Investigating an Interoperability Platform for Sustainable Land Management

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Key words: Building Information Model, 3D Ownership Information, Sustainable Land Management, Open Standards, Interoperability.

SUMMARY

Land has always been an asset of great value to man, being used for dwelling, economic and social purposes. Technological development and urbanization have, among others, led to overpopulation, intensive exploitation of land and increased number of necessities in modern societies, which result to the need of constructions above and/or below the ground. Therefore Sustainable Land Management (SLM) becomes of paramount importance.

SLM is based on two essential principles: a) Sustainable use and development of land and b) Operational Land Administration Systems. Sustainability (LAS) is an interesting aspect of the Architecture Engineering Construction Operation (AECO) industry, due to the fact that sustainable development focuses mainly on maximizing the quality of the built-up environment while minimizing or eliminating negative impact on the environment. Building Information Modeling (BIM) is a fast-growing technology and a promising development in AECO industry that allows for the development of an n-Dimensional (nD) virtual model of the facility by involving many stakeholders throughout its lifecycle. Using BIM data generated during design and built over the whole project lifecycle enables faster, safer, less wasteful construction and more cost-effective, sustainable operation, maintenance and eventual decommissioning (6D BIM). The cadastre is at the core of any land administration system providing integrity and unique identification of every land parcel. Facing the development of three dimensional (3D) spaces, developing a 3D cadastral management mode is imperative. Therefore, the integration of BIM and cadastre would exceedingly be useful to this scope. Owing to many disciplines involved in the aforementioned parts, an interoperability platform for SLM is crucial.

This paper facilitates an overall understanding of an interoperability platform for optimal land management. It also assists identifying an ideal collaborative platform for servicing the needs of governments, private businesses and the public, utilizing the latest technologies, servicing rights, restrictions and responsibilities (RRRs) and risks in relation to land and delivering much broader information about sustainable development.

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1. INTRODUCTION

Over the last two decades, population density has increased considerably making land use more intense. On one hand, this trend has triggered a growing importance of ownership of land, which has even changed the way humans relate to land. On the other hand, this pressure on land in urban areas and especially business centers may be detrimental to the environment, restricting the possibilities for appropriate land management. Therefore, sustainable use and development of land and operational LASs are of paramount importance for sustainable land management. The main objective of SLM is to promote human coexistence with nature with a long-term perspective, so that the provisioning, regulating, cultural and supporting services of ecosystems and man-made environment are ensured.

For this harmonization, many steps have to be implemented. The importance of the existence of an operational LAS has been highlighted by many researchers. Sustainability is an interesting aspect of the AEC industry due to the fact that sustainable development focuses mainly on maximizing the quality of the built environment while minimizing or eliminating negative impact on the environment. BIM is the new technology that is transforming the way AECO projects are designed, engineered, built and managed allowing nD modeling of the facility**.** Using BIM for the construction of a facility, there are possibilities from the early stages to collect, manage and use data which will contribute to a faster, safer, less wasteful construction and more cost-effective, sustainable operation, maintenance and eventual decommissioning (6D BIM). BIM tools cover a wide range of domains offering a variety of factions capable of making a constructed facility simultaneously considering the environment.

Taking into consideration the above mentioned facts, in conjunction with the critical impact of a 3D Cadastre and BIM for the development of a SLM, it seems that a combination of tools would be a solution, thus requiring an interoperability platform to support. This paper aims to provide a toolbox of best practices for designing an interoperability platform for the SLM with emerging tools that are tailored to each specific nation. Interoperability bases mainly on open standards with the IFC open standard being the most popular and widely used. This paper firstly, focuses on the potential of BIM to record and represent information about ownership and boundaries of properties, which is core land administration information. Secondly, it investigates the transformation of national BIM into a BIM Server, considering the development of an integrated interoperability platform.

2. ARE CADASTRE AND BIM MODELS USEFUL TOOLS FOR SLM?

2.1. Cadastre

Land management is the process by which the resources of land are put into good effect (UNECE 1996). Sustainable land management depends on the LAS managed by every country. Within every country's context, the land management activities may be described by three components: Land Policies, Land Information Infrastructures and Land Administration Functions in support of Sustainable Development (Enemark, 2005). The core of the aforementioned paradigm of land management is the Land Administration Functions that ensure proper management of RRRs and risks in relation to property, and natural resources and are completely supported by an operational LAS which is based on an operational cadastre. Thus, a complete Cadastral System can bring the optimal outcomes for the SLM.

The existing cadastral systems have been developed based on a two-dimensional (2D) mapping system. However, in the real world, the actual ownership rights are more than a two-dimensional parcel as they can extend above and below the earth surface (Shojaei, 2014). Therefore, 2D polygons that are used for defining ownership rights in 3D space are not sufficient. Consequently, a 3D cadastre is a tool in a land administration system to digitally manage and represent stratified RRRs (legal objects) and their corresponding physical objects such as building utilities on, above or under the ground surface in 3D space. A 3D cadastre has the capability to capture, store, edit, query, analyze and visualize multi-complex properties (Aien, 2013).

