Survey Review

ISSN: 0039-6265 (Print) 1752-2706 (Online) Journal homepage: www.tandfonline.com/journals/ysre20

BIM/IFC-LADM mapping framework for Sarawak country profile

Ainn Zamzuri, Alias Abdul Rahman, Muhammad Imzan Hassan & Peter van Oosterom

To cite this article: Ainn Zamzuri, Alias Abdul Rahman, Muhammad Imzan Hassan & Peter van Oosterom (17 Jul 2025): BIM/IFC-LADM mapping framework for Sarawak country profile, Survey Review, DOI: 10.1080/00396265.2025.2532947

To link to this article: https://doi.org/10.1080/00396265.2025.2532947

Published online: 17 Jul 2025.

BIM/IFC-LADM mapping framework for Sarawak country profile

Ainn Zamzuri *[a], **Alias Abdul Rahman** [a], **Muhammad Imzan Hassan**[a] and **Peter van Oosterom**[b]

This paper enhances the Sarawak LADM Country Profile by proposing a structured workflow for mapping IFC elements (e.g. IfcSpace, IfcWall, IfcSlab) to LADM classes to improve the representation of legal space boundaries. The methodology focuses on extracting legal space information from IFC models, mapping it to LADM using Enterprise Architect, and structuring the data for future integration with PostgreSQL. The mapping framework supports strata title management and 3D cadastral in Sarawak. Additionally, this study outlines a conceptual workflow for visualising legal space boundaries using CesiumJS. The proposed approach enhances data interoperability between BIM and land administration, advancing BIM-driven cadastral systems.

Keywords: BIM-LADM, strata ownership, legal space, land administration, IFC elements

1. Introduction

The integration of Building Information Modelling (BIM) and Land Administration Domain Model (LADM) represents a significant advancement in bridging the gap between spatial (legal space boundaries) and non-spatial (ownerships) in cadastre, especially in strata property management. BIM, one of the data sources that provides 3D spatial and rich semantic information representation of buildings (e.g. high-rise, complex buildings), enables effective property management. Its standardised data schema, Industry Foundation Classes (IFC), allows a seamless exchange of information across different software platforms (e.g. Autodesk Revit, Solibri, Bentley, etc.). Meanwhile, LADM, a conceptual model standardised as ISO 19152, provides a framework for managing legal, administrative, and spatial aspects of land, property, and associated rights. Integrating BIM/IFC with LADM holds immense potential for enhancing legal and administrative workflows, particularly in urban development and land management contexts (ISO 2013, buildingSMART 2020).

The increasing complexity of urban environments necessitates robust frameworks for integrating building-level data with land administration systems. Through its detailed modelling of buildings and infrastructure, BIM offers comprehensive spatial and non-spatial data that aligns with LADM's emphasis on rights, restrictions, and responsibilities (RRRs). IfcBuilding, IfcSpace, and IfcSite are part of IFC's comprehensive data schema. They can map to the administrative parcels and spatial units of LADM. Connecting these domains allows it to digitally represent legal spaces within buildings, such as leased units, ownership boundaries, and shared facilities. This integration improves data accuracy, interoperability, and decision-making among land administrators, developers, and government agencies (Lemmen *et al.* 2015).

One of the critical challenges in integrating BIM/IFC with LADM is the transformation of geometric and semantic data. While IFC models provide detailed 3D representations of boundaries, surfaces, and volumes, converting these into LADM-compliant spatial units while preserving legal accuracy remains complex. Additionally, the lack of automation in the mapping process presents a significant barrier, as current BIM/IFC–LADM workflows primarily rely on manual data conversion, increasing the risk of errors and inefficiencies. Integrating BIM (IFC-based) and cadastral (LADM-based) data models also presents challenges in database interoperability. There is no standardised procedure for confirming that extracted legal spaces in a cadastral system are accurate. Moreover, there is currently no standardised approach to verify the accuracy of legal spaces derived from BIM models within cadastral systems, revealing a significant gap in guaranteeing the reliability of 3D land administration data.

This study aims to enhance the Sarawak LADM country profile by mapping the relevant IFC elements to LADM classes for representing legal space boundaries. This mapping process considers spatial and legal data consistency in land administration and minimises errors in cadastral management. The mapping workflow consists of extracting IFC elements, linking the relevant

[a]Department of Geoinformation, Universiti Teknologi Malaysia, Johor Bahru, Malaysia
[b]GIS Technology Group, Faculty of Architecture, Delft University of Technology, Delft, The Netherlands

*Corresponding author. Email: ainnalfatihah@gmail.com

Received 14 April 2025; accepted 3 July 2025
DOI 10.1080/00396265.2025.2532947

IFC elements to existing LADM classes or attributes, and establishing a structured spatial database using PostgreSQL to manage legal and administrative data efficiently. Though currently conceptual, this approach aims to enhance data storage, retrieval, and interoperability for future applications. The study will explore a case in Sarawak, focusing on strata title management and 3D cadastral workflows. This study will conceptually demonstrate the feasibility of BIM-LADM integration within Sarawak's legal and land administration framework. Additionally, the study will discuss 3D visualisation and validation techniques using CesiumJS to evaluate the potential for assessing legal boundaries extracted from BIM models, ensuring they align with cadastral and land registry requirements.

While previous research (Alattas *et al.* 2021, Atazadeh et al. 2021, Gkeli and Potsiou 2023) has explored conceptual mappings between BIM and LADM, this study introduces several key advancements. Firstly, it establishes a structured and partially automated methodology for transforming IFC data into LADM-compliant formats, reducing manual interventions and enhancing data consistency. The workflow follows a conversion process from IFC to glTF (Graphics Language Transmission Format) and subsequently to b3dm (Batched 3D Model), theoretically enabling seamless visualisation in Cesium while preserving metadata. Secondly, while PostgreSQL integration remains conceptual, its proposed role in dynamic legal space management provides a scalable approach for future implementations. The platform allows continuous updates and advanced spatial querying capabilities.

Furthermore, the study discusses the potential of 3D visualisation tools such as CesiumJS and GIS platforms for validating BIM-derived legal spaces, which could improve strata ownership representation and legal boundary assessments. Lastly, the case study-based evaluation provides theoretical insights into the real-world applicability of BIM-LADM integration in Sarawak's cadastral system, identifying challenges, benefits, and directions for further research. By outlining this framework in a practical context, the study contributes to the ongoing development of digital land administration systems while acknowledging the need for future implementation and validation.

The remainder of this paper is structured as follows. Section 2 describes the strata management in Sarawak. Section 3 provides a comprehensive review of existing research on BIM-LADM integration by discussing past methodologies, identifying key challenges, and highlighting gaps in current implementations. This literature review forms the foundation for the proposed approach by identifying key areas where improvements are needed. Section 4 presents the proposed methodology, detailing the tools, data extraction process, and BIM/IFC-LADM mapping transformation workflow. This section outlines the step-by-step implementation of the workflow and the technologies involved. Section 5 discusses the case study validation and results, evaluating the effectiveness of the proposed framework in the strata title registration scenario in Sarawak. This section also highlights key findings and assesses the accuracy and efficiency of the integration process. Lastly, Section 6 concludes the findings.

