The Extraction of BIM/IFC Model for LADM Legal Spaces

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Abstract

Strata management in Malaysia faces persistent challenges due to delays in strata title issuance, fragmented data systems, and inefficiencies in legal space administration. Integrating Building Information Modelling (BIM) with the Land Administration Domain Model (LADM) offers a structured approach to addressing these issues. This study explores the extraction of Industry Foundation Classes (IFC) elements from BIM models to enhance the representation of legal spaces within the Malaysian LADM country profile. The research focuses on mapping key IFC elements such as IfcSpaces, IfcBuildingElements, and ownership attributes to LADM classes for strata title registration. Using Google Colab for data extraction and Enterprise Architect for schema mapping, the methodology ensures seamless integration between spatial and legal property data. The results demonstrate the potential of BIM-IFC in supporting 3D property rights visualisation and legal space definition, contributing to a more efficient, transparent, and data-driven approach to strata property management.

Keywords: Land Administration Domain Model (LADM), Building Information Modelling (BIM), Data Model, Legal Space, Ifc Element.

1. Introduction

1.1 The Motivation

Strata management plays a critical role in managing multi-unit developments such as condominiums, serviced apartments, and office buildings in Malaysia. Due to rapid urbanisation and increasing developments, effective management of these properties has become more complex and essential. Governed primarily by the Strata Titles Act 1985, amended by the Strata Titles (Amendment) Act 2013, and the Strata Management Act 2013, the legal framework aims to ensure proper ownership rights, governance, and maintenance of shared properties. Despite these regulatory advancements, Malaysian authority faces significant challenges, including delays in strata title issuance, fragmented data systems, and prolonged reliance on Joint Management Bodies (JMBs). In Selangor (one of the states in Malaysia) alone, over 138,000 lots are without strata titles (Lim, J. & Priya, S., 2024). The lack of simultaneous issuance of vacant possession with strata titles also contributes to these delays (Zainul, E., 2024). Recent technological advancements, such as Building Information Modelling (BIM), offer promising solutions by providing detailed 3D models that integrate spatial and legal data, enhancing transparency and decision-making (Atazadeh B. et al., 2021; Zamzuri A. et al., 2024). The Malaysian authority has introduced several incentives, including grants and tax exemptions, to encourage BIM adoption among stakeholders. Furthermore, Mustafa H. et al. (2023) agreed that transparency in property transactions can be enhanced by integrating BIM with other technologies, such as Geographic Information Systems (GIS).

Following technological advancements, the development of the Malaysian Land Administration Domain Model (LADM) country profile by Zulkifli A. et al. (2014) presents another significant approach to improving strata management in the country. The LADM framework provides a standardised data model for managing land administration (LA), which includes cadastral parcels, ownership rights, and property transactions. In the context of strata management, the country profile enhances data interoperability between agencies or stakeholders by ensuring a consistent representation of strata property rights, restrictions, and responsibilities (RRRs), Zulkifli et al., (2014). However, despite its potential, LADM alone does not fully address the need for real-time, spatially accurate building representations. The lack of integration between cadastral systems and building management platforms has resulted in inconsistent property records, difficulties in tracking ownership changes, and inefficiencies in regulatory compliance.

To address these gaps, BIM presents an advanced digital approach that enhances the efficiency, accuracy, and transparency of legal spaces and strata management. By integrating LADM with BIM, a comprehensive digital representation of strata properties can be achieved, incorporating detailed building components while linking cadastral data. This integration enables real-time updates, improves data consistency, and streamlines strata title issuance and property transactions. Several researchers worldwide (see Section 2) have proposed similar integrations for enhancing land, strata management and legal spaces.

Thus, this research aims to integrate BIM into the Malaysian LADM country profile to develop a comprehensive, data-driven framework for strata management and legal spaces. This fusion of BIM and LADM will bridge the gap between spatial and legal property information, enhancing data interoperability, reducing administrative inefficiencies, and improving decision-making for stakeholders, including government agencies, developers, and strata management bodies. This study aims to pave the way for a more resilient and sustainable property industry in Malaysia by fostering a more efficient, data-driven, and transparent strata management system. The remaining paper discusses related works around the globe in Section 2, the methodology in Section 3, the results and discussion in Section 4, and the conclusion in Section 5.

