Incorporating Legal Space Details of Building from BIM/IFC to the LADM Sarawak Country Profile

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Key words: LADM Sarawak Country Profile, LADM Edition II, BIM/IFC, Legal Space

SUMMARY

This paper expands the Land Administration Domain Model (LADM) Sarawak Country Profile by incorporating legal space details from Building Information Modelling (BIM). Sarawak, located on Borneo Island, practices a distinct land administration system compared to Peninsular Malaysia. While Peninsular Malaysia follows the National Land Code of 1965, Sarawak adheres to the Sarawak Land Code 1958, which includes provisions for indigenous customary land rights. The Malaysia country profile has been developed based on the LADM standard, considering the 3D situation. Since both regions (Peninsular Malaysia and Sarawak) are under different legal frameworks, this study attempts to further develop the Sarawak country profile based on its current land administration system, including adopting some classes and attributes from the existing Malaysia country profile. The study investigates the potential of incorporating legal space details from the BIM/Industry Foundation Class (IFC) model into the Sarawak country profile. The conceptual model details the fundamental LADM components (Party, Administrative, and Spatial Unit), along with details on the legal space sourced from BIM/IFC. This mapping process requires BIM/IFC data to contain sufficient information for distinguishing property spaces and their boundaries.

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1. INTRODUCTION

Digitalizing the built environment represents one of the most profound transformations in industry and profession, especially in rapidly developing countries. At the forefront of this transformation is Building Information Modelling (BIM), which has emerged as a primary contributor to spatial development. Over the past decade, many country profiles have been developed based on the Land Administration Domain Model (LADM) Edition I to represent the legal aspects of land administration, covering land tenure (Kalogianni, 2021). While LADM provides a robust framework for legal entities (e.g., parcels, rights, and restrictions), it lacks detailed semantic components related to buildings. BIM, on the other hand, excels in capturing rich 3D data about building elements and materials (Zamzuri et al., 2024). Several studies (Mao, P., 2024; Guler et al., 2022; Broekhuizen, 2021) have discussed the implementation of BIM in land administration, highlighting its potential to contribute valuable semantic information. Therefore, integrating BIM's detailed building information with LADM's legal framework can significantly enhance the precision and utility of land administration. Incorporating legal space details, particularly in buildings, is crucial to ensuring that all descriptions of spaces (e.g., property boundaries, ownership rights, and restrictions) are well-defined. This integration ensures land records accurately reflect the physical reality of buildings and their legal status, which is essential for sustainable development and planning (Alattas et al., 2021). Clear and precise legal details are vital in preventing conflicts related to property boundaries and rights. Furthermore, aligning legal space details with physical building models, such as those provided by BIM, supports digital transformation. It enables the creation of integrated digital records that can be used for various purposes, including land management.

Sarawak possesses a unique land administration system, where all land-related activities and registrations are managed by a single agency, namely the Department of Land and Survey Sarawak. This department serves as the leading entity in managing land surveys, land registration, valuation, and spatial planning, with all related branches (Land, Survey, Valuation, and Planning) located under one 'roof' (Zamzuri et al., 2023). Sarawak has a well-established and unified land administration and registration system based on Torren's principle. The system ensures a secure and efficient method of recording land ownership and transactions, providing legal certainty by maintaining a register of land titles (Osman & Kueh, 2010). Within this system, cadastral information such as parcel boundaries, spatial features and land rights are meticulously recorded. Sarawak features a variety of land tenure systems, including strata titles for multi-story buildings. These titles, encompassing both individual and shared ownership of common areas, require a clear approach to legal space delineation. Integrating BIM/IFC data with the LADM Sarawak Country Profile ensures that the legal complexities of strata titles, such as boundaries of individual units and common properties,

are accurately represented. Now, Sarawak is embracing digital transformation in its governance and development strategies. Integrating BIM/IFC data with the LADM Sarawak Country Profile aligns with these initiatives, creating a robust digital infrastructure for land administration. This technological integration facilitates data sharing, improves decision-making processes, and supports smart city development. Therefore, this paper develops a unified model that integrates both legal information from LADM with BIM's spatial and semantic information. BIM data has been explored, and several details of legal space (e.g., spaces in particular units, common units, private units, determination of boundaries for each unit) are linked to the suitable classes in LADM. Throughout the process, bridging the gap between the legal context (LADM) and spatial representation (BIM) within buildings required careful alignment, considering the challenges encountered during the integration process – most cases outlined that BIM data are not fully ready for the modelling task.
The paper is structured as follows: Section 2 covers the integration of LADM and BIM/IFC, including details on strata management in Sarawak. Section 3 outlines the methodology, starting with the identification of legal spaces and types of rights (restrictions, responsibilities), followed by the implementation and development of a conceptual model that integrates LADM and legal space details. Finally, Section 4 discusses the results and issues encountered during the integration process.

