A BIM-Driven Approach to Managing Common Properties within Multi-Owned Developments

Behnam ATAZADEH, Abbas RAJABIFARD, Mohsen KALANTARI and Jihye SHIN, Australia

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SUMMARY

There has been a significant growth of multi-owned developments in cities around the world. These developments include a combination of different types of residential and commercial uses of urban spaces. Common property areas in multi-owned developments typically include a wide range of shared spaces and facilities. Clear and correct delineation of the spatial extent of common properties must be considered to avoid unintended consequences and costs in managing facilities within complex developments. Currently, subdivision plans are used as an artefact of knowledge for managing common properties in building developments. Communication and management of the spatial extent of both unlimited and limited common property areas could be a challenging task for Owners Corporation (OC) managers. Therefore, there is a need for providing not only a better approach to manage common properties in a more visual way but also adopt digital data management methods. One such approach – Building Information Modelling (BIM) – is currently used in the building industry. BIM is widely recognised as a common data environment for 3D lifecycle management of buildings. In this research, we suggest that BIM can be used to digitize 3D spatial structures of common properties in multi-owned developments.

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1. INTRODUCTION

There has been a significant growth of multi-owned developments in cities around the world. These developments include a combination of different types of residential and commercial uses of urban spaces. Common property areas in multi-owned developments typically include a wide range of shared spaces and facilities such as loading docks, fire stairs, façades, entrances and exits, plazas or piazzas, lifts, electrical plant and infrastructure, air conditioning plant and infrastructure, water, fire safety systems and gardens. Clear and correct delineation of the spatial extent of common properties must be considered to avoid unintended consequences and costs in managing facilities within complex developments. In multi-owned developments, different groups of lot owners are entitled to use various parts of shared facilities and spaces. For instance, in a mixed-used development, some elevators are used by residents of apartment units while retail stores use their own elevators for their commercial activities.

In Australian jurisdictions, Owners Corporations (OCs) are responsible for managing and maintaining common property areas. To define a fair approach for managing maintenance costs, unlimited and limited OCs are typically created in mixed-use developments. Unlimited OC has unlimited functions, powers, and responsibilities throughout the whole development. Each limited OC typically serves a specific part of common property area which is used by a group of lot owners residing within the development. There are typically multiple OCs involved in multi-owned developments. Currently, subdivision plans are used as an artefact of knowledge for managing common properties in buildings. Communication and management of the spatial extent of both unlimited and limited common property areas could be a challenging task for OC managers. This stems from the fact that OC managers use 2D-based subdivision plans to disambiguate the 3D spatial extent of common properties. In current practices, several spatial problems associated with common property management can arise in complex developments. Some of these problems are:

- A land surveyor may use the building lines on the ground to define lot boundaries. The upper building levels may have balconies which are not inside the vertical line extended from the building line on the ground floor. If he notates that everything outside the lots is part of the common property, then the balconies are considered as common property.
- If the boundary between lots and common property is defined by referencing a physical structure (e.g. a wall), it is sometimes challenging to identify what part of that structure belongs to the common property. This is because that physical structures are not shown on 2D subdivision plans.

- In a multi-owned development, it may be difficult to determine the physical structure that is spatially referenced within a specific common property among multiple common property areas.
- OC managers, who have limited background in cadastral surveying, may encounter difficulties in understanding of the full spatial extent of the common property area for which they are responsible.

These spatial problems indicate that there is a need for providing not only a better approach to manage common properties in a more visual way but also adopt digital data management methods.

In this research, we suggest that Building Information Modeling (BIM) can be a feasible approach to digitizing 3D spatial structures of common properties in multi-owned developments. BIM is widely recognised as a common data environment for 3D lifecycle management of buildings in the construction industry. Currently, various investigations showed the feasibility of BIM models for managing 3D ownership rights in multi-storey developments (Atazadeh, Kalantari, Rajabifard, & Ho, 2017; Atazadeh, Kalantari, Rajabifard, Ho, & Champion, 2017; Barton, Marchant, Mitchell, Plume, & Rickwood, 2010; El-Mekawy & Östman, 2015; Oldfield, van Oosterom, Beetz, & Krijnen, 2017); however, there is limited investigation into the application of these models to common property management in multi-owned developments. Therefore, the aim of this research is to develop a BIM-driven approach for managing common properties in the 3D digital data environment. To address this research aim, we conducted this research in four phases:

- Identifying the data elements required for common property management (Section 3.1)
- Decipher suitable mechanisms inside the BIM environment for modelling common properties (Section 3.2)
- Implementation of a prototype BIM model with multiple common property areas (Section 4)
- Comparing the BIM-based approach with current practices and highlighting the benefits of BIM and major challenges inhibiting its use in common property management (Section 5)

The main focus of this study is on the technical aspects of common property management. However, the importance of the juridical issues was also recognised, which needs to be explored in further investigations.

2. RELATED WORK

The Subdivision Act (1988) and its respective regulation, Subdivision (Registrar's Requirements) Regulations (2011), allow the registration of the common properties. According to Section 30 of the Subdivision Act (1988), a common property is defined as the co-ownership of common areas by the lot owners as ‘tenants in common’ in shares proportional to their lot entitlements. Although 3D situations of common properties are not explicitly described in the Subdivision Act, the Registrar Requirements Regulations provides specific examples of registering common properties in 3D situations (VictorianGovernment, 2011).

The Owners Corporation Act (2006) and its respective regulation, the Owners Corporation Regulations (2007), provides the legal instruments for managing common properties after its registration. Management of common properties are based on a set of rules. The owners Corporation Regulations provides a set of predefined model rules for managing common properties. The model rules are associated with the matters related to health, safety, security, administration, use of common property, use of lots, behaviour of owners, residents and visitors, and dispute resolution. Alternatively, the responsible OC may define new rules in accordance with the matters provided in Schedule 1 of the Owners Corporation Act. In addition, the OC can change and revoke its rules by notifying the Registrar of Titles.

In our view, there are two distinct but interlinked dimensions for common property management in multi-owned developments: governance structure and spatial arrangement. The governance structure behind common properties has been extensively studied in the property research domain. However, there are limited studies about the spatial arrangements of common properties and how 3D digital environments, such as BIM, can support the spatial structure of common properties in complex developments. Here, we will review the research relevant to both dimensions.

2.1 Governance structure

Registration of a multi-owned development results in creating some legislative constraints and forming a group of owners with a communal interest. Therefore, a good governance structure is required for managing common properties in a multi-owed development. The term 'governance' is defined as 'structures, processes and practices that determine how decisions are made in a system and what actions are taken within that system' (Easthope & Randolph, 2009, p. 247). The governance structures behind common properties are typically dependent on the jurisdictional setting of a country or state. Blandy, Dupuis, and Dixon (2010) provide a wider context for managing multi-owned developments in a range of countries around the world such as Australia, New Zealand, Singapore, England and Wales. In Australian jurisdictions, the legislative mechanisms for common property management may not vary from one jurisdiction to another; however, the adopted terminologies would be significantly different among Australian states and territories. A comprehensive study of the terminological differences associated with common property management in Australian jurisdictions was presented in (Everton-Moore, Ardill, Guilding, & Warnken, 2006; Renae Johnston & Reid, 2013). Compared to other terms, such as 'Body Corporate', the term 'Owners Corporation' would provide a more transparent representation of the governing bodies behind common properties.

In the Victorian jurisdiction, this term came into effect after the Owners Corporation Act (2006) in 2007. For multi-owned housing schemes established under this act, the OCs are formed by individual lot owners whose communal ownership are defined within the common property areas. There are three main elements considered in OCs, namely the communal ownership of the common property and amenities, formation of behaviour governing rules in a multi-owned development, establishment of a governing body to administer and monitor the common property and behaviour rules (Sherry, 2009).

In Australian jurisdictions, the governance structure of OCs is typically a hierarchical one, which is composed of a chair, committee members, and lot owners. In some multi-owned developments, particularly mixed-used ones, there are typically several OCs involved in managing various common properties for a different group of owners. These OCs are typically governed under a nested hierarchical structure (Townshend, 2006).