2. Related Works

Several countries have explored the integration of LADM and BIM/IFC to enhance their land and property management. In the Netherlands, efforts have been made to adopt BIM for LA, aiming to improve the representation of three-dimensional (3D) multi-floor building rights by linking BIM and LADM standards. The country has been involved in various smart city initiatives and digital construction projects that leverage BIM and LADM for efficient urban planning and land management (Oosterom, P., & Stoter, J. 2013). For instance, the Dutch Cadastre (Kadaster) has investigated integrating BIM data with cadastral systems, particularly emphasising enhancing the management of building information and land parcels (Stoter, J., et al., 2024). Recent studies (Broekhuizen et al. 2024; Mao, P. 2024) have demonstrated the potential of utilising BIM, particularly IFC models, as input for 3D Land Administration Systems (LAS) to register apartment rights. However, challenges persist, including the absence of essential attributes (e.g., IfcSpace) for identifying legal units within the Dutch 3D LAS. Recommendations and guidelines have been formulated to address these issues, aiming to improve the integration process and support the development of automated web services for validation, conversion, and visualisation of BIM data in LA contexts.

China is actively exploring the integration of BIM with LADM to enhance its LA and urban planning. However, challenges remain, such as a lack of government leadership and legal uncertainties (Zhou Y. et al., 2019). Despite these obstacles, some researchers have explored BIM-based 3D spatial models for condominium ownership, integrating LADM to support urban LA and 3D cadastral systems in China (Liu et al., 2023). The study addressed the limitations of traditional 2D cadastral systems, which often fail to define ownership boundaries clearly in high-density urban environments. By developing a 3D spatial ownership model using BIM-IFC and LADM, the research provided a more precise representation of property rights, restrictions, and responsibilities (RRRs). Through case studies of legal disputes, the model effectively clarified ownership demarcation, improved legal transparency, and assisted in property registration. However, challenges remain, particularly in standardising data integration, ensuring interoperability between BIM and GIS, and addressing the legal and institutional barriers to full-scale implementation. Despite these hurdles, the study highlights BIM-LADM integration as a promising approach for urban land management, offering a framework that could streamline property transactions, improve dispute resolution, and support China's transition towards a more efficient and transparent digital land administration system.

Meanwhile, in Australia, Atazadeh B. et al. (2017) have proposed extending the IFC standard within BIM to include legal information pertinent to land administration. This extension aims to facilitate a more integrated and efficient system for managing property rights in urban settings. Other studies have investigated the feasibility of BIM-driven approaches to support building subdivision workflows, aligning them with LADM to manage complex strata developments (e.g., mixed-use buildings, high-rise) and underground properties (Olfat et al. 2019). These studies explored how BIM can enhance property rights (RRRs) representation within multi-storey developments.

From the previous works, various countries have explored the integration of LADM and BIM/IFC to improve land and property management, focusing on 3D building rights, condominium ownership, and strata developments. These studies highlight the potential of BIM-LADM integration in addressing challenges in strata management, particularly in automating 3D property rights registration and legal space definition. Based on these approaches, this study proposes a structured methodology to extract, map, and validate BIM-IFC elements within the Malaysian LADM country profile, focusing on strata ownership structures and boundary delineation.

3. The Methodology

This study employs a structured methodology to extract and map BIM-IFC elements to the Malaysian LADM country profile, ensuring seamless integration between spatial and legal property data. The methodology consists of the following steps (see Figure 1).