2. Requirements of strata management in sarawak

Sarawak has shown a growing interest in BIM adoption, particularly in large-scale infrastructure and land administration projects. In collaboration with industry stakeholders, the state government has initiated pilot projects to explore integrating BIM and IFC standards. These efforts include using BIM for spatial planning, cadastral mapping, and property registration. Adopting IFC4 and higher LoD levels is a key enabler for aligning BIM data with LADM workflows, supporting the state's digital transformation goals (Philip 2024).

Compared to Peninsular Malaysia, there are significant differences between the Sarawak LADM country profile and the Malaysian LADM country profile. Despite different legal frameworks (Sarawak follows the Sarawak Land Code 1958 while Peninsular Malaysia follows the National Land Code 1965), native rights and titles are also quite different where Sarawak recognises Native Customary Rights (NCR) land under the governing law and granted to indigenous communities based on customary practices, with restrictions on transfer to non-natives. The Aboriginal Peoples Act 1954 recognises the lands of indigenous people in Peninsular Malaysia, known as the Orang Asli. Still, it does not grant them the same level of land rights as Sarawak's Native Customary Rights (NCR) system. Zamzuri et al. (2023) provide a detailed discussion of Sarawak's land profile. In terms of strata ownership, Sarawak enforces the Strata Management Ordinance (2019), while Peninsular Malaysia uses the Strata Titles Act 1985. Integration of strata ownership for the Sarawak LADM profile may require specific adaptations for NCR lands and local regulations.

2.1. Process of strata ownership registration in sarawak

Sarawak enforces the Strata Management Ordinance (2019) (Chapter 76) as a guideline to govern the management and maintenance of subdivided buildings and lands, outlining the responsibilities of developers, joint management bodies (JMB), and management corporations (MC). This guideline defines strata and legal space boundaries primarily through strata subdivision plans. In Sarawak, strata refer to the subdivision of buildings or land into multiple individually owned units within a multi-level development while incorporating shared common property. The boundaries of strata parcels are determined based on certification from land surveyors and architects, ensuring that the buildings or land parcels are capable of subdivision under the Strata (Subsidiary Titles) Ordinance, 2019. The subdivision plan must indicate parcels, common properties, and accessory parcels, specifying which are appurtenant. Developers must submit these details to the Commissioner, and once approved, the proposed share units assigned to each parcel serve as the basis for management and governance. Figure 1 illustrates the process of registering strata ownership.

2.2. Legal space boundaries in sarawak

In Sarawak, legal space boundaries are defined by a unit's inner walls, lower ceilings, and upper floors, as illustrated in Figure 2. The apartment owner owns only the internal volume (the airspace inside). Structural elements such as

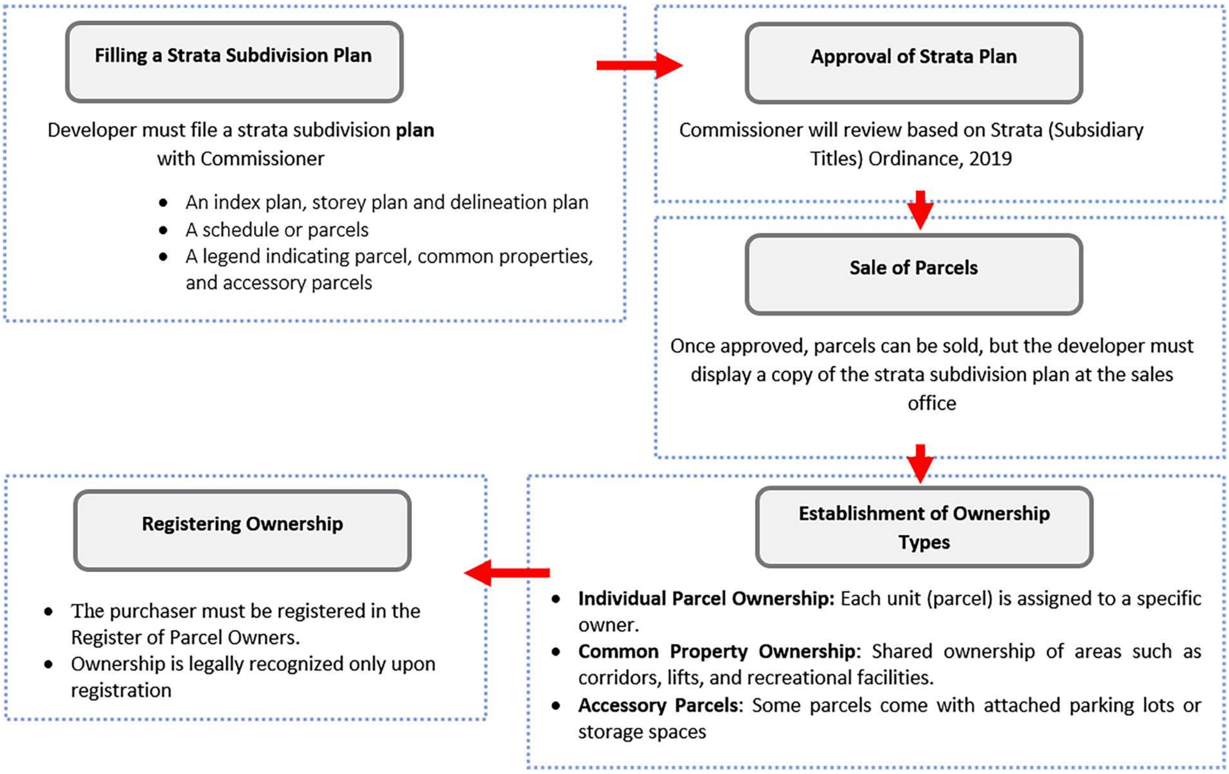

Figure 1. **Process of strata ownership registration in Sarawak.**

external walls, beams, columns, slabs, and roof structures are defined as common property, even if they enclose the unit. Depending on the regulations, shared walls between units may be classified as either split ownership or common property. Meanwhile, windows, doors, and balconies might be part of the private parcel or common property, depending on the strata plan (Strata Management Ordinance 2019).

Understanding legal space boundaries is crucial for representing strata ownership within a digital land administration system. These boundaries define ownership rights within multi-level developments and ensure that private and common properties are distinctly classified. In Sarawak, structural components such as inner walls, floors, and ceilings primarily define legal space boundaries. At the same time, regulations classify shared elements like external walls and columns as common property (Zamzuri et al. 2024). This distinction is essential for managing property rights (RRRs) in strata developments.