2.2. BIM

Among others, the improved awareness of energy consumption has raised concerns about several environmental impacts in modern societies. In many countries, buildings' energy consumption is responsible for the most energy consumed. Therefore, sustainability is an interesting aspect of the AEC industry due to the fact that sustainable development focuses mainly on maximizing the quality of the built environment while minimizing or even eliminating negative impact on the environment. Design and construction have always been a part of human activity. The initial stride that focused on the assessment of a building first occurred in the UK is known as Building Research Establishment Assessment Method (BREEAM), (Kibert, 2013). BREEAM was recognized by AECO industry because it was a means of evaluating a building's performance and proposed a standard definition for green building. The concept of green building consists of not only the energy performance of a building but also the consumption of water, location, indoor environmental quality, use of materials to name but a few. It is obvious that a BIM model can completely support and develop sustainable constructed facilities since any BIM software has the abilities of performing the aforementioned functions.

BIM as a digital representation of the physical and functional characteristics of a facility forms a reliable basis for decision-makings during its life cycle from inception onward. BIM facilitates the energy performance of a building throughout the project life cycle due to many uses and functions taken place. Using BIM for the construction of a facility, there are possibilities from the early stages to collect, manage and use data which will then contribute to a faster, safer, less wasteful construction and more cost-effective, sustainable operation, maintenance and eventual decommissioning. The most important reasons that make BIM suitable for sustainable development are the following:

- Better Informed Decision-Making: During the design phase of a construction process any involved architect/constructor has the ability to consider various options and information and select the most suitable for the sustainable design of the facility.

- Better analysis: BIM software represents the model virtually, so different kinds of analysis such as quantity takeoffs are easy, quick and cost effective to apply to the BIM model. These different kinds of analysis can result as different alternatives to each BIM model in order to select the most appropriate sustainable design for a construction project.
- Easier access to Information: Any BIM model has a central database which maintains all the information related to the model. Also, BIM models consist of intelligent tools and the modeling of them follows the parametric method. Therefore, any time a user can easily obtain and assess information that will contribute to a sustainable design and construction of a facility.

2.3. Integration of BIM and Cadastre

Taking into account the aforementioned sections, if it is possible to integrate BIM with 3D cadastral information, SLM would be a reality. The benefits of using BIM models in the geospatial domain have been demonstrated for different urban applications, which require both indoor and outdoor spatial information, such as evacuation (El-Mekawy, 2012) and fire response management (Isikdag, 2008). Consequently, Land Administration as a sub-area of the geospatial domain can also utilize BIM technology to fulfill its needs.

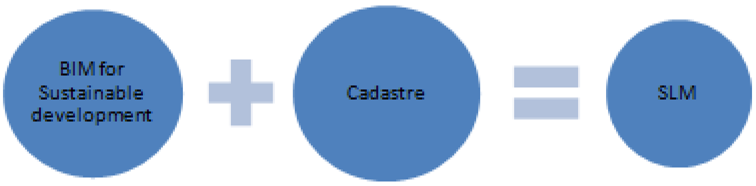


Figure 1: Schematic of the main subject analyzed in the paper

Looking back at the relevant BIM literature for 3D RRR data management, some approaches have been conducted:

- Clemen and Grundig, (2006): stated that the IFC models have the ability to support 3D topology and geometric representation of building elements, so they can be extended for land surveying purposes.
- El-Mekawy and Ostman, (2015): proposed to enrich the Unified Building Models (UBM) with all types of boundaries required to define RRR spaces in the context of Swedish jurisdiction.
- Atazadeh, et al. (2016): implemented what Clemen and Grundig have stated about IFC models.

3. INTEROPERABILITY CHARACTER OF BIMs

Interoperability is defined as a characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, present or future, in either implementation or access without any restrictions. Interoperability in the AECO industry is of paramount importance due to the increased number of involved stakeholders in a construction process. Therefore, the main goal of interoperability is to give users the ability to get the right data in the right format at the right time, at the same time, trying to delete the waste on recreating, editing and converting building data during the whole process. A successful interoperability between BIM applications would give AECO industry better chances of working together (Sheata, 2011) bridging the gap built in the construction process. Building model exchange is not simple, since models do not represent only geometry and shapes but also objects corresponding to real elements with attributes and properties. There are not restrictions when participants use the same BIM tools or compatible ones but when models are managed by different tools, a wide range of problems and disconnections come up. Consequently, several steps have to be established in order to enhance interoperability of BIM technology.