For instance, Figure 1 shows two examples of nested hierarchical structures for a mixed-use development. In the first example, there is only one unlimited OC and there are limited OCs, each of which providing benefits for the group of lot owners who have liability and entitlement in that limited OC. In this case, although residential lot owners, for example, do not directly have interest on limited common property areas being used by retail lot owners, they have an indirect interest in these retail common properties since the unlimited OC owns all the limited common properties (see Figure 1a). The second example shows two different unlimited OCs with their own limited OCs. The unlimited OC1 governs the limited OCs which provide benefits for the residential owners, while the unlimited OC2 and its limited OCs are for the benefit and interest of the retail owners. In this case, there would be a shared service agreement between two unlimited OCs for those utility services shared among all residential and retail lot owners (see Figure 1b). The second example can be a better approach for defining nested hierarchical structures as it provides the ability to isolate maintenance costs associated with common properties fairly.

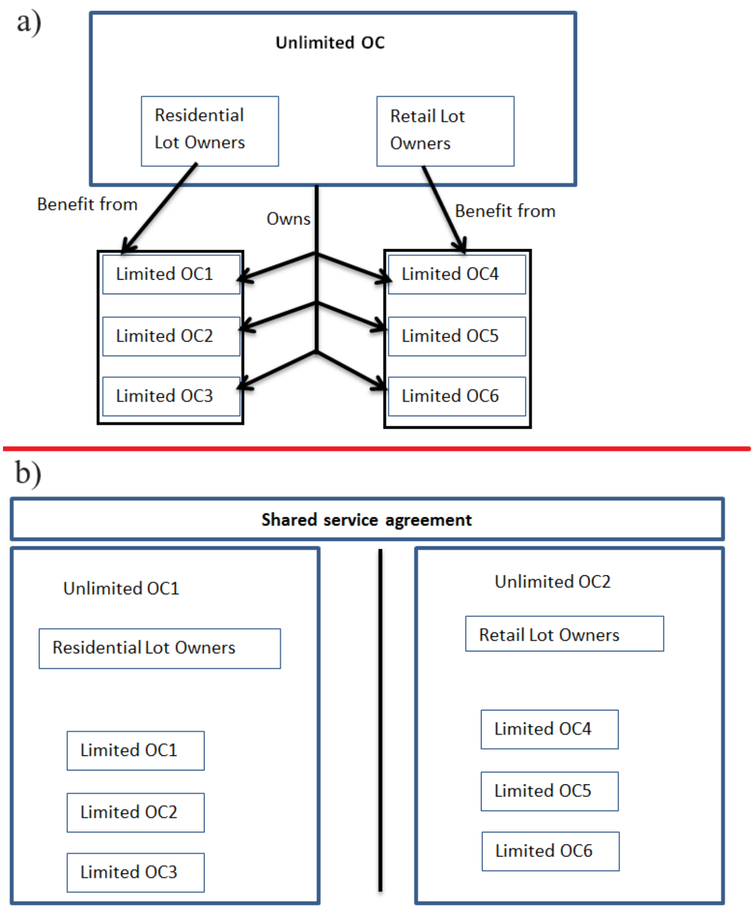

Figure 1. Two examples of nested hierarchical structures of OCs in multi-owned developments

2.2 Spatial arrangements

Spatial arrangements of common properties, like other stratified legal interests, in current practices are mainly defined by 2D subdivision or strata plans. However, research and developments in the domain of 3D digital cadastre have mainly studied the 3D spatial arrangement of common properties implicitly along with other types of legal interests. Rajabifard, Atazadeh, and Kalantari (2018)reviewed various 3D spatial information models in terms modelling legal interests and boundaries defined in the Victorian jurisdiction. Table 1 shows the possible entities, excerpted from international 3D standards, that can be used in spatial modelling of common properties in 3D digital environments.

Table 1. Possible entities for modelling common properties in various 3D standards, adapted from (Rajabifard et al., 2018)

3D spatial information model	Common property	
	Individual spatial parts	**The entire spatial structure**
LADM (ISO19152, 2012)	LA_SpatialUnit LA_LegalSpaceBuildingUnit	LA_BAUnit
ePlan (Cumerford, 2010)	VolumetricLot Parcel	Parcel
CityGML (Groger, Kolbe, Nagel, & Hafele, 2012)	LandUse BuildingPart BuildingInstallation IntBuildingInstallation Room	CityObjectGroup
IndoorGML (Lee et al., 2014)	CellSpace	PrimalSpaceFeatures
Industry Foundation Classes (IFC) (ISO16739, 2013)	IfcSite IfcBuildingElement (and its concrete subclasses) IfcDistributionElement IfcGeographicElement IfcCivilElement IfcSpace IfcExternalSpatialElement	IfcZone IfcSpatialZone
LandInfra/InfraGML (Scarponcini, Gruler, Stubkjær, Axelsson, & Wikstrom, 2016)	LandParcel BuildingPart	LandPropertyUnit PropertyUnit