Identifying and mapping the relevant IFC elements is essential for effectively modelling these legal boundaries

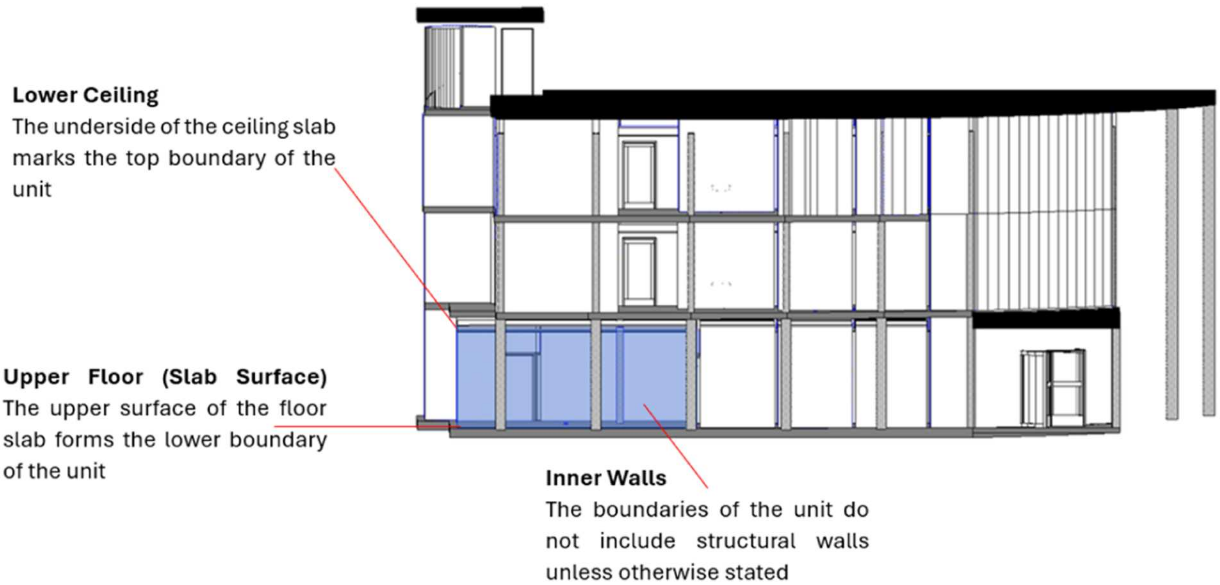

Figure 2. **Legal space boundaries based on the Strata Management Ordinance (2019) (source: Solibri open-sourced data).**

within the BIM–LADM framework. IFC provides a standardised schema representing building components, spatial divisions, and ownership relationships. By aligning IFC entities such as IfcSpace, IfcRelSpaceBoundary, and IfcBuildingElement with LADM classes, it is possible to capture legal ownership structures within a 3D environment digitally. The following section (Section 3) explores key IFC elements that support this integration, highlighting their roles in defining spatial and legal components of strata properties.

3. IFC elements discussed in the previous works

Table 1 presents various IFC elements discussed by previous works, highlighting their roles in strata ownership and legal space boundaries. These elements are essential for structuring, building, and ownership information to align with the LADM.

At the highest level, IfcSite represents the entire parcel or land lot. At the same time, IfcBuilding defines the

Table 1. IFC elements discussed in previous works.

IFC element(s)	Description(s)	Reference(s)
IfcSite	represents the entire parcel or land lot	Liu et al. (2024), Gkeli and Potsiou (2023), Andritsou *et al.* (2024), Gürsoy Sürmeneli *et al.* (2022), Guler *et al.* (2022), Broekhuizen (2021), Petronijević et al. (2021), Meulmeester (2019)
IfcBuilding	represents the overall building structure	Liu et al. (2024), Gkeli and Potsiou (2023), Andritsou *et al.* (2024), Gürsoy Sürmeneli *et al.* (2022), Guler *et al.* (2022), Broekhuizen (2021), Petronijević et al. (2021), Meulmeester (2019)
IfcBuildingStorey	represents individual floors within the building	Liu et al. (2024), Gkeli and Potsiou (2023), Andritsou *et al.* (2024), Gürsoy Sürmeneli *et al.* (2022), Guler *et al.* (2022), Broekhuizen (2021), Petronijević et al. (2021)
IfcZone	represents ownership units (e.g. private apartments, shared facilities)	Liu et al. (2024), Gkeli and Potsiou (2023), Andritsou *et al.* (2024), Gürsoy Sürmeneli *et al.* (2022), Guler *et al.* (2022), Broekhuizen (2021), Petronijević et al. (2021), Meulmeester (2019)
IfcSpace	represents individual rooms or spaces within ownership units	Liu et al. (2024), Gkeli and Potsiou (2023), Gürsoy Sürmeneli *et al.* (2022), Guler *et al.* (2022), Broekhuizen (2021), Petronijević et al. (2021), Meulmeester (2019)
IfcBuildingElement	represents physical elements such as walls, floors, roofs, doors, and windows	Liu et al. (2024)
IfcRelSpaceBoundary	defines ownership boundaries between different spaces	Liu et al. (2024), Gkeli and Potsiou (2023), Andritsou *et al.* (2024), Gürsoy Sürmeneli *et al.* (2022), Guler *et al.* (2022), Petronijević et al. (2021)
IfcRelationship	represents relationships such as: • BuildingApportionment (Shared spaces among all owners) • StoreyApportionment (Shared spaces among owners on the same floor) • PartialApportionment (Shared spaces between a subset of owners) • Subsidiary – Exclusive Relationship (Exclusive subsidiary area, e.g. balconies)	Liu et al. (2024)
IfcConnectionSurfaceGeometry	represents geometric boundary connections between different ownership units	Liu et al. (2024), Gkeli and Potsiou (2023), Guler *et al.* (2022), Broekhuizen (2021), Petronijević et al. (2021)
IfcRelAggregates	establishes hierarchical relationships among parcels, buildings, floors, and ownership units.	Guler *et al.* (2022), Broekhuizen (2021)
IfcOwnershipZone	captures ownership boundaries, rights, restrictions, and responsibilities (RRR)	Broekhuizen (2021)
IfcOwnershipSpace	represents legal spaces linked to Rights, Restrictions, and Responsibilities (RRR).	Gkeli and Potsiou (2023), Broekhuizen (2021)
IfcLegalSpaceBuildingUnit	represents legal spaces linked to property rights, restrictions, and responsibilities (RRR)	Andritsou *et al.* (2024)
IfcRelAssignsToGroup	establishes legal property relationships, linking spaces to ownership rights.	Gürsoy Sürmeneli *et al.* (2022)
IfcActor	represents property owners or stakeholders in a land administration system	Guler *et al.* (2022), Meulmeester (2019)
IfcBuildingPropertyUnit	introduces a new spatial class to define ownership units, such as apartments and common areas	Petronijević et al. (2021)
IfcPropertySet	stores legal attributes such as cadastral parcel numbers, apartment numbers, and space types (private/shared)	Meulmeester (2019)

overall structure of a building. Within the building, IfcBuildingStorey represents individual floors, and IfcZone captures ownership units such as private apartments or shared facilities. IfcSpace provides a more detailed representation by defining individual rooms or spaces within an ownership unit.

IfcBuildingElement includes walls, floors, roofs, doors, and windows to capture the physical structure. Meanwhile, IfcRelSpaceBoundary defines ownership boundaries between different spaces. These boundaries ensure that legal divisions within the building, such as strata parcels, are established. Additionally, IfcConnectionSurfaceGeometry represents geometric boundary connections between ownership units, further supporting accurate spatial representation. Ownership relationships are critical in strata management; several IFC elements address this aspect. IfcRelationship represents various property relationships, including shared and exclusive ownership. IfcRelAggregates establishes hierarchical relationships among parcels, buildings, floors, and ownership units, ensuring a structured representation of multi-level developments. Meanwhile, IfcOwnershipZone and IfcOwnershipSpace explicitly capture ownership boundaries, and RRRs provide a foundation for legal property management.

