical space and this materialisation of the legal object by linking it to its corresponding physical object is considered as a complex task (Dimopoulou et al., 2018).

The revision of LADM (Lemmen et al., 2018b) considers using different technical models and encodings for this purpose. Several researches analyzed the possibility of using OGC CityGML to link legal and physical spaces, by the means of Application Domain Extension (ADE), paying particular attention to the buildings (Góźdź et al., 2014; Rönsdorf et al., 2014). 3D buildings at LOD2 level may be created as a combination of 2D digital building ground plans derived from the official digital cadastral map and LIDAR data (Roschlaub and Batscheider, 2016). OGC LandInfra / InfraGML (OGC, 2017) is another candidate specification that should be considered for the integrated footprint and face volumetric encoding of spatial units (Thompson et al., 2016). Furthermore, when a single building contains multiple spatial units, then indoor data is also needed. IndoorGML is intended to support development of indoor navigation systems and it is complementary to generic 3D standards such as CityGML or IFC and it can also be combined with LADM (Zlatanova et al., 2016). LandInfra conceptual model (encoded in InfraGML) contains the Condominium requirements classes that can be used to represent buildings and building units and its class BuildingUnit is related to ifcSpatialZone class of IFC. BIM is very important in order to establish a link to the land administration for spatial planning and tracking the lifecycles of buildings (Lemmen et al., 2018b). Atazadeh et al. (2017b) proposed an extension to the BIM standard to show the potential capability of using BIM for modeling 3D ownership rights, while the performance of such models was measured by Atazadeh et al. (2017c). BIM models are also used to update the cadastre in Costa Rica (van Oosterom et al., 2014).

Considering its wide user community, we believe that BIM/IFC has probably the most potential to be adopted for the representation of 3D spatial units, especially considering the fact that the indoor is needed for the representations of spatial units contained in V sheet and it is already available in this format, while in other formats it has to be created. However, technological push in other direction might put focus on other specifications in the future.

3. Process model of Serbian cadastre

3.1. Methodology for the process model definition

Methodology used for developing the process model in Serbian cadastre includes functional modeling (Mayer et al., 1992) and business process modeling (Aguilar-Savén, 2004). Functional modeling provides a functional hierarchy perspective of the modeled system. IDEF0 (FIPS PUBS, 1993) notation used for that purpose, is a modelling technique for developing structural graphical representations of processes of complex systems. It shows the high-level activities of a process indicating major activities and the input, control, output, and mechanisms associated with each major activity. The processes can be further decomposed to show lower-level activities, but at some point the required view of the system will need another notation to portray aspects such as branch control. That is where BPMN notation may be used.

Business processes are usually modeled using a standard Business Process Model and Notation (BPMN) which is a graphical notation that will provide businesses with the capability of understanding their internal business procedures in a graphical notation and will give organizations the ability to communicate these procedures in a standard manner. Furthermore, the graphical notation will facilitate the understanding of the performance collaborations and business transactions between the organizations (OMG, 2011). While other notations used to represent system behavior are technical oriented, BPMN tends to be more domain experts oriented and to close the gap between domain and technical experts. In short, BPMN graphical notation contains a set of symbols to represent business processes, among which the most commonly used are rounded rectangles that represent particular tasks within a process. Tasks are combined in sequence flows which can converge and diverge within a process. Gateways are used to control how these sequence flows interact as they converge and diverge. Gateways are represented by a diamond symbol with an appropriate icon attached depicting different types of gateways (exclusive, event-based, parallel, inclusive, complex…). Branching or merging sequence flow behavior may be controlled by exclusive gateways (represented with X or empty symbol inside a diamond), which will require to choose between alternative flows. Forking and joining require parallel gateways (represented with + symbol inside a diamond) and are used for activities that are carried out in parallel. For a full set of BPMN symbols, a reader is referred to the BPMN specification (OMG, 2011).

The first step in determining the set of processes is defining business tasks in the cadastre that arise from the needs of different users - internal in the cadastre and external, like right holders, the Government and many other organizations. These needs define business tasks and data sets necessary to successfully perform the task. The next step is to define the process itself, and then implement the process in the appropriate architecture.

Navratil and Frank (2004) organize processes in the cadastre in two groups: processes that change the data in the system and the processes by which data are downloaded or viewed. Processes that change the data can further be divided according to the data group, that is, the processes of changing surveying, legal and additional data. The change of data indicates transactions for entering, modifying or deleting the corresponding data. Processes for data review involve viewing, searching, printing and downloading surveying, legal and other data. The analysis of business processes in Serbian cadastre shows that such basic process division is applicable as an initial step in the process hierarchy. A top-down strategy was selected for describing the processes. This strategy increases the decomposition of the process from general to specific, thus creating an insight into the elements of the subsystem. At the highest level, a system overview is defined without the introduction of process details. Each subsequent level introduces more details, or processes, as long as the level specification is not reduced to basic processes or activities.

IDEF0 notation was used to describe the hierarchical structure of the process in the real estate cadastre. IDEF0 is the language for functional modeling. It is suitable for top-down modeling, starting from the basic process division in the system, by defining process groups that contain the basic system processes. The basic processes in the system can further combine less complex processes and concrete activities. At the lowest level it is necessary to introduce more details, such as participants, events, branching, activity flows, message flows, etc. For the description of the workflow, BPMN is more appropriate, so this notation is used to describe the lowest level of the processes.

Fig. 1 shows the hierarchical organization of the process levels. Process A, at the first level, is decomposed to processes A1 and A2 at the second level. Then, A2 is decomposed to A2.1 and A2.2 at the third level. A2.1 is decomposed to A2.1.1, whereas A.2.2 is decomposed to A.2.2.1 and A.2.2.2 at the fourth level. At the lowest fifth level, individual processes from the previous level, such as A2.1.1, are modeled in a workflow. Similar decomposition pattern can be followed for process B. Adding the appropriate prefix when naming the process marks its parent process.

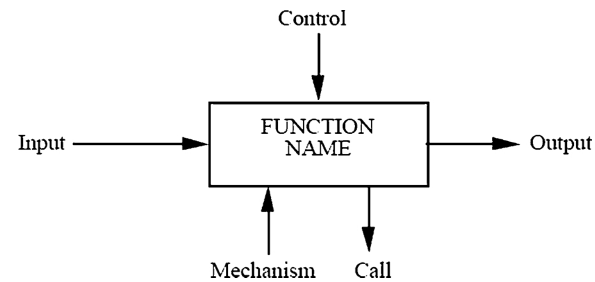


Fig. 2. The basic semantics of rectangles and arrows in the process (FIPS PUBS, 1993).

Two basic modeling elements for IDEF0 notations are functions (represented by rectangles) and data that connect functions (represented by arrows). Fig. 2 shows the basic semantics of the meaning of rectangles and arrows in the process description (FIPS PUBS, 1993).

An input refers to events that trigger an activity or data that is transformed within an activity. Control refers to conditions that govern or regulate activity. Unlike inputs, controls do not change during the activity. These may be some documents and materials. Mechanism represents the resources needed to carry out the activities, e.g. people, equipment, financial resources, etc. Call is a type of mechanism arrow that enables the sharing of detail between models (linking them together) or within a model. Output represents activity results, processed or transformed data.

3.2. Developing process model of Serbian cadastre

Before specifying process model, it is necessary to understand and define different roles in the cadastral system, which are required to characterise the processes performed by the diverse types of actors (Ottens and Stubkjær, 2007). Different types of actors in cadastral system are defined by the rulebook on systematization of work types by geodetic authority and are shown on Fig. 3. The main division of actors

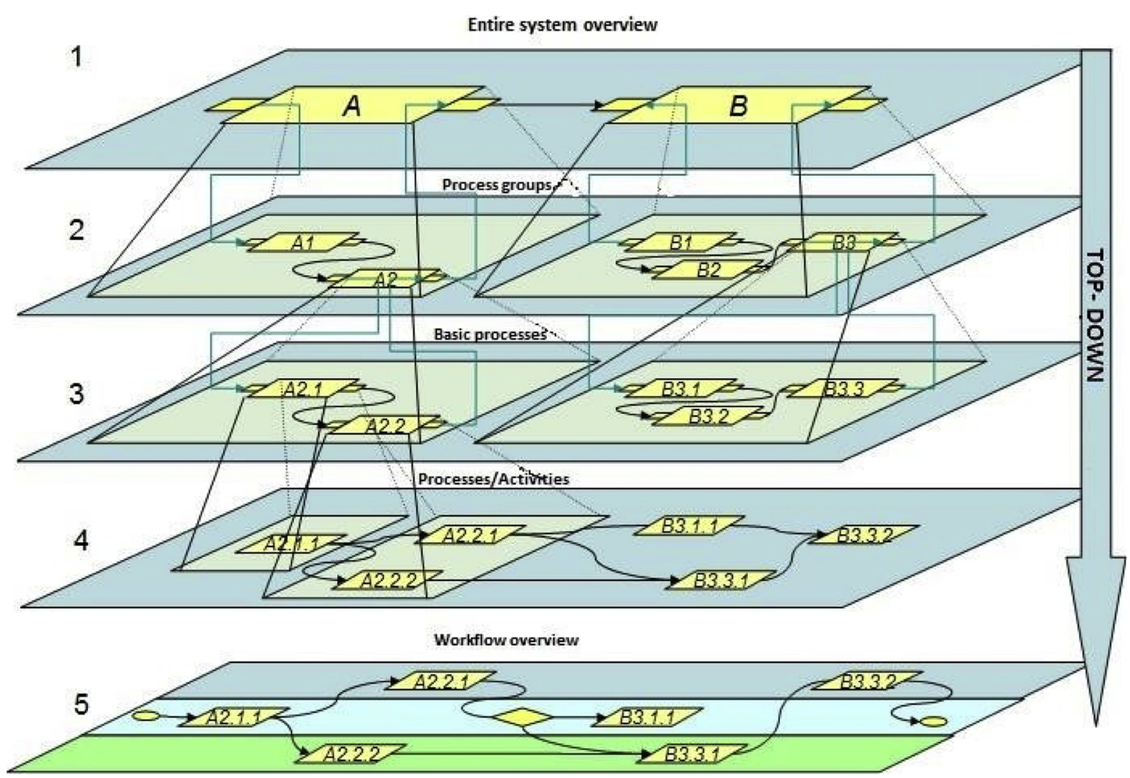


Fig. 1. Process levels – top-down strategy.

