Towards Sustainable Land Governance: Extending the LADM to Support Global Initiatives Parameters - A Case Study in Indonesia

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Key words Land Administration Systems, Global Initiatives, LADM, Indigenous Rights, Women Rights

SUMMARY

Effective Land Administration Systems (LASs) are critical to economic stability, social equity, and environmental sustainability. By accurately recording rights, restrictions, and responsibilities (RRRs) associated with land, LASs facilitate transactions, prevent conflicts, and promote sustainable management practices. In response to global challenges such as population growth, disasters, and resource scarcity, continuous assessment and enhancement of LASs are essential. Global initiatives, including the SDGs, the New Urban Agenda (NUA), and the Framework for Effective Land Administration (FELA), emphasize the importance of system validation and integration, with data models playing a central role in aligning LASs with these global trends.

Despite the recognized need for improvements, existing research often fails to comprehensively integrate parameters from global initiatives, particularly within the Land Administration Domain Model (LADM), an ISO data model. This study addresses this gap by extending the LADM to incorporate essential parameters such as indigenous land rights, informal rights, women's rights, and valuation and taxation. Adopting a holistic approach, this research aligns the LADM with contemporary global trends and addresses the specific land governance challenges of Indonesia, which serves as the case study.

The study's methodology includes a continuous literature review, conceptual and logical model design, and practical implementation. The extended LADM framework is tailored for Indonesia, showcasing its applicability in addressing the country's unique challenges. The study’s findings demonstrate that integrating these critical parameters into LADM leads to a more comprehensive and effective LAS, better aligned with global initiatives.

A crucial aspect of demonstrating the feasibility and practical implications of the proposed extension involves implementing a physical model of the extended LADM in a database schema. Utilizing Enterprise Architecture to extract Data Definition Language (DDL) lays the foundation for the database schema. Subsequently, PostgreSQL is employed to implement the SQL codes derived from the modified DDL, effectively translating the extended LADM framework into a functional database system. By executing queries on the implemented system, the study illustrates the capabilities and functionalities of the new extension for LADM, underscoring its potential to address identified parameters and support sustainable land management practices.

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1. INTRODUCTION

A country's economic stability and sustainability are strongly connected to its land. Effective land administration involves understanding its tenure, value, and use, which are documented and disseminated through Land Administration Systems (LASs) (United Nations Economic Commission for Europe, 1996; Williamson et al., 2010). These systems play a vital role in maintaining the relationship between people and land, improving the accuracy of records regarding rights, restrictions, and responsibilities (RRRs), and enhancing disaster management and resilience, aligning with Sustainable Development Goals (SDGs). The significance of effective and efficient LASs in disaster management, including prediction, prevention, preparedness, mitigation, emergency response, search and rescue, evacuation, temporary shelter, and post-disaster restoration, reconstruction, and recovery, has been extensively emphasized, playing a vital role in enhancing community and regional resilience (Barra et al., 2020).

Between 2011 and 2018, only 25.4% of adults in 33 surveyed countries possessed legally recognized land documentation, falling short of SDG target 1.4.2 (United Nations Human Settlements Programme (UN-Habitat) & World Bank, 2022). One of the reasons for advancing LASs is to effectively address the critical challenges that arise in community resilience and sustainability (Jahani Chehrehbargh et al., 2023). By modernizing LASs, these challenges can be better confronted, as they are currently not efficiently addressed. This is necessary to ensure that LASs are effective, efficient, regularly updated, validated, and maintain data consistency.

Advancing LASs has been and continues to be an ongoing process, which should be in line with the latest global initiatives, technological trends, and new community expectations. Recent research and global development projects indicate that even traditionally efficient cadastral systems need updating due to the rapid societal changes occurring worldwide (Riekkinen et al., 2016). The World Bank (WB), the United Nations (UN), and the International Federation of Surveyors (FIG) have all discussed the need for advancing LAS in many documents and declarations (Ting, 2002). The need for advancement has become increasingly evident since international bodies and land professionals have been working hard to improve land administration practices by developing several LASs-related frameworks and models, such as SDGs, Framework for Effective Land Administration (FELA), and New Urban Agenda (NUA), all of which affect LASs directly or indirectly.