To integrate ownership rights into the model, IfcRelAssignsToGroup links spaces to ownership rights. IfcLegalSpaceBuildingUnit correctly assigns property rights and responsibilities to legal spaces. Additionally, IfcActor represents property owners or stakeholders in a land administration system, supporting governance and management processes. Further, IfcBuildingPropertyUnit introduces a spatial classification for ownership units, such as apartments and common areas. In contrast, IfcPropertySet stores legal attributes like cadastral parcel numbers, apartment numbers, and space types. Overall, these IFC elements provide a structured approach to integrating building and ownership information into LADM, supporting strata title management and legal space representation in the Sarawak context. This mapping ensures better data interoperability and enables a more efficient approach to digital land administration.

4. BIM/IFC to LADM mapping

4.1. Software and platforms

Google Colab was chosen as the primary computational environment for extracting IFC elements due to its cloud-based capabilities, allowing efficient processing of large BIM datasets without requiring high-end local hardware. It also supports Python-based IFC libraries such as ifcopenshell, enabling automated data extraction. Then, the relevant spatial and non-spatial attributes that define the boundaries, stories, geometric details, and ownership-related information, such as RRRs, will be identified. Meanwhile, Enterprise Architect was selected for schema mapping because it provides UML modelling and database design tools, making it suitable for aligning BIM-IFC elements with LADM classes in a structured and visual manner. The data model would establish the relationship between BIM and cadastral models, supporting interoperability. Finally, open-source data will test the framework. This combination ensures an efficient workflow for extracting spatial and non-spatial data, mapping them to legal attributes, and validating their integration within the LADM framework. The goal is to ensure data interoperability and consistency between BIM (IFC-based) and LADM, enabling its application in 3D land administration, including legal property management.

4.2. The mapping workflow

4.2.1. *IFC data extraction*

Figure 3 illustrates the python script (consists of eight (8) steps), designed to run in Google Colab, extracts IFC elements from an uploaded IFC model using the ifcopenshell library. The process begins by installing ifcopenshell and importing the necessary libraries. The script then prompts the user to upload an IFC file and dynamically retrieves the uploaded filename. Next, it loads the IFC model for further processing. The script includes a function to identify all unique IFC entity types in the model. Another function extracts elements dynamically, grouping them based on their IFC type and storing them in a dictionary. During extraction, it prints the number of elements found for each type (see Figure 4). Finally, the script summarises the extraction results, displaying the number of elements retrieved per type and indicating the completion of the process. This approach helps efficiently analyse and organise IFC data for further use, such as mapping to LADM.

4.2.2. *IFC-LADM mapping*

Following the extraction of IFC elements, the next step involves mapping these elements to the corresponding classes in the LADM. This process ensures that the extracted IFC elements, which include spatial and legal attributes, align with the structured framework of LADM. By leveraging predefined mappings, the system integrates IFC entities such as IfcSpaces, IfcBuildingElements, and ownership-related attributes into the relevant LADM classes. This mapping facilitates the representation of strata ownership, legal spaces, and RRRs within the LADM schema. The structured transformation of IFC data into LADM-compliant formats enables better interoperability between BIM and land administration systems, providing a standardised approach for managing property information. The following section details the methodology used to establish this mapping, ensuring that the extracted IFC elements correctly correspond to their respective LADM entities.

Figure 5 illustrates the transformation of an IFC building model into a structured representation suitable for LADM integration. The left side of the image depicts a multi-story building with its hierarchical breakdown into IfcSite, IfcBuilding, and IfcBuildingStorey elements. These elements define the overall structure and spatial organisation of the building. The right side of the image provides a more detailed representation of internal spatial elements. It represents the segmentation of IfcSpaces into individual parcels and common property. IFC elements such as IfcWalls, IfcDoors, IfcSlabs, and IfcRelSpaceBoundary highlight how building components define legal and functional spaces. This structured decomposition enables the accurate mapping of

```python
# Step 1: Install ifcopenshell
!pip install ifcopenshell

# Step 2: Import required libraries
import ifcopenshell
from google.colab import files

# Step 3: Upload IFC file from your local system
print("Building.ifc")
uploaded = files.upload()  # This allows user to upload an IFC file

# Get the uploaded file name dynamically
ifc_filename = list(uploaded.keys())[0]

# Step 4: Load the IFC model
ifc_model = ifcopenshell.open(ifc_filename)

# Step 5: Function to get all unique IFC element types
def get_all_ifc_types(ifc_model):
    """Retrieve all unique IFC entity types present in the model."""
    return set(entity.is_a() for entity in ifc_model.by_type("IfcProduct"))

# Step 6: Function to extract all elements dynamically
def extract_all_elements(ifc_model):
    """Extracts all elements from the IFC model grouped by their IFC type."""
    all_elements = {}  # Dictionary to store extracted elements
    ifc_types = get_all_ifc_types(ifc_model)

    for ifc_type in ifc_types:
        elements = ifc_model.by_type(ifc_type)
        if elements:
            all_elements[ifc_type] = elements
            print(f"Extracted {len(elements)} elements of type {ifc_type}.")

    return all_elements

# Step 7: Run the extraction process
ifc_elements = extract_all_elements(ifc_model)

# Step 8: Print extraction summary
print("\n=== Extraction Summary ===")
for ifc_type, elements in ifc_elements.items():
    print(f"{ifc_type}: {len(elements)} elements extracted.")

print("\nIFC Extraction Complete.")
```

Figure 3. Python script for extracting IFC elements in Google Colab.

IFC elements to LADM spatial units, supporting strata management by distinguishing private ownership areas from shared common spaces.

Meanwhile, Table 2 presents a structured mapping of relevant IFC elements and their associated attributes, facilitating the integration of IFC-based building models with LADM. Each IFC element, such as IfcBuilding, IfcBuildingStorey, IfcSpace, IfcWall, IfcDoor, IfcSlab, and IfcRelSpaceBoundary, is detailed with its key attributes, including Name, GlobalId, ObjectType, and geometric properties. These attributes provide essential information for defining spatial units, ownership boundaries, and property rights in the LADM framework. For instance, IfcSpace represents individual units or parcels, while IfcRelSpaceBoundary defines legal boundaries distinguishing private and common properties. IfcBuildingElements further enhances spatial representation by delineating structural elements contributing to legal and physical demarcations. The entities have been mapped to LADM classes, as shown in Figure 7.