3. MODELLING COMMON PROPERTIES IN BIM

To model common properties in BIM, two steps are considered in this research. First, the data elements associated with common property management were identified. In the second step, the identified data elements were mapped onto the open BIM schema or IFC standard**.**

3.1 Data elements of common properties

There are two major data elements for a common property: attributes and spatial structure of the common property. Attributes of the common property specify the type of the common property, a list of the affected lots, and the details of the limitation for limited common properties (see Table 2)

Table 2. Required attributes specific to common property

Attribute	Description
Common Property Type	There are two types of common property: Limited and Unlimited. Unlimited commonly owned properties are for the use and benefit of all owners, whereas limited ones must be used by a specific group of owners.
Land Affected	This includes a list of those lots that are affected by the owners corporation being responsible for managing the common property.
Limitation Details	This attribute is optional, and it should be used to provide limitation details for limited common properties.

A spatial structure behind a common property is complex and it typically includes a combination of a wide range of functional spaces, physical built structures and geographic features. More specifically, in current subdivision practices in Victoria, the common property may include spaces between and separating each lot, such as walls, roof, ceilings, floors, roof space and airspace above the roof, and the building facade. In addition, gardens, gymnasiums, stairs, elevators, parking areas, driveways, security and air conditioning systems, as well as water, sewerage, electrical and fire connection systems can be part of the common property. In master planned developments, roads, golf courses, parkland, and marinas may be defined as part of the entire spatial structure of the common property.

3.2 Mapping the data elements onto the IFC standard

As it was mentioned in Section 2.2, Rajaibfard et al (2018) has identified the suitable IFC entities for modelling common properties. IfcSpatialZone and IfcZone are both suitable for modelling common properties. However, there is a difference between these entities. IfcZone has a direct relationship with a group of only internal spaces (IfcSpace), while IfcSpatialZone is more comprehensive and it can include various types of internal and external spaces as well as built structures and geographical features. A spatial zone is related to its constituent elements via the objectified "IfcRelReferencedInSpatialStructure" relationship entity. This relationship entity has two important attributes used for defining the spatial structure of a spatial zone:

- RelatingStructure: This attribute refers to the IfcSpatialZone entity to define the entire structure of the spatial zone.
- RelatedElements: This attribute refers to a set of products which are referenced within the spatial zone. A product (IfcProduct) refers to any spatial and physical element.

To define the entire spatial structure of an individual common property, RelatedElements attribute refers to a set of "IfcSpace, IfcExternalSpatialElement, IfcBuildingElement, IfcDistributionElement, IfcCivilElement, and IfcGeographicElement" entities (see Figure 2)

To incorporate the attributes of the common property into the IFC, defining a subclass for IfcSpatialZone is not the correct solution. The extension mechanisms allowed within the IFC schema should be used for defining the attributes proposed for common properties. One of these extension mechanisms is the concept of property sets (IfcPropertySet) which can be used to assign attributes to the IfcSpatialZone entity defining the common property. Table 3 provides the specific attributes (Pset_CommonProperty) for common property spatial zones. This property set can be related to the IfcSpatialZone entity using the IfcRelDefinesByProperties entity.

