BIM/IFC files for 3D real property registration: an initial analysis

Eftychia KALOGIANNI, Efi DIMOPOULOU, Greece, Christiaan LEMMEN and Peter van OOSTEROM, Netherlands

Key words: Building Information Model (BIM), 3D Land Administration System (LAS), standardization, information reuse

SUMMARY

Land Administration is a quite inter-disciplinary field involving experts and knowledge regarding legal aspects, institutional support to establish relationships between involved parties and technical support to realize it. Today, land administrators and development organizations are challenged by an unprecedented demand to utilise space above and below earth's surface, which mandates the use of 3D information. At the same time, the current societal demand for sustainability, is driving the need to integrate independent systems with standalone databases with different aspects of buildings in their lifecycle phases.

In parallel, the evolution and applications of Building Information Modelling (BIM) towards integrated sustainable design and dissemination of information is gaining ground at international level. The requirements for more circular design thinking and digitalisation through technologies such as BIM can pave the ways for incremental step changes to achieve collaboration within building's lifecycle and strategic design for decision-making.

The impact of BIM on land administration domain is recognized, and it is being seen from governmental perspective as a digital reform and transition that will bring together technology, process improvements and digital information, to radically improve project outcomes and asset operations. One of the strong characteristics of BIM is that it is considered as a strategic enabler for improving decision-making and delivery for both buildings and public infrastructure assets across their whole lifecycle.

In this scene, taking into consideration the continuing increase of BIM/ IFC files, recent research focuses on the potential role of BIM in the context of circular economy and circular design, and the reuse of BIM/ IFC files in buildings' lifecycle. This paper presents an initial analysis on a BIM-based approach to support the registration of 3D property information. The research introduces the concepts and significance of circularity thinking and lifecycle approach at an era where there is mass amount of information, that needs to be handled efficiently. To this end, an extensive literature review on standardization approaches regarding BIM at international and national level is presented, followed by a state-of-art in the field of BIM exploitation as input for land administration purposes.

BIM/IFC files for 3D real property registration: an initial analysis

Eftychia KALOGIANNI, Efi DIMOPOULOU, Greece, Christiaan LEMMEN and Peter van OOSTEROM, Netherlands

1. INTRODUCTION

One of the key characteristics of our era is the explosive increase in information production and registration. It has been estimated that human societies had accumulated roughly 12 exabytes until the digital era; then, annual information growth rates of 30%, raised the total to over 1.800 exabytes by 2011(Gant, 2011; Turner et al., 2014). In the most recent period, the total more than doubled every two years, towards a projected 175 zettabytes by 2025 (O'Dea, 2020), as the rapid development of digitalization contributes to the ever-growing global datasphere. Within this digitalisation wave, the extensive growth of data has been put forward. It is accordingly of crucial importance that the tools and methodologies using these data are interoperable, in order to translate the huge amount of data into 'ready-to-use' information by decision-makers.

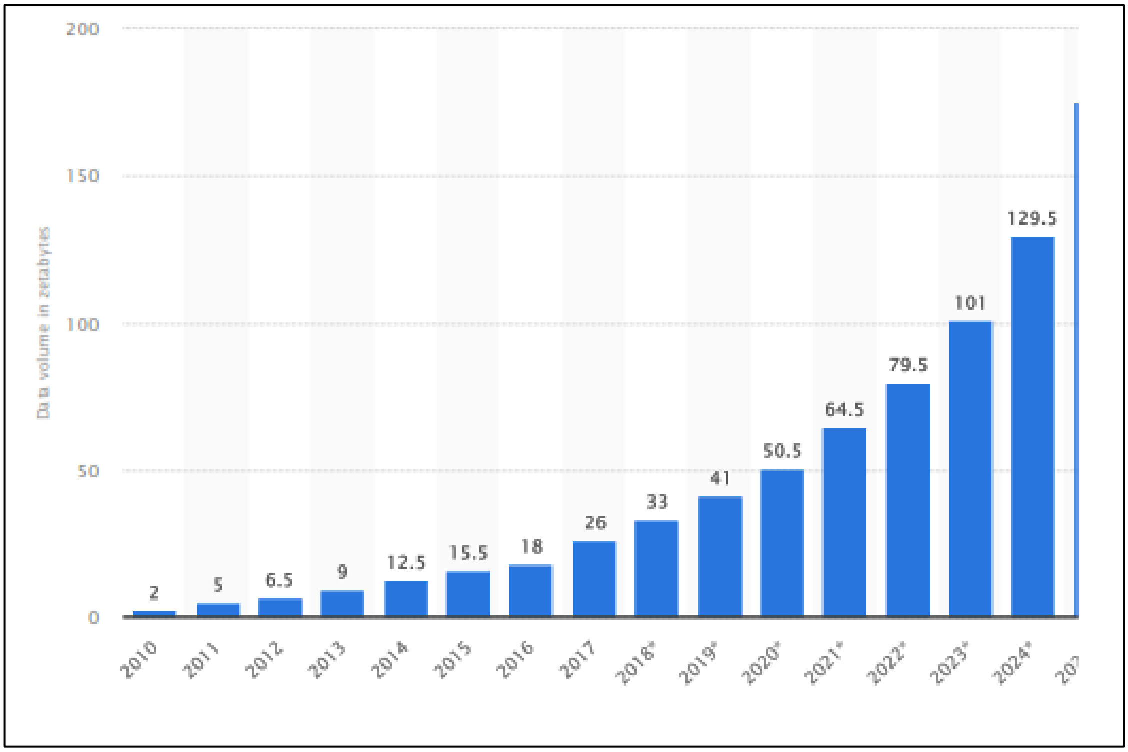


Figure 1. Volume of data/ information created worldwide from 2010 to 2025 (in zetabytes) (O'Dea, 2020)

The afore-mentioned explosive growth of digital information relates to Architecture, Engineering, Construction and Operations (AECO) industry in various ways. In this scene, data is the key – the ownership of it and the ability to understand and act on it (EC, 2017). Industry, government, organisations and professionals need to adjust in order to take advantage of the emerging opportunities. On one end of the spectrum, new information sources (such as smartphones and sensors) produce big data and provide information related to users and conditions in the built environment. On the other hand, there are established information and communication technologies that have already become common place and ubiquitous (standards, procedures, etc.). In between these two extremes, several domain-specific technologies that aim to shape AECO processes and knowledge are encountered and currently, paramount among these is the Building Information Model (BIM). (Koutamanis, 2019).

BIM is defined by international standards as "*a shared digital representation of physical and functional characteristics of any (to be) built object […] which forms a reliable basis for decisions*" (ISO, 2018). According to UK BIM Task Group (2013) "*BIM is essentially value creating collaboration through the entire life-cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them.*" Therefore, it is an attractive tool for project owners as its potential extends beyond planning and design, providing a process platform to share and integrate complex levels of building information. If implemented effectively, BIM can generate cost savings over the entire life cycle of a project (Imperiale et al., 2018).

Today, BIM modelling is used worldwide, although with a different rate of adoption and differences in regulation (see sub-section 2.3 for further information). The construction industry is making a shift towards digitization and automation, where also BIM and its rapid adoption play a key role; leading to more and more BIM/ IFC files being generated and becoming available. In this scene, taking into consideration the continuing increase of BIM/ IFC files, recent research focuses on the potential role of BIM in the context of circular economy and circular design (den Berg, 2019) and the reuse of BIM/ IFC files in buildings' lifecycle. Precisely, a number of studies have been carried out the last years to explore the possibility to use BIM/ IFC input files to establish 3D cadastre solutions to support the registration of multi-level properties and apartments. Since, the increasing structural complexity of high-rise buildings is a growing trend and tends to become the new normal in the built environment, it has significant impact on the registration of property Rights Restrictions and Responsibilities (RRRs) which current Land Administration Systems (LASs) need to face. 3D LAS could benefit from the lifecycle thinking, by reusing geometries from earlier phases of the lifecycle and specifically from the design and permitting stages (Kalogianni et al., 2020).

Given this background, the rest of the paper is structured as follows. Section 2 introduces the concept of lifecycle approach and reuse information within in, highlighted the role of BIM modelling in the design phase. Section 3 presents an overview of BIM standardization approaches at national and international level, while the next section presents the state-of-the-art in reusing BIM/ IFC files for land administration purposes. Finally, section 5 discusses the potential of this approach and future steps.

2. CIRCULARITY AND LIFE CYCLE THINKING (LCT) APPROACH

The concept of a circular economy is recently gaining momentum and is applied to various aspects of AECO industry. The key principle of the circularity and LCT approach lies on the collaboration between the involved parties and reuse of sources, incorporating digital technology. Hence, by translating them into the research for the built environment, BIM can be seen as a pillar towards the implementation of this approach.