2. BIM/IFC AND LADM

There are several works of literature related to BIM and LADM. For example, Atazadeh et al. (2017) examined methods for storing legal property within an IFC model and developed a prototype model for a 3D LAS with input from the model. Moreover, Oldfield et al. (2018) investigated the BIM as input for 3D LAS. They proposed using IfcSpace to represent legal spaces and IfcZone to group these spaces into legal zones. Furthermore, Olfat et al. (2019) investigated the integration of BIM into the workflow of sharing, documenting, visualizing, analyzing, interpreting, and reusing 3D LA data throughout a building's life cycle. Also, Meulmeester (2019) enriched an IFC model with legal data allowing integration in LA (e.g., unit Id). He investigated the requirements for IFC models to be defined as legal spaces within the Dutch LAS. Sun et al. (2019) proposed a framework for integrating BIM with land information, where both the IFC and CityGML models were stored in an LADM database. Moreover, Atazadeh et al. (2021) used the IFC schema to model features and attributes in LADM. Furthermore, Alattas et al. (2021) developed an approach that integrates IFC and LADM to represent the legal spaces of properties in Saudi Arabia. Barzegar et al. (2020) proposed a schema for a 3D LAS in which 3D spatial queries can be performed. Further, Guler et al. (2022) suggested a conceptual framework for Turkey that integrates digital building permitting and 3D representation of condominium rights using BIMs. Broekhuizen (2021) evaluated BIM/IFC models in terms of IfcSpace existence, geometric validity, overlap, and the ability to georeference, identifying several technical issues that still need to be addressed. Finally, Mao, P. (2024) investigated novel 3D LA visualization techniques including rights, restrictions, and responsibilities (RRRs). The RRRs visualization for instance, information of the particular apartment unit is shown in detail via representation of relationship between the related to the properties and ownership (e.g., LA_Party, LA_BAUnit, LA_SpatialUnit).

Previous research shows that there are some integration challenges between BIM and LADM. Existing studies have explored various aspects, including legal-spatial fusion, semantic alignment, and interoperability. However, challenges persist in seamlessly linking the legal context (LADM) with detailed spatial information (BIM). Researchers have proposed several solutions, such as using IfcSpace for legal spaces, enriching IFC models with legal data, and integrating BIM into land administration workflows. The synergy between LADM and BIM aims to create context-aware building models that benefit land professionals, urban planners, and policymakers.

BIM/IFC files contain much information, including 3D geometries of indoor spaces, constructions, and building infrastructure. However, no explicit information defines individual units (property units). Therefore, the IFC is enriched with legal space (from LADM) to fully automatically extract the 3D spaces that belong to one unit. Some main benefits are that open data formats enable different software vendors to cooperate better and increase efficiency by eliminating interoperability problems when files are exchanged. However, the concept of registering rights using the IFC format as a source for legal space is still missing. Second often occurring problem is missing geo-referencing in national Coordinate Reference System (CRS). Hence, this study aims to enrich the IFC data model with legal information and to extract 3D legal spaces from existing IFC BIMs for the registration of strata buildings.

2.1 Strata Management in Sarawak

Transactions or applications for strata titles in Sarawak are mostly in 2D representation. Although there have been attempts to address this in 3D, these efforts fall short of providing a comprehensive 3D solution. As mentioned by Meulmesteer (2019), BIM is the main source of 3D information, but the application of BIM and these types of IFC files are not freely available. Current BIM implementation in Sarawak is hardly available due to a lack of BIM knowledge and awareness. The readiness for BIM adoption is still low due to the absence of supportive policies, inadequate training for staff, and insufficient investment in software and hardware (Lee et al., 2022). Thus, our research aims to raise this awareness among the related parties.

An integrated e-submission system for Strata Titles Application and Strata Titles Survey has been developed by the department, requiring the standardization of digital submission mediums. The Strata Titles Plans can be submitted in .dxf (Drawing eXchange Format), .pdf (Portable Document Format), and .xls (digital spreadsheet) formats. The Certified Strata Plans (CP) shall have the prefix CP, as a filename followed by the Division number, allotted serial number, and suffix ISP with a running number (e.g., CP_01_132_ISP2). Strata Subdivision Plans (SSP) follow a similar naming standard but with a different prefix, SSP (e.g., SSP_01_132_ISP3). The boundaries of each proposed parcel within the floor shall be defined by reference to walls (centre/external of wall/permanent features), and the total area shall be calculated from the defined boundaries specified in the SSP. The Survey Strata Title System (SSTS) is being implemented to facilitate and pre-check the approval of strata subdivision plans, operating from the initiation of the submission to the endorsement of the subdivision plan. The system has the following aspects: submission of SSP, checking of SSP, verification of SSP, submission of Limited Common Property Plans (LCP), checking of LCP, verification of LCP, viewing of full computation reports, viewing maps in 2D/3D, and CadViewer, including pre-check and fieldbook entry. There are nine categories of personnel that are able