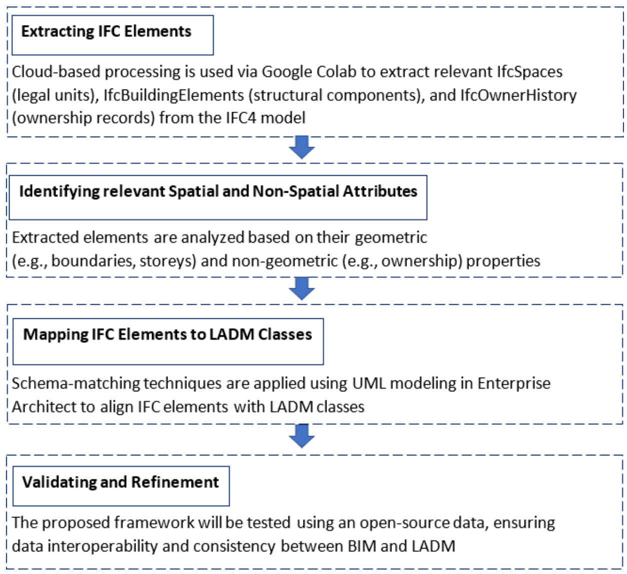

Figure 1. The Workflow

This methodology ensures that BIM-IFC data can be effectively structured and integrated into LADM, supporting automated strata title registration and transparent property management. 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, the framework will be tested using open-source data. 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. It enables it to be practised in 3D land administration, including legal property management.

4. Results & Discussion

An IFC4 model has been applied in this study to extract key elements relevant to strata management (see Figure 2). The focus is on retrieving IfcSpaces (individual units and common areas), IfcBuildingElements (walls, slabs), and IfcOwnerHistory (ownership records) to be mapped into LADM.

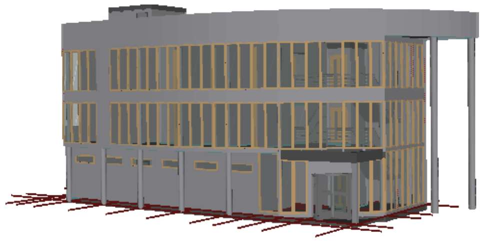

Figure 2. An example of the IFC model used in the study (open-source data)

4.1 Extraction Process

An IFC extraction script (see Figure 3) was developed to automate this process, allowing the identification of legal spaces, physical structures, and ownership records.

```
# Upload IFC file
ifcopenshell.open('Building.ifc')
ifc_model = ifcopenshell.open('Building.ifc')
```
#1

```
# Extract elements (e.g., walls, doors, and slabs)
def extract_elements(ifc_model, ifc_type):
    """
    Extract elements of a specific IFC type from the model.

    Args:
        ifc_model: The loaded IFC file model
        ifc_type: The type of element to extract (e.g., 'IfcWall', 'IfcDoor', etc.)

    Returns:
        A list of elements of the specified type.
    """
    elements = ifc_model.by_type(ifc_type)
    print(f"Found {len(elements)} elements of type {ifc_type}.")
    for element in elements[:5]:  # Print the first 5 elements for inspection
        print(f"GlobalId: {element.GlobalId}, Name: {element.Name}")
    return elements
```
#2

```
# Extract specific types of elements

walls = extract_elements(ifc_model, "IfcWall")
doors = extract_elements(ifc_model, "IfcDoor")
slabs = extract_elements(ifc_model, "IfcSlab")
space = extract_elements(ifc_model, "IfcSpace")

print("Extraction complete.")
```
#3

Figure 3. Scripts for extracting IFC elements

Codes in the **Box #1** use the ifcopenshell library to open and read the IFC file (building model as Figure 2). The first line specifically opens the IFC file where the file's name is building.ifc and *ifcopenshell.open()* function is used to load the contents of the building.ifc file into a variable named *ifc_model*. This variable now holds the entire IFC model, which can be used for further processing, such as extracting building elements like walls, spaces, doors, and more. Meanwhile, codes in the **Box #2** and **Box #3** extract the specific building elements, such as walls, doors or slabs. This function *(extract_elements(ifc_model, ifc_type))* analyses the elements within the model, where *ifc_model* is used for representing the loaded IFC file and *ifc_type* denotes the class of IFC elements to be retrieved (e.g., IfcWall, IfcDoor). Upon extraction, it retrieves all instances of the specified *ifc_type* using the *by_type* method and prints out the total number of elements found. For verification and inspection purposes, it further prints the GlobalId and Name of the first five extracted elements. This allows for a quick overview of the retrieved data and ensures correct element identification. Finally, the function returns the full list of elements, making it a reusable utility for downstream tasks such as data transformation, visualisation, or integration with other systems like GIS or database platforms.