BIM refers to virtual 3D building models containing 3D digital spatial information, as well as semantic information about a building to support decision making throughout its lifecycle (Tardif, 2009). It improves how built environment assets get designed, built and operated. As stated by Aguiar et al. (2019), BIM is a good technology to bring all involved parties together during the lifecycle of a building and share all the information among them. The consistency of all the static and dynamic data of the building is the solution to create a platform of information for the design, construction, in use and reuse phases. In this scene, the collaboration across different stakeholders in the lifecycle of a building is crucial, as today they operate quite autonomously, using custom-made, independent methodologies, software and workflows (Kalogianni et al., 2020). It is considered as a platform for central integrated design, modelling, planning and collaboration within the built environment (BCG, 2016), providing all stakeholders with a digital representation of a building's materials, systems and characteristics throughout its lifecycle, as presented in Figure 2.

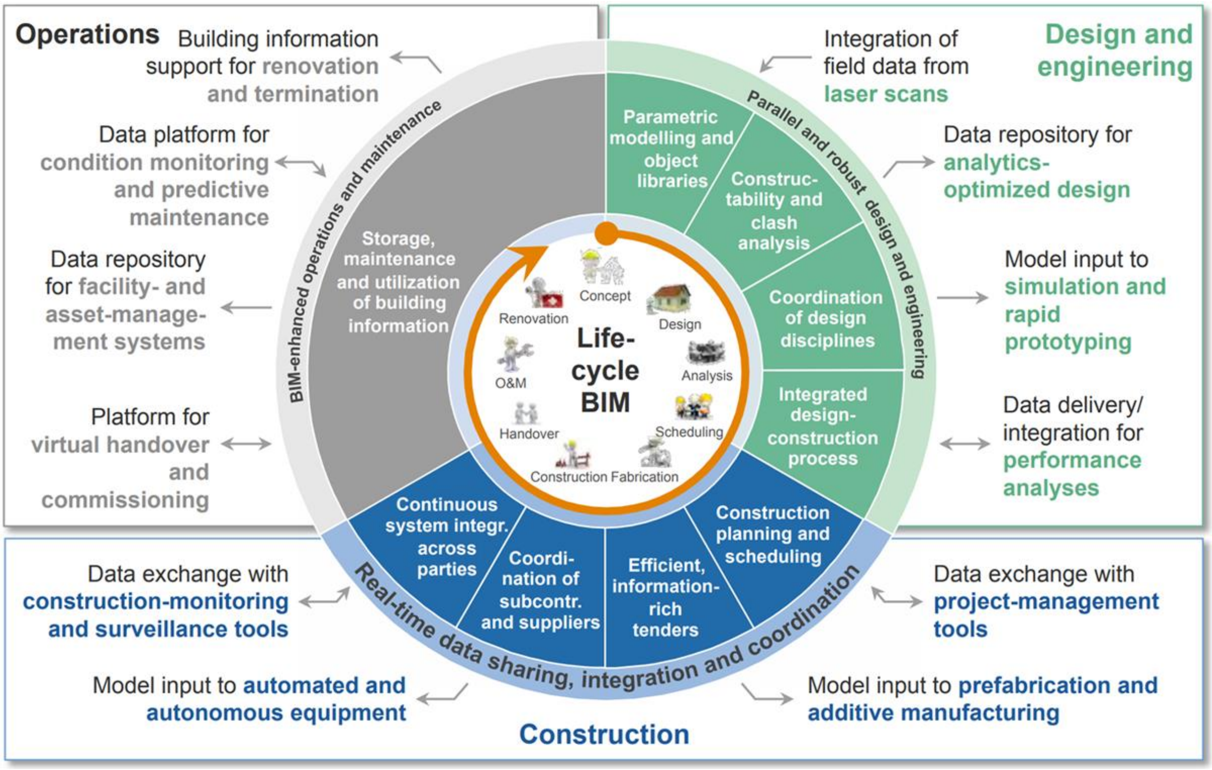


Figure 2. Application of BIM along the Buildings Lifecycle Value Chain (BCG, 2016)

Vital step on an asset's/ building's lifecycle is its registration at the LAS. Currently, this phase is quite autonomous and not directly linked with the rest of building's lifecycle. Framed from a circularity perspective, research on the built environment should focus on the better communication between the asset's registration with the other phases of the lifecycle, as well as within all the phases. Such cooperation is expected to enable new ways of data harmonisation and use in this complex environment, to improve efficiency of design and data acquisition, to improve data quality (in relation to specific regulations), to minimise inconsistencies, data loss, mismatch and overlap between the various stages, and to enhance data re-use from design phase to end user and registration/operation phases (Kalogianni et al., 2020).

The more circular approach requires close collaboration and coordination between stakeholders, relevant legislative framework, as well as standards that enable this communication both in data and systems' level. The key aspect of using BIM/ IFC files in their full potential for circularity is that they can also be used for design, financing, permitting, construction, registration and operation phases.

Zooming into the lifecycle of a building, at its design phase, usually, the architect starts by creating the architectural BIM model, which only includes the physical elements of the building. This is a 3D model that contains the basic information, starting with spaces and attaching to them information related to walls, floors, roofs, materials, etc. Similarly, the structural and MEP engineers develop their own models, commonly creating separate 3D models with their elements. Each one of the engineering disciplines develop the corresponding 3D models using appropriate software and at the end, mutual exchange happens based on IFC files (for further information see subsection 2.2). As the process follows, more and more information is added enriching the IFC model(s), so called 'as-designed BIM'. To achieve the desirable result and quality of the model, especially in large-scale projects, it is common that the client establishes from the beginning of the project an Information Delivery Manual (IDM) defining the information exchange requirements, specifications, ID's and properties that should be set in an IFC file (buildingSMART, 2012). As different stakeholders are involved using BIM, all have different needs and interests which affects the type and detail of information. Hence. the ISO 29481-1:2010 "Building information modelling - Information Delivery Manual - Part 1: Methodology and format" (ISO, 2010) standard has been developed to provide a methodology to capture and specify processes and information flow during the lifecycle of a building.

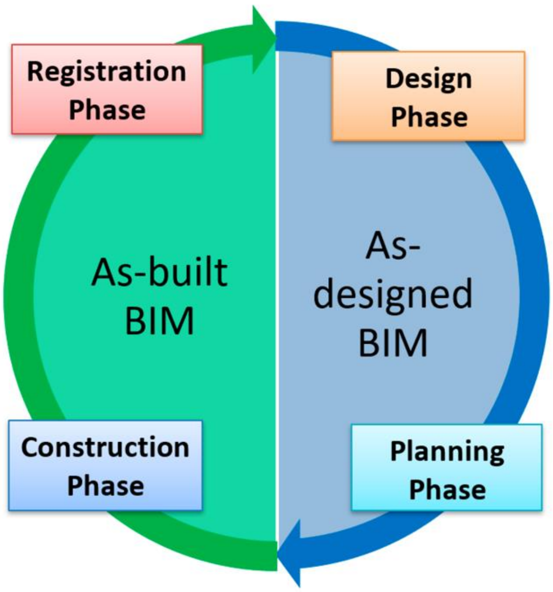


Figure 3. BIM-driven approach along the Buildings Lifecycle (Olaf et al., 2019)

Usually, in most of the countries, the planning phase follows the design stage, where an application for planning permit should be submitted. At this stage, for instance in Victoria, it is proposed that the land surveyor enriches the BIM model by adding legal boundaries, ownership rights, and attributes, as well as administrative information (Figure 3), which is then submitted to the relevant authority to obtain the permit. Depending on the jurisdiction and the legislation, this IFC model could be used (as it is or with further manipulation/ simplification) for registration purposes at the corresponding LAS. In other countries, that the registration of an object occurs after its construction within its lifecycle, the version of the IFC file(s) where the information of the sub-contractors, manufacturers and suppliers is combined (hence, including the exact profile shapes, fixings, materials, etc.) could be used for such purposes (as-built model). Regardless the version of the IFC model, it is expected that IFC files derived from the design or construction phase could be used as input for 3D cadastral registration, as they are rich in geometry and semantics. Current research and potential developments in this direction are further described in Section 3.

Therefore, an effective data management and exploitation of BIM can comprehensively support the dissemination of building information in the whole life cycle. Shared data can enlarge knowledge, improve efficiency, consistency, and decision-making, as well as provide equal level playing field. However, it should be noted that not all the information included or attached to BIM/ IFC models is relevant or even reliable.