Attributes such as TowerNo, SubTowerNo, SchemaNo, SubSchemaNo, MezzanineFloorNo, and OwnershipType are proposed to suit Sarawak's current strata administration. Figure 6 shows an example of information recorded for strata registration in Sarawak. TowerNo identifies the main building or tower in a strata development; SubTowerNo distinguishes different sections or wings within a single tower.; ParcelNo represents the unique identifier for each unit; FloorNo specifies the floor level of a parcel within the tower; SchemaNo represents the overall strata development, covering multiple towers or buildings; and SubSchemaNo identifies multiple phases, sections, or clusters of buildings within a single development. It helps differentiate between different blocks or phases within a larger strata project. These attributes structure multi-level ownership, ensuring

1	GlobalId	Name	Type	ObjectType	Tag
93	27bKPm$3TEQO3ND8Choa5L	Slab-02	IfcSlab		4148CA2B-1581-48D9-85-9F-32AF5850E4CD
94	1sNzeVQAT3yhBzHlce4NOn	Roof-03	IfcSlab		08106D4F-C8D4-4204-8B-AA-77681B53930E
95	2yJC4jUxv30PiLO7SZ2mSz	Slab-02	IfcSlab		4148CA2B-1581-48D9-85-9F-32AF5850E4CD
96	2Z$Vmt1q9DuBoUfuwizK33	Slab-03	IfcSlab		4148CA2B-1581-48D9-85-9F-32AF5850E4CD
97	02OVZomeDAUAIzVN5cIMPQ	Slab-03	IfcSlab		66EC56E4-8B82-4241-9F-30-E7AE20F32F0A
98	3CYGbpKDT5l9Wol3C8pIrP	Slab-7	IfcSlab		E7F44874-AA9E-4597-9A-CF-6635CCEEAE3A
99	3xtr5rin144wIVyfyAE$Yl	Slab-04	IfcSlab		4D474E79-5EB5-40D8-88-D0-3583123EA359
100	14DoX4J7j1GQo2sjMPem0r	Roof-01	IfcSlab		A7D0B687-B66E-4C11-92-D2-0B5132C24736
101	2Nv5yGyGD3KBz3s3UUmiry	Roof-02	IfcSlab		CEEC08D5-9075-4286-BC-DE-11EE126A6C61
102	0cnYh7HMPD3vwPoG73hck9	Stair-02	IfcStair		C4EF521A-CA5C-4FFB-BB40-AE16C69BE91B
103	29n2CJF3v7NeNLN8wcGGNR	Stair-01	IfcStair		D9F54547-DB9B-46CB-BEE4-CE584144ED58
104	1$jAZD6w11W9WKBa59k$mZ	Stair-01	IfcStair		D9F54547-DB9B-46CB-BEE4-CE584144ED58
105	0f$lhRWXH4Nwro0CoqjHDb	Stair-02	IfcStair		C4EF521A-CA5C-4FFB-BB40-AE16C69BE91B
106	2uovqky9b7RhykXhAqYXY$	Stair-01	IfcStair		D9F54547-DB9B-46CB-BEE4-CE584144ED58
107	1zmzPyE6L738WKMuJemilK	Wall-12	IfcWallStandardCase		25916B70-E8B4-489D-8A-ED-D921D0AD4E32
108	2kb8kLMDX1t8P_Avrc5P$M	Wall-21	IfcWallStandardCase		CEFB2294-6A57-4CBA-B7-88-D266E90A542B
109	2L5fTAdBX6CwMMuZ5gtWrY	Wall-22	IfcWallStandardCase		61747490-532F-4817-B7-5B-5362CE6A40A1
110	0BlHnp86557RaHTojk9cOe	Wall-23	IfcWallStandardCase		F372779D-85B5-4E9C-9F-C1-C86F82F5E4ED
111	3JHL58Z9v6qBglhrDZLXbr	Wall-20	IfcWallStandardCase		9E219219-EB8B-4070-8F-DE-2AD5C757B3BC
112	2Fe$zS4_X73BGbsFEKlE__	EW-3	IfcWallStandardCase		3719F359-BCB1-4F1B-9D-87-BC53FD82744F
113	3Q61UxJLb7Mus52SSVqjnJ	Wall-01	IfcWallStandardCase		23FA5C4F-39F1-4460-9B-BF-D9E73DE6F289
114	2p1VCkKP10nxvD2UPCoERN	Wall-02	IfcWallStandardCase		64FA9859-D454-4CF6-8D-60-6519785406A0
115	0wD5Ddw$T4Rw87w4N$Br8N	Wall-05	IfcWallStandardCase		A25D7B75-B2FC-4F5D-97-37-0D4278C29725

Figure 4. Part of the extracted IFC elements.

accurate strata properties representation in BIM/IFC and LADM.

Figure 7 represents the mapping of IFC elements to LADM classes, providing a structured integration of BIM-based building information with land administration concepts. The image effectively illustrates how spatial and legal aspects of a building model align with LADM spatial units and ownership structures. LADM components such as WS_Party, WS_RRR, and WS_BAUnit define key ownership and administrative relationships on the left side. These elements represent stakeholders (WS_Party), rights, restrictions, and responsibilities (WS_RRR), and basic administrative units (WS_BAUnit). IfcSite and IfcZone from IFC map to BAUnit, demonstrating that site-level elements are crucial in defining ownership structures. In the central section, the system maps the hierarchical organisation of IFC building elements to the spatial structures of LADM. WS_SpatialUnit and WS_LegalSpaceBuilding correspond to IfcBuilding, IfcBuildingStorey, and IfcSpace, demonstrating how spatial units in LADM structure around BIM elements. IfcSpace is particularly important, as it defines legal units within a building, mapping to WS_LegalSpaceBuilding for ownership delineation.

On the right side, detailed IfcBuildingElement components such as IfcWall, IfcSlab, IfcColumn, and IfcWindow contribute to defining spaces' physical and legal boundaries. IfcRelSpaceBoundary is a critical linkage element, ensuring that spatial divisions align with legal ownership boundaries in LADM. In Sarawak, specific boundary definitions govern strata ownership,

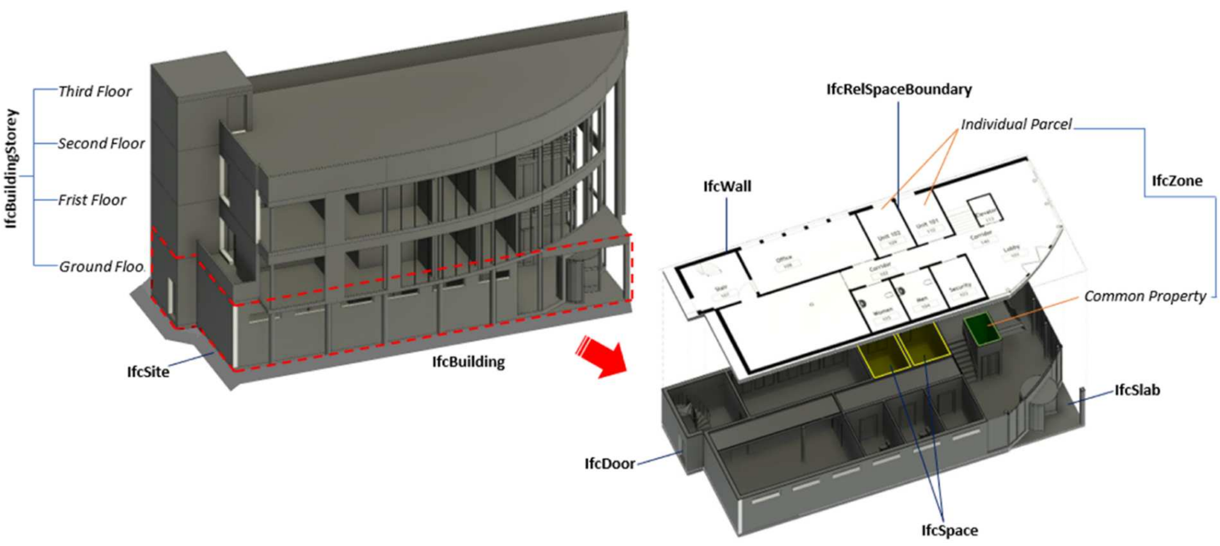

Figure 5. Mapping of IFC elements to LADM spatial units.