to access the system, namely, private surveyor, survey technical assistant (TA), staff surveyor, planning branch TA, planning officer, land TA, land officer, superintendent, and registrar.
The issuance of strata titles legally defines the boundaries of individual units (parcels) and common property. These titles are registered with the land office, providing legal recognition and protection of ownership rights. The management corporation is responsible for the administration, management, and maintenance of common property, operating in accordance with the guidelines established in the Strata Management Ordinance, 2019. All parcel owners share the responsibility for maintaining common property (relation to a sub-divided building or land). This includes contributing to maintenance fees and participating in decision-making processes through the management corporation. While parcel owners have the right to use the common property, they must comply with the rules and regulations set by the management corporation to ensure the proper upkeep and harmonious use of shared facilities.

3. METHODOLOGY

Figure 1 illustrates the methodology for implementing legal space details from BIM/IFC into the LADM Sarawak Country Profile. The flowchart indicates a process where the legal spaces and types of ownership involved are identified, followed by the development of the Sarawak country profile and the implementation of extracted legal space details.

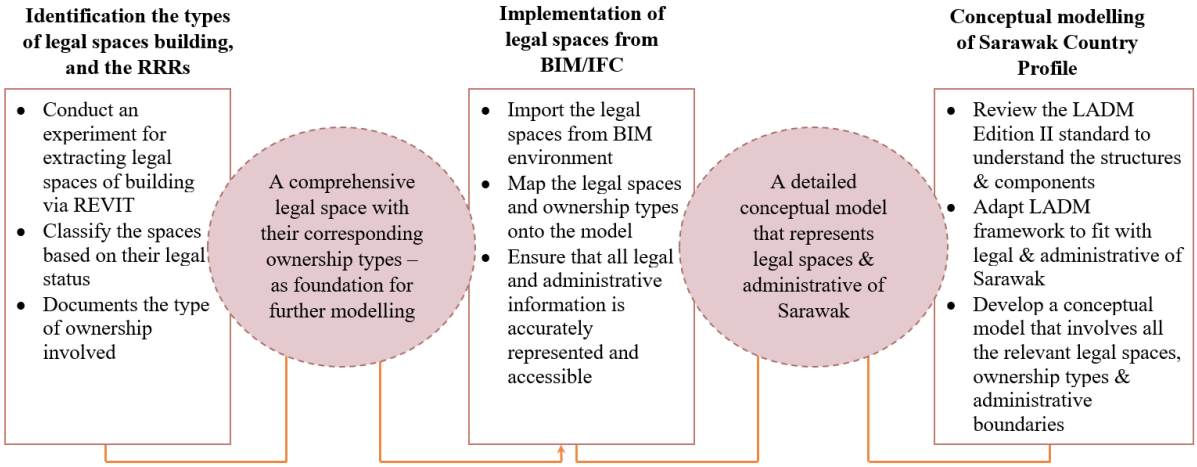

Figure 1. The methodology for implementing legal space details from BIM/IFC onto LADM Sarawak country profile

The following sections explain Figure 1 in detail.

3.1 Identification the types of legal spaces building, and the RRRs

This step involves identifying and classifying the legal space information within buildings, such as individual units, common areas, and other relevant spaces. According to the Survey Administrative and Technical Circular No.1/2022, the legal spaces are divided into several classes: prominent common areas (e.g., elevator, lobby, and staircase), non-prominent common areas (e.g., storage room and car park), and individual units. The example of the IFC model (residential building) is shown in Figures 2a and 2b. The goal is to extract legal space

information from the IFC model via Autodesk Revit, which is widely used in the BIM environment and supports parametric modeling and detailed 3D design. This software offers several tools for designing, documenting, and managing building projects. It also supports integration with various data formats, making it suitable for linking BIM data with LADM.

Figure 2a. A 3D model of residential building

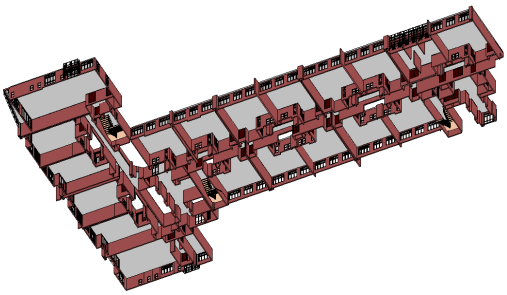

Figure 2b. 3D view of selected level

Sarawak consists of two types of ownership, namely individual units (parcels) and common property (prominent and non-prominent), as shown in Figure 3. According to the Strata (Subsidiary Titles) Ordinance 2019, an individual unit, also known as a parcel, refers to a specific portion of a subdivided building that is individually owned. Each parcel is defined by its boundaries and is legally recognized as a separate property. The owner of a parcel holds a subsidiary title, which grants them exclusive ownership rights over their unit, including the rights to occupy, use, and transfer the property. Some parcels may have accessory parcels attached, such as parking spaces or storage rooms, which are used in conjunction with the main unit. Meanwhile, common property refers to all parts of the subdivided building that are not included in any individual parcel. This includes areas and facilities also roof and facades that are shared by all parcel owners.