As a first step that has to be dealt with and followed by AECO industry is the use of neutral and open-vendors standards for the exchange of data which is described in the section 2.2.1. Open standards will give industry the ability to exchange data between applications that are compatible with them (open BIMs) streamlining workflows and facilitating automation. A second invaluable step would be the unification of all models created by each discipline by the deployment of an open BIM server which is elaborated in section 2.2.2. An open BIM server is defined as a central server based on open standards that can host BIM models centrally allowing project team to work in an integrated and collaborative fashion. Finally, connecting BIM servers to cloud via open standards is of urgent need offering the optimal outcomes.

3.1. Open standards

The adoption of open standards in the AECO industry is very important because participants are not obligated to employ specific property applications. Moreover, interoperability is advantaged open standards, since each software application does not have to develop direct translators back and forth for all other software which seeks to communicate with. Open standards, instead, allows each software company to develop only two translators for exporting from and importing to its application (Bolpagni, 2016).

BuildingSMART International is an industry body consisting of both public and private sector partners that have come together to provide technical expertise to develop open standards which can offer open and public data representation and exchange in the built environment sector. BuildingSMART focuses on standardizing processes, workflows and procedures for BIM. Users of standardized BIM-processes reap the benefits of them, covering a wide range of disciplines, AECO industry, software vendors, educators, building owners, everybody in society (BuildingSMART.org). All in all, the main goal of open standards is the creation of a new digital language which will allow advanced information technology to openly exchange information provided throughout the lifecycle to enhance and improve AECO industry processes. In the following sections six basic standards will be described, focusing on their characteristics for better interoperability.

3.1.1. Industry Foundation Class, IFC

IFC is the most popular and widely used open standard in the AECO industry. IFC standard is defined using STEP (ISO 10303) description methods and appeared as a result of the efforts of bSI organization for improvement of collaboration among all involved users in construction processes. In the IFC model there are many classes that are used to describe a variety of things that have common characteristics. In 2005, IFC became an ISO Publicly Available Specification (as ISO 16739). Nowadays, most of applications have the ability to import and export their models as IFCs. The IFC models are structured via ‘model schemata’. There are four conceptual layers which use a strict referencing principle and a set of model schemata is defined for each layer.

The first layer is called resource layer and is characterized by abstract concepts which are independent of application or domain. The next layer is called core and provides the basic structure of the IFC object model and defines more general concepts that will be used by higher layers. The interoperability layer follows the previous two mentioned layers and its main goal is the provision of schemata that define classes common to two domain models at least. These schemata enable interoperability between different domain models. The last layer is called domain layer and provides more detailed concepts depending on the type of application or domain process. The domain layers consists of electrical, HVAC, Architecture domains to name but a few (Isikdag, 2015).

The Industry Foundation Classes provide a comprehensive reference to the totality of information that is needed within the lifecycle of a constructed facility. IFC can be characterized as an incredible expression of what the EACO industry can do when it decides to work collaboratively. IFC deals with the whole information produced throughout the lifecycle of a constructed facility. However, many difficulties arise when a set of information has to be extracted from the IFC model in order to meet the specific needs of a user. It is clear that most software solutions do not need to implement everything within the IFC schema. Therefore, a key issue that has to be resolved is what parts of the IFC schema should be implemented for the user’s requirement. A view is going to give the right solution. IFC certification is carried out against views. Certification is a procedure for testing that an IFC compliant software solution will reliably export and/or import IFC data according to established testing criteria (buildingSMART.org). Here the MVD standard comes up to define views.

3.1.2. Model View Definition, MVD

An MVD standard is the set of information from the information model (IFC model) that can be supported by a type of software information. As aforementioned, all information in an information model is not necessary and part of them has to be extracted via views. The absence of a clear view of what is going to be exchanged leads to errors, misunderstandings and omissions. Since the effective use of BIM depends on the specific information used at specific time, at specific stage of construction processes by a specific software application, it is worth saying that a subset of the defined information by MVD standard is necessary and is called IDM.

3.1.3. Information Delivery Manual, IDM

The IDM standard provides a common understanding of the building processes and of the information that is needed for and results from their execution. Specifically, IDM proposes a methodology that gives users the ability to extract specific information that is complied with exchange requirements. In other words, IDM is designed as a methodology that can break down the IFC schema into smaller, useful but still related parts (buildingSMART.org). In contrary to IDM standard, IFC is intended to support all business requirements at all project stages. But it is not the way that project information is usually delivered. The information has to be exchanged about a particular topic and the level of detail provided to be driven by the project stage in order to support one business requirement over one or more project stages (buildingSMART.org). The main faction of IDM is described by the following workflow.

3.1.4. buildingSMART Data Dictionary/IFD, International Framework for Dictionaries, BsDD

BsDD is used as an invaluable tool for standardization, previously called IFD. BsDD is a library that consists of elements with their attributes. It is not fully implemented and provides terminology for linking data of existed databases. BsDD define all building components, internationally standardized and make standardized terminology computable. Thus, bsDD is going to automate and assure many manual processes in value chain (buildingSMART.org). In other words, bsDD standard is capable of identifying elements in built environment with their attributes regardless of the used language. For instance, the 'door' has the same meaning in Israel and Island.