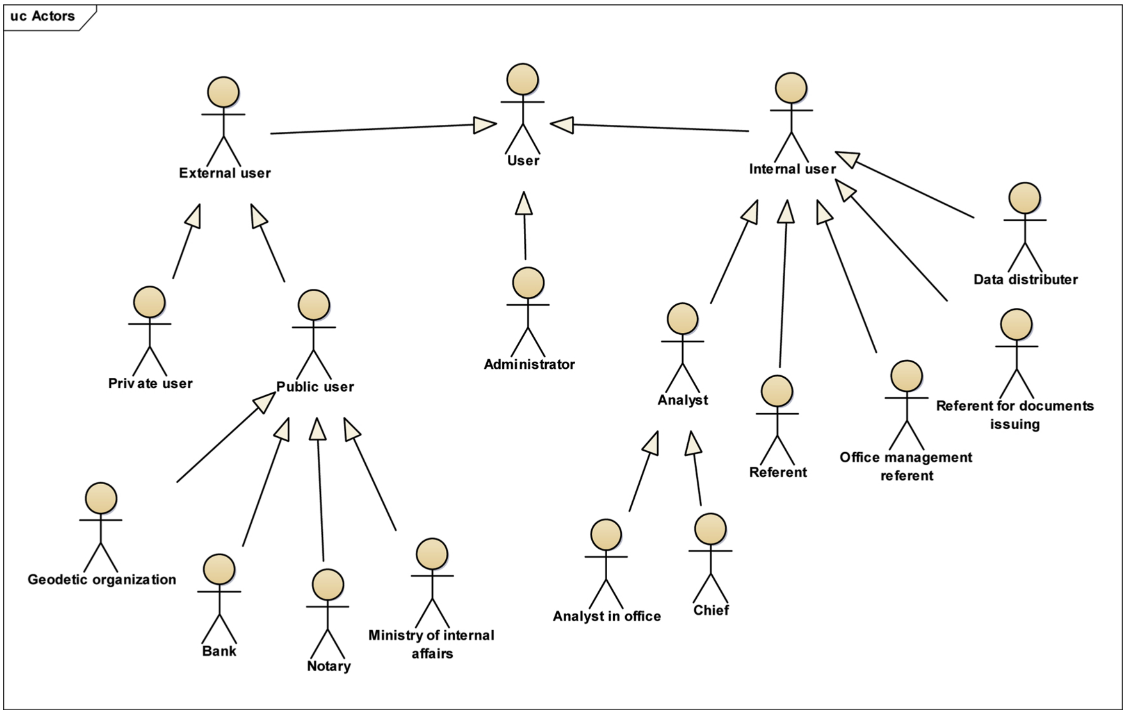


Fig. 3. Different types of actors in cadastral system.

in cadastral system includes administrator of the information system, internal users that are employees in cadastral offices and external users that can be private or public users like banks, notaries, geodetic organizations, etc. Internal users can be further divided by the role that employee has in cadastral processes, like referent, office management referent, referent for document issuing, chief, etc.

The highest level of hierarchy is called the context. In the case of Serbia's cadastral system, this is Level 1 which contains an overview of the entire system. According to the basic division of the process from the beginning, at this level the processes *KN1-Overview of data* and *KN2-Changes on data* are arranged (Fig. 4).

Process hierarchy for both KN1 and KN2 processes are described by Radulović (2015). Processes and workflows are described according to the Law on State Survey and Cadastre (2009), the Rulebook on Cadastre Survey and Real Estate Cadastre (2016) and the Law on the Procedure for Registration in the Real Estate Cadastre and Utility Network Cadastre (2018). The Law from 2018 introduces the novelty that each property is identified with unique property identification number (UPIN). This is used to link that property in a 3D data source. Process hierarchy is extended with processes that enable overview and registering 3D data in the real estate cadastre.

For the KN1 process, Level 2 contains process groups that relate to overview of office management data, overview of parties, parcels, buildings and parts of building. Level 3 shows basic processes of the *KN1.2 – Overview of buildings* process. This level covers processes for searching active and history data about buildings, issuing the documents and overview of geometry (*KN1.2.6 – Overview of building geometry*). Level 4 contains processes and activities that specifically describe a process, while Level 5 contains the workflow in the BPMN notation. Level 4 shows processes that can be executed in order to view geometry of the building. Fig. 5 shows the workflow for overview of building geometry. Based on the search parameters, a user obtains unique property identification number (UPIN), which is then checked for the type of geometry. If the geometry of the building is only available in 2D, a process *KN1.2.6.2 – Overview of 2D building* is called. If the geometry of the building is 3D, a process *KN1.2.6.3 – Overview of 3D building* is called. Based on the retrieved data, proper geometry viewer is started and data is displayed to the user.

For the KN2 process, Level 2 contains processes that describe how data can be changed. Processes can be grouped into processes of changing surveying data, i.e. changes on real properties (*KN2.1 - Change of real estate data*), processes of changing rights and restrictions on data (*KN2.2 – Change of rights and restrictions data*), processes of changing data about parties (*KN2.3 – Change of data about parties*) and changes on other data such as office management (*KN2.4 - Change on office management data*) or code lists (*KN 2.5 – Change of code list data*). This is shown on Fig. 6.

For the *KN2.1 – Change of real estate data* process, Level 3 contains basic processes that relate to the change of real property data. These processes relate to changes on parcels, buildings and parts of buildings like flats, business spaces, etc. For the Level 4, the process *KN2.1.2 – Change of building data* is chosen to show processes and activities that are performed during the change of building data, like inserting, editing or deleting the data. Fig. 7 shows this process using BPMN notation in order to specify the flow of the processes and activities that are part of it, and the participants and the messages that are exchanged between them.

There are four participants in the process, the user that is external user like private or public user, the office management referent, who registers the request in the form of subject, the referent who performs the change of the data and creates the draft decision on change, and the chief who signs the decision, which the referent prints and forwards to the office management referent. The office management referent sends a decision on the change to the user.

Fig. 8 shows the workflow for the process *KN 2.1.1.4 – Edit new version of the building*. An input to this process is the data on selected buildings for the change. Depending on the type of the change, there are two basic flows of execution. If only the attributive data of the building are changed, such as the address, legal status, usage, number or area, the geometry of the building is not changed, and after the submitting, the process ends or starts from the beginning if there were more selected buildings. The second flow of the process relates to changes of geometric data. Two flows of activity are distinguished. The first flow consists of activities that are performed if the 2D data is