In 1994, FIG's Commission 7 established a working group to anticipate trends and envision the future of land information systems. Tasked with developing a 20-year vision for the modern cadastre, the group formulated the "Cadastre 2014" statements, widely acknowledged

as a seminal document (Kaufmann & Steudler, 1998). Its impact extends to being widely read, quoted, and critiqued, reflecting its significance in the field (Lemmens, 2010).
In 2012, the Food and Agriculture Organization (FAO) of the UN published voluntary guidelines on responsible land tenure governance, emphasizing improved policies, legal frameworks, and transparency. These guidelines, known as VGGT, serve as a reference for globally accepted practices in LASs and verifies that up-to-date information that is consistently available and accessible over space and time is crucial for effective land administration, promoting good land governance, and fostering sustainable development (Food and Agriculture Organization of the United Nations, 2012). In 2021, a report utilized VGGT and the Framework and Guidelines on Land Policy in Africa to enhance tenure governance and environmental use (Christensen, 2021). Also, the World Bank introduced the Land Governance Assessment Framework (LGAF) in 2012, offering an evaluation framework for LASs. LGAF assesses policies, practices, and legal frameworks related to land governance, identifying indicators for policy intervention (Deininger et al., 2012).
In 2015, the UN's SDGs framework has been endorsed by all UN members (United Nations, 2015). The majority of SDGs are interlinked and complementary, and the achievement of one depends on the achievement of all the others (Chigbu, 2021). In accordance with this agenda, five goals are directly related to LASs, each with targets and indicators to achieve them. Habitat III endorsed the New Urban Agenda (NUA) in 2016, aligning with sustainability goals and contributing to SDG 11. The second version of NUA with implementation and monitoring aspects was published in 2020 (United Nations Human Settlements Programme (UN-Habitat), 2020).
The FIG and World Bank collaboration since 2009 led to the Fit-for-Purpose Land Administration (FFP-LA) approach in 2016. FFP-LA aims to provide secure tenure and land use control for all, emphasizing efficient, effective and integrated LAS (Enemark et al., 2014).
The Global Land Indicators Initiative (GLII), initiated in 2012, focuses on monitoring land governance using 15 indicator sets. In its second phase (2016-2021), GLII aims to make global-scale land governance monitoring a reality by 2030, aligning with VGGT and Framework and Guidelines for Land Policy in Africa (Jahani Chehrehbargh et al., 2022; Kumar & Quan, 2017). Doing business of the WB was another tool that assessed land administration quality. It has been paused in 2021 due to some irregularities in the data (World Bank Group, 2021).
The UN Committee of Experts on Global Geospatial Information Management (UNGGIM) requested the development of the FELA framework in 2020, aligning with the Integrated Geospatial Information Framework (IGIF). FELA provides guidance for establishing, strengthening, coordinating, and monitoring national or subnational land administration, emphasizing integrated geospatial information (United Nations Committee of Experts on Global Geospatial Information Management, 2020).
Figure 1 shows some of the land-related global initiatives and tools from 1998 to 2021. These initiatives collectively offer invaluable insights into the future of LASs and the critical parameters for advancing and shaping them. They emphasize the requirement for the effective, efficient, integrated LAS that is ongoing upgraded, validated and ensures consistency of data (Jahani Chehrehbargh et al., 2022).