Table 3. Proposed property set for common property

Property Set Name	**Pset_CommonProperty**	
Name	**Property Type**	**Data Type**
CommonPropertyType	IfcPropertyEnumeratedValue	IfcLabel
LandAffected	IfcPropertySingleValue	IfcText
LimitationDetails	IfcPropertySingleValue	IfcText

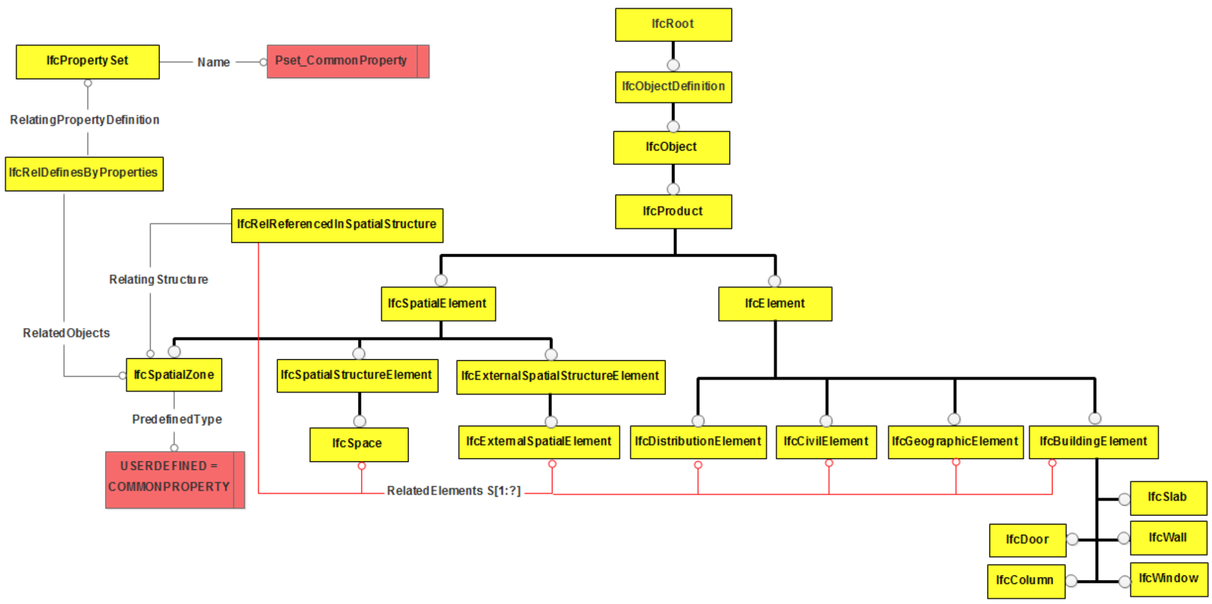

Figure 2. Modelling the spatial arrangements of common properties in the IFC standard

4. IMPLEMENTATION OF A PROTOTYPE BIM MODEL

A three-storey complex development located in Melbourne was selected for showcasing the proposed BIM-driven approach for common property management. This multi-owned development includes an unlimited common property and 4 limited common properties. Autodesk Revit was used to create the common property spaces within the BIM model. The BIM model was implemented based on the as-built condition of the building after the registration of the properties. There may be differences between design BIM and as-built BIM due to changes during pre-construction phases of a development. Design BIM model was delivered in the planning phase. The design model goes under several approval processes, such as getting planning permits and council certifications, before the final registration of the development by the land registry organization. In the context of common property management, the legal boundaries between common properties and lots may change before the registration. After registration, these legal boundaries come into existence and they remain unchanged. Therefore, the as-built BIM model we implemented in this research was based on the plans finalised after the registration phase of the multi-owned development.

The coordinates in BIM models are often refer to an arbitrary local coordinate system. Therefore, to define real-world coordinates for the legal boundaries, the BIM model needs to be georeferenced. This requires transformation of the coordinates from the project coordinate system into the geospatial reference system. There are two major points in this transformation, namely setting the geospatial coordinates for the project origin and coinciding the project north with the true north (Arroyo Ohori, Diakité, Krijnen, Ledoux, & Stoter, 2018). Some inconsistencies may happen in geo-referencing BIM models due to such factors as the accuracy of the base map, the adopted georeferencing approach, and accuracy of the BIM model. These georeferencing issues can be eliminated if we use a spatially accurate base map as well as a BIM model with a good modelling accuracy.

Various common property areas in the implemented prototype BIM model are represented in Figures 3 and 4. In Figure 3, the unlimited common property No. 1 is represented and only the slabs among other physical structures are highlighted. Other structures, such as walls defining boundaries, also belong to the common property No. 1, are not highlighted in Figure 3; however, they are accessible under the spatial zone defined for this common property in the BIM viewer. The limited common properties are defined based on the internal spaces inside the development. Each limited common property provides benefits to a particular group of owners. For instance, the limited common property No. 4 is the corridor areas used by the lot owners residing in the north side of the development, while the limited common property No. 3 is the corridor areas used by the lot owners residing the south side the development.