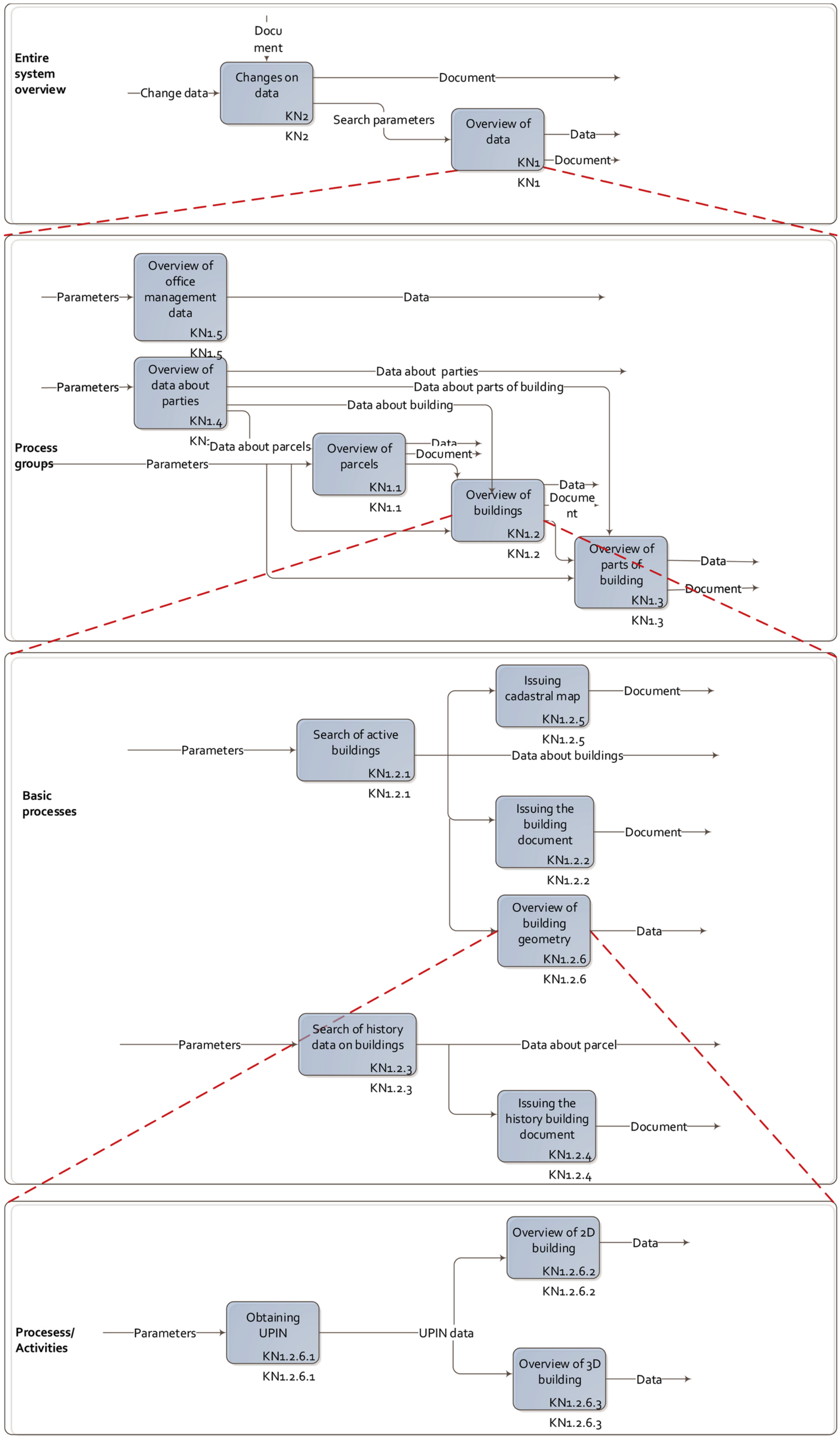


Fig. 4. An example of the hierarchy for the KN1 process.

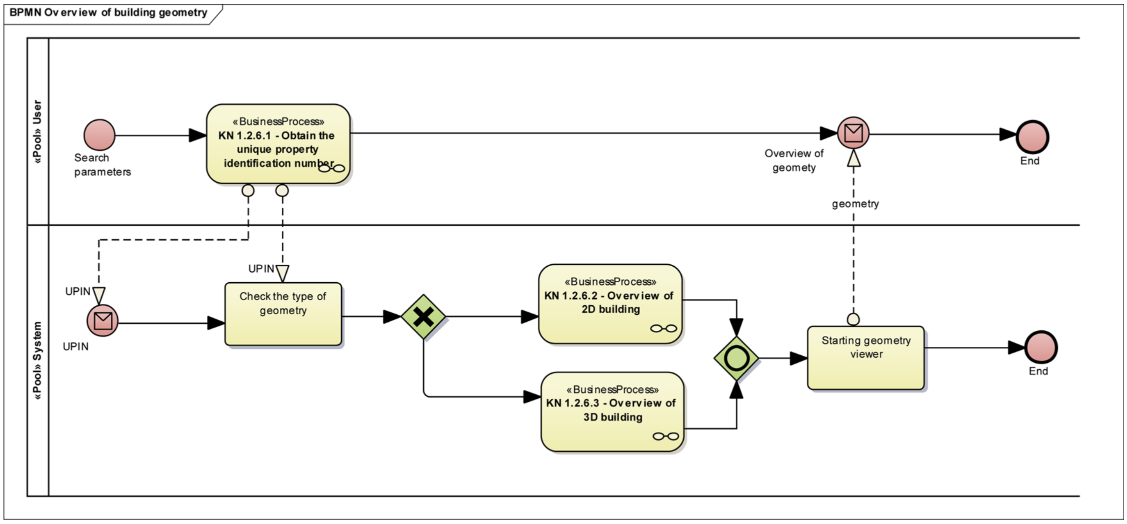


Fig. 5. Workflow for the overview of the building geometry.

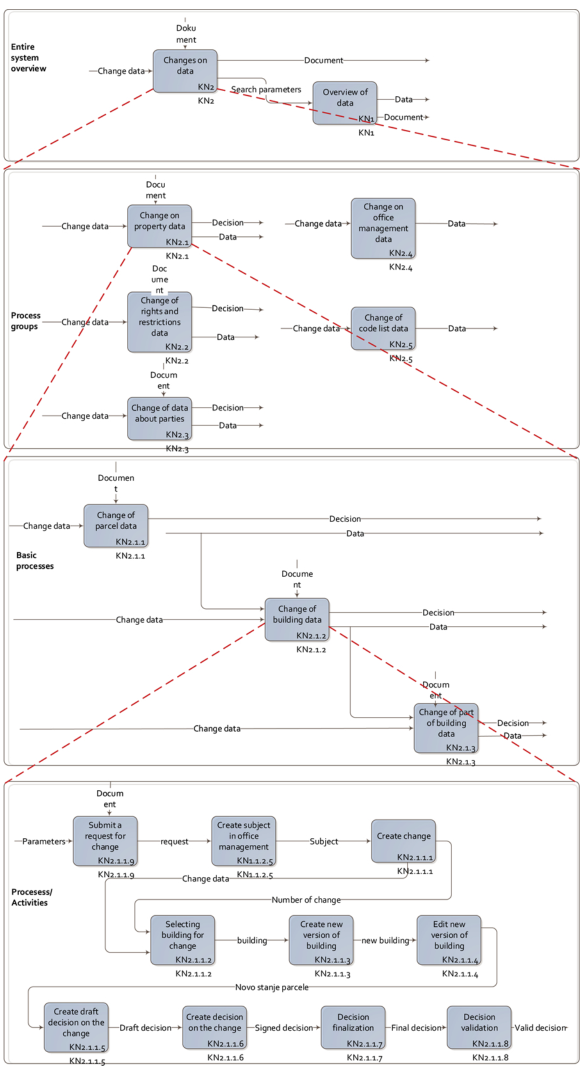


Fig. 6. An example of the hierarchy for the KN2 process.

changed. This flow implies inserting, editing and deleting a 2D building. If it is necessary to change building's descriptive data, the flow leads to this set of activities, after which the process ends. The second flow consists of activities that expand the process to support 3D data. First step is to obtain unique property identification number. This flow relates to insert, replace and delete 3D spatial source of the building. If the data is inserted or replaced it is necessary to link the new source with UPIN. This flow also enables the change of attributes, after which the process ends.

This method can be used to describe all processes of the system starting from the process groups of the second level. After the process decomposition, individual processes can be obtained on fourth level and appropriate workflow can be modeled.

4. Discussion on possibilities for using buildingSMART openBIM standards to implement 3D related processes in Serbian cadastre

Previous Section described abstract process model, independent of its implementation (a platform neutral specification). However, to instantiate it and implement it in SOA, we analysed the possibility of using buildingSMART openBIM standards to support 3D related processes (other processes are or will be implemented using ordinary WSDL or RESTful Web services). The reason for this is that BIM data is already available for buildings that are planned for construction, restauration or legalization. These BIM models are produced in different proprietary software and usually contain very detailed information about buildings that is not necessary for the purpose of rights registration. Therefore, it is necessary to identify what subset of this information is required for this purpose.

buildingSMART has adopted five basic methodology standards that may be used to support processes described in the previous Section. First to mention is Industry Foundation Classes (IFC), a common data schema for the exchange of relevant data between different users and software applications with the goal to enable interoperability. Second standard, the Model View Definitions (MVD) is used to define the subset of the IFC data model that is necessary to support the specific data exchange requirements, since IFC is very rich semantic model with a large number of classes. However, only subset of these classes is needed for a specific purpose such as mapping legal spaces within a building and it can be specified in MVD. Mapping of terms is supported by International Framework for Dictionaries (IFD) to support multilingualism and it is convenient for the cross-country interoperability of land administration systems. Information Delivery Manual (IDM) is a process standard used to capture and integrate business processes that provide detailed specifications of the information that a user fulfilling a particular role would need to provide at a certain moment, e.g. processes of registration of 3D spatial units, viewing property rights in 3D,