Given this background and aiming at a harmonized result, today large contracting companies around the world, employ standardized BIM-Manuals when procuring design services, setting out general and project-specific requirements. There are many BIM software solutions and several national standards are attempting to make the shared use of BIM/ IFC files more accessible. At the next Section the BIM standardization approaches are listed.

3. BIM STANDARDIZATION APPROACHES

BIM is growing popular both among industry's professionals, governmental organisations and public authorities worldwide, as its benefits are recognised; i.e. cost estimation and construction cost reduction, phasing and 4D scheduling (3D space + 1D time), building management, visualisation, quantity survey, sustainability, constructability and building performance analysis (Azhar, 2011). BIM has revolutionized the design and construction industry around the world during the last years, while national and governmental BIM councils, roadmaps, standards and strategies are being established in various countries worldwide.

One particular area where standardisation on BIM is needed is the exchange of information between software applications used in the AECO industry. It is important to consider that in standardization approaches at national levels, the focus of the standardized approach may vary, depending on national legislation, requirements, needs and expectations. At international level, the leading organisation in this domain is buldingSMART, which has developed and maintains Industry Foundation Classes (IFCs) as a neutral and open specification for BIM/ IFC files data model. Other standardisation work includes data dictionaries (International Framework for Dictionaries Libraries) and processes (data delivery manuals) (EC, 2017).

EC (2017) divides the standardization profile of BIM into three parts (Figure 4) being: Concepts (conceptual model), Data Model (technical model/ encoding) and Process (workflow between different actors/ stakeholders). Common concepts and classification of concepts are necessary for stakeholders to speak the same language. Neutral formats for data models required for systems and vendors to exchange information clearly. Finally, uniform processes for information delivery and a common working methodology is necessary.

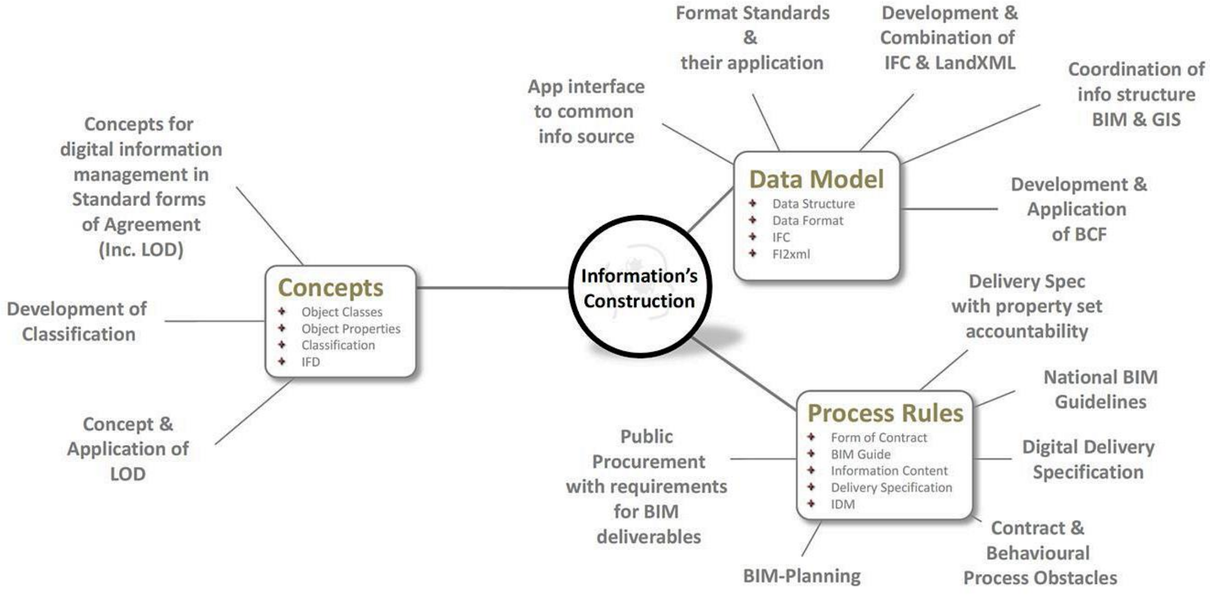


Figure 4. BIM standardization platform (EC, 2017)

In this scene, this section comprises of three sub-sections; at the first one the standardization at international level is presented listing ISO, OGC and standards approached by other organizations; the second one provides insights for IFC as the most common neutral and open specification for BIM data worldwide; while the latest provides the advances in BIM adoption and adaptation in national level in countries around the world.

3.1 BIM standardization efforts worldwide

BIM standards and workflows provide a universal mechanism for supporting integrated design, realization, and operation of buildings and in the future, other assets of the built environment. BIM standardization efforts and guideline can be used from BIM users as a platform to jumpstart their BIM adoption. Today, there is a wide range of BIM protocols and implementation plans in circulation. However, the terms used are open to interpretation and it is unclear which information is superfluous and which is missing. To eliminate these ambiguities numerous standards and protocols have been developed in national and international level, which represent at the same time the relevance of BIM in built environment industry. In this scene, Figure 4 represents the current status of BIM standardization in international level and the stakeholders involved. The organizations involved, as they appear in Figure 5 are (EC, 2017):

1. CEN TC442 BIM: Standardization in the field of structured semantic life-cycle information for the built environment by the technical committee of European Committee for Standardisation (CEN) on the European level, which develops and maintains standards in the BIM domain.
2. CEN TC287 GIS: standardization in the field of digital geographic information for Europe.

3. ISO/ TC211 GIS: Standardization in the field of digital geographic information.
4. ISO/ TC59/ SC13 BIM: Organization of information about construction works.
5. ISO/ TC184/ SC4 STEP: Standards that describe and manage industrial product data throughout the life of the product.
6. Open Geospatial Consortium (OGC): International non-profit organization committed to making quality open standards for the global geospatial community.
7. buildingSMART: International organization which aims to improve the exchange of information between software applications used in the construction industry.
8. EU BIM Task Group: It's aim is to bring together national efforts into a common and aligned European approach to develop a world-class digital construction sector. The European Commission has awarded the EU BIM Task Group (EU BIM Task Group, 2017) to deliver a common European network aimed at aligning the use of Building Information Modelling in public works.

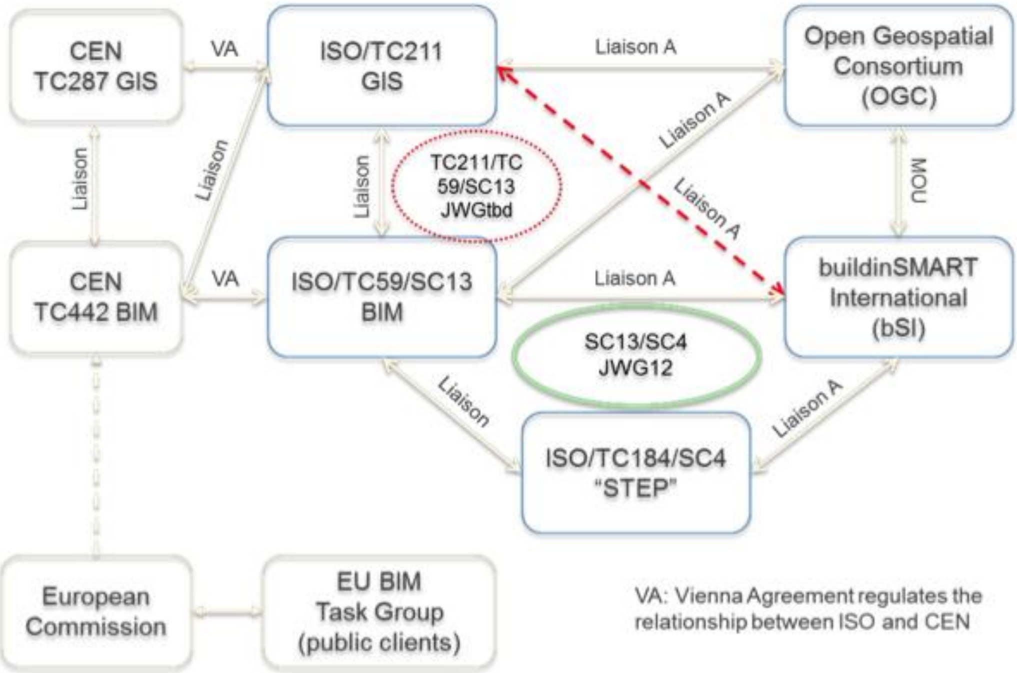


Figure 5. International BIM standardization (EC, 2017)

Last but not least, ISO published several BIM-related standards; namely: the ISO/TS 12911:2012, which establishes a framework for providing specifications for the commissioning of BIM and the ISO 29481-1:2016 - IDM (ISO, 2016), as described at the previous section, specifies a methodology that links the business processes undertaken during the construction with the information's specification required by these processes, and a way to map and describe the information processes across the life cycle of construction works.