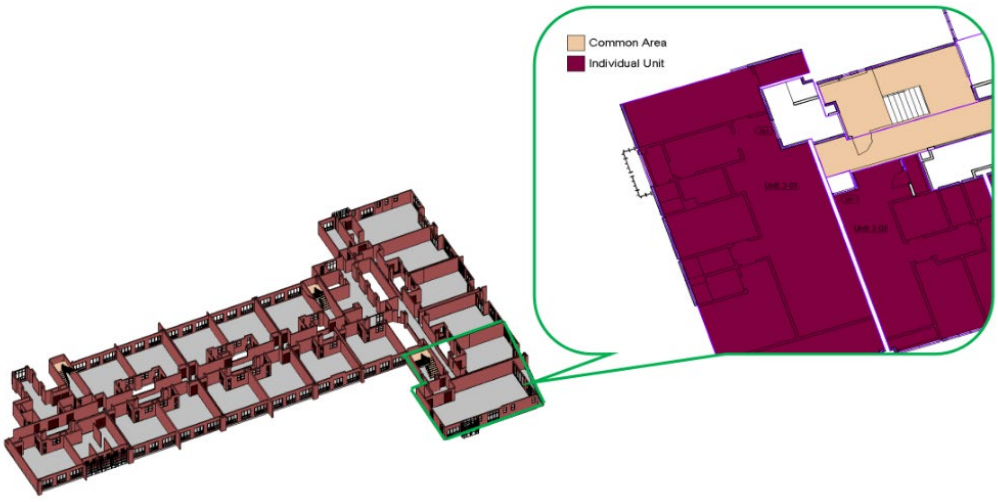

Figure 3. Types of ownership

Since BIM/IFC contains extensive semantic information, it is essential to selectively filter elements for LADM integration. The filtering process need to consider the elements that relevance to LADM such as elements (e.g., IfcSpace) that define legal spaces (unit boundaries, common areas, and accessory parcels). It also important to include the elements (e.g., IfcBuildingElement) that contain information about RRRs. The filtering process can be done via software-based filtering, for example Autodesk Revit by using filters and views button. During the exploration of the 3D model of the building, issues of missing elements and spaces need to be resolved before applying the current unit's subdivision procedures. The missing elements, such as walls, are shown in Figure 4. Autodesk Revit is used to explore the IFC-model as well as generating rooms in the model where rooms (IfcSpace) was not present. Missing elements result in an incomplete 3D model, which leads to inaccuracies in representing the physical and spatial characteristics of the building. Walls and other structural elements play an important role in defining the boundaries and spatial relationships within the building. Another issue is the absence of IfcSpace. The spaces are used to define the ownership unit's legal boundary for the 3D representation of legal spaces.

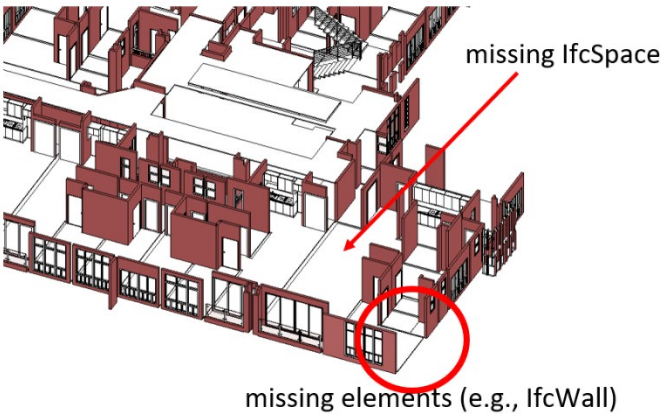

Figure 4. Missing elements (e.g., IfcWall) in 3D model

The missing architectural components, such as walls and floors, are generated through the software. After the elements have been edited, then the IfcSpace for each unit can be generated. The IfcSpace contains information on area, volume, ownership type, floor number, etc. These IfcSpace are later implemented into the unified model (Sarawak country profile).