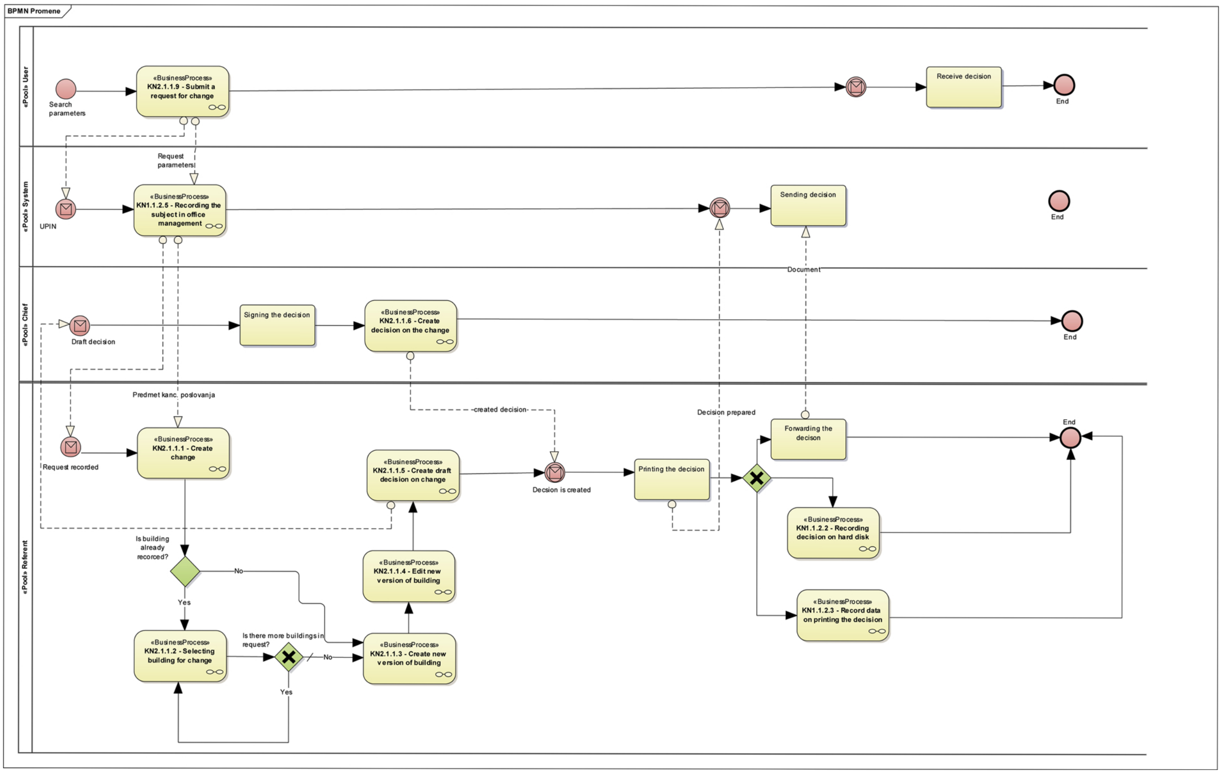


Fig. 7. Model of the business process for changing building data.

etc. Finally, BIM Collaboration Format (BCF) is an open standard XML schema that encodes messages to enable workflow communication between different BIM software tools. It also provides RESTful web service bcfAPI that enables software applications to exchange BCF data seamlessly in BIM workflows and coordinate changes in the project. However, it can also be used by the employees in cadastre to exchange and view data about 3D spatial units and request changes, if necessary.

4.1. Modeling business processes using Information Delivery Manual (IDM)

Related to processes in land administration in general and toward cadastre, it is worth paying special attention to the Information Delivery Manual (IDM), a process standard, whose purpose is to specify processes and information flow during the lifecycle of a facility. Considering that the lifecycle of a facility is highly related to land administration activities it makes sense to link cadastral processes to this methodology. This relation is reflected in the sense that land administration provides means to secure tenure and make large investments possible. Even to begin a construction project it is necessary to obtain building permit that requires several requests to local cadastral office. The methodology can be used to document existing or new processes and describe the associated information that have to be exchanged

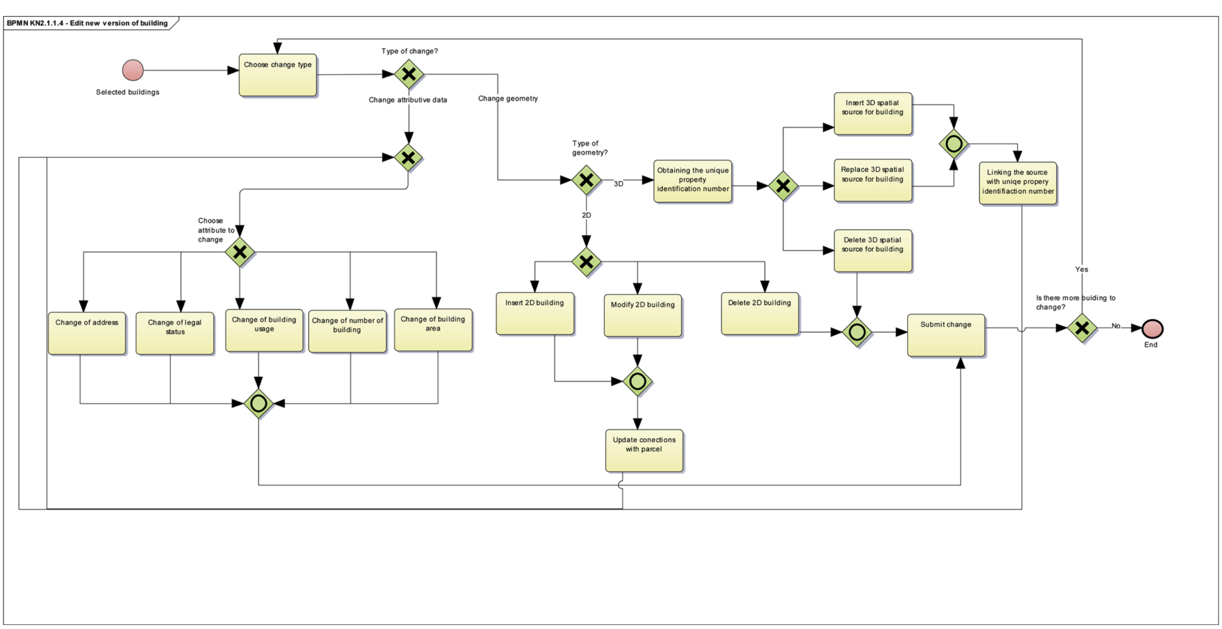


Fig. 8. Model of the business process for editing new version of building.

Fig. 9. Transformation of needs into operational solutions (adapted from See et al., 2012).

between parties. The output from the standard can afterwards be used to specify a more detailed specification that can form the basis for a software development process. It is important to state that in order to make an information delivery manual operational for intended exchange scenarios it has to be supported by software. Therefore, existing software solutions used in cadastral offices in Serbia would require either a new tool or extension of existing tools to support 3D cadastre activities. We investigated whether existing open source solutions, such as bimserver (BIMserver, 2019), can be used for this purpose and concluded that they can form the basis for this implementation, but further development is needed. This will be shown in the following case study.

It is the purpose of an IDM to capture processes and exchange requirements, while MVD is aiming at mapping exchange requirements to a data schema (IFC), and potential constrains to the used data model (this can refer to validity of data), so the business processes can be supported or automated through the use of information technology. The development process starts with identifying user needs in IDMs, which are used to create more technical specification in MVD. The requirement specification is used to implement a software solution that preferable should be certified before it is released for use. This solution should also provide BIM data validation. Fig. 9 (adapted from See et al., 2012) shows how this development process can be applied to processes in 3D cadastre. BIM data validation enables the end user to verify that a BIM, that has been exported from a certified application, meets all the requirements defined in the original IDM and MVD for the exchange of 3D data. IDM should be developed on the national level for the purpose of 3D cadastre, preferably supported by international standards, and supported by appropriate software solutions. The proposed IDM should be submitted to buildingSMART members in order to get an official status. However, our goal is to test whether this method is appropriate for introducing 3D legal spaces in Serbian land administration procedures, whereas an official IDM is out of scope at this moment. For the development of IDM at a national level, processes from the lowest level described in the previous Section can be used, since they are detailed enough, and IDM also requires using BPMN notation for the specification of processes.

4.2. Spatial structure of 3D spatial units encoded in IFC

IFC is a large schema with many entities related to the design and construction of a building. However, it is not necessary to use the entire IFC schema to represent 3D spatial units. For that purpose, entities of the spatial structure of a building, spatial zones and boundaries may be used.

Basic entities of spatial structure of a building are shown on Fig. 10 in EXPRESS-G notation (ISO 10303-11, 2004). A spatial structure element (ifcSpatialStructureElement) is the generalization of all spatial elements that might be used to define a spatial structure. Spatial structure element types are: site, building, building storey and spaces. Spatial structure hierarchy uses ifcRelAggregates which is a special type of the general composition/decomposition (or whole/part) relationship to establish a spatial structure including site, building, building section and building storey. IfcProject indicates the undertaking of some design, engineering, construction, or maintenance activities and establishes the context for information to be exchanged or shared, to provide the root instance and the context for all other information items included. A site (ifcSite) is a defined area of land on which the project construction should take place and it can contain zero or more buildings (ifcBuilding). A site can be linked to one or more parcels on which the construction project started. The building storey (ifcBuildingStorey) has an elevation and represents a horizontal aggregation of spaces that are vertically bound, such as apartments on a single floor. A space (ifcSpace) represents an area or volume bounded actually or theoretically. Spaces are areas or volumes that provide certain functions within a building. A space is associated to a building storey (or in case of exterior spaces to a site) and may span over several connected spaces, such as rooms in an apartment.