Table 2. The relevant IFC elements and their associated attributes.

Entity	Attributes
IfcSite	+GlobalID +Name +planNo +Description +RefLatitude +RefLongitude +RefElevation +SiteAddress.Region +SiteAddress.Country
IfcBuilding	+GlobalID +Name +Description +ifc_parent_id +ifc_unique_id
IfcPropertySet	+Name +SchemaNo +SubSchemaNo
IfcBuildingStorey	+GlobalID +Name +Elevation +TowerNo +SubTowerNo
IfcBuildingElement	+GlobalID +Name +Description +ifcType +ifc_parent_id +ifc_unique_id
IfcBuildingStoreyElevation	+GlobalID +Name +Description +MazanineFloorNo
IfcRelSpaceBoundary	+GlobalID +Name +Description +OwnershipType
IfcSpace	+GlobalID +Name +Description +ifc_parent_id +ifc_unique_id +Area +Level +Perimeter +Volume
IfcRelAssignsToGroup	+GlobalID +Name +Description +RelatedObjects
IfcZone	+GlobalID +Name +Description +Category

determining property rights and maintenance responsibilities. These boundaries categorise different structural elements as privately owned or common property, ensuring clarity in ownership and management. Table 3 represents the boundary types that regulate parcel ownership and shared responsibilities in strata developments.

This structured mapping ensures interoperability between IFC-based BIM models and LADM-compliant land administration systems, consistently representing legal space definitions, ownership rights, and physical boundaries. The diagram highlights the necessity of bridging spatial data from BIM with cadastral systems, supporting strata management by differentiating private, shared, and public spaces.

4.2.3. *Database integration (conceptual proposal for PostgreSQL)*

The design of a conceptual database schema facilitates the seamless integration of BIM and LADM within a PostgreSQL/PostGIS environment. This schema is structured to store key IFC elements (such as IfcSpace, IfcWall, and IfcSlab) alongside their mapped LADM counterparts (e.g. spatial units and legal space boundaries). The integration aims to preserve legal and spatial relationships while ensuring data interoperability for strata title management. By linking IFC elements to LADM classes, the database provides a structured representation of legal spaces, ownership rights, and shared property responsibilities. The PostgreSQL schema supports spatial queries, enabling advanced geo-spatial analysis for strata property management. This integration allows for efficient management of parcel ownership details, building components, and regulatory constraints within a unified database system. Although the system has not fully implemented this step, the proposed approach is expected to enhance cadastral workflows by automating data retrieval, validation, and spatial visualisation. Key challenges include ensuring consistency between BIM-generated data and cadastral standards, handling complex ownership structures, and optimising database performance for large-scale 3D spatial data. Future implementation will focus on refining data import frameworks, enforcing LADM-compliant constraints, and validating schema efficiency through real-world strata property datasets.

4.2.4. *Visualisation in Cesium (conceptual workflow)*

3D visualisation is crucial in strata title management by providing an intuitive and interactive representation of property boundaries, ownership spaces, and building structures. By integrating BIM-derived data with Cesium, stakeholders can explore the spatial extent of legal spaces, structural components, and shared properties in a dynamic virtual environment. This approach facilitates better decision-making for property transactions, legal disputes, and regulatory compliance. The proposed workflow for Cesium visualisation converts IFC-derived 3D models into a Cesium-based format, allowing efficient streaming and rendering on web-based platforms. The integration process includes:

- Extracting spatial and attribute data from the PostgreSQL database.
- Converting BIM geometries (IfcSpace, IfcBuildingElement) into a Cesium-compatible format (IFC – glTF – b3dm).
- Loading and visualising the 3D model in Cesium, with metadata linked to database records.
- Implementing interactive query functions to retrieve ownership and legal information from the database.

The proposed methodology for integrating BIM models into Cesium involves a structured conversion workflow that retains essential metadata. The process begins with IFC to glTF conversion, where the IFC model is transformed into the glTF to ensure lightweight, efficient rendering while preserving semantic attributes. The next step is converting glTF to b3dm,

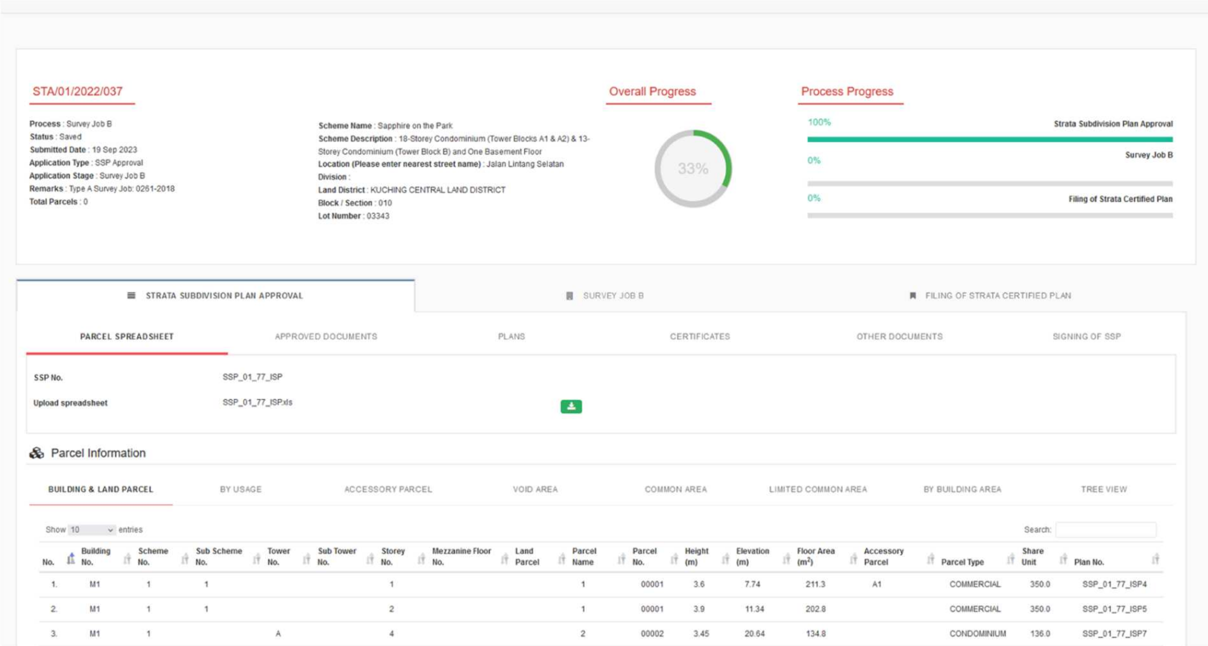

Figure 6. Example of information needed for Sarawak strata registration.

a format optimised for Cesium's 3D Tiles framework. This conversion embeds metadata, such as spatial attributes and ownership information, ensuring that interactive querying and visualisation capabilities are maintained. Unlike direct mesh-based conversions, this workflow ensures that the resulting 3D model retains both geometric accuracy and legal semantics, enabling users to visualise strata title boundaries, ownership details, and building elements within a Cesium-based web viewer as discussed by Meulmeester (2019), Broekhuzen (2021), Liu et al. (2024). By structuring the data in b3dm format, the visualisation supports LoD (Level of Detail) rendering, efficient streaming, and real-time interaction, making it a practical approach for strata title management applications.