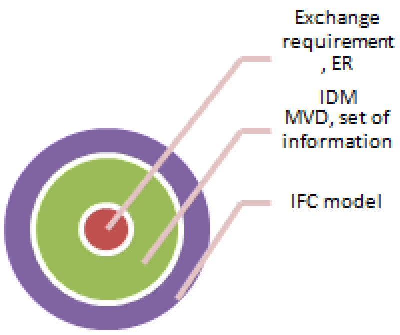


Figure 2: Illustration of coexistence IDM and MVD in an IFC model

3.1.5. BIM Collaboration Format, BCF

BCF is an XML schema developed by two software companies, Tekla and Solibri Inc. Recently bSI received the ownership and the rights of the BCF schema to adopt and keep it as an open standard (buildingSMART,2013b). BCF focuses on transmitting issues found in a BIM model instead of exchanging large BIM files over the Internet and allows the addition of textual comments, screenshots in order to encode messages that inform one BIM tool of issues found by another. Softwares that support BCF are Solibri Model Checker, MagiCAD, Tekla Structures, Tekla BIMsight, DDS and many other BIM tools. Any of the mentioned softwares check the BIM models to identify problems or actions that need to be addressed. After checking, issues found will be saved into an open format like BCF and used in any modelling software. Consequently, BCF enables a powerful and open collaboration between parties in any construction project .

3.1.6. BIMSie, BIM Service interface exchange

BIM started as a data-driven concept. Standardization of an API for online BIM services creates the opportunity to innovate the industry with BIM services automatically interacting with each other. Especially when an application needs to connect to several different APIs (for example for a user that works on different projects) the problem gets big fast and a standardized API becomes the solution. To really make use of benefits of cloud computing the BIMSie project was started (www.nibs.org). BIMSie is an odd one in the information exchange projects because it does not standardize data but creates a standard application-programming interface, an API (openbimstandards.org).Thus, BIMSie creates an opportunity for the industry to build small niche applications that are very good at one (or a couple) task. No single software tool or 'platform' is able to hold all the needed features for a building project. Given the fragmented nature of the industry this will be the situation for at least the next decade. Moving tools to 'the cloud' doesn’t solve this problem, unless these tools can be connected in an automated way. The BIMSie concept makes efficient use of the fragmented nature of our industry, instead of competing it.

3.2. Open BIM Server

Open BIM Server is defined as an open and stable software which can build reliable BIM software tools. The core of the software is based on the open standards like IFC open standard. The main goal of an open BIM Server is to unify the construction process. For instance, an architect designing a building develops an ‘architecture BIM model’ and seamlessly passes this on to the structural designer. The structural designer in turn then takes this model and effortlessly converts it into a ‘structural BIM model’. The process can be repeated for the remaining design consultants and also in fact for the constructor.
However, the aforementioned method is not the true version of a federated model development and progression (RICS, 1st edition). Therefore, the BIM model Server has the ability to host BIM models centrally giving users the potential to work in an integrated and collaborative way. Bringing an open BIM Server into the cloud via open standards such as BIMSie open standard will contribute to visualize the storage environment forming a virtual data center available on Internet. This will be beneficial for the AECO industry due to the fact that applications used in various stages of the building’s life cycle will work within a distributed environment and the information backbone of the construction project (BIMs) will reside in a virtual data center.

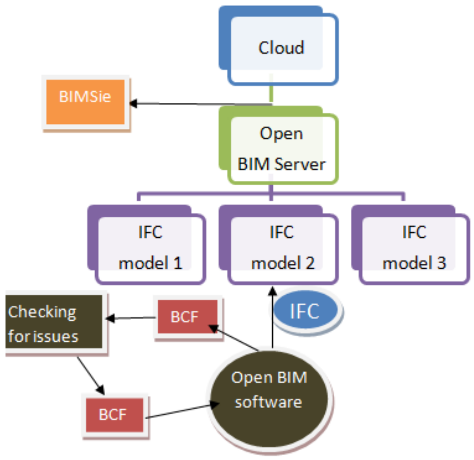


Figure 3: Example of scheduling open standards in interoperability platform

4. APPLICATION ON A PILOT BUILDING

As previously mentioned, an interoperability platform for SLM seems to be very crucial. Therefore, the application which will be described in the following sections aims at accomplishing this goal. In the first section, choosing Revit as BIM software, an approach for integrating cadastral information is presented (Federated Model). In the second section an interoperability platform based on the aforementioned federated model is analyzed, emphasizing on open standards and new technologies in information management. An office building at Chalandri, Attica, Greece was chosen as pilot for this research.