Figure 1. Land Related Initiatives Time Series from 1998 to 2021 (Source: Jahani Chehrehbargh et al., 2024b)

These global initiatives stress the importance of an effective, efficient, integrated LAS that is ongoing upgraded, validated, and ensures consistency of data by highlighting key parameters essential for LAS advancement. Achieving data validation and integration according to global trends can be facilitated through a data model, a central element of the LAS data lifecycle (Kalantari et al., 2006). Different countries and regions employ diverse cadastre data models, selecting the most suitable model based on the specific needs and demands of the area. Among the frequently utilized models are the Land Administration Domain Model (LADM), the Social Tenure Domain Model (STDM) (a specialization of LADM), the Integrated Land and Property Information System (ILPIS), Infrastructure for Spatial Information in Europe (INSPIRE), and ePlan.

2. LADM

Effective land administration must organize and ensure the majority of feasible connections between people and land, a function facilitated by the LADM (ISO, 2012; Lemmen et al., 2015). The LADM, defined as the ISO 19152 International Standard, encompasses fundamental components of land administration, including water and land areas, and elements above and below the Earth's surface. It provides a conceptual framework with packages covering parties, basic administrative units, rights, responsibilities, restrictions, and spatial units, along with terminology simplification for practical use across diverse jurisdictions (ISO, 2012). It supports software development, ensuring data exchange, interoperability, and quality management in distributed LASs (van Oosterom et al., 2022). Actively employed ISO standards undergo periodic revisions approximately every six to ten years. There is potential to enhance LADM's ability to achieve sustainability by incorporating further enhancements. Notably, processes such as data acquisition, maintenance, or dissemination were out of the scope of the first edition of LADM (Lemmen et al., 2017). However, there are plans to address this by extending the existing edition of the LADM to include processes, as indicated in the proposed LADM revision (Križanović et al., 2021).
In March 2017, the UNGGIM Expert Group on Land Administration and Management advocated for an acceleration in efforts to document and recognize global land rights,

supporting the imminent review of ISO 19152 – LADM by ISO-TC211 and OGC, aiming to comprehensively enhance tenure security and land rights; given the intricate nature of land administration, a diverse range of stakeholders, including UN-Habitat, UN-GGIM, the World Bank, GLTN, FIG, ISO, IHO, OGC, and RICS, are engaged in the revision process (van Oosterom et al., 2022). Suggestions included addressing inconsistencies, global issues like oceanic cadastre, and the integration of land use/cover information and 3D land administration (ISO, 2018).
Based on TC 211 members' suggestions and workshop outcomes, FIG proposed a NWIP to ISO/TC 211 in April 2018, outlining LADM extensions in conceptual model scope, current model improvements, encodings/technical models, and process models for survey procedures. However, the ISO/TC 211 did not accept FIG's NWIP in April 2018, citing the need to publish LADM Edition II as a multipart standard. The ISO Stage 0 project for LADM Edition II commenced in May 2018 in Copenhagen, Denmark. In the 48th Plenary Meeting Week of ISO/TC 211, SCC proposed LADM Edition II as a multipart standard with parts covering fundamentals, land registration, marine space georegulation, valuation information, spatial plan information, and implementations. While the second edition of LADM has not been published yet, several studies have been released addressing various parts of this data model (Lemmen et al., 2021). The development timeline of LADM is shown in Figure 2.

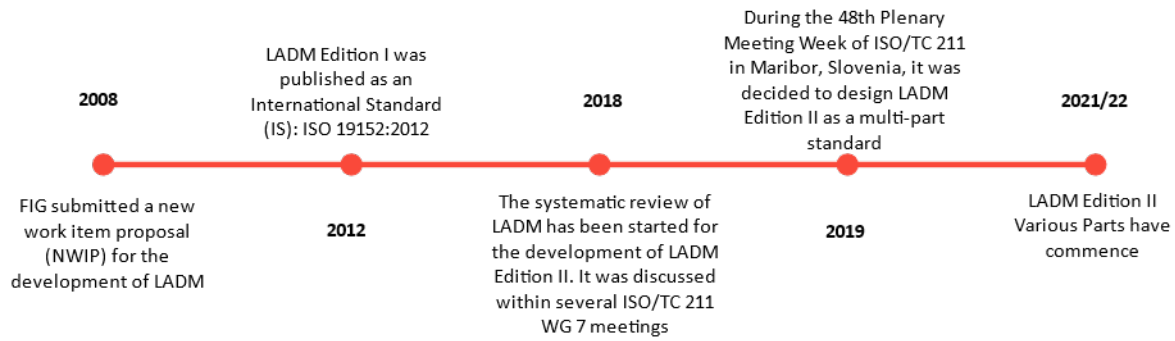

Figure 2. The development timeline of LADM (Body et al., 2022)