This is an ongoing research work, therefore, data accessibility, strata properties visualisation, and interactive legal space queries will be developed as part of the research's outcome. Figure 8 shows the potential of the strata properties visualisation. Potential limitations including data conversion challenges, maintaining real-time updates between the database and Cesium, and optimising rendering performance for large-scale models also need to be discussed. Future research will enhance real-time synchronisation and integrate user-friendly interfaces for strata property analysis.

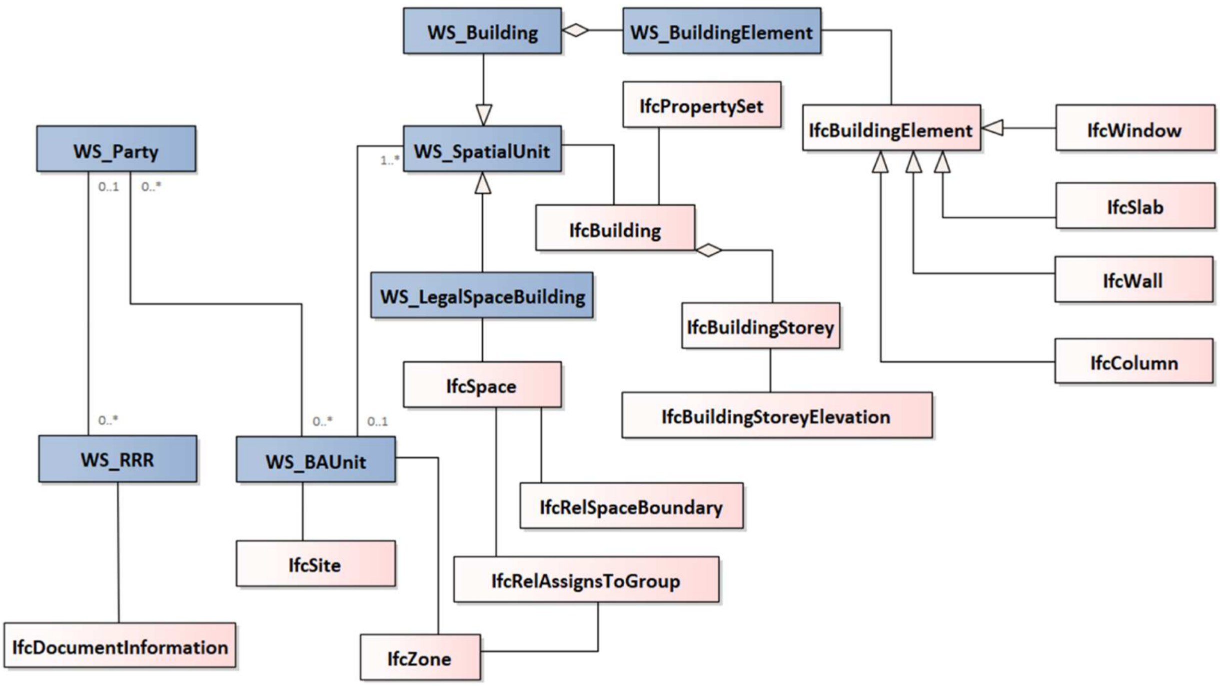

Figure 7. IFC elements mapped to LADM classes.

Table 3. Types of boundaries in defining legal ownership in Sarawak.

Type of boundary	Description
Median Boundaries (Party Walls)	When two parcels share a wall, both owners split the ownership and are responsible for maintaining their half of the wall. They must handle any disputes regarding repairs or modifications jointly
Interior Boundaries	Suppose the boundary is based on the inner face of the walls. In that case, the parcel owner owns up to the inner surface of the wall, while the wall structure remains a common property. This applies to most internal apartment walls
Exterior Boundaries	The system treats any load-bearing structural elements, such as walls, beams, and columns, as common property, even if they are within an individual unit, unless the strata title explicitly assigns them to the parcel
Structural Walls & Columns	Any load-bearing structural elements, including walls, beams, and columns, are common property, even within an individual unit, unless explicitly assigned to the parcel in the strata title
By-Laws & Agreements	By-laws of the Management Corporation (MC) or strata management agreements define specific ownership rules regulating how shared walls can be modified, repaired, or maintained

5. Discussion

Integrating BIM and GIS for strata title management necessitates an efficient data conversion and visualisation workflow. The proposed methodology involves converting IFC models to Cesium-compatible formats without losing critical metadata. This process follows a structured workflow: IFC to glTF to b3dm. Initially, the IFC format, which stores detailed semantic and geometric information about building elements (e.g. IfcSpace, IfcBuildingElement), is converted to glTF. This format ensures lightweight, efficient 3D model storage while preserving essential attributes. The system then transforms the glTF model into b3dm, a Cesium-compatible format optimised for large-scale 3D visualisation. This approach ensures seamless integration into Cesium while retaining metadata for strata ownership representation. By leveraging this conversion workflow, the proposed system facilitates real-time visualisation and interaction with strata units within a web-based 3D environment. Users can explore spatial and ownership details efficiently, improving urban planning and land administration decision-making. However, challenges such as data loss during conversion, model simplification trade-offs, and performance optimisation, especially for large datasets, may need to be addressed. Future work will focus on refining the conversion workflow, improving metadata retention, and integrating real-time database updates for enhanced usability in a 3D cadastral system.

6. Conclusion

This study presents a structured approach to integrating BIM/IFC and the Sarawak LADM country profile, facilitating strata ownerships and legal spaces boundary representation. The mapping workflow demonstrates how the IFC elements can be linked to LADM classes, considering land administration requirements in Sarawak. This study triggers better digital land management by incorporating PostgreSQL for data storage and CesiumJS for 3D visualisation. Challenges arise throughout the integration process, particularly in real-time database synchronisation and optimising spatial queries, especially for larger datasets. During the transformation from IFC to b3dm, the system might lose metadata due to differences in data schema and inconsistencies in attribute mapping. Since this is ongoing research, the future work inevitably focuses on integrating automated processes and establishing a database schema including 3D strata visualisation for the state strata properties. The findings would eventually offer a solution for digital strata properties management within BIM-LADM integration.