IfcSpace entity has an attribute which references the IfcRelSpaceBoundary entity that stores the geometric information about the boundary of the space. Spaces can be grouped into a zone represented by ifcZone entity using ifcRelAsignsToGroup relationship. This grouping may be linked to a basic administrative unit in LADM which represents homogenous rights, restrictions and responsibilities over multiple spatial units. Another entity that may be used for grouping legal spaces is ifcSpatialZone entity, which is more flexible and provides the ability to combine different physical and spatial elements. A spatial zone is a non-hierarchical and potentially overlapping

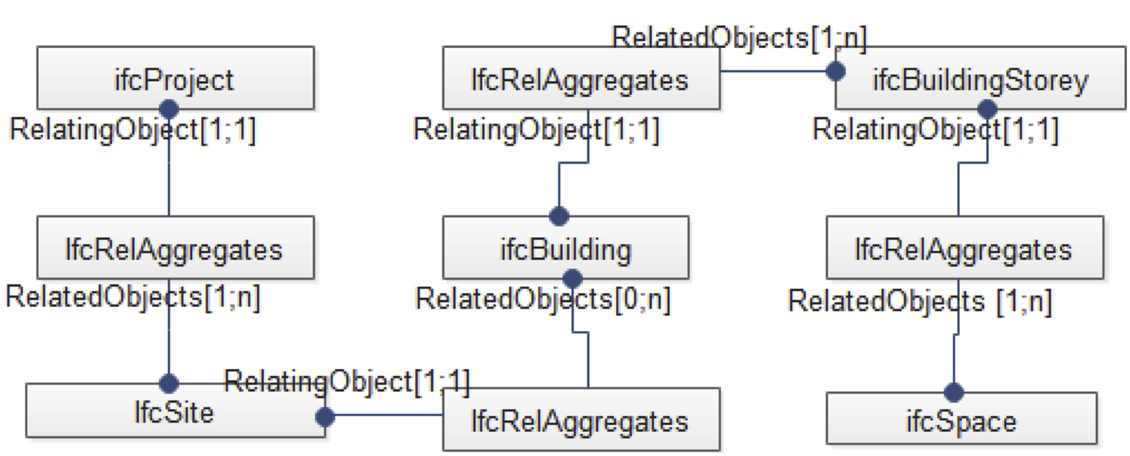


Fig. 10. Spatial structure of a building project.

decomposition of the project under some functional consideration. It might be used to represent a thermal zone, a construction zone, a usable zone or in the case of cadastre, a legal zone. In addition, ifcSpatialZone may have its independent placement and shape representation to define legal boundaries, which is in some cases necessary, such as when a land is included in a common property or for managing complex 3D legal spaces. After defining legal zones/spaces, cadastral attributes, such as rights, restrictions and responsibilities, may be assigned to it. If the unique property identification number (UPIN) is assigned as an attribute, then a link to the cadastral database may be established to retrieve all other information about a legal space. In Serbian cadastre, according to the current Law, basic administrative unites which are called real estate folios can contain only a single property / spatial unit, such as parcel, building or building unit. The Law also recognizes the concept of common ownership, which can be applied, for the common parts of the building, such as elevators, roof, attic, stairs, and corridors. Owners of apartments, garages, and business offices have the right of common indivisible ownership to these parts, which are considered as a single common property whose discontinuous legal space may be modeled by ifcSpatialZone.

When the set of IFC classes are selected to represent legal spaces, appropriate Model View Definition should be developed for this purpose. Model View Definitions are encoded in an XML based format called mvdXML. Software applications may make use of MVDXML to support functionalities such as: exporting data that is automatically filtered to include only data within a model view, prompting users to provide missing information, e.g. if UPIN is missing, providing attribute editing functionality for high-level concepts instead of low-level data, etc. mvdXML files may be generated and edited using a tool called ifcDoc, or any other XML editor.

4.3. BCF workflow for handling requests by cadastral offices

BIM Collaboration Format (BCF) is an open file XML format bcfXML that supports workflow communication in BIM processes and the RESTful web service bcfAPI enables software applications to exchange BCF data in BIM workflows in SOA environment. It provides the possibility to exchange machine readable BCF-Topics with attached BIM-Snippets (small components of a BIM-model), attached multiple viewpoints, etc. BCF is mainly used by the collaborators on the project to communicate about the issues of a BIM model during its design cycle. BCF issue holds a description of the issue, a status, links to a BIM model and objects, a picture of the issue and a camera orientation. The BCF standard is based on the file exchange. BCF issues are packed into a ZIP file (.bcfzip) and sent to project partners, but there are also new cloud based proprietary solutions that support issue management among various BIM tools. In regard to open source software, van Berlo and Krijnen (2014) developed BCF server software as an extension to bimserver for the centralized exchange of BCF issues, instead of sending it as a file. This type of solution may be used by cadastral offices to communicate request or issues about legal spaces. BCF services provided in BCF API include HTTP GET requests to retrieve the project, a collection of topics related to a project, possibly with a snippet related to a topic, collection of IFC files or file references, comments and viewpoints related to a topic and related documents such as legal requirements, etc. The BCF standard proposes Comment, Issue, Request and Solution as the enumeration values for TopicType, where in land administration domain the mostly used topic type would be a request, but also in the process of retrieving a building permit other topic types would also be usual, since issues often arise during this process that need further processing.

Land administration workflows can make use of BCF server and bcfAPI in general by exchanging issues during property registration, requests for changes, viewing of data, etc. As mentioned before, this could also be useful in the process of acquiring building permit, which requires several requests toward cadastral office and it would facilitate employees to view issues and propose solution. By linking BCF server to bimserver it is possible for a topic/request to visualize data retrieved from IFC file in bimserver and zoom directly to required part of building based on camera and viewpoint parameters. The existing deployment of the web services could be improved with this data sharing/viewing mechanism, although further development is needed. This way, already developed SOA environment in this domain would be enhanced with the workflows that include 3D data. Web services that are already developed in Serbia and in Montenegro (Govedarica et al., 2018) can be integrated with the web services providing access and visualization of 3D data.

This analysis on the possibility to use openBIM standards to support 3D related processes will be demonstrated in the following case study.

5. Case study on the process of the legalization of buildings

Legalization of buildings is the process of recording rights for the buildings that are built without building permit, and consequently these buildings are not part of the official real estate cadastre register. With over more than 2 million illegal buildings in Serbia (MCETI, 2019), legalization is considered an important and intensive process by the Government. Many private agencies are involved in this process. In this regard, a set of laws have been adopted with the goal to speed up the process and to legalize as many buildings as possible. Only for the buildings built before year 2015, the citizens have the right to claim legalization (this is checked on the satellite imagery), otherwise they will be demolished. The legalization workflow usually includes BIM models of buildings under legalization developed by architects (usually in ArchiCAD, but tools such as Revit or SketchUp are also used) and geodetic situational draft developed by surveyors in CAD tools. A geodetic situational draft is made to display position and elevation data on all visible natural and built features of the land surface in the construction area. The overview of the BIM based workflow for the legalization of buildings is shown on Fig. 11. This workflow is applicable when BIM is used, although using BIM is not mandatory in the process of legalization. It shows four pools of processes that relate to the four types of actors: client that requests legalization, authority that processes the request, cadastral office and a private agency. It is necessary that a client proves the ownership on land where facilities were built. This can be achieved by invoking the process: *KN1.1.2.1-Issuing the real estate folio for the parcel*. The private company engaged by the client is responsible to deliver the report on the existing situation on the ground place. This report includes the development of the geodetic situational draft and the development of the technical documentation of the built facilities, using BIM tools. Given all the necessary documents and if preconditions defined by the law are met, the legalization authority makes decision on the legalization of a building. If the decision is positive, it initiates the process of registration by invoking the cadastral process: *KN2.1.1.9 Submit request for a change* (see Fig. 6). Two BIM related processes are colored in red on Fig. 11. These can be included in IDM for a building. The process *Development of technical documentation* implies that an architect integrates the legal space requirements in the BIM of the building that will be submitted to the cadastre as a source of 3D geometry. This depends on how spatial units will be encoded in IFC. The process *KN2.1.1.9 Submit request for a change* comprises the registration of building which includes recording 3D spatial characteristics of the building, and registration of the rights on the building.