In this context, an international standard for Data Dictionaries (EN ISO 12006-3:2016 – Organization of information about construction work – Part 3 Framework for object-oriented information) has been developed (ISO 12006, 2016). A Data Dictionary connects the entire world's domain terminology with internationally standardized and machine-readable concepts by specifying concepts (entities, properties, classification and other concepts) and their relations. It is possible to connect existing and new databases and registries, different data dictionaries and to harmonize the understanding of their content. Such a harmonized dictionary of properties could be used for an unambiguous information exchange either in direct communication with Data dictionaries or other exchange flows based on IFC (EC, 2017).

3.2 Industry Foundation Classes - IFC

IFC (Industry Foundation Classes) is standardised by buildingSMART International (bSI) in collaboration with ISO. It specifies a conceptual data schema and an exchange file format for BIM data. It represents an open international standard for BIM data that is exchanged and shared among software applications used by the various participants in a built environment construction or asset management project.

IFC is an international standard, EN ISO 16739:2018 (the previous version was ISO 16739:2013) (ISO, 2018) for data sharing in the construction and asset management industries. All physical building elements can be modelled, stored, and managed hierarchically in the IFC standard, which makes it easy to exchange building information for multiple purposes in different BIM platforms (Sun et al., 2019).

The IFC model is necessarily large and complex, as it includes all common concepts used in building industry projects, from feasibility analysis, through design, construction, and operation of a built facility (BuildingSmart, 2012). It serves primarily as an exchange format, with instances delivered throughout the lifecycle of a project and in parallel to 'working' versions in formats that are native to commercially available modelling software. It serves the multiple purposes demanded at different stages of design, construction and maintenance, supporting efficient change management provided by the BIM Collaboration Format (BCF) (OGC, 2020). BCF allows different BIM applications to communicate model-based issues with each other by leveraging IFC models that have been previously shared among project collaborators. BCF works by transferring XML data and it was created for facilitating open communications and improving IFC-based processes to more readily identify and exchange model-based issues between BIM software tools, bypassing proprietary formats and workflows (buildingSMART, 2020).

IFC files can contain many types of classes. The geometry of BIM/ IFC files in the IFC format can be represented using Boundary Representation (B-Rep), but also parametric modelling techniques of Constructive Solid Geometry (CSG), Sweep Volume, allowing the modeller to choose a representation type that best suits the object and design process (buildingSMART, 2019). Elements are modelled in local coordinate systems defined by a hierarchical set of transformations that correspond to the levels in a decomposition structure (typically a site, project, building and individual floors) and are linked to national/ global reference systems (via IFCproject).

Last but not least and although there is less evidence of support for IFC at the urban scale, the standard is being extended to provide construction detail for roads, rails, bridges, tunnels, ports, waterways, landscape and urban design.

3.3. BIM standardization efforts at national level

As mentioned before, around the globe BIM is gaining rapid visibility within the industry and governments are starting to demand and even mandate BIM deliverables. Therefore, nations around the world are feverishly developing BIM standards and BIM manuals taking into account legal, institutional and technical considerations. BIM standards and manuals are part of the government's and industry's efforts to demystify BIM and to give clarity on the requirement of BIM usage at different stages of a project. As BIM/IFC files are very complex, in order to achieve interoperability and maximum data reuse, at minimal efforts, it is crucial to specify the minimal, obligatory elements of BIM/IFC conceptual model, which must be included in an exchange file (for obtaining permit, fulfilment of clients' requirements, etc.).
Figure 6 presents a map showing the level of BIM technology around the world, the file was made available courtesy of the Nemetschek Group.

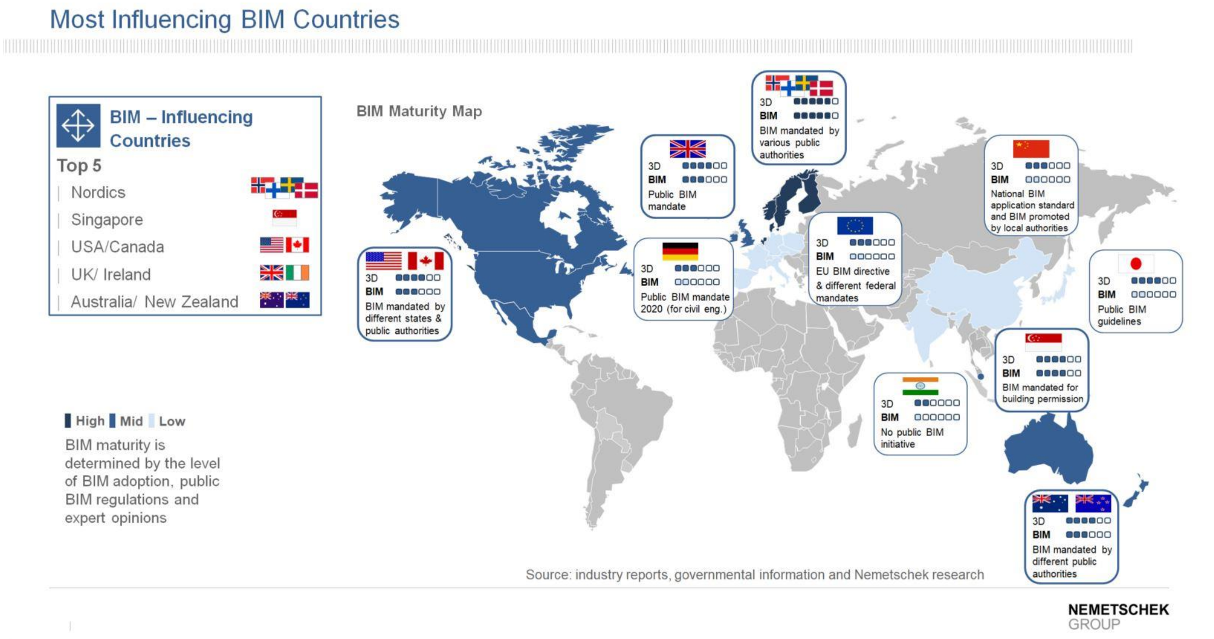


Figure 6. Most influencing BIM countries (Naborczyk, 2020)

The Institute for BIM in Canada (IBC) is a steering committee composed of constituent organizations that represent key industry associations, which have developed and published significant Canadian BIM Resources that support BIM adoption, such as the BIM Contract Appendix and the BIM Project Execution Toolkits (PxP). The BIM PxP Complete Guide contains three toolkits for the Design Development Phase, the Construction Phase and the Handover and Maintenance Phase. Each toolkit is based around real world examples that have been compiled together to create a composite illustrative project.

In parallel, CanBIM is a nation-wide not-for-profit organization that serves as Canada's business voice for the entire building and infrastructure community. CanBIM, among others, produces and publishes documents such as their annual publication CanBIM Innovation Spotlight and the AEC (Can) BIM Protocols (CanBIM, 2020) providing information, knowledge and certification to professional, educational, construction, fabrication and supply chain members related to digital technologies and processes.

In the Asian territory, and specifically in Hong Kong, the Hong Kong Institute of Building Information Modelling (HKIBIM, 2020) is responsible to establish and advance standards of building information management practice in the industry and provide guidance on careers in building information management profession. Furthermore, in Singapore, the Building and Construction Authority (BCA) led a multi-agency effort, already in 2008 to implement the world's first BIM electronic plan submission (e-submission), called 'Construction and Real Estate Network (CORENET)', established in 2011. (CORENET, 2020a). BIM e-submission system streamlines the process for regulatory submission and since 2015 BM e-submissions is required for all projects greater than 5,000 square meters (w.r.t. gross floor area) in Singapore. BCA has published in 2013 a reference guide that outlines the roles and responsibilities of project members when using BIM. 'Singapore BIM Guide' (CORENET, 2020b) consists of both BIM Specifications (where BIM elements per discipline are specified, rules for quality assurance are defined, modelling guidelines are presented, etc.) and BIM Modelling and Collaboration Procedures.