Despite the ongoing need for LAS advancements, current research on LAS lacks a comprehensive integration of global trends' parameters into LAS data models, especially in the context of ISO standards. This gap is evident due to limited evidence or studies addressing the integration of global trends into the LAS data model. Each study only focuses on one global trend (Chen et al., 2023) or addresses one specific parameter (Cagdas et al., 2016; Paixao et al., 2015). Also, the existing literature on LAS advancements often highlights the need for modernization but falls short of thoroughly addressing the inclusion of emerging global trends, leaving a gap in understanding how these trends can be effectively integrated into LAS data models, particularly within established standards like ISO. Our study aims to fill this gap by examining indigenous rights, women rights, informal rights, taxation, and land valuation within the LAS ISO data model (LADM). By focusing on these parameters, which are particularly relevant to vulnerable and marginalized communities, our research takes a more comprehensive approach by exploring multiple aspects simultaneously. The ultimate objective is to extend the LADM in a manner that considers all these elements collectively,

aligning with global trends and ensuring that the rights and needs of these communities are adequately addressed. Our study recognizes that there is room for improvement in each research effort, emphasizing the need for ongoing enhancement in understanding and incorporating these crucial components into LAS.
The following section outlines the methodology employed in this study, followed by the implementation details in Section 4, which includes the chosen parameters for advancement and the extension of classes and attributes of LADM. The paper concludes in Section 5 with key findings and directions for future research concerning the advancement of LASs.

3. METHODOLOGY

The methodology employed in this study is designed to advance Land Administration Systems (LAS) in alignment with global initiatives by extending the Land Administration Domain Model (LADM). The research process comprises three key phases:

1. Data Requirement Analysis: The study began with a thorough review of global initiatives related to land administration. Document analysis was conducted in three steps: skimming, reading, and interpreting (Bowen, 2009). The process involved:

- **Skimming:** Initial examination of documents to identify relevant global initiatives.
- **Comprehensive Examination:** Detailed analysis to extract necessary parameters for advancing LAS, focusing on land-related aspects.
- **Interpretation:** Identifying similarities, categorizing parameters, and mapping them to the land management paradigm. Key parameters identified include gender equality, indigenous land rights, valuation and taxation, and informal rights, along with attributes like tenure type, boundary type, and data source type.

2. Conceptual and Logical Extension of LADM: Following the data requirement analysis, the research focused on modifying LADM classes:

- **Conceptual Model Design:** A robust conceptual model was designed, synthesizing modified attributes into a coherent framework, represented using UML diagrams.
- **Logical Model Implementation:** The conceptual model was translated into a logical model using Enterprise Architect (EA). This step involved defining the arrangement of data elements and their interconnections, serving as a blueprint for the physical database. The logical model validated the conceptual framework and provided practical insights into implementation challenges, facilitating the creation of DLL schemas for databases like PostgreSQL, Oracle, and SQL Server.

3. Implementation for Indonesia: The study aims for global applicability but uses Indonesia as a case study to illustrate the practical implementation of the extended LADM:

- **Country-Specific Considerations:** Recognizing the jurisdiction-based nature of cadastral systems, the study includes Indonesia-specific parameters.
- **Case Study Focus:** Introducing additional code lists and features aligned with the recommended extensions, tailored to Indonesia's unique land governance challenges. The country’s high number of unregistered land titles presents an ideal context for

implementing the extended LADM, which aims to enhance transparency and applicability in Indonesia's LAS.