For a case study, we analysed demo data sets (BIM models) developed in two different tools (ArchiCAD and SketchUp) for the legalization purposes, obtained by the architects involved in the process. These models were exported in IFC format. ArchiCAD models were already classified according to IFC spatial structure shown on Fig. 10, whereas the SketchUp models needed to be further reclassified using the classifier toolbar for the IFC classification system. Furthermore, attributes of spatial entities were edited to include cadastral data such as unique identifiers of properties, building attributes such as number of parcel

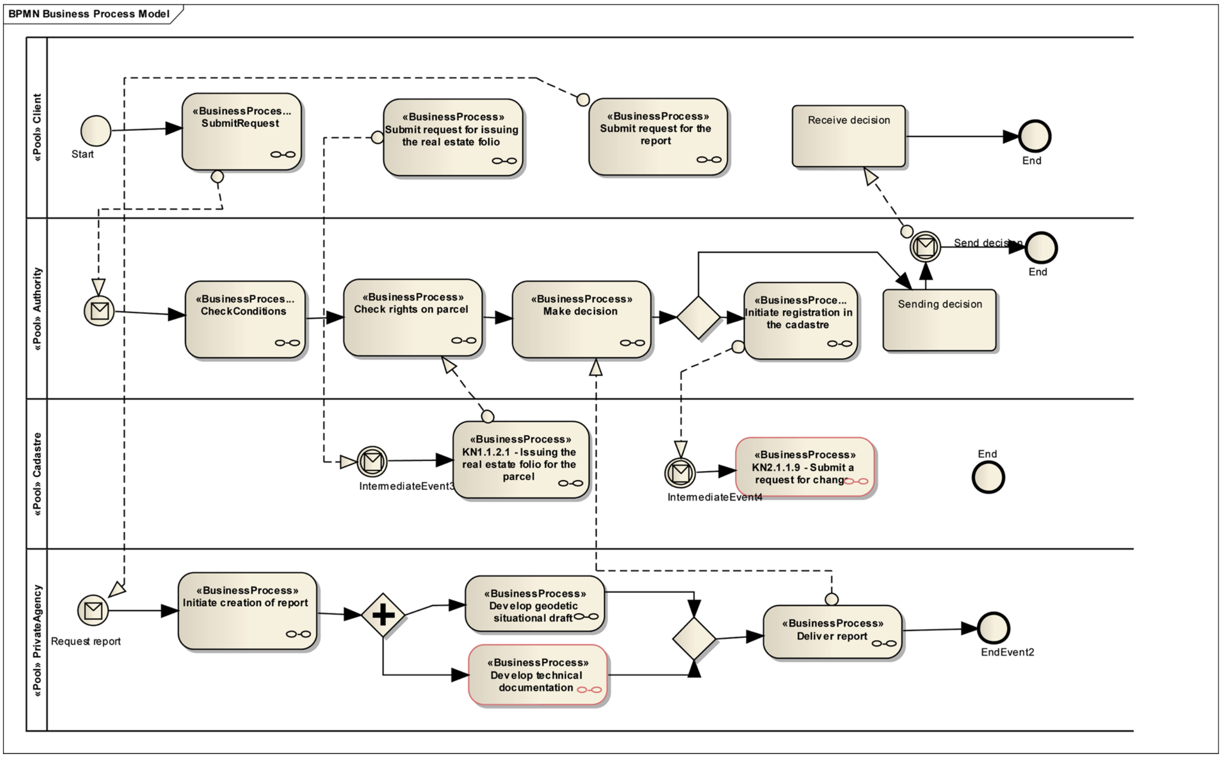
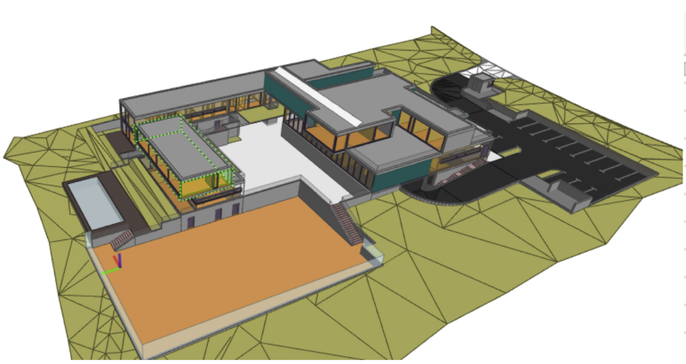


Fig. 11. Overview of the BIM based workflow for the legalization of buildings.

and building, or type of building unit such as business premises of different purposes (Fig. 12). These attributes help to distinguish different model elements from the cadastral perspective but are not necessary for data search and retrieval. The drawback of this approach is that not all architectural designs are suitable for representing legal spaces and further modifications of the developed model are necessary. Therefore, it would be useful to provide guidance to architects, surveyors or technical drawers how to develop a model in order to fit the purpose of 3D cadastre, without significant influence on their work if possible. It is also useful to develop MVD for the IFC sub-schema that describes legal spaces. This MVD will be then used to validate the obtained IFC file. This requires further research and will be aligned with the announced LADM revision to include IFC as a possible encoding for 3D legal spaces.

To support the automation of BIM based processes in cadastral workflows, we analyzed open BIM BCF REST API (BCF-API, 2019) and the possibility of using web based open source solutions such as bimserver. Bimserver is used for the visualisation purposes, while BCF server is used for the exchange of building project related topics, mostly related to its construction and potential issues. However, in the following it will be explained how this collaboration may be extended for cadastral purposes. Fig. 13 shows a deployment diagram of the interaction of cadastral system with a BCF/BIM server. In this example, a user (e.g. referent) searches the system to view a 3D building. In this case the process: *KN 1.2.6.3 Overview of 3D building* is invoked. The user enters the search criteria such as UPIN or other attributes of the building if she/he does not know UPIN (number of the parcel, subnumber of the parcel, number of the building, address, etc.). After the user uniquely identified the building that she/he wants to view and retrieved the right UPIN, the system sends a request to a cadastral database to retrieve a GUID of the building. All IFC and BCF elements contain global unique identifiers (GUIDs) by which they can be distinguished and searched. However, cadastral search is based on UPIN. Therefore, the means for mapping has to be established and kept in the database. Another option would be to enrich IFC entities representing spatial units with cadastral attributes including UPIN, but this would require an additional searching mechanism to be developed. Searching topics related to a specific spatial unit may be performed using UPIN that is mapped to GUID. The server returns the response about the topic request in JSON format, together with attached BIM snippet in IFC format. The entire IFC file can also be retrieved. Viewing spatial unit can be achieved with the type of request that returns a snapshot in jpg



Type	Name	Description
Project	f39bc88a-6700-45f9-...	Project of the current ...
Site	753f05ea-c753-4076-...	Building 80284-949-1-...
Building	21b8ec6f-a49d-4d12-...	Building 80284-949-1-...
Building ...	21b8ec6f-a49d-4d12-...	Storey - Building 8028...
Buildin...		
Footings		
Roofs		
Spaces		
Space	735ff869-31a8-46ba-...	Business premises
Space	569c47db-4e1f-426e-...	Business premises of c...
Space	234c7088-0795-4a34-...	Business premises for ...

Fig. 12. Reclassified building model in IFC format with edited attributes.

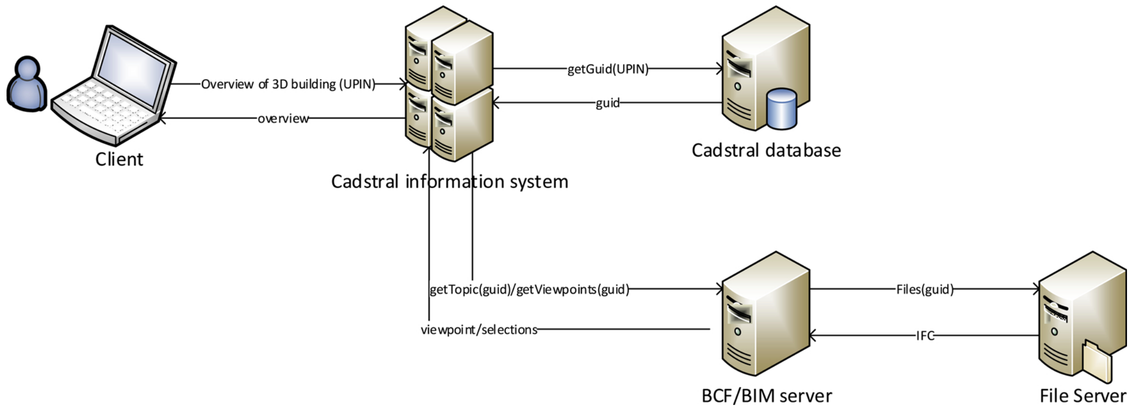


Fig. 13. Using BCF and BIM server to support cadastral workflows.

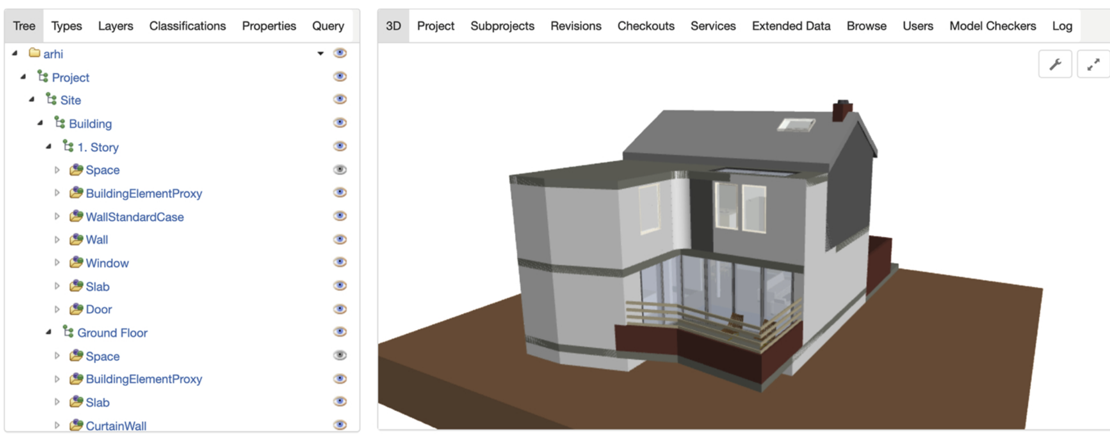


Fig. 14. IFC model imported in bimserver.

or png format. More advanced and interactive option of viewing 3D spatial units may be achieved with the viewpoint/selection type of request. This type of request returns a list of selected IFC components (such as ifcSpaces that represent spatial units) with their GUIDs, that can be rendered in a specialized visualisation tool. The viewpoint service also offers the possibility to choose the color that will be used to render a selection of IFC components, such as a group of ifcSpaces that represent an apartment.