Dubai is the only Emirate within the UAE that has prescribed the implementation of BIM. BIM was first introduced as a requirement in Dubai in 2013 by virtue of Dubai Municipality, which provided for the application of BIM for the "architectural and MEP work" on buildings above 40 floors; buildings with areas larger than 300,000 sq. feet; special categories of buildings such as hospitals and universities and others similar to that, as well as all governmental projects. In 2015, this mandate was updated and applied to all government projects; buildings above 20 floors; buildings and facilities and compounds with areas larger than 200,000 sq. feet and special categories of buildings. Although no minimum standard is required, the benefits of BIM are already apparent in relation to Dubai based developments and hence, BIM was recently utilised for the prestigious Dubai Opera project and other major projects in other Emirates (CMS, 2020).

Recently, a new strategy for BIM has been announced in Dubai that enables a faster and more efficient building permit system (Budden, 2019). The newly developed e-submission and automated code checking prototype application allows importing BIM model files to the system through a web page (Figure 7) and their validation against the necessary regulations and buildings codes. The system highlights any non-compliance issues directly on a 3D view of the model, enabling consultants to resolve issues before re-uploading the model for validation again. Building information is then extracted from BIM model into the 'building card' and as a last step BIM model is converted to GIS and visualised through a 3D web viewer.

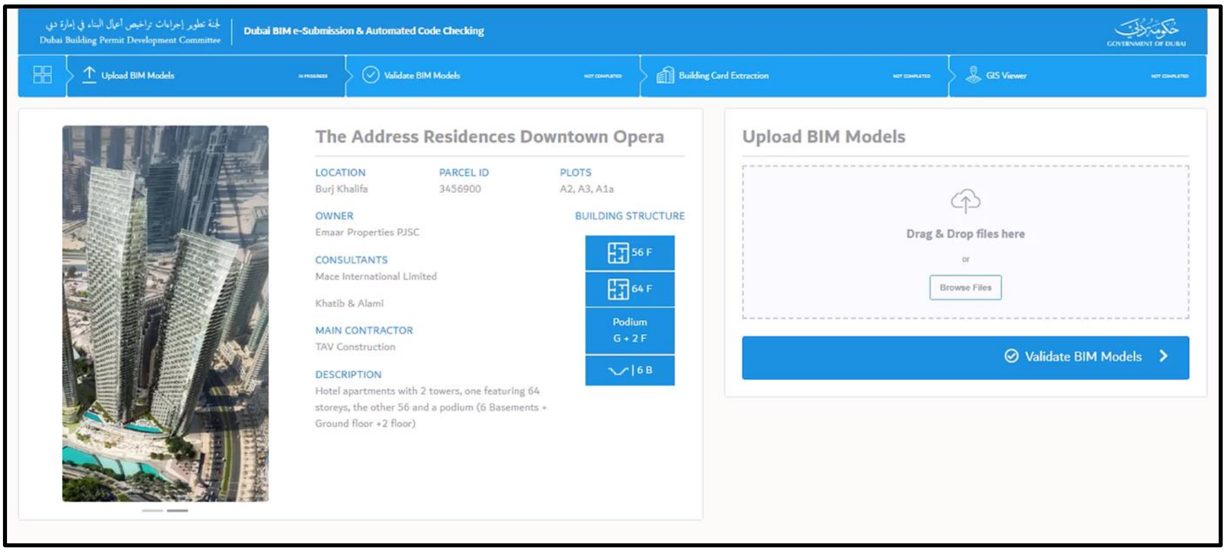


Figure 7. Interface of the BIM-based permit system in Dubai (Budden, 2019)

Through the implementation of this new strategy, it is expected that the country's World Bank 'Ease of Doing Business' score (World Bank, 2020) for dealing with construction permits will increase. The UAE is currently ranked fifth in the world.

The UK government, being very active and ambitious to one of the global leaders in BIM has, since 2011, its own BIM Task Group spawning the UK BIM Strategy, which mandates a certain level of BIM implementation on public projects by 2016. Whilst, the UK BIM Framework sets out the approach for implementing BIM in the UK using the framework for managing information provided by the BS EN ISO 19650-1:2018 series (NBS, 2018). It includes the published standards called upon to implement BIM in the UK, the UK BIM Guidance Framework and useful links to other resources. As part of the Government's push towards implementation of BIM, much has been done in terms of publication of technical documents and this also includes the Construction Industry Council (CIC) Building Information Model Protocol. The BIM Protocol was developed by the United Kingdom's (UK) Construction Industry Council. It's a standardised supplementary legal agreement that can be incorporated into professional service appointments and construction contracts by a simple amendment (The B1M, 2020).

The UK Government realized early on that BIM maturity levels promote collaborative working in the AECO industry and since April 2016, has required construction suppliers tendering for centrally procured government projects, including buildings and infrastructure, to be working at Level 2. Since this BIM mandate in the UK resulted in improved safety and growth of the construction industry, in 2019, the Government made it mandatory for builders and contractors to implement BIM in all residential projects, considering also building safety norms (NIBS, 2015; Siresiya, 2019).

Scandinavian countries have been pioneers in BIM, with active governments developing BIM strategies and demanding BIM as mandate in many projects. In this direction, the Norwegian Homebuilders Association has actively promoted the use of BIM together with the Norwegian directorate of Public Construction and Property (Statsbygg), a public administration body responsible for organizing and planning public assets projects in Norway. Statsbygg BIM Manual v.1 launched in 2008 in Norway and the present version, based on an earlier 2013 edition, is called 'SIMBA' (Statsbygg, 2020) and is being updated constantly to provide a BIM guide in the country. Since 2010, all Statsbygg projects have been using IFC and BIM file formats for the entire lifecycle of their buildings.

The Netherlands, where the use of BIM is increasing both in public and private sector, has established a BIM Gateway, the BIM Loket (BIM Loket, 2020) focusing on Open BIM Standards and guidelines, while the Building Information Council (BIR) stimulates the implementation of BIM within the Dutch building industry. The use of BIM is increasing in the Netherlands, being driven both by public and private sector, however, its use or procurement is not in any way made mandatory by law or policy (Bruggeman, 2019). To remove ambiguities that arise from the use of BIM by various disciplines, the BIR BIM Protocol working group has developed two models: the "National BIM Protocol Model' and the 'National BIM Execution Plan Model'. The BIM Protocol Model can be used to establish project-specific contract provisions for BIM projects. The BIM Execution Plan Model is a template that project teams can use to establish BIM work agreements. The models also introduce a uniform conceptual framework that harmonizes with the developments in the countries around us and prepares for future European BIM standardization.

What is more, the Central Government Real Estate Agency, Rijksvastgoedbedrijf, uses BIM to obtain up-to-date, concrete and reliable information about buildings under management. For this purpose, Rijksvastgoedbedrijf has developed its own BIM tools for buildings such as an object type library (OTL), a database (CMDB), specifications (RVB BIM Specifications and Rijksgebouwendienst (Rgd) BIM Norm, which describe the specifications of BIM extracts and accompanying deliverable files) and a BIM data room (in some cases in the tender stage a BIM data room is used to deliver the information required to make a bid in digital format) (Bruggeman, 2019; Rijkswaterstaat, 2020).

Although Germany shows growing BIM uptake, currently, the use of BIM is not mandatory, while there are no BIM standards developed. However, the Federal Ministry of Transport and Digital Infrastructure (BMVI) has developed – in coordination with the private industry – an action plan with the objective to implement and disseminate BIM in Germany. The preparatory phase (2015 – 2017) covered the setting of standards and the resolution of legal issues; the second phase till 2020 works as pilot on the usage of BIM in selected infrastructure projects, with the intention that from 2020 onwards, BIM will be applied as mandate to all new (infrastructure) projects of the BMVI (Fuchs, 2017).

The contribution of BIM to constructions' planning and management has also been acknowledged by the European Union (EU), which established the EU BIM Task Group (2017) to encourage the common adoption of BIM in public works, with the common aim of improving value for public money, quality of the public estate and for the sustainable competitiveness of industry (NBS, 2018).

Given this background, it is evident that the evolution and application of BIM towards integrated sustainable design and dissemination of information is well-recognised at a global level, however there are still many technical and institutional challenges to be tackled, as well as legal implications to be taken into consideration especially in national level.

4. STATE OF THE ART REVIEW: BIM AND 3D LAND ADMINISTRATION SYSTEMS

The previous section listed briefly various standardization efforts at national and international level regarding BIM adaptation, which rate varies per country. Similarly, the Land Administration Systems and policies around the world vary and depend on legislation, regulations and institutional aspects. Therefore, it seems challenging to work towards the communication of those two worlds, aiming at the maximum reuse of information in the context of lifecycle approach. It is evident, that as both systems (BIM and LAS) depend on nation-wide aspects, there is not a unique solution with regards to their interaction. However, general principles and guidelines on how to use BIM/ IFC files for Land Administration (LA) purposes can be drawn at international level and become more detailed into national extent.