Below (Figure 4) is the output from the script, which represents part of the IFC elements extracted from the model. The output shows the numbers of IFC elements as highlighted in the red boxes (e.g., IfcWall, IfcSpace) together with their Ids, which can be mapped with the LADM classes or attributes.

```
Found 114 elements of type IfcWall.
GlobalId: 1zmzPyE6L738WKMuJemiIK, Name: Wall-12
GlobalId: 2kb8kLMDX1t8P_Avrc5P$M, Name: Wall-21
GlobalId: 2L5fTAdBX6CwMMuZ5gtWrY, Name: Wall-22
GlobalId: 0BlHnp86557RaHTojk9cOe, Name: Wall-23
GlobalId: 3JHL58Z9v6qBgIhrDZLXbr, Name: Wall-20
Found 38 elements of type IfcDoor.
GlobalId: 1uarWbjTH0j8CevvmtN4dv, Name: Door-07
GlobalId: 0cksUmi1PBtgT$C0h7AGyD, Name: Door-06
GlobalId: 2kOc3itEL76RQkxZxJ6qJQ, Name: Door-11
GlobalId: 2Vq6Wz_0H15h$aF_4doFGE, Name: Door-05
GlobalId: 0pmGuDFKz2KfKk6vSWpAO9, Name: Door-09
Found 9 elements of type IfcSlab.
GlobalId: 27bKPm$3TEQO3ND8Choa5L, Name: Slab-02
GlobalId: 1sNzeVQAT3yhBzHlce4NOn, Name: Roof-03
GlobalId: 2yJC4jUxv30PiLO7SZ2mSz, Name: Slab-02
GlobalId: 2Z$Vmt1q9DuBoUfuwizK33, Name: Slab-03
GlobalId: 02OVZomeDAUAIzVN5cIMPQ, Name: Slab-03
Found 60 elements of type IfcSpace.
GlobalId: 2eoowy7qXE29kLLnOEez1s, Name: 111
GlobalId: 0ueshXLYz13R$3ztEQsFqB, Name: 125
GlobalId: 2gl5Ui5bDB1BOKQH5BlzNu, Name: 140
GlobalId: 0ibEaFXkXBIh5A1rvkv0wW, Name: 102
GlobalId: 2mzWIvgGf0GBbcVXrKIjC7, Name: 110
Extraction complete.
```

Figure 4. Some of the extracted IFC elements

4.2 Identification of relevant spatial and non-spatial attributes

The extraction process of IFC elements enables for identification of spatial and non-spatial attributes. Then, the extracted elements can be used for mapping (BIM-LADM). Below are some of the IFC elements with their connectivity to LADM.

- Physical or geometric elements (spatial units in LADM)
  i. *IfcBuilding* – maps to LADM's LA_Building
  ii. *IfcSpace* – represents rooms or areas that can be mapped to LA_SpatialUnit
  iii. *IfcSite* – corresponds to LA_BAUnit or MY_LandParcel
  iv. *IfcBuildingStorey* – represents spatial divisions, useful for legal subdivisions of floor
  v. *IfcWall, IfcDoor, IfcWindow, IfcSlab* – structural boundaries for ownership or access rights

- Non-geometric elements (attributes)
  i. *IfcPropertySet* – represents additional information on ownerships (e.g., owner, lessee); the purpose of space (e.g., residential, commercial); valuation (e.g., costs, market value) that can be aligned with VM_ValuationUnit.

ii. *IfcDocumentReference* – legal documents tied to a building or land parcel (e.g., deeds, titles, permits)