4.1 Integration of BIM and Cadastre

4.1.1. Revit as BIM Software

Revit was chosen as BIM Software due to its specific characteristics. Firstly, it is widely adopted since many architectural companies are using BIM (Jiang, 2011). Revit provides design ability with drafting elements and object oriented parametric modeling (Hardin, 2009). Object oriented has the roots from the fact that Revit involves representing a design as combinations of objects such as walls, doors, windows, stairs that carry their geometry, relations and attributes. Object based parametric modeling uses many of the characteristics which are called parameters that are capable of demonstrating the attributes (e.g. wall thickness, material) of each object and associated rules that clarify relationships between them. Parametric characteristics of each object allow some degree of automation in the modeling process, any change to an object within the model will be automatically reflected in the rest of the views of the project. Last but not least, Revit has the ability to interface with open standards and formats such as IFC, being the basis for the integration of Revit and cadastral information that will be analyzed.

4.1.2. Revit research in land administration

Ownership data elements in high-rise structures can be classified into two main categories: 3D legal objects and 3D physical objects. In order to demonstrate the feasibility of using Revit for 3D digital management of ownership rights, the pilot building consisted of four levels over the ground and one level under the ground was selected.

As a first step, a CAD footprint of the building has been inserted aiming at the georeference of the model. A Revit project has internal coordinates for all the elements that compose each model. Also, every project has a base point and a survey point. The base point defines the origin (0,0,0) of the project coordinate system and the survey point represents a known point in the physical world, such as a geodetic survey marker. The survey point was used to correctly orient the building's geometry in the coordinate system of the office block via the CAD drawing. The linkage of the two coordinate systems was accomplished via the common point (0,0,0) and the survey point was moved to a known corner and modified in order to take the right coordinates .

The creation of 3D physical objects follows the process of the georeference(Figure 4).3D physical objects can be utilized as auxiliary components to facilitate understanding of such boundaries for non-specialists (Atazadeh & Kalantari 2016). The most widely used building elements for representing physical boundaries are walls, doors, windows, floors and slabs. These elements comprise the spaces that are useful for the representing of 3D legal objects. The physical objects were created using 2D paper-based floor plans and sections of the building in order to have the right dimensions. Then, each of building element was enriched with attributes such as material. The resulting model reaches the Level of Detail 4 (LOD).

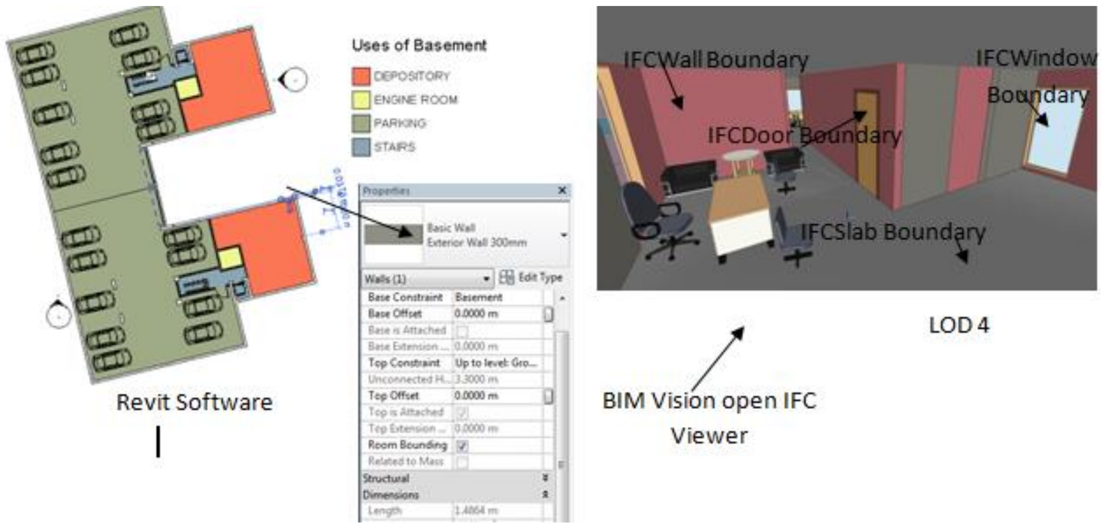


Figure 4a: Creation of physical objects

Three types of 3D legal objects, including private spaces, common spaces and sole uses to the rights are then created by utilizing ‘Area’ capability in Revit. Area tool gives user the ability to identify the 2D boundaries for each needed space. Exterior and median boundaries were followed for the exterior and interior/common walls, accordingly. In the next stage, cadastral information about the legal objects is inserted via the ‘Schedule’ capability of Revit. Schedules consist of rows and columns that have information for a chosen building element e.g. Door Schedule and can be embedded with a variety of data such as material, dimensions, level, RRRs. Apart from the 3D, 2D sole uses appear, pertained to parking spots and foregarden which are identified on the toposurface. Since Revit does not show 3D legal spaces, the model is then exported in 2x3 IFC format which provides for presenting shows in regards to its module. To visualize ownership 3D space there many open IFC viewers such as Solibri Model Viewer, BIM Vision Viewer and so on.