In this scene, research is being carried out in the field of linking Land Administration (LA) information to 3D digital representations (usually of the urban environment). Specifically, the reuse of 3D digital models and specifically BIM is currently being investigated, as it is expected to have capabilities to specify semantics, which can identify property units accurately, represent cadastral boundaries better, and visualise complex buildings in more detail (Sun et al., 2019).

There are several reasons to support the use of BIM for 3D digital management of properties. Indicatively, in the design phase of a building subdivision process that applies in several countries (i.e. Australia, Malaysia, etc.), the 2D CAD files are created by architects and surveyors create subdivision plans for high-rise buildings based on these 2D files (Ho et al., 2015), while more and more 3D BIM/ IFC files are currently developed by architects. Therefore, it is more probable that in future, land surveyors would use the 3D BIM/ IFC files produced by architects for the purpose of subdividing ownership of properties (Atazadeh, 2017) and those, will be then used for registration purposes.

The last decade, several studies have investigated the capabilities of BIM in urban land and property management. El-Mekawy et al. (2014) described how 3D property and BIM domains can interact to serve the requirements for effective information handling. The authors proposed a cadastral extension of the Unified Building Model (UBM) as a possible solution to facilitate the interaction between BIM and 3D property formation. This indicates that the enrichment of UBM or BIM-based data models with 3D RRR data elements could bring new opportunities to enable further collaboration between land administration and BIM domains.

The same authors (El-Mekawy et al., 2015) presented a theoretical framework related to the interaction between IFC and CityGML (representing 3D physical models), and LADM (representing 3D legal models). They found that the proposed extension to UBM would efficiently model legal aspects of 3D properties, particularly in complex structures and concluded that a fully operational 3D cadastral system should incorporate both legal and physical dimensions of 3D properties in urban built environments.

The afore-mentioned approaches were mostly implemented in theoretical level. The first actual implementation attempts in using BIM/IFC data as a source for 3D land administration have been explored and presented by Atazadeh et al. (2017) and Oldfield et al. (2017 and 2018). Oldfield et al. (2017) investigated the possibility of obtaining data from BIM as an input into 3D Cadastre and as a conclusion, she suggested that space objects (IfcSpace), and the grouping of adjacent spaces (i.e. the various rooms of an apartment), or disconnected parts (e.g. storage in basement with rooms) as legal zones (IfcZone), could underpin the utilization of BIM/ IFC files in 3D cadastres. To demonstrate the usability of BIM data for 3D land administration Model View Definition (MVD) was used, aiming to stay within the resources of the IFC's common schema and not try to extend the model further. The presented workflow, in the context of lifecycle thinking, described how land administration data requirements could be efficiently communicated between project stakeholders, which would, in turn, facilitate procedures for obtaining legal spaces from BIM/ IFC files.

A more in-depth and technical study was carried out by Atazadeh (2017) who developed an extension of BIM-based data models to support 3D digital management of complex legal spaces in Melbourne. In this research, a range of data elements required to model 3D rights, restrictions and responsibilities (RRR) associated with private and common properties, as well as easements, were added to IFC files and to test its functionality a prototype BIM model for a multi-story building development was implemented. This is a files-based/ project-based approach to store legal and physical characteristics of buildings, which are therefore converted to a registration by the relevant authorities in a cadastral (LADM-based) versioned database.

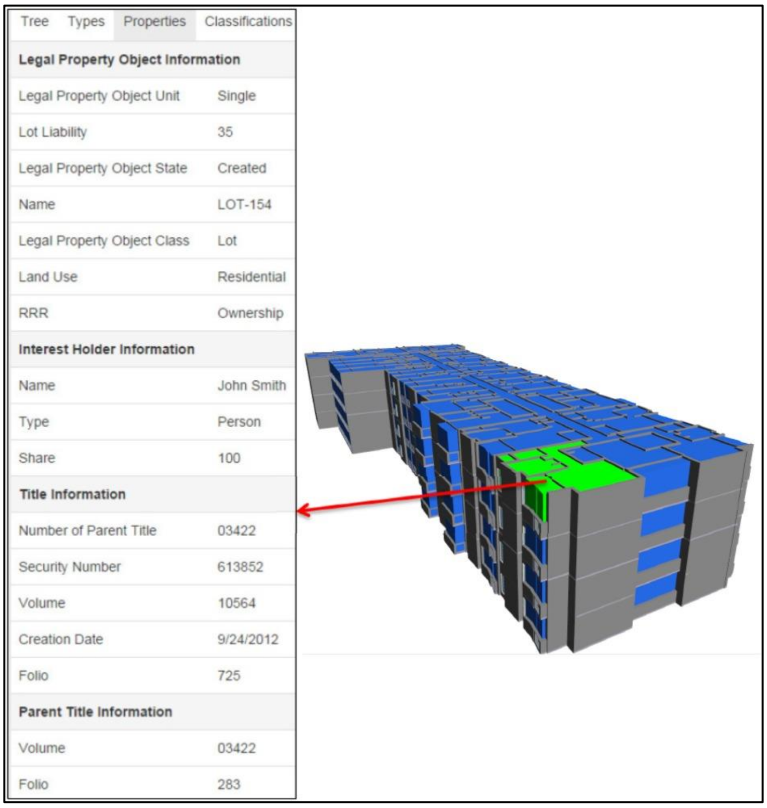
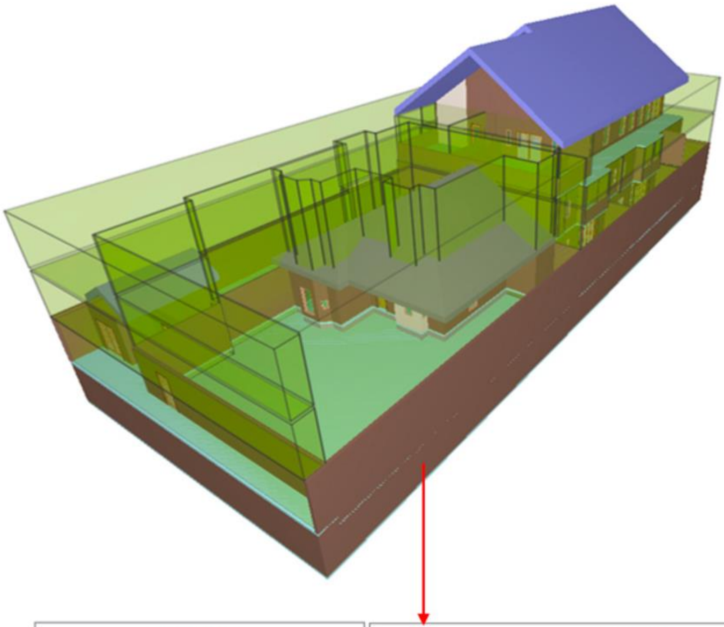


Figure 8. Managing the legal information in the developed prototype BIM model (Atazadeh et al, 2017)

Moreover, Atazadeh et al. (2017) identified a suitable approach for mapping 3D property boundaries into the BIM environment. This study found that using a BIM-driven approach has various benefits in managing multi-storey properties. One benefit is legal spaces (car park, storage and apartment unit) associated with a specific private property in high-rise buildings can be found easily by grouping into a spatial zone using semantic relationships (Figure 8). Another advantage is the capability of BIM environment to support visualization of building objects as part of common property spatial zones, which can help the owners' corporations to understand their responsibilities in managing facilities.

Last but not least, Meulmeester (2019) proposes a proof of concept of a complete data processing chain for registering new apartment rights in 3D in the Netherlands (with minimal change of the current procedures), by enriching IFC files with property unit information. The IFC model is enriched with property unit information by designing a user defined property set with cadastral information, called 'Cadastral Information user defined property set'. The Dutch regulations regarding the requirements for the 2D apartment floorplan drawings are projected on a 3D representation, which results in the contents of the cadastral information user defined property set. Then, mapping between IFC and LADM classes was performed to be able to automatically extract 3D legal spaces for apartment registration, store them into an LADM-compliant database and disseminate them through a 3D web-visualization platform.