3.2 Implementation of legal spaces from BIM/IFC

This step focuses on integrating the identified legal spaces from BIM/IFC. It includes mapping the legal spaces and ownership types onto the physical building model within the BIM environment. The IfcSpace (rooms) were generated, covering the inner surfaces of the walls, floors, and ceilings following the Strata (Subsidiary Titles) Ordinance, 2019 guideline. This means;

- Walls: The boundary is usually the inner surface of the wall
- Floors: The boundary is the upper surface of the floor
- Ceilings: The boundary is the lower surface of the ceiling

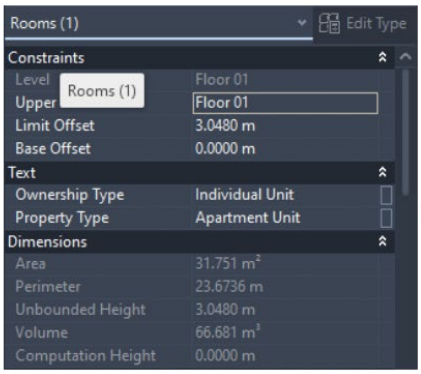

Figure 5a. Part of the 3D space information

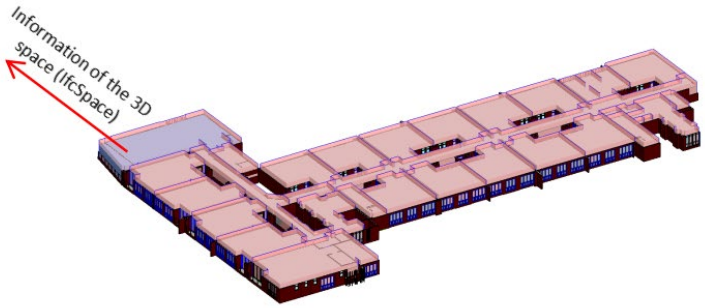

Figure 5b. 3D spaces of units

Each building's space consists of additional information representing the building's information and ownership, such as individual units or common property (see Figure 5a; Figure 5b indicates the 3D spaces). Several attributes have been added to the model, as shown in Table 1. The proposed attributes are adopted and revised by Alattas et al. (2021) following the Sarawak strata legislation.

Table 1. Attributes and their description for the 3D building space

Attributes	*Description*
Building Unit Type	The type of the building (e.g., apartment, office)
Property No	The property number as the ID
RRR Type	Represents the types of ownership
Accessory Type	The type of facility (e.g., car park, garden, storage place)
Common Unit Type	The type of service (e.g., elevators, escalators)
Limited Common Unit Type	The type of limited common area (e.g., balcony, rooftop)
Void Unit Type	The type of void area (e.g., stairs, corridors, air ducts, chutes)
Zone	Used as ID corresponding to the attached properties such as apartment unit and parking space

The integration of IFC elements with the LADM by Al-Attas et al. (2021) and Guler et al. (2022) served as a guide for mapping IFC data to land administration systems. Their studies provide a foundation for understanding how to align the detailed spatial and semantic information from BIM/IFC with the legal and administrative structures of LADM. Table 2 illustrates the proposed IFC elements and its mapping to LADM, demonstrating how specific IFC entities correspond to LADM components. This mapping ensures that the legal spaces and attributes defined in the IFC model are accurately represented within the LADM framework (see Appendix B and Appendix C), facilitating a seamless integration of spatial and legal data.

Table 2. Proposed IFC entities and its mapping to LADM (adopted and revised from Meulmeester, 2019)

IFC Entity Type	*LADM*
IfcZone: unit number, space type	WS_SpatialUnit, WS_BAUnit
IfcBuildingElement: structural building	WS_BoundaryFace, WS_BuildingElement
IfcSpace: IfcGloballyUniquedId ; geometric representation	WS_LegalSpaceBuildingUnit, WS_SpatialUnit, WS_BAUnit

3.3 Conceptual modelling of Sarawak country profile

The conceptual model is developed based on the existing land administration in Sarawak. Some of the classes from the LADM standard (ISO, 2012) have been adopted, and the concept of associating the related classes is referred to previous studies such as Guler et al. (2022), Al-Attas et al. (2021), Meulmeester (2019), and the existing Malaysia country profile (Zulkifli, 2014). The unified model is discussed based on three parts: party, administrative, spatial unit, and surveying & representation packages together with the Ifc elements.

3.3.1 Party package with IFC element

WS_Party inherits all the LADM attributes with some additions to LA_PartyRoleType (landOfficer, planningOfficer, privateSurveyor, staffSurveyor, superintendent, and surveyTechnicalAssistant) considering the current strata administration in Sarawak. IfcActor can be used to depict the WS_Party feature. A party is associated with zero or more [0..*] instances of a subclass of WS_RRR. WS_Party is also associated with WS_BAUnit to cater for the fact that a basic administrative unit can be a party (e.g., a basic administrative unit holding an easement on another basic administrative unit). A party may be associated with zero or more [0..*] administrative sources via the WS_RRR class. Meanwhile, WS_GroupParty inherits all the attributes from WS_Party with some additions to LA_GroupPartyType (native), representing the indigenous people in Sarawak, such as the Dayak communities and the Orang Ulu. Class WS_GroupParty is a subclass of WS_Party, thus allowing instances of class WS_GroupParty to have an association with instances of class WS_RRR (and thereby also to class WS_BAUnit). A group party consists of two or more [2..*] parties. Conversely, a party is a member of zero or more [0..*] group parties (see Appendix A).