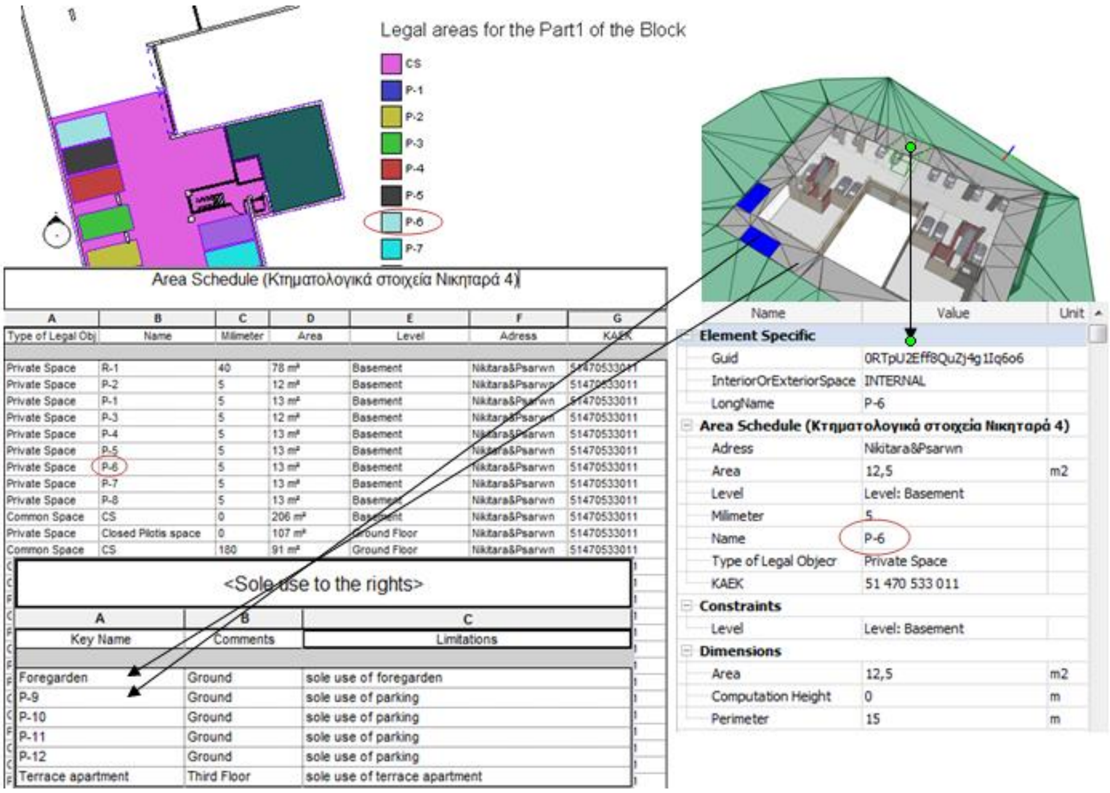
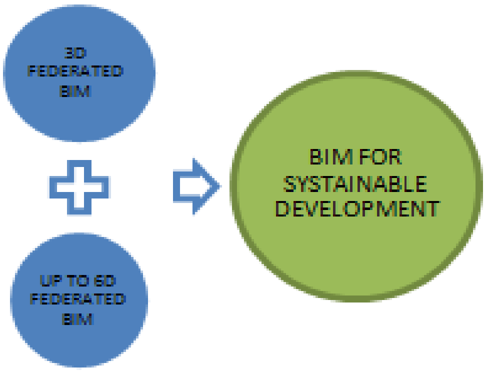
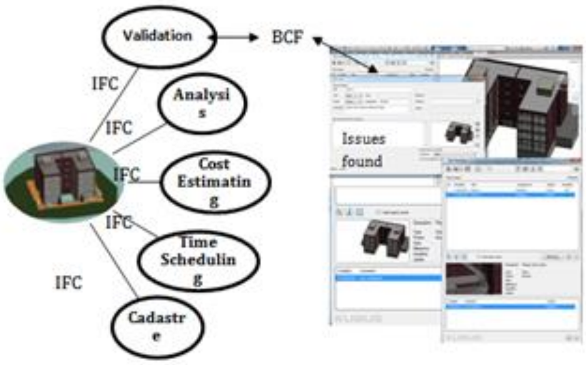


Figure 4b: Illustration of the process of integrating Revit model with cadastral information