Site Attributes	
Property	**Value**
RefElevation	22.5 m
RefLatitude	-37 ° 51 ' 43.13413 "
RefLongitude	144 ° 59 ' 53.94939 "
SiteAddress	138 Alma Road, St Kilda East 3183

Pset_PlanInfo	
Property	**Value**
Administrative Date	2014-07-15
Head Of Power	Subdivision Act 1988 and Owners Corporation Act 2008
Lots No	12
Plan No	PS704971N
Stage No	Not Applicable
Status	Planning Permit Applied
Survey Type	Surveyed

Figure 9. Integrated BIM model comprising legal and physical objects, as well as administrative information for the case study building (Olfat et al, 2019)

A similar approach, investigating the feasibility of a BIM-driven approach to support building subdivision workflows in Victoria, Australia, where IFC files are enriched by adding Property Sets within the IFC file, has been recently proposed by Olfat, et al. (2019). This resulted in an integrated as-designed BIM model that includes both legal and physical objects (Figure 9).

Within this context, among the aspects that attracts more and more attention is the reuse of information as input for 3D LAS and specifically, expanding 3D digital Architecture, Engineering and Construction models such as BIM/IFC models with information related to 'legal spaces', compulsory for application permits, financing and registration of property (units).

5. DISCUSSION

The development, evolution and modernization of Land Administration Systems around the world vary a lot, as they depend on national legislation, regulation, institutional arrangements and system's technological maturity. However, global trends and considerations towards effective and well-operational 3D LASs are constantly being recognised and usually addressed through policies, guidelines and standards at international level. In this scene, decision-makers require access to efficient land and property information, which is 3D, spatially accurate, and dynamic containing interests in land (rights, restrictions and responsibilities), as well as linked to a corresponding detailed 3D physical model. BIM/ IFC files and other 3D technical models, such as CityGML that are more and more available and occur at the lifecycle of an asset, are seen as useful tools towards this direction.

Today, the evolution that BIM has brought in the built environment industry, both in the infrastructure and building sectors, can be seen as a need and a challenge, being addressed and promoted through manuals, standards and specifications globally and nationally. It is expected that BIM users, leaders at the building industry and governments can truly reap the benefits of BIM by integrating it into their workflows, from contractual documentation, feasibility studies and design, to permit, registration, construction and facility management.

This paper presents the challenges and current research carried out in the context of circularity thinking in buildings' lifecycle aiming at data reuse from one stage to the other. Specifically, BIM data is expected to have capabilities to specify semantics, which can identify property units accurately, represent cadastral boundaries better, and visualise complex buildings in more detail. Such detailed input is crucial for cadastral registration.

At this initial analysis, various standardization efforts at national and international level regarding BIM adaptation are presented, highlighting the continuous research and advances in this domain. Next, the need of land administration domain to meet the requirements of the constantly changing environment and the challenges of 3D registration of multi-level properties are highlighted, followed by the research carried out till today in the field of reusing BIM/ IFC files for LA purposes. Finally, this work challenges an initial report concerning current methods of utilizing BIM/ IFC files for cadastral purposes, also tracing its advantages and limitations.

Future work includes:

- methodology for extracting BIM/IFC data for 3D parcel registration through prototype testing. Concluding remarks from such a prototype, regarding: the structure of BIM model, the exchange format, the necessary elements and classes that should be defined in its structure, the necessary identifiers (IDs) that should be defined to allow the link with LA databases, etc. will initiate a discussion regarding the general principles that should occur to enable the successful extraction from BIM files for 3D parcel registration.
- Investigation of how various legal systems around the world define legal spaces, which could be further related to LADM country profiles. Based on the different definitions, the mapping between the IFC classes that are needed and the corresponding concepts of the different legal system shall be performed to examine which is the optimal way to derive IFC-related information for 3D parcel registration in different legal systems.
- Apart from the original IFC format, which was defined primarily for building construction, there are extensions such as IFC Bridge and IFC Rail. As a next step, it should be investigated which elements from those IFC files could be used for the registration of such assets/ objects and test the workflow at a prototype.

REFERENCES

Aguiar, A., Vonk, R. and F Kamp (2019). *IOP Conf. Ser.: Earth Environ. Sci.* **2019,** *225*.

Atazadeh, B. Building Information Modelling for Urban Land Administration. Ph.D. Thesis, The University of Melbourne, Melbourne, Australia, 2017.

Atazadeh, B.; Kalantari, M.; Rajabifard, A.; Ho, S. and Ngo, T. (2017). Building Information Modelling for High-rise Land Administration. *Transactions in GIS,* **2017**, *21(1),91-113*.

Azhar, S.; Khalfan, M. and Maqsood, T. (2012). Building information modelling (BIM): now and beyond. Australasian Journal of Construction Economics and Building, 12(4), 15–28. https://doi.org/10.5130/ajceb.v12i4.3032.

BCG. Digital in Engineering and Construction. The Transformative Power of Building Information Modelling; Boston Consulting Group: 2016.

BIM Loket (2020). Available at: https://www.bimloket.nl/English (Accessed on: 15 February 2020).

Bruggeman, E.M. (2019). Legal aspects of Building Information Modelling (BIM) in the Netherlands: the procurement of a work with a BIM component - Part 1 and Part 2. *Construction Law International,* **2018/2**, *p. 40-50.* **2019/4**, *p. 56-64.*

Budden, R. (2019) A New BIM Strategy for Dubai. Available online: https://www.linkedin.com/pulse/new-bim-strategy-dubai-richard-budden/. (Accessed on 30 November 2019).

buildingSMART (2012). An Integrated Process for Delivering IFC Based Data Exchange. Available at: https://standards.buildingsmart.org/documents/IDM/IDM_guide-IntegratedProcess-2012_09.pdf. (Accessed on: 15 March 2020).

buildingSMART (2019). bSI Standards, Available online: https://www.buildingsmart.org/standards/bsi-standards/. (Accessed on 27 November 2019).

buildingSMART (2020). BIM Collaboration Format (BCF). Available at: https://technical.buildingsmart.org/standards/bcf/. (Accessed on: 3 April 2020).

CanBIM (2020). Available at: https://www.canbim.com/about. (Accessed on: 25 March 2020).
CMS (2020). CMS Expert Guide to Building Information Modelling - United Arab Emirates. Available at: https://cms.law/en/int/expert-guides/cms-expert-guide-to-building-information-modelling-bim/united-arab-emirates. (Accessed on: 28 April 2020).
CORENET (2020a). Singapore e-submission. Available at: https://www.corenet-ess.gov.sg/ess/. (Accessed on: 8 March 2020).
CORENET (2020b). Singapore BIM Guise. Available at: https://www.corenet.gov.sg/media/586132/Singapore-BIM-Guide_V2.pdf. (Accessed on: 28 March 2020).
Den Berg, M.C. van (2019). Managing Circular Building Projects. Ph.D. Thesis, University of Twente, The Netherlands, 2019.
European Commission (2017). Building Information Modelling (BIM) standardization. JRC Technical Reports, Martin Poljanšek, ISBN 978-92-79-77206-1.
El-Mekawy, M.; Paasch, J.M. and Paulsson, J. (2014). Integration of 3D Cadastre, 3D Property Formation and BIM in Sweden. In: 4th International Workshop on 3D Cadastres, 9-11 November 2014, Dubai, United Arab Emirates.
El-Mekawy, M.; Paasch, J.M. and Paulsson, J. (2015) Integration of Legal Aspects in 3D Cadastral Systems. *Int. J. E-Plan. Res.* **2015**, *4*, *47–71*.
EU BIM Task Group (2017). Handbook for the Introduction of Building Information Modelling by the European Public Sector Strategic Action for Construction Sector Performance: Driving Value, Innovation and Growth; European Union: 2017, Luxembourg, Luxembourg.
Fuchs, B. (2017). BIM – Status of Implementation in Germany. In: 2017 Annual Conference of the European Society of Construction Law University of Fribourg Switzerland. Available at: https://www3.unifr.ch/ius/baurecht/de/assets/public/files/handouts/BIM_Status%20ImplementationGermany%202017-11-03FuchsBastian09072018a.pdf. (Accessed on: 25 April 2020).
Gantz, J. and Reinsel, D. (2011). "Extracting value from chaos." Available at: https://www.emc.com/collateral/analyst-reports/idc-extracting-value-from-chaos-ar.pdf. (Accessed on: 5 February 2020).
HKIBIM (2020). Hong Kong Institute of Building Information Modelling. Available at: https://www.hkibim.org. (Accessed on: 15 March 2020).
Ho, S., Rajabifard, A. and Kalantari, M. (2015). 'Invisible' constraints on 3D innovation in land administration: A case study on the city of Melbourne. *Land Use Policy* **2015**, *42:412–425*.
Imperiale, J.; Hamilton LLP, P. and Chase, M. (2018). Standardization of BIM Implementation in the United States. consensusDocs Construction Law Newsletter (Vol. 4, Issue 5).
ISO (2016). ISO 29481-1:2016: Building Information Models—Information Delivery Manual—Part 1: Methodology and Format; International Organisation for Standardisation: Geneva, Switzerland, 2016.
ISO. (2016) ISO 12006-3:2016: Building construction - Organization of information about construction works - Part 3: Framework for object-oriented information (ISO 12006-3:2007); International Organisation for Standardisation: Geneva, Switzerland, 2016.
ISO (2018). ISO 16739-1:2018: Industry Foundation Classes (IFC) for Data Sharing in the Construction and Facility Management Industries—Part 1: Data Schema; International Organisation for Standardisation: Geneva, Switzerland, 2018.