The retrieved IFC file may than be imported and viewed in bimserver (Fig. 14). Bimserver is a BIMSie (BIM Service interface exchange) compliant server for IFC data. It is an open standard API for BIM Web services. Bimserver uses bimvie.ws, a JavaScript client for Building Information Modelling, that uses open standards such as IFC, BCF and BIMSie. It includes JavaScript library BIMSurfer as a 3D viewer for IFC models. For the BCF based collaboration, BCF Server and Forum may be used (BCF-Forum, 2014). This is a stand-alone application, non-compliant with the BCF REST API. However, more specialized tool would be useful in this case, such as a potential plugin for bimvie.ws client, to integrate the process of requests exchange and visualisation.

6. Conclusion

The paper presented the process model for Serbian cadastre. Process model was developed using functional modeling and business process modeling. A top-down strategy was selected for describing the processes, which increases the decomposition of the processes from general to specific. At the highest level, a system overview is defined without the introduction of process details. Each subsequent level introduces more details, or processes, as long as the level specification is not reduced to basic (atomic) processes or activities. Processes are organized in two general groups: processes that change the data in the system and the processes by which data are downloaded or viewed. This hierarchical organization of the cadastral processes can be used as a roadmap to describe cadastral processes in countries, in the sense that it can deal with a vast number of processes by organizing them into more general groups. The advantage of the proposed process model is reflected in the fact that it can support the automation and acceleration of existing procedures in the cadastre. This is especially important for the real estate market and for improving the efficiency of cadastral services to private and public parties. Although described as an abstract model, it should be emphasized that some processes in Serbian land administration have already been implemented as Web services such as sending requests or viewing legal (non-spatial) and 2D spatial data. This trend of introducing new electronic services will continue.

However, to bring these processes on a 3D level, an extensive further work is required which includes a development of new specifications and new tools, but also changes in regulations. Currently, surveyors use 2D CAD files that they receive from architects to represent buildings and building units and it is likely that this workflow will continue in 3D environment as well. This means that surveyors will receive 3D models of the buildings from architects in the format they use the most (BIM/IFC). However, it requires more elaborate analysis how spatial units should be integrated in IFC. Furthermore, although available tools can be used, more specialized tools would be useful to support such workflows. An important step toward achieving this goal would be standardization in the field of 3D cadastre to provide guidance and facilitate further work on a national level.

Declaration of Competing Interest

The authors declare no conflict of interest.

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References

Aguilar-Savén, R.S., 2004. Business process modelling: review and framework. Int. J. Prod. Econ. 90 (2), 129–149. https://doi.org/10.1016/S0925-5273(03)00102-6.

Aien, A., Kalantari, M., Rajabifard, A., Williamson, I., Wallace, J., 2013. Towards integration of 3D legal and physical objects in cadastral data models. Land Use Policy 35, 140–154. https://doi.org/10.1016/j.landusepol.2013.05.014.

Alattas, A., Zlatanova, S., van Oosterom, P., Chatzinikolaou, E., Lemmen, C., Li, K.-J., 2017. Supporting indoor navigation using access rights to spaces based on combined use of IndoorGML and LADM models. ISPRS Int. J. Geoinf. 6, 384. https://doi.org/10.3390/ijgi6120384.

Atazadeh, B., Kalantari, M., Rajabifard, A., Ho, S., Ngo, T., 2017a. Building information modelling for high-rise land administration. Trans. Gis 21, 91–113. https://doi.org/10.1111/tgis.12199.

Atazadeh, B., Kalantari, M., Rajabifard, A., Ho, S., Champion, T., 2017b. Extending a BIM-based data model to support 3D digital management of complex ownership spaces. Int. J. Geogr. Inf. Sci. 31 (3), 499–522. https://doi.org/10.1080/13658816.2016.1207775.

Atazadeh, B., Rajabifard, A., Kalantari, M., 2017c. Assessing performance of three BIM-Based views of buildings for communication and management of vertically stratified legal interests. ISPRS Int. J. Geoinf. 6 (7), 198. https://doi.org/10.3390/ijgi6070198.

BIM, 2019. BIM And the Future of AEC, What Is BIM? Available online: https://www.autodesk.com/solutions/bim (accessed on 18 March 2019). .

BCF-API, 2019. buildingSMART/ BCF-API. Available online: https://github.com/BuildingSMART/BCF-API (accessed on 18 March 2019). .

BCF-Forum, 2014. opensourceBIM/ BCF-Forum. Available online: https://github.com/opensourceBIM/BCF-Forum (accessed on 18 March 2019). .

BIMserver, 2019. Open Source BIMserver – in the Heart of Your BIM!. Available online: http://bimserver.org/ (accessed on 18 March 2019). .

buildingSMART, 2019. Open Standards - the Basics. Available online: https://www.buildingsmart.org/standards/technical-vision/open-standards/ (accessed on 18 March 2019).

Bydłosz, J., 2015. The application of the Land Administration Domain Model in building a country profile for the polish cadastre. Land Use Policy 49, 598–605. https://doi.org/10.1016/j.landusepol.2015.02.011.

Davenport, T.H., Short, J.E., 1990. The new industrial engineering: information technology and business process redesign. Sloan Manage. Rev. 31 (4), 11–27.

Dimopoulou, E., Karki, S., Roić, M., Almeida, J.-P.D., Griffith-Charles, C., Thompson, R., et al., 2016. Initial registration of 3D parcels. In: Proceedings of the 5th International FIG 3D Cadastre Workshop, 18–20 October. Athens, Greece. pp. 105–132.

Dimopoulou, E., Karki, S., Roić, M., Almeida, J.-P.D., Griffith-Charles, C., Thompson, R., Ying, S., Paasch, J., van Oosterom, P., 2018. Chapter 2. Initial registration of 3D parcels. In: van Oosterom, P. (Ed.), Best Practices 3D Cadastres. FIG publication, pp. 67–94.

Drobež, P., Fras, M., Ferlan, M., Lisec, A., 2017. Transition from 2D to 3D real property cadastre: the case of the Slovenian cadastre. Comput. Environ. Urban Syst. 62, 125–135. https://doi.org/10.1016/j.compenvurbsys.2016.11.002.

El-Mekawy, M., Paasch, J.M., Paulsson, J., 2014. Integration of 3D cadastre, 3D property formation and BIM in Sweden. In: Proceedings of the 4th International FIG 3D Cadastre Workshop, 9-11 November. Dubai, UAE. pp. 17–34.

FIPS PUBS, 1993. Integration Definition for Function Modeling (IDEF0), Draft Federal Information Processing Standards Publication 183. Available online: http://www.idef.com/wp-content/uploads/2016/02/idef0.pdf (accessed on 18 March 2019). .

Govedarica, M., Radulović, A., Sladić, D., Popović, D., 2018. LADM – experiences and challenges in implementation. In: Proceedings of the 7th International FIG Workshop on the Land Administration Domain Model, 11-13 April. Zagreb, Croatia. pp. 194–212.

Góźdź, K., Pachelski, W., van Oosterom, P., Coors, V., 2014. The possibilities of using CityGML for 3D representation of buildings in the cadastre. In: Proceedings of the 4th International Workshop on 3D Cadastres. 9-11 November. Dubai, UAE. pp. 339–362.

Ho, S., Rajabifard, A., 2016. Towards 3D-enabled urban land administration: strategic lessons from the BIM initiative in Singapore. Land Use Policy 57 (30), 1–10. https://doi.org/10.1016/j.landusepol.2016.05.011.

Isikdag, U., 2015. Enhanced Building Information Models: Using IoT Services and Integration Patterns. Springer International Publishing, Heidelberg, Germany.

ISO 10303-11, 2004. ISO 10303-11:2004 Industrial Automation Systems and Integration - Product Data Representation and Exchange - Part 11: Description Methods: the EXPRESS Language Reference Manual.

Janečka, K., Souček, P., 2017. A country profile of the Czech Republic Based on an LADM for the development of a 3D cadastre. ISPRS Int. J. Geoinf. 6 (5), 143. https://doi.org/10.3390/ijgi6050143.

Lemmen, C., van Oosterom, P., Bennett, R., 2015. The land administration domain model. Land Use Policy 49, 535–545. https://doi.org/10.1016/j.landusepol.2015.01.014.

Lemmen, C., van Oosterom, P., Unger, E.M., de Zeeuw, K., Kalantari, M., 2018a. Exploring options for standardization of processes and transactions in Land administration. In: Proceedings of the 7th International FIG Workshop on the Land Administration Domain Model, 11-13 April. Zagreb, Croatia. pp. 141–150.