The extraction of IFC elements facilitates the identification of both spatial and non-spatial attributes essential for BIM-LADM integration. By mapping these elements to corresponding LADM classes, a structured representation of legal and cadastral information can be established. Spatial units such as IfcBuilding, IfcSpace, and IfcSite correspond to key LADM entities, ensuring accurate delineation of property boundaries and legal ownership. Additionally, structural components like IfcWall, IfcDoor, and IfcSlab provide critical insights into access rights and ownership demarcation. Beyond geometric data, non-spatial attributes such as IfcPropertySet and IfcDocumentReference contribute to enriching cadastral records with ownership details, valuation data, and legal documentation. This comprehensive integration ensures that BIM-based models effectively support 3D cadastre and land administration processes. The next step involves systematically mapping these extracted IFC elements to LADM classes, establishing a seamless connection between BIM and the land administration model.

4.3 Mapping IFC Elements to LADM

The integration of BIM with LADM requires a structured approach to mapping legal and physical spaces. This section focuses on defining the relationships between BIM/IFC entities and LADM classes, ensuring that spatial and legal representations are accurately reflected in land administration processes. By leveraging UML diagrams, this section illustrates how different IFC elements, such as IfcSpace and IfcBuildingElement, correspond to LADM entities, facilitating seamless data exchange and interoperability. This structured mapping provides a foundation for managing strata ownership, rights, and responsibilities in compliance with the Malaysian country profile.

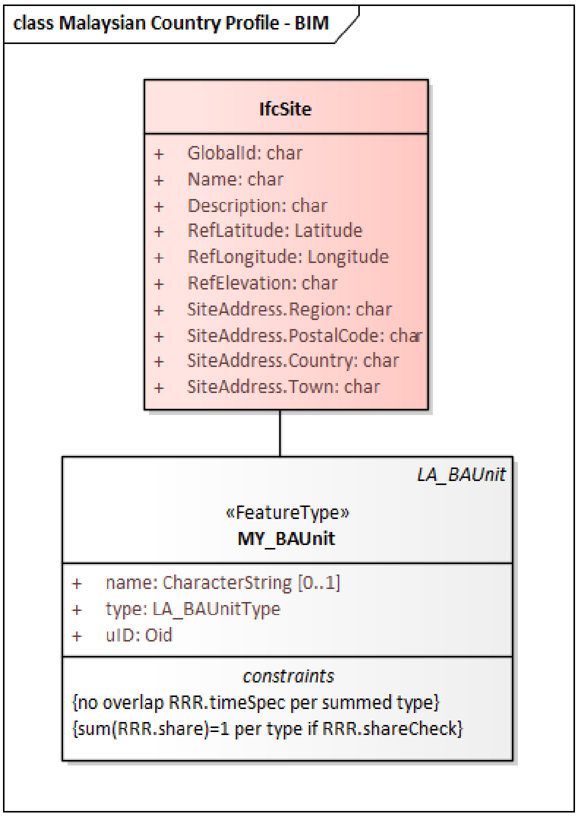

Figure 5. The connection between IfcSite and MY_BAUnit

Figure 5 represents the connection between IfcSite and MY_BAUnit. The IfcSite class (IFC element), represents a physical site with attributes such as GlobalId, Name, Description, and geographic location details (RefLatitude, RefLongitude, RefElevation). This class is linked to MY_BAUnit, a class in LADM that represents a basic administrative unit (BAUnit) for land tenure, ownership, or rights. The integration aims to connect spatial information from BIM with legal land administration, ensuring a structured representation of property ownership. The constraints applied to MY_BAUnit, such as no overlap in RRRs at the same time, highlight compliance with LADM ownership principles. By linking IfcSite to MY_BAUnit, the model enables interoperability between BIM-based spatial data and cadastral land administration systems, facilitating seamless data exchange in strata and land tenure management.