Kalogianni, E.; van Oosterom, P.J.M.; Dimopoulou, E. and Lemmen, C. (2020). 3D Land Administration: A Review and a Future Vision in the Context of the Spatial Development Lifecycle. *ISPRS Int. J. Geo-Inf.* **2020**, 9, 107; doi:10.3390/ijgi9020107.

Koutamanis, (2019). Building Information - Representation and Management Fundamentals and Principles. TU Delft Open. https://doi.org/10.5074/T.2019.003

Meulmeester, R.W.E. BIM Legal. Proposal for Defining Legal Spaces for Apartment Rights in the Dutch Cadastre Using the IFC Data Model. Master's Thesis, Delft University of Technology, Deft, The Netherlands, 2019.

Naborczyk, K. (2020). 9 Reasons why Norway is the best in BIM! In: BIM Corner, March 2020. Available at: https://bimcorner.com/9-reasons-why-norway-is-the-best-in-bim/. (Accessed on: 22 April 2020).

National Institute of Building Sciences (NIBS) (2015). National BIM Standard - United States Version 3.

NBS (2018). BS EN ISO 19650-1:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - information management using building information modelling. Concepts and principles. National British Specification, UK, 2018.

OGC (2020). Built environment data standards and their integration: an analysis of IFC, CityGML and LandInfra. Integrated Digital Built Environment (IDBE), OGC Document 19-091r1, Version1, 2 March 2020.

Oldfield, J.; van Oosterom, P.J.M.; Beetz, J.; Krijnen, T.F. Working with Open BIM Standards to Source Legal Spaces for a 3D Cadastre. *ISPRS Int. J. Geo-Inf.* **2017**, *6, 351*.

Oldfield, J.; Bergs, R.; van Oosterom, P.; Krijnen, T.; Galano, M. 3D Cadastral Lifecycle: An Information Delivery Manual ISO 29481 for 3D Data Extraction from the Building Permit Application Process. In Proceedings of the 7th International FIG Workshop on the Land Administration Domain Model, Zagreb, Croatia, 12–13 April 2018.

Olfat, H.; Atazadeh, B.; Shojaei, D.; Rajabifard, A. The Feasibility of a BIM-Driven Approach to Support Building Subdivision Workflows—Case Study of Victoria, Australia. *ISPRS Int. J. Geo-Inf.* **2019**, *8, 499*.

Rijksvastgoedbedrijf (2020). Rgd BIM Standard v1.0.1 EN v1.0_2. Available at: https://english.rijksvastgoedbedrijf.nl/expertise-and-services/b/building-information-modelling-bim. (Accessed on: 22 April 2020).

Siresiya, V. (2019). BIM Mandatory in UK High Rise Residential Projects: Implications for Builders & Designers. In: United-BIM, June 2019. Available at: https://www.united-bim.com/bim-mandate-in-uk-high-rise-residential-projects-implications-for-builders-designers/. (Accessed on: 2 April 2020).

O'Dea, S. (2020) Information created globally 2010-2025. In: Statista, Feb 28, 2020. Available at: https://www.statista.com/statistics/871513/worldwide-data-created/ (Accessed on: 5 May 2020).

Statsbygg (2020). Statsbygg BIM Manual. Available at: http://www.eubim.eu/wp-content/uploads/2019/08/2019-08-28_EU_BIM_Task_Group_Statsbygg_BIM_Manual_20_v101.pdf. (Accessed on: 12 February 2020).

Sun, J.; Mi, S.; Olsson, P.-O.; Paulsson, J.; Harrie, L. Utilizing BIM and GIS for Representation and Visualization of 3D Cadastre. *ISPRS Int. J. Geo-Inf.* **2019**, *8, 503*.

Tardif, M.; Smith, K.D. Building Information Modelling: A Strategic Implementation Guide; John Wiley & Sons: Hoboken, NJ, USA, 2009.

The B1M (2020). BIM Protocol Explained. Available at: https://www.theb1m.com/video/bim-protocol-explained. (Accessed on: 22 April 2020).
Turner, V., Reinsel D., Gantz J. F. and Minton S. (2014). "The Digital Universe of Opportunities". Available at: https://www.emc.com/leadership/digital-universe/2014iview/digital-universe-of-opportunities-vernon-turner.htm (Accessed on: 12 February 2020).
UK BIM Task Group (2020). BIM. Available at: http://www.bimtaskgroup.org/bim-faqs/ (Accessed on: 22 April 2020).
World Bank (2020). Ease of Doing Business ranking. Available at: https://www.doingbusiness.org/en/rankings (Accessed on: 15 April 2020).

BIOGRAPHICAL NOTES

Eftychia Kalogianni is a PhD candidate in GIS Technology Section, at the Delft University of Technology. Her PhD research topic is about adopting a holistic approach to treat 3D Land Administration Systems within the spatial development lifecycle, in the context of LADM ISO 19152 revision. She holds MSc in Geoinformatics from NTUA and MSc in Geomatics from TUDelft. She is an active member of FIG Young Surveyors Network.

Efi Dimopoulou is Professor at the School of Rural and Surveying Engineering, NTUA, in the fields of Cadastre, Spatial Information Management, Land Policy, 3D Cadastres and Cadastral Modelling. She is the Programme Director of the NTUA Inter-Departmental Postgraduate Course «Environment and Development».

Christiaan Lemmen is full Professor Land Information Modeling at the Faculty of GeoInformation Science and Earth Observation of the University of Twente in the Netherlands. His other main job is as Senior Geodetic Advisor at Kadaster International, the international branch of the Netherlands Cadastre, Land Registry and Mapping Agency. He is director of the OICRF, the International Office of Cadastre and Land Records, one of the permanent institutions of the International Federation of Surveyors (FIG). He is co-editor of the International Standard for the Land Administration Domain, ISO 19152 and the designer of the Social Tenure Domain Model (in co-operation with UN HABITAT and FIG). He holds a PhD from Delft University of Technology, The Netherlands.

Peter van Oosterom obtained an MSc in Technical Computer Science in 1985 from Delft University of Technology, the Netherlands. In 1990 he received a PhD from Leiden University. From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague. From 1995 until 2000 he was senior information manager at the Dutch Cadastre, where he was involved in the renewal of the Cadastral (Geographic) database. Since 2000, he is professor at the Delft University of Technology, and head of the 'GIS Technology' Section, Department OTB, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands. He is the current chair of the FIG Working Group on '3D Cadastres'. He is co-editor of the International Standard for the Land Administration Domain, ISO 19152.

CONTACTS

Eftychia Kalogianni
PhD Candidate, Delft University of Technology
10 Monis Petraki, 11521,
Athens, GREECE
E-mail: E.Kalogianni@tudelft.nl

Prof. Efi Dimopoulou
Professor, National Technical University of Athens
School of Rural & Surveying Engineering
9, Iroon Polytechneiou, 15780 Zografou, GREECE
E-mail: efi@survey.ntua.gr

Prof. Christiaan Lemmen
University of Twente
Faculty of Geo-Information Science and Earth Observation/ITC
P.O. Box 217
7500 AE Enschede
THE NETHERLANDS
Phone: + 31 6 52481717
E-mail: c.h.j.lemmen@utwente.nl
Website: www.itc.nl

and

Cadastre, Land Registry and Mapping Agency
Kadaster International
P.O. Box 9046
7300 GH Apeldoorn
THE NETHERLANDS
Phone: +31 88 183 4417
E-mail: Chrit.Lemmen@kadaster.nl
Website: www.kadaster.nl

Prof. Dr. Peter van Oosterom
Professor, Delft University of Technology
Faculty of Architecture and the Built Environment
P.O. Box 5030, 2600 GA Delft, THE NETHERLANDS
Tel.: +31 15 2786950
E-mail: P.J.M.vanOosterom@tudelft.nl
Website: http://www.gdmc.nl