4.1.3. Federated model

Each model that is generated in BIM may require the development of a number of project-specific models. The Revit package consists of three software applications; Revit MEP, Revit Structure and Revit Architecture (Azhar, 2008). Mechanical engineers can use Revit MEP to create a model of piping, ducts for HVAC details, structural engineers use Revit Structure for analyzing and structural design purposes and Revit Architecture as used in the previous application is utilized for architecture design (Latiffi, 2013). Furthermore, the ability for IFC exports makes Revit tool very useful for many tasks. As previously mentioned, IFC open standard provides disciplines involved in every project the ability to export part of an IFC model (MVD) and import it at specific software for e.g. energy analysis based on specific exchange requirements (IDM). For instance, the IFC model exported from Revit is imported in Solibri Model Checker software in order to validate the BIM model (Figure 4). SMC contains parametric rules that are applied against the model to check different aspects such as accessibility, model errors and clash detection. After the problems have been identified the open standard BCF will be utilized for exchanging appropriate set of information to Revit to resolve them. There are many software applications that are compatible with the IFC open standard and can be utilized for making BIM model safer, less wasteful and more cost-effective aiming at sustainable operation, maintenance and eventual decommissioning. Consequently, these models after modifications, checks and analysis are combined via IFC standard to create a federated model to produce a centralized repository of information for the entire project.





Figures 5, 6: The concept of federated up to 6D BIM for SLM (left), Illustration of the process of the creation of federated BIM in the application - Solibri Model Checker (right)

4.1.4. Interoperability platform

Developing the federated model, an interoperability platform is of paramount importance. The open BIM Server platform was selected to create an interoperability platform for the aforementioned application. The word ‘open’ describes the ability for: open interface to any vendor’s BIM models, open API which allows any external application and service to enhance stored BIM models via software on any computer, open to any third party app to extract and use the BIM model, Based on open standards; IFC, COBie, Collada, CityGML, it is built for the cloud because it has fully implemented the BIMSie standard to support the Federated BIM model.
BIMserver is an open source model server project and relatively unique for the AEC software industry, where closed source licenses and high per-user licensing costs, especially for BIM software, is the norm (Harisson, 2009). The main goal of an open BIM Server is to unify the construction process. AECO professionals and specialists create models for specific purposes like architecture, structure, electrical, plumbing, costs and timing. The intended results come after the consolidation of all models that have to be created. The BIM Server has the ability to host and store BIM models centrally giving users the potential to work in an integrated and collaborative fashion. Apart from the storage and the open exchange of data, many functions make BIM server essential for the interoperability (Figure 7 & 9);

1. BIM models are converted and stored semantically as topology, disciplines and layers (Carl Heinz, 2013).
2. Integrity and consistency; due to the consolidation that takes part in BIM Server (Gandhi, 2013).
3. Revisioning; all revisions are always stored, so the track of the work is never lost (bimserver.org).
4. Maximum safety; BIM Server has IFC core, so IFC objects are stored ‘as is’ and there in no loss of data during mapping (bimserver.org).
5. The open and extensive API Server provides a managed external access to BIM models. Thus, all data stored in a BIMserver can be exposed to client application through a series of well controlled and documented interfaces. Many advantages come up, the most significant being all client applications read from, and write to, the same digital model (Harisson, 2009). Therefore, it is possible for external apps and services to extract part of this information for many tasks

such as modifying, doing complex operations like rendering, clash detection, measurements, costing, energy calculations and so on (Carl Heinz, 2013).

6. Open BIM languages; BIMQL and MVDxml capabilities are shipped with every BIM Server for advanced queries and filters (bimserver.org).
7. A BIM model hosted in the BIM Server exists as a live entity, distinct from the client applications that interact with (Harisson, 2009). This characteristic in combination with open BIM languages helps client application because they do not need to comprehend the entire model but only specific tasks, asking via queries. (Figure 7) Moreover, external services can be implemented in the BIM Server, for example in order to monitor changes (Léon van Berlo, 2013).

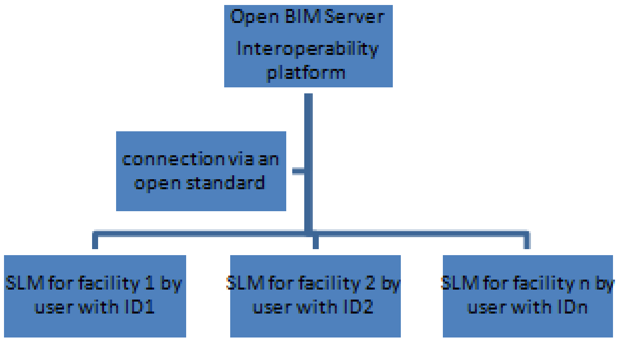


Figure 7: Paradigm of an interoperability platform

IFC model was converted via the tetra4D converter in 3D pdf file opened via the Adobe Reader in order to enrich interoperability. Thus, anybody interested is able to interact with the model without having specific software.