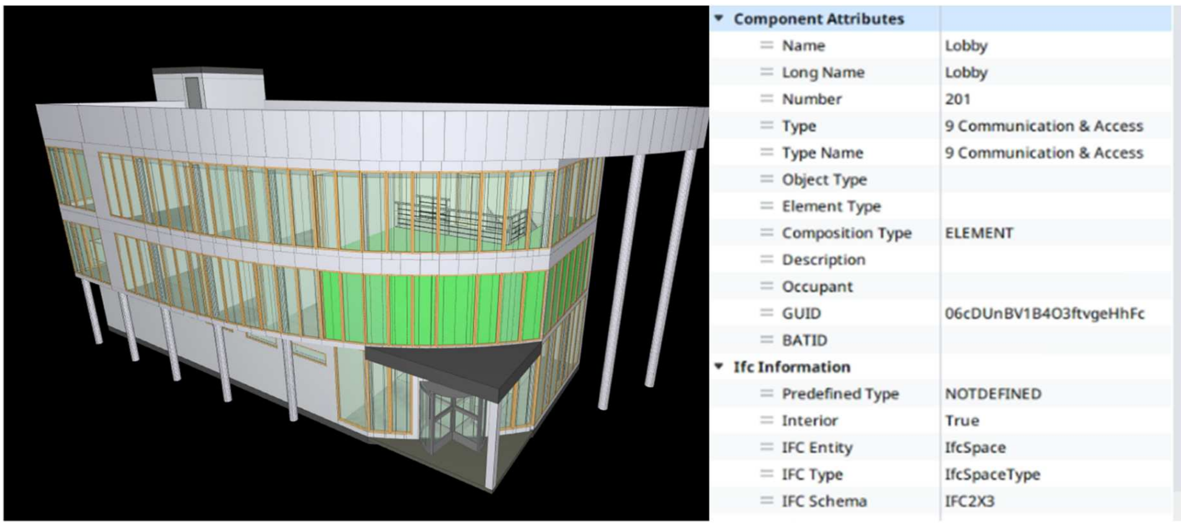

Figure 8. The queries will display the expected details.

Acknowledgement

The authors would like to thank the Research Management Centre (RMC) of Universiti Teknologi Malaysia (UTM) for the support and the Sarawak Premier Research Grant (R.J130000.7352.1R087) for the funding.

Funding

This work was supported by Sarawak Foundation [grant number R.J130000.7352.1R087].

Notes on contributors

Ainn Zamzuri is a PhD student at the Department of Geoinformation, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia (UTM), Skudai, Johor, Malaysia. She earned her degree in Geoinformatics from UTM in 2019 and completed her MSc in Geoinformatics in 2022. She is pursuing her PhD, focusing on the Malaysian LADM Country Profile with BIM and Valuation Information for 3D Strata Buildings.

Alias Abdul Rahman is a professor at the Department of Geoinformation, Faculty of Built Environment & Surveying, Universiti Teknologi Malaysia (UTM). He holds a bachelor's degree in surveying and Mapping Sciences from the University of East London, a Postgraduate Diploma and MSc in GIS from ITC, Netherlands, and a PhD from the University of Glasgow. He leads the 3D GIS research group at UTM.

Muhammad Imzan Hassan is a member of the 3D GIS group at the Faculty of Built Environment and Surveying, UTM. He has an MSc from ITC, Netherlands, a BSc in Geoinformatics from UTM, and a PhD from UTM. His expertise includes 3D cadastre, spatial data modelling, and spatial databases.

Peter van Oosterom is a Delft University of Technology professor and the GIS Technology group head. He holds an MSc in computer science from Delft University of Technology and a PhD from Leiden University. He has worked with TNO-FEL Laboratory and the Dutch Cadastre, focusing on cadastral database renewal.

ORCID

Ainn Zamzuri http://orcid.org/0009-0006-6743-6716
Alias Abdul Rahman http://orcid.org/0000-0001-5263-8266

References

Alattas, A., et al., 2021. Mapping private, common, and exclusive common spaces in buildings from BIM/IFC to LADM. A case study from Saudi Arabia. *Land use policy*, 104, 105355. doi:10.1016/j.landusepol.2021.105355.

Andritsou, D., Soile, S., and Potsiou, C., 2024. Merging BIM, land use and 2D cadastral maps into a digital twin fit—for—purpose geospatial infrastructure. *In*: T.H. Kolbe, A. Donaubauer, and C. Beil, eds. *Recent advances in 3D geoinformation science.* 3DGeoInfo 2023. Lecture Notes in Geoinformation and Cartography. Cham: Springer, 211–232.

Atazadeh, B., et al., 2021. Linking land administration domain model and BIM environment for 3D digital cadastre in multi-storey buildings. *Land use policy*, 104, 105367. doi:10.1016/j.landusepol.2021.105367.

Broekhuizen. 2021. *BIM/IFC- les as input for 3D Land Administration Systems.* Thesis (MSc). Delft University of Technology.

buildingSMART. 2020. Industry Foundation Classes (IFC) Specification. Available from: https://technical.buildingsmart.org/standards/ifc/.

Gkeli, M., and Potsiou, C., 2023. 3D crowdsourced parametric cadastral mapping: pathways integrating BIM/IFC, crowdsourced data and LADM. *Land use policy*, 131, 106713. doi:10.1016/j.landusepol.2023.106713.

Guler, D., van Oosterom, P., and Yomralioglu, T. 2022. How to exploit BIM/IFC for 3D registration of ownership rights in multi-storey buildings: an evidence from Turkey. Geocarto international, 37 (27), 18418–18447. doi:10.1080/10106049.2022.2142960.

Gürsoy Sürmeneli, H., Alkan, M., and Koeva, M. 2022. Towards investigation of integrating LADM, BIM, and CityGML of 3D condominium rights for cadastral purposes: the case of turkish cadastral system. *10th international FIG workshop on the land administration domain MODEL*, 31 March–2 April 2022, Dubrovnik, Croatia..

ISO, 2013. *ISO 19152: land administration domain model (LADM)*. Geneva: International Organization for Standardization.

Lemmen, C., van Oosterom, P., and Bennett, R., 2015. The land administration domain model. *Land use policy*, 49, 535–545.

Liu, C., et al., 2024. BIM/IFC-based 3D spatial model for condominium ownership: a case study of China. *Geo-spatial information science*, 27 (5), 1638–1656. doi:10.1080/10095020.2023.2246518.

Meulmeester. 2019. *BIM Legal Proposal for defining legal spaces for apartment rights in the Dutch cadastre using the IFC data model.* Thesis (MSc). Delft University of Technology.

Petronijević, M., et al., 2021. The extension of IFC for supporting 3D cadastre LADM geometry. *ISPRS international journal of Geo-information*, 10, 297. doi:10.3390/ijgi10050297.

Philip, Z. 2024. *Sarawak JKR to lead digital transformation with BIM system*. BERNAMA. Available from: https://www.bernama.com/en/news.php/news.php?id=2372376&utm_m

Strata Management Ordinance. 2019. Laws of Sarawak (Chapter 76).

Zamzuri, A., et al. 2023. 3D land administration system for Wilayah Sarawak based on LADM edition II– Preliminary works. *11th international FIG land administration domain model/3D land administration workshop*, 11–13 October 2023, Gävle, Sweden.

Zamzuri, A., et al. 2024. Incorporating legal space details of building from BIM/IFC to the LADM Sarawak country profile. *12th international FIG land administration domain model & 3D land administration workshop*, 24–26 September 2024, Kuching, Malaysia.