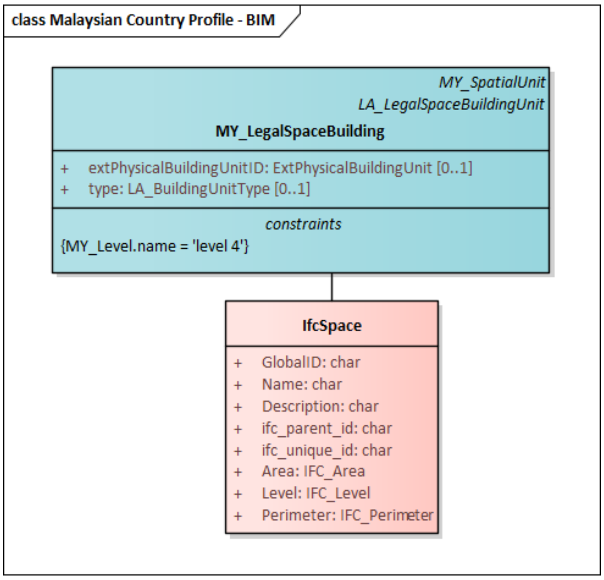

Figure 6. The connection between IfcSpace and MY_LegalSpaceBuiilding

Figure 6 shows how IfcSpace is mapped to MY_LegalSpaceBuilding, which is a subclass of MY_SpatialUnit from LADM. This class represents a legal space unit within a building (e.g., strata-titled property) which extPhysicalBuildingUnitID links to an external physical building unit such as IfcBuilding or IfcBuildingStorey (from IFC). This mapping ensures that legal ownership boundaries align with actual building geometry. This diagram is a crucial step in integrating BIM (IFC) data with LADM for strata title management. It allows accurate legal space extraction from BIM models, ensuring compliance with cadastral and land administration requirements.

Meanwhile, Figure 7 focuses on both legal spaces (MY_Building) and physical building elements (MY_BuildingElement). The MY_Building class, derived from LA_LegalSpaceBuildingUnit, contains attributes such as building ID, type, parcelRef, and floor information, ensuring a legal representation of built structures. It is linked to MY_BuildingElement, which represents individual building components like walls, columns, slabs, and windows, each mapped to its corresponding IFC entity (IfcWall, IfcColumn, IfcSlab, IfcWindow). These IFC elements store essential attributes such as GlobalID, Name, Description, Ifc_parent_id, and Ifc_unique_id, ensuring a structured relationship between physical BIM components and legal land administration objects. This model enables seamless integration of 3D building data with cadastral and legal records, facilitating better strata management and 3D cadastral workflows.

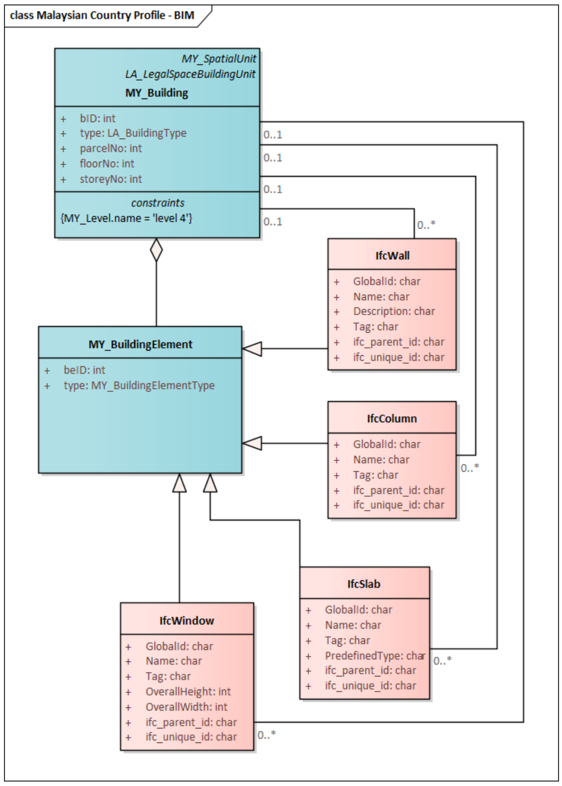

Figure 7. The connection between IfcWall, IfcColumn, IfcSlab, and IfcWindow with MY_Building and MY_BuildingElement