4. Physical Data Model Implementation: The final phase involved implementing the extended LADM in a physical data model using PostgreSQL. The steps included:

- **Schema Creation**: Translating the logical model into a physical schema, with tables for each LADM class and additional attributes for Indigenous rights, gender, and informal rights.
- **Data Insertion**: Populating the tables with sample data, including entries for Indigenous groups, gender data, and informal settlements.
- **Query Execution**: Running SQL queries to validate the model's capability to handle complex land administration queries. Examples include listing parcels owned by indigenous groups, analysing the gender distribution of parcel owners, and detailing informal settlements.

Figure 3 shows the steps of the methodology used in this study.

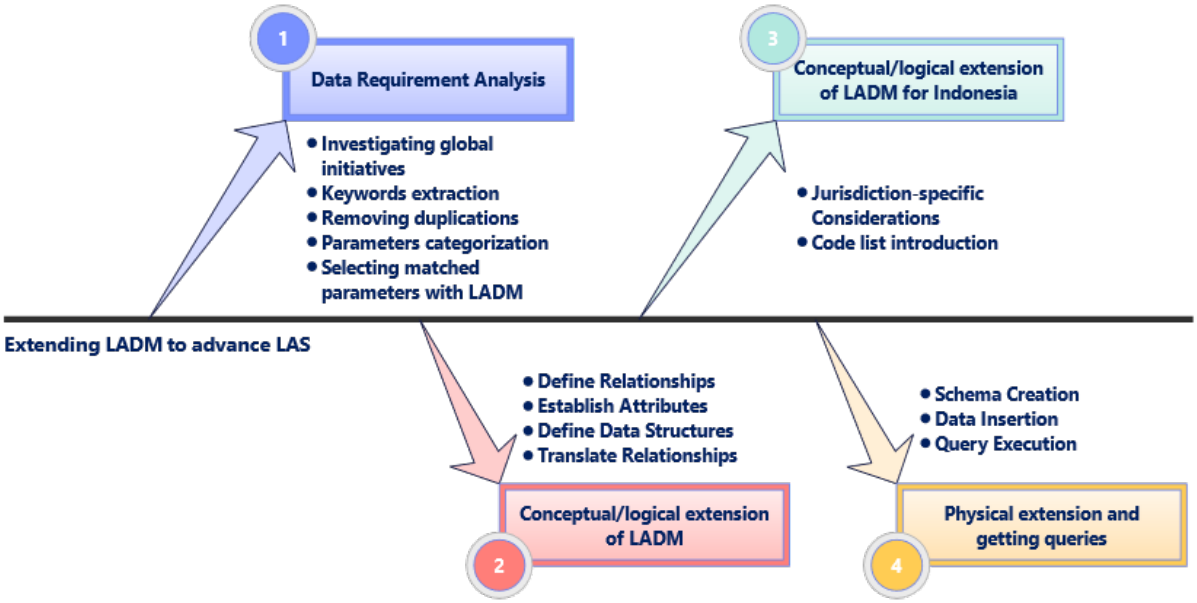

Figure 3. The methodology of extending LADM to advance LAS.

4. PROPOSED EXTENSION OF LADM

Investigating global initiatives has identified essential parameters for advancing Land Administration Systems (LAS) in alignment with global trends (Jahani Chehrehbargh et al., 2024b). These parameters encompass gender equality, Indigenous land rights, valuation and taxation, dispute resolution, informal rights, and specific attributes like tenure type, boundary type, and data source type. These elements are particularly critical for supporting vulnerable and marginalized communities, who often face significant challenges in securing their land tenure and accessing land-related services. Performance evaluation, education, and

collaboration are also crucial for enhancing the national context of land management. As depicted in Figure 4, these parameters are carefully integrated into the land management paradigm, a fundamental framework in this domain. Addressing these parameters within LAS is crucial for promoting sustainability in land management.