3.3.2 Administrative package with IFC elements

WS_BAUnit is associated with the class WS_Party (a party may be a basic administrative unit in exceptional cases). A basic administrative unit should be associated with one or more [1..*] instances of right, restriction, or responsibility. IfcZone can be used to depict the WS_BAUnit feature. A basic administrative unit can be associated with zero or more [0..*] administrative sources. WS_BAUnit has a constraint requiring that the sum of all the shares for one basic administrative unit and no overlap be allowed between timeSpecs for the same RRR type and the same basic administrative unit shall equal 1 for the same subclass of class WS_RRR. Considering the rights of indigenous people in Sarawak, extra information in the code list LA_BAUnitType has been added, such as NCRLand, individualParcel, communalLand,

reserveLand, and state-ownedLand. In LA_MultimediaType, additional information, namely dxf, xls, and pdf, are added to comply with the Sarawak strata management. A basic administrative unit is associated with zero or more [0..*] spatial units. A basic administrative unit can be associated with zero or more [0..*] spatial sources (depicted by IfcSpace). IfcDocumentInformation can be used to depict the WS_SpatialSource feature. Class WS_RRR is an abstract class. Subclasses of WS_RRR are WS_Right, WS_Restriction, and WS_Responsibility. If it is a right or responsibility, then it is associated with exactly one [1] party and exactly one [1] basic administrative unit. If it is a restriction, then it is associated with zero or one [0..1] parties and exactly one [1] basic administrative unit. An instance of a subclass of WS_RRR shall be associated with one or more [1..*] administrative sources (see Appendix B).

3.3.3 Spatial Unit and Surveying & Representation packages with IFC elements

WS_SpatialUnit (depicted by IfcSpace) is associated with zero or more [0..*] WS_BAUnit. WS_SpatialUnit may be associated with zero or one [0..1] WS_Level (it cannot be associated with more than one level). Level 1 is for customary, level 2 for 2D lots, level 3 for 3D lots, level 4 for strata, and level 5 for utility. WS_SpatialUnit is associated with one or more [1..*] WS_SpatialSource and can include zero or more [0..*] other spatial units for further specialization into building units. Classes WS_Customary, WS_ReservedLand, WS_GenericLot, WS_Lot2D, and WS_Lot3D are adopted from the existing Malaysia country profile. The LA_BuildingUnitType has been expanded into several categories based on Sarawak legislation, which are:

- WS_TypeOfCommonUnit (e.g., escalator, elevator, swimming pool)
- WS_TypeOfLimitedCommonUnit (e.g., balcony, rooftop, garden area)
- WS_TypeOfIndividualUnit (e.g., residential unit)
- WS_TypeOfVoidUnit (air ducts, corridor, lobby, chutes)
- WS_TypeOfAccessoryUnit (car park, air conditioning ledge)

All the classes and code lists in this package are illustrated in Appendix C.

4. DISCUSSION AND RECOMMENDATIONS

This paper produces a conceptual model for integrating BIM/IFC data into LADM. The integrated model comprises nine (9) main classes of LADM and 12 sub-classes, whereas the Ifc information has been connected to into the existing LADM classes as additional attributes and code lists. This model still has to be validated for the Sarawak land management scenario. At the moment, various aspects of the land administration (LA) have been considered in the modelling process; however, they have yet to be tested. The model could be improved by having more attributes related to the details of building elements, especially for other disciplines and usage in the state of Sarawak. As it is, the model is valid for land administration, as declared in the Strata Management Ordinance, 2019.

Integrating BIM and LADM can benefit data harmonization, where BIM data, which includes detailed spatial and semantic information about buildings, can be synergized with LADM, which focuses on legal and administrative aspects. Additionally, the spatial data in LADM

can accurately reflect the real-world locations and dimensions of properties, while BIM data provides precise 3D models of buildings that can be georeferenced to align with cadastral maps and other geospatial datasets. Moreover, using BIM input for several LADM classes allows for automated validation processes. For instance, the physical dimensions in BIM and legal boundaries in LADM can be automatically detected and resolved, ensuring data accuracy. Inevitably, integrating BIM with LADM would enhance detailed semantic information for complex situations and generate quick and accurate information. Furthermore, all relevant information about a certain property can be shown in a single, unified model.