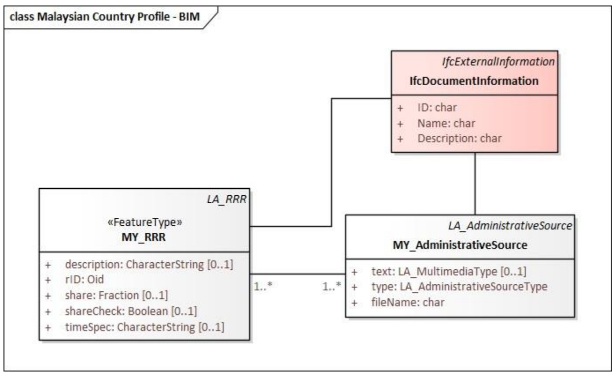

Figure 8. The connection between IfcDocumentInformation with MY_RRR and MY_AdministrativeSource

Next, Figure 8 represents the integration of rights, restrictions, and responsibilities (RRR) and administrative sources with BIM (IFC) and LADM in the Malaysian Country Profile. The MY_RRR class, based on LA_RRR, defines legal interests related to property and includes attributes such as description, RRR code, share fraction, shareCheck (a boolean for validation), and timeSpec (temporal specification). It is linked to MY_AdministrativeSource, which represents legal and administrative records, including multimedia documents, source types, and filenames, ensuring structured documentation of legal ownership. Additionally, IfcDocumentInformation is associated with these records, containing details such as ID, Name, and Description, providing a bridge between IFC-based documentation and cadastral legal sources. This model enables accurate management of property rights and associated legal documents within a BIM-integrated cadastral system, facilitating a comprehensive and verifiable 3D land administration framework.

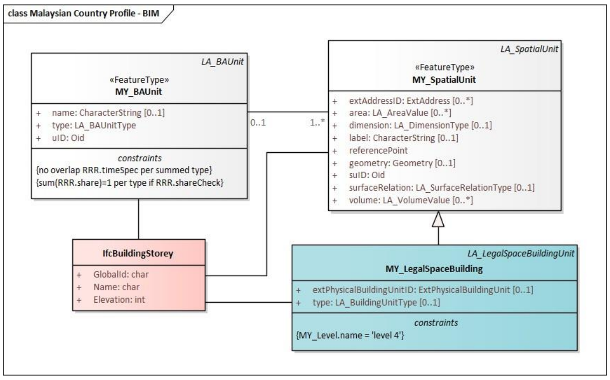

Figure 9. The connection between IfcBuildingStorey with MY_BAUnit, MY_SpatialUnit and MY_LegalSpaceBuilding

Meanwhile, Figure 9 represents the integration of spatial units, legal spaces, and building structures. The MY_SpatialUnit class, derived from LA_SpatialUnit, defines cadastral space attributes such as extAddressID, area, dimension, volume, and surface realization types, ensuring compliance with LADM spatial representation. It is linked to MY_LegalSpaceBuilding, which represents legal building spaces with attributes like external physical building unit ID and building unit type, constrained by floor level (e.g., level 4). The MY_BAUnit class, based on LA_BAUnit, represents basic administrative units, holding ownership or usage rights and ensuring that RRR (Rights, Restrictions, and Responsibilities) are validated through share checks. Additionally, IfcBuildingStorey is associated with this model, incorporating GlobalID, Name, and Elevation to provide BIM-specific building story details.

This mapping represents the relationships between key BIM/IFC elements and LADM classes, emphasising the hierarchical structure of spatial units and legal spaces. The diagram illustrates how IfcSpace is associated with LADM's spatial unit class, establishing the connection between physical and legal boundaries. Additionally, IfcBuildingElements, such as walls and floors, are linked to boundary definitions within the LADM model, ensuring that legal extents correspond to the architectural design. This representation clarifies the integration process by highlighting attribute mappings and relationships necessary for effective land administration, ensuring that legal rights and restrictions are maintained throughout the lifecycle of a building or development project.