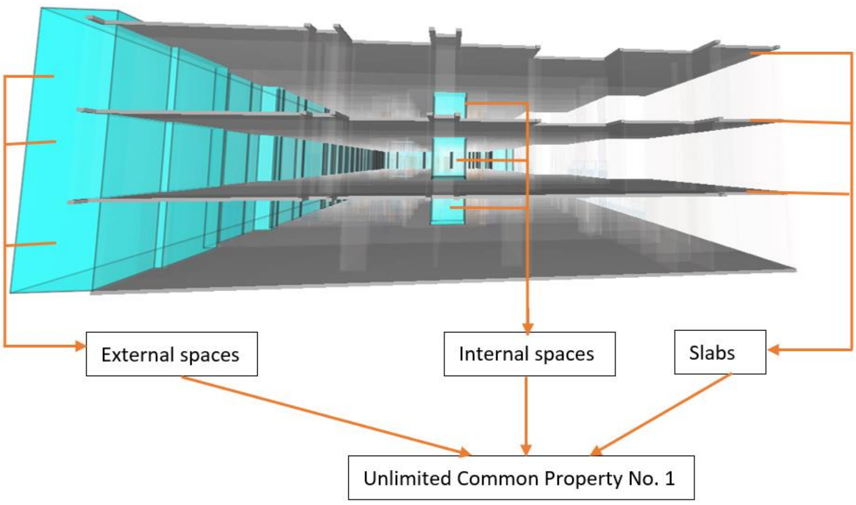

Figure 3. Part of the unlimited common property within the development

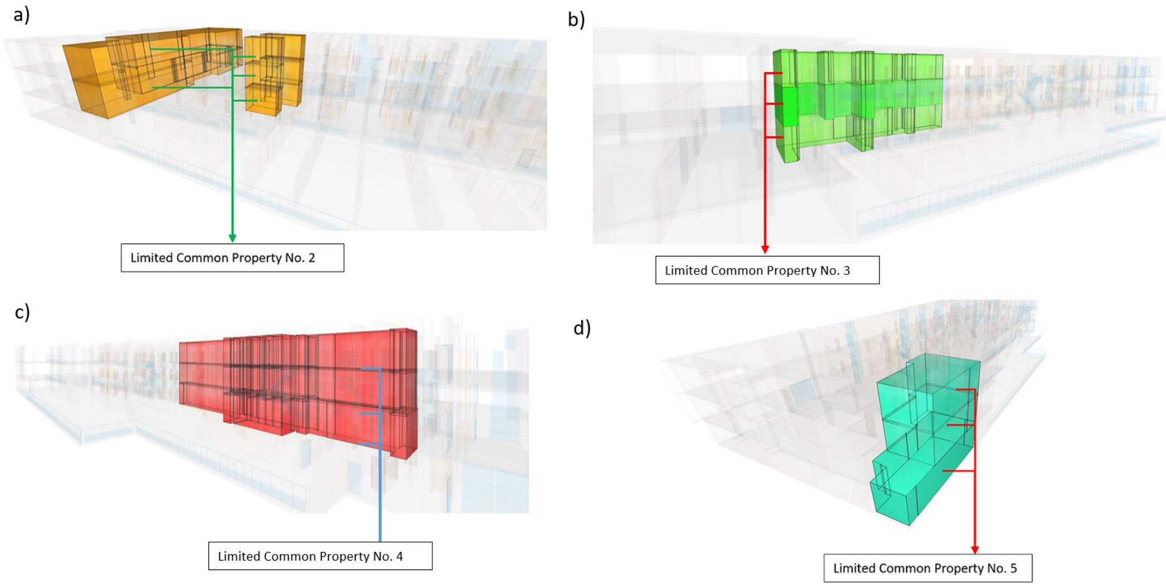

Figure 4. Limited common properties within the development

5. DISCUSSION AND CONCLUDING REMARKS

Current practices provide an abstract representation of the physical structures in 2D plans, which results in challenges in identifying which part of a development belongs to the common property in spatially complex situations. In this paper, we mainly looked at the technical aspect of using the BIM environment for the common property management. The full extent of the legal spaces defining common properties can be visually communicated in the BIM environment. In addition, the physical elements deemed to be part of a common property are not abstracted in the BIM environment and this makes it easier to identify those building structures belonging to the common property. However, this requires developing a new BIM-based tool for supporting common property management in complex structures.