Lemmen, C., van Oosterom, P., Kalantari, M., 2018b. Towards a New working item proposal for edition II of LADM. In: Proceedings of the 7th International FIG Workshop on the Land Administration Domain Model, 11-13 April. Zagreb, Croatia. pp. 331–354.

Mađer, M., Vučić, N., Vranić, S., Roić, M., 2018. Initial 3D cadastre registration in the Republic of Croatia by cadastral resurvey. In: Proceedings of the 6th International FIG 3D Cadastre Workshop, 2-4 October. Delft, The Netherlands. pp. 57–74.

Mayer, R., Painter, M.K., deWitte, P., 1992. IDEF Family of Methods for Concurrent Engineering and Business Re-engineering Applications. Knowledge Based Systems, Inc., College Station, TX, USA.

MCETI, 2019. Ministry of Civil Engineering, Transportation and Infrastructure. Database of Unlawfully Built Facilities. Available online: https://www.mgsi.gov.rs/cir/dokumenti/baza-nezakonito-izgradjenih-objekata (accessed on 18 March 2019). .

Navratil, G., Frank, A.U., 2004. Processes in a cadastre. Comput. Environ. Urban Syst. 28, 471–486. https://doi.org/10.1016/j.compenvurbsys.2003.11.003.

OGC, 2017. OGC LandInfra / InfraGML. Available online: https://www.opengeospatial.org/standards/infragml (accessed on 04 July 2019). .

Oldfield, J., van Oosterom, P., Beetz, J., Krijnen, T.F., 2017. Working with open BIM standards to source legal spaces for a 3D cadastre. ISPRS Int. J. Geoinf. 6 (11), 351. https://doi.org/10.3390/ijgi6110351.

Official Gazette, 2009. Official Gazette of the Republic of Serbia, The Law on State Survey and Cadastre. Available online: http://www.rgz.gov.rs/content/Datoteke/Dokumenta/01%20Zakoni/Zakon%20o%20drzavnom%20premeru%20i%20katastru%20-%2007.09.2009.pdf (accessed on 18 March 2019). .

Official Gazette, 2016. Official Gazette of the Republic of Serbia, The Rulebook on Cadastre Survey and Real Estate Cadastre. Available online: http://www.rgz.gov.rs/content/Datoteke/Dokumenta/02%20Pravilnici/Pravilnik%20o%20katastarskom%20premeru%20i%20katastru%20nepokretnosti%2003.02.2016.pdf (accessed on 18 March 2019). .

Official Gazette, 2018. Official Gazette of the Republic of Serbia, The Law on the Procedure for Registration in the Real Estate Cadastre and Utility Network Cadastre. Available online: http://www.rgz.gov.rs/content/Datoteke/Dokumenta/01%20Zakoni/Закон%20о%20поступку%20уписа%20у%20катастар%20непокретности%20и%20водова_%2041_2018-16(1).pdf (accessed on 18 March 2019). .

Ottens, M., Stubkjær, E., 2007. 6 a socio-technical analysis of cadastral systems. In: Zevenbergen, J., Frank, A., Stubkjaer, E. (Eds.), Real Property Transactions: Procedures, Transaction Costs and Models. IOS Press, pp. 143–166.

OMG, 2011. Business Process Model And Notation Specification Version 2.0. Available online: https://www.omg.org/spec/BPMN/2.0/PDF (accessed on 18 March 2019). .

Popović, D., Pajić, V., Jovanović, D., Sabo, F., Radović, J., 2017a. Semi-automatic classification of power lines by using airborne lidar. In: Proceedings of the FIG Working Week, May 29–June 2. Helsinki, Finland.

Popović, D., Govedarica, M., Jovanovic, D., Radulović, A., Simeunović, V., 2017b. 3D visualization of Urban Area using lidar technology and CityGML. IOP Conference Series: Earth and Environmental Science Vol. 95. pp. 1–8. https://doi.org/10.1088/1755-1315/95/4/042006.

Radulović, A., Govedarica, M., Pržulj, Đ., 2011. Recommendation for the development of 3D cadastre. In: Serbian Geodetic Congress, 1-3 December, Republic Geodetic Authority. Belgrade, Serbia.

Radulović, A., 2015. Domain and Service Model for Real Estate Cadastre Geoinformation System. Ph.D thesis Available online:. University of Novi Sad. http://nardus.mpn.gov.rs/bitstream/handle/123456789/1854/Disertacija.pdf?sequence=1&isAllowed=y.

Radulović, A., Sladić, D., Govedarica, M., 2017. Towards 3D cadastre in Serbia: development of Serbian cadastral domain model. ISPRS Int. J. Geoinf. 6, 312. https://doi.org/10.3390/ijgi6100312.

Ristić, A., Bugarinović, Ž., Vrtunski, M., Govedarica, M., Petrovački, D., 2017. Integration of modern remote sensing technologies for faster utility mapping and data extraction. Constr. Build. Mater. 154, 1183–1198. https://doi.org/10.1016/j.conbuildmat.2017.07.030.

Rönsdorf, C., Wilson, D., Stoter, J., 2014. Integration of Land administration domain model with CityGML for 3D cadastre. In: Proceedings of the 4th International Workshop on 3D Cadastres, 9-11 November. Dubai, UAE. pp. 313–322.

Roschlaub, R., Batscheider, J., 2016. An INSPIRE-conform 3D model building model of Bavaria using cadastre information, Lidar and image matching. ISPRS – International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences Vol. XLI-B4. pp. 747–754. https://doi.org/10.5194/isprs-archives-XLI-B4-747-2016.

See, R., Karlshøj, J., Davis, D., 2012. An Integrated Process for Delivering IFC Based Data Exchange. buildingSMART International. Available online: http://iug.buildingsmart.org/idms/methods-and-guides/Integrated_IDM-MVD_ProcessFormats_14.pdf/at_download/file (accessed on 18 March 2019).

Stoter, J., Ploeger, H., Roes, R., van der Riet, E., Biljecki, F., Ledoux, H., Kok, D., Kim, S., 2017. Registration of multi-level property rights in 3D in the Netherlands: two cases and next steps in further implementation. ISPRS Int. J. Geoinf. 6 (6), 158. https://doi.org/10.3390/ijgi6060158.

Sladić, D., Radulović, A., Govedarica, M., 2018. processes in cadastre: process model for Serbian 3D cadastre. In: Proceedings of the 6th International FIG 3D Cadastre Workshop, 2-4 October. Delft, The Netherlands. pp. 39–56.

Tekavec, J., Lisec, A., 2018. A framework for assessing cadastral data as a source for 3D indoor modelling. In: Proceedings of the 6th International FIG 3D Cadastre

Workshop, 2-4 October. Delft, The Netherlands. pp. 243–260.
Thompson, R., van Oosterom, P., Karki, S., Cowie, B., 2015. A taxonomy of spatial units in a mixed 2D and 3D cadastral database. In: Proceedings of the FIG Working Week. Sofia, Bulgaria.
Thompson, R., van Oosterom, P., Soon, K.H., Priebbenow, R., 2016. A conceptual model supporting a range of 3D parcel representations through all stages: data capture, transfer and storage. In: Proceedings of the FIG Working Week. Christchurch, New Zealand.
Thompson, R., van Oosterom, P., Soon, K.H., 2017. LandXML encoding of mixed 2D and 3D survey plans with multi-level topology. ISPRS Int. J. Geoinf. 6 (6), 171. https://doi.org/10.3390/ijgi6060171.
van Berlo, L., Krijnen, T., 2014. Using the BIM collaboration format in a server based workflow. Procedia Environ. Sci. 22, 325–332. https://doi.org/10.1016/j.proenv.2014.11.031.
van Oosterom, P., Stoter, J., Ploeger, H., Lemmen, C., Thompson, R., Karki, S., 2014. Initial analysis of the second FIG 3D cadastres questionnaire: Status in 2014 and expectations for 2018. In: Proceedings of the 4th International FIG 3D Cadastre Workshop, 9-11 November. Dubai, UAE. pp. 55–74.
Vučić, N., Roić, M., Mađer, M., Vranić, S., van Oosterom, P., 2017. Overview of the Croatian land administration system and the possibilities for its upgrade to 3D by existing data. ISPRS Int. J. Geoinf. 6 (7), 223. https://doi.org/10.3390/ijgi6070223.
Hollingsworth, D., 1995. Workflow Management Coalition. The Workflow Reference Model. TC00-1003. Available online: http://www.wfmc.org/standards/docs/tc003v11.pdf (accessed on 17 July 2019). .
Zevenbergen, J., Frank, A., Stubkjaer, E. (Eds.), 2007. Real Property Transactions: Procedures, Transaction Costs and Models. IOS Press, Amsterdam, The Netherlands ISBN 978-1-58603-581-5.
Zlatanova, S., Li, K.-J., Lemmen, C., van Oosterom, P., 2016. Indoor abstract spaces: linking IndoorGML and LADM. In: Proceedings of the 5th International FIG 3D Cadastre Workshop, 18-20 October 2016. Athens, Greece. pp. 317–328.