4.4 Validating and Refinement

Following the extraction and mapping of IFC elements to LADM classes, the process must undergo several checks to verify spatial coherence and semantic accuracy. This step ensures that legal space boundaries are not only geometrically valid but also compliant with land administration requirements, particularly for strata properties in the Malaysian context. The process involves validating the reliability of extracted IFC elements using their geometric and non-geometric attributes. Parameters such as IfcSpace's volume, perimeter and floor levels are cross-checked against the LADM's My_LegalSpaceBuilding attributes to ensure spatial units accurately represent their corresponding legal ownership boundaries. On the other hand, physical components such as IfcWall, IfcSlab, and IfcDoor are assessed to confirm their contribution to delineating private parcels versus common property. These checks help to avoid redundancy, misalignments, or boundary overlaps that may compromise the legal interpretation of space.

In parallel, the validation of non-spatial attributes focuses on ownership records and administrative data. IFC elements like IfcPropertySet and IfcDocumentReference are examined to ensure they are correctly linked with LADM components such as MY_RRR and MY_AdministrativeSource. This ensures that metadata, including share values, temporal rights, and ownership documents, is logically consistent and legally verifiable. Attribute checks also include verifying the presence of essential identifiers (e.g., GlobalId, parcel number, schemaNo) and ensuring they are not duplicated or incorrectly referenced across entities.

Additionally, visual validation plays a crucial role in this framework. By linking the extracted BIM model with 3D visualisation tools (e.g., CesiumJS), users can assess the accuracy of spatial boundaries and ownership zones in an intuitive environment. The spatial relationships between units, such as adjacency, enclosure, and elevation, can be visually inspected to confirm they align with legal definitions and strata plans. This step is particularly valuable for identifying modelling errors that are not easily detectable through database or code-level checks alone. Refinement and validation also address model interoperability by ensuring that the IFC data exported from design software (e.g., Revit) is in the correct IFC4 schema. Earlier versions, such as IFC2x3, may lack critical attributes needed for full LADM integration. Thus, IFC models must be exported in a unified and complete format, combining architectural and structural components. This is typically achieved using IfcOpenShell to merge separate files into a single, coherent model for downstream processing.

These processes ensure that BIM-derived legal spaces meet both technical and regulatory standards. It establishes a foundation for accurate registration of 3D strata units, reliable legal documentation, and seamless interoperability between BIM and land administration systems. Future implementation will enhance this process by incorporating automated rule-checking, dynamic data correction, and integration with spatial databases like PostgreSQL for real-time validation and query support.

4.5 Issues and Challenges

Throughout this study, several challenges arise where one of the key challenges in the BIM-to-LADM integration process is ensuring that the model is in IFC4 format. The raw data is initially in IFC2x3, which lacks certain attributes and capabilities required for seamless transformation and interoperability. Hence, the IFC model must be exported as IFC4 from Revit, ensuring both structural and architectural components are included. However, since Revit exports these components as separate files, they can be combined using IfcOpenShell, allowing for a unified representation of the building model before further processing.

Another issue arises during the transformation from FME to 3D Tiles, where errors occur due to projection mismatches. The original data is stored in local coordinates, which are incompatible with Cesium's global coordinate system. Thus, it is necessary to verify and reproject the coordinate system into a world-based reference system, ensuring that the model is accurately positioned for web visualisation. Without this step, the model may appear in the wrong location or fail to load properly in CesiumJS.

Additionally, it is crucial to check metadata related to unit measurements (meters or feet). Since different datasets may use varying local Cartesian systems, proper identification and standardisation of units must be performed. This ensures consistency in spatial calculations and visualisation, preventing scaling errors or misalignment when integrating with other geospatial data sources. Addressing these challenges systematically will enhance the accuracy, interoperability, and usability of the BIM-to-LADM workflow within a 3D cadastral and web-based environment.

5. Conclusion

In general, by integrating BIM-IFC with the Malaysian LADM country profile, this study enhances strata property management through automated data processing, legal space visualisation, and improved interoperability between cadastral and building models. However, key challenges such as standardising BIM-LADM data structures, ensuring legal compliance, and improving integration with existing land administration systems need to be addressed. Future work will focus on validating the framework through real-world strata developments, ensuring its practical implementation for Malaysia's digital land administration transformation.

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