For the 3D LAS input, the IFC model should contain IfcSpace (for SpatialUnit), which represents rooms for each unit. These rooms can be grouped as a unit (IfcZone for BAUnit). Since the usage of BIM is still at an early stage, most of the information is handled in an analogue manner. We believe integrating BIM/IFC-based systems, e.g., digitizing the analogue documents into a 3D model, will be beneficial. Once digitized, the extracted data must be integrated into the BIM/IFC environment. This involves mapping the information to the corresponding entities and attributes in the IFC schema. For instance, legal boundaries and ownership details can be mapped to IfcSpace and IfcZone entities. The digital data should then be validated against the original analogue documents by cross-referencing to ensure all legal and spatial information is correctly represented. The validated data can then be used to create 3D models of the legal spaces within the BIM domain, including defining the geometry and spatial relationships of the legal spaces, such as boundaries, ownership units, and easements. Finally, updating and maintaining the digital cadastral information is crucial to ensure that changes in ownership, boundaries, or other legal details are reflected in the BIM/IFC model.

In these ongoing efforts (this paper) to enhance land administration processes, several innovative directions need to be explored. Firstly, the aim is to incorporate 3D legal objects beyond traditional apartment settings, such as tunnels, underground and above-ground utilities, and water columns. This will provide a more comprehensive representation of legal spaces. Additionally, BIM database and registration system that aligns with the physical concepts of the LADM for legal information need to be established. This database will serve as a foundational platform for various applications, facilitating seamless integration and data sharing. The developed Sarawak country profile will be incorporated with Part 4 – Valuation Information for better land administration and validated where FME will be utilized to extract and convert the legal spaces from the enriched IFC files, including storing legal spaces in a PostgreSQL database with a PostGIS extension. CesiumJS will be incorporated as part of the validation and visualization processes. Lastly, future workflows and legislative frameworks for registering BIM/IFC models in LA and other related domains need to be explored and to ensure the approaches remain at the forefront of technological and regulatory advancements.