From a technical point of view, using a BIM-driven approach also provides the possibility to define organisational relationships in managing multiple common properties. For instance, in the IFC standard, the IfcOrganizationRelationship entity can be used to establish an association between an unlimited OC and one or more limited OCs. However, this 3D digital environment could also have a significant impact on the interactions among various OCs in a multi-owned development. During the lifecycle of common properties in a multi-owned development, the function and tasks of limited OCs is ancillary to the overarching unlimited OC. Although OCs may be resistant to change common property management practices from using current 2D plans to 3D BIM environments, a BIM-driven approach would potentially facilitate their collaboration during the building lifecycle by providing more transparent and integrated representation of the complex spatial structure of common properties. However, the organisational impact of the BIM environment in managing common properties still needs to be further investigated. Therefore, new guidelines for adopting a BIM-based approach for managing common properties should be developed in future studies.

In addition to the organisational aspects, a BIM-driven approach would have legal implications. The adoption of a BIM-based approach may need to be considered in the Subdivision Act and Subdivision (Registrar's Requirements) Regulations 2011 for registering a BIM-driven common property. In addition, managing common properties using BIM models may need to be reflected in the Owners Corporation act and regulations. Therefore, another future research could be proposing appropriate amendments in the legislations adopted for common property registration and management.

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BIOGRAPHICAL NOTES

Behnam Atazadeh is a post-doctoral research fellow in the Centre for Spatial Data Infrastructures and Land Administration, Department of Infrastructure Engineering, the University of Melbourne. He has extensive experience in using 3D building information models and other 3D digital technologies for advanced land administration in urban areas.

Abbas Rajabifard is Professor at the University of Melbourne and head of the Department of Infrastructure Engineering and Director of both the Centre for SDIs and Land Administration and the recently established Centre for Disaster Management and Public Safety. He is immediate Past-President of Global SDI (GSDI) Association and is an Executive Board member of this Association. Abbas was Vice Chair, Spatially Enabled Government Working Group of the UN Global Geospatial Information Management for Asia and the Pacific. He has also consulted widely on land and spatial data policy and management and SDI.

Mohsen Kalantari is a Senior Lecturer in Geomatics Engineering and Associate Director at the Centre for SDIs and Land Administration (CSDILA) in the Department of Infrastructure Engineering at The University of Melbourne. He teaches Land Administration Systems (LAS) and Building Information Modelling and his area of research involves the use of 3D digital and spatial technologies in LAS and SDI. He has also worked as a technical manager at the Department of Sustainability and Environment (DSE), Victoria, Australia.

Jihye Shin is a PhD candidate in Geomatics in the Centre for Spatial Data Infrastructures and Land Administration, Department of Infrastructure Engineering, the University of Melbourne. As part of her PhD, she will be investigating and developing a BIM-based approach to design and management of common properties.

CONTACTS

Behnam Atazadeh
Department of Infrastructure Engineering, University of Melbourne
VIC 3010 AUSTRALIA
Email: behnam.atazadeh@unimelb.edu.au
Web site: http://www.csdila.unimelb.edu.au/people/behnam-atazadeh.html

Abbas Rajabifard
Department of Infrastructure Engineering, University of Melbourne
VIC 3010 AUSTRALIA
E-mail: abbas.r@unimelb.edu.au
Website: www.ie.unimelb.edu.au/

Mohsen Kalantari
Department of Infrastructure Engineering, University of Melbourne
VIC 3010 AUSTRALIA
Email: mohsen.kalantari@unimelb.edu.au
Web site: http://www.csdila.unimelb.edu.au/people/saeid-kalantari-soltanieh.html

Jihye Shin
Department of Infrastructure Engineering, University of Melbourne
VIC 3010 AUSTRALIA
Email: jihyes@student.unimelb.edu.au