Figure 8: Visualization of IFC model in Adobe Reader

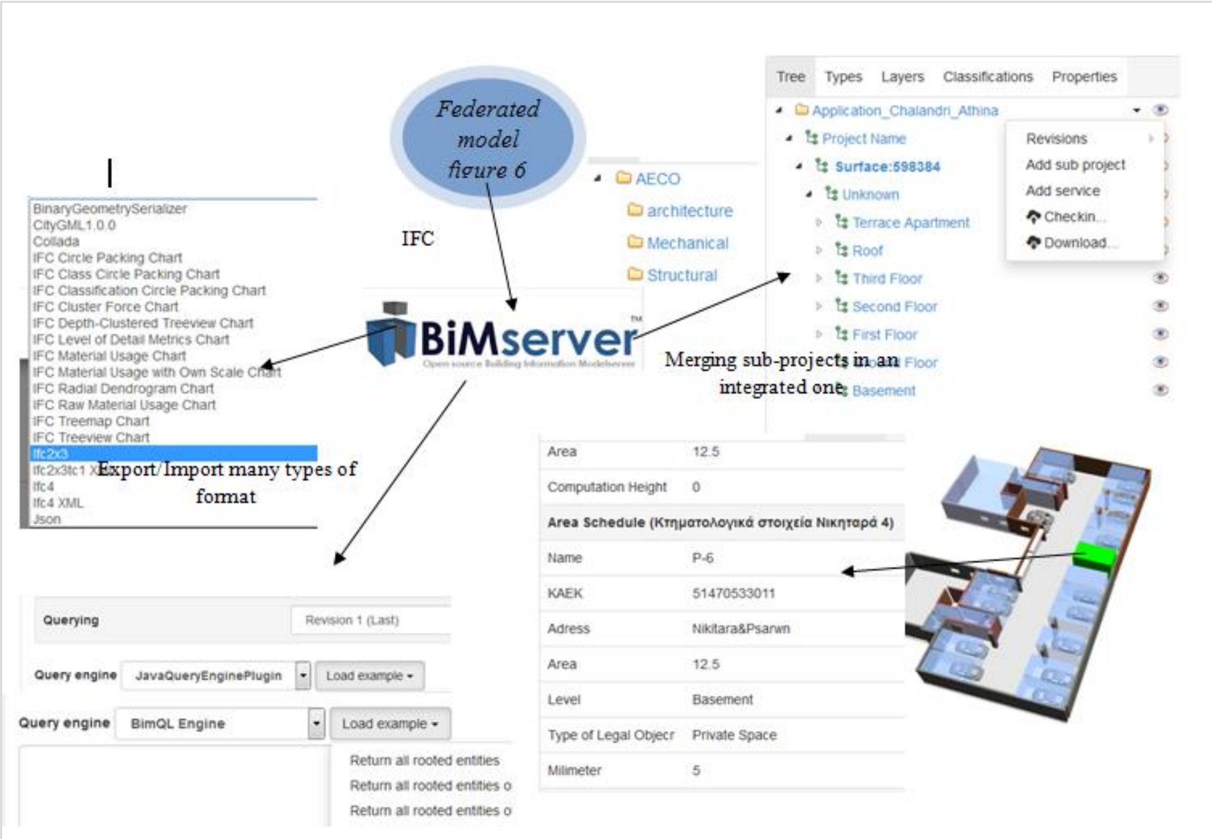


Figure 9: Interoperability platform of the application

5. CONCLUSION AND FUTURE WORK

In this paper, it has been elucidated that Revit BIM models can be enriched with cadastral information being the basis for an operational interoperability platform for SLM. The proposed platform brings many advantages. It provides improved visualization of ownership boundaries of multi-layered properties because of the integration of BIM with cadastral information. Moreover, it gives users involved in construction process, invaluable tools such as automated computation of volume which is crucial for many purposes e.g. taxation. Furthermore, this integration within the same dataset prevents data issues and inconsistencies due to the fact that BIMs are object-oriented parametric modeling processes. This platform mitigates the interoperability issues which have been intense over the last decades. Open standards that are the basis for advanced interoperability would operate at maximum efficiency. Specifically, the capacity of the IFC standard to support a rich amount of semantic information and the encoding of 3D legal objects into it enriches these objects with semantic information, thus facilitating interoperability of LAS. Finally, open standards assist in exchanging the required part of data, to be used in other tasks e.g. analysis in a compatible software. Operational federated models and stronger interoperability would be the outcome.

It is worth noting that a problem appeared during the aforementioned application, which was the limitation of IFC2x3 to only one IFCsite. Therefore, for the 2D legal objects of sole uses pertained to parking spaces and front-gardens which are identified on the toposurface IFC2x3 cannot preserve information in export. The latest version, IFC4, was also tested but the information was not kept. Consequently, only the visualization of them was accomplished via the ‘toposurface’ tool of Revit software.

Future investigation could be on the evaluation of the interoperability platform in three aspects namely, efficiency, usability and reliability. Moreover, algorithms to automatically extract appropriate building elements from the BIM models would be useful, thus saving time and enriching interoperability. Finally, further research on IFC format has to be implemented in order to resolve the aforementioned issue and make processes more flexible.

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