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BIOGRAPHICAL NOTES

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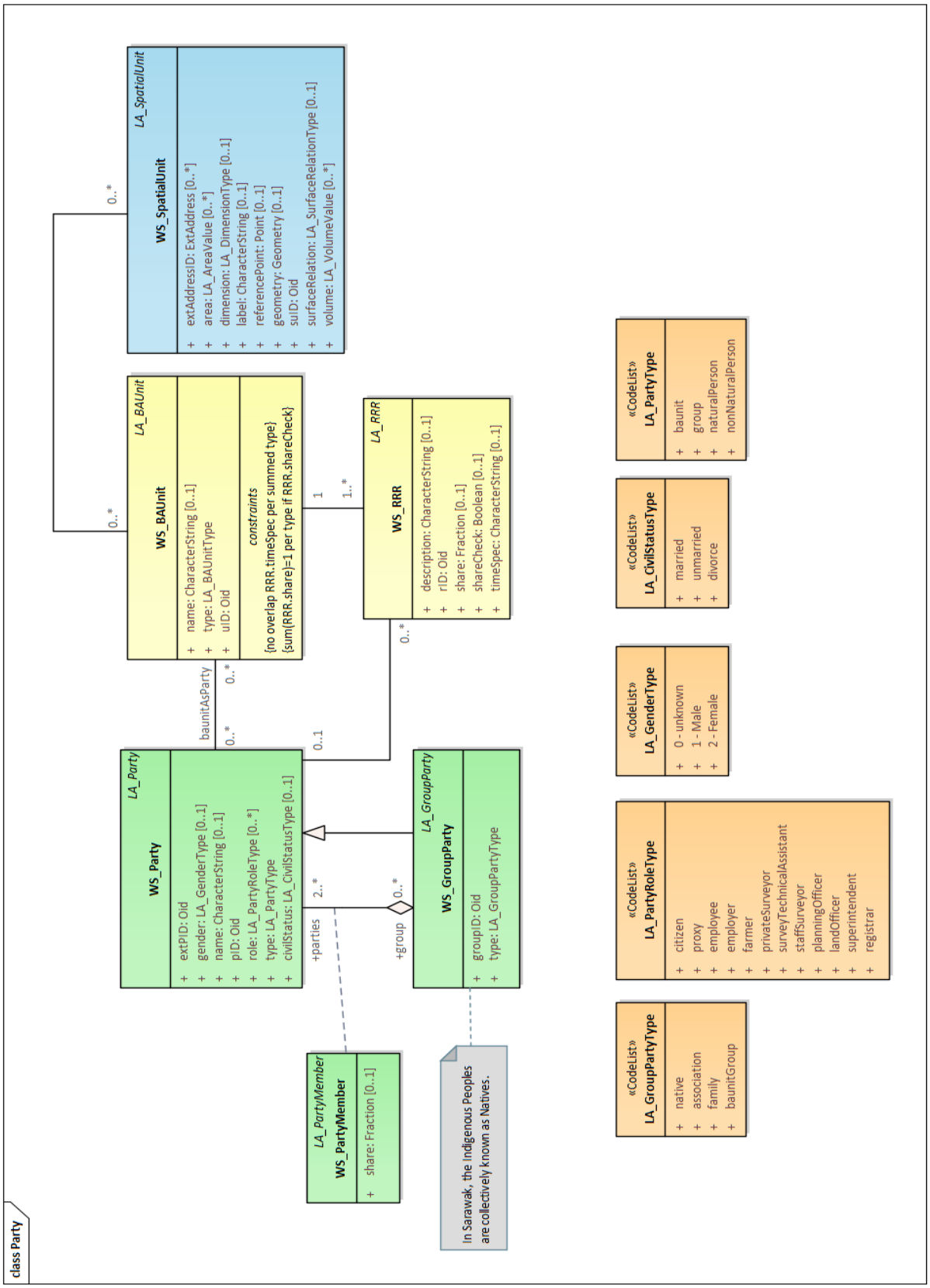
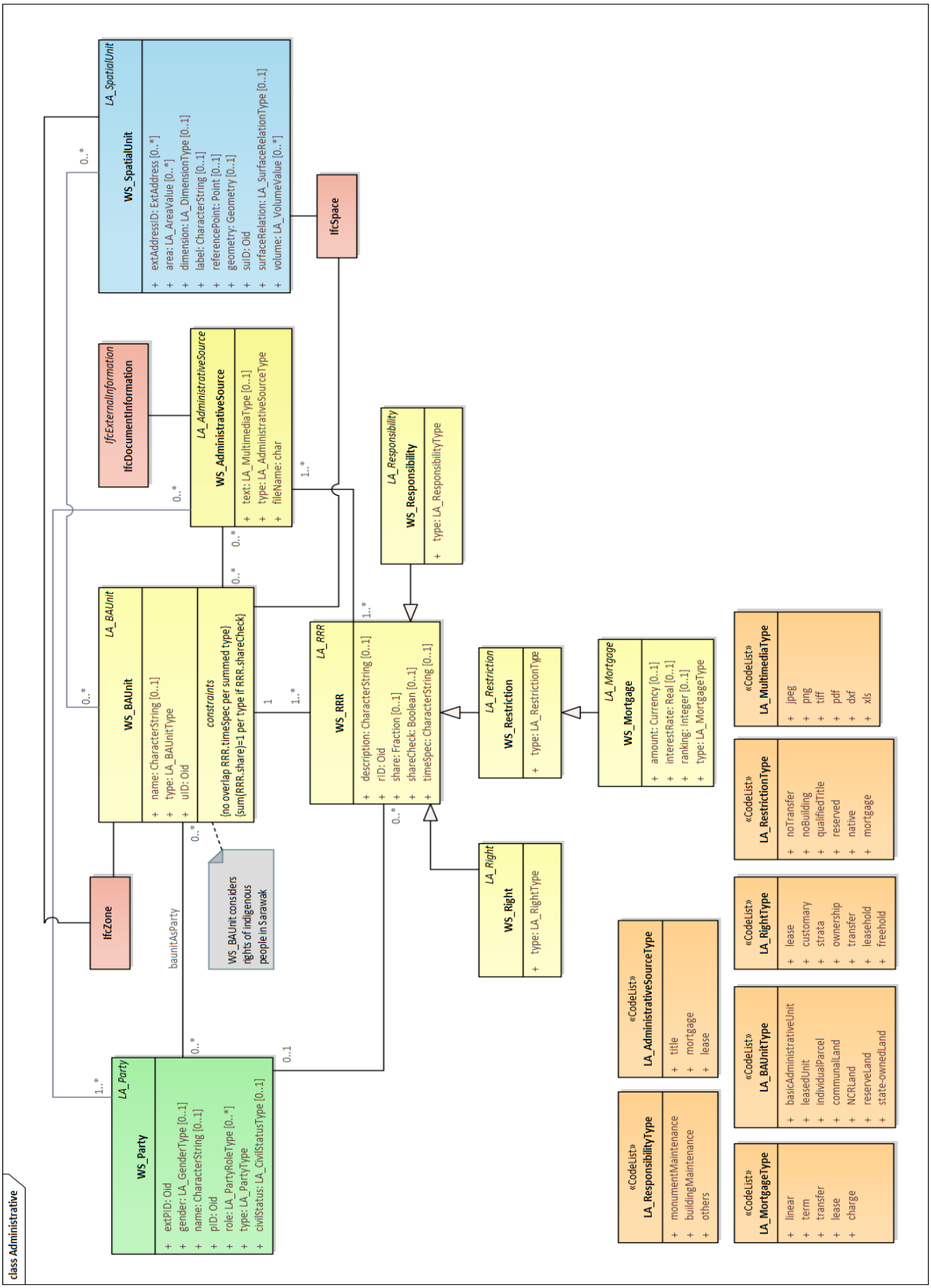
APPENDICES

Appendix A: Party package



Appendix B: Administrative package with Ifc elements



Appendix C: Spatial Unit and Surveying & Representation packages with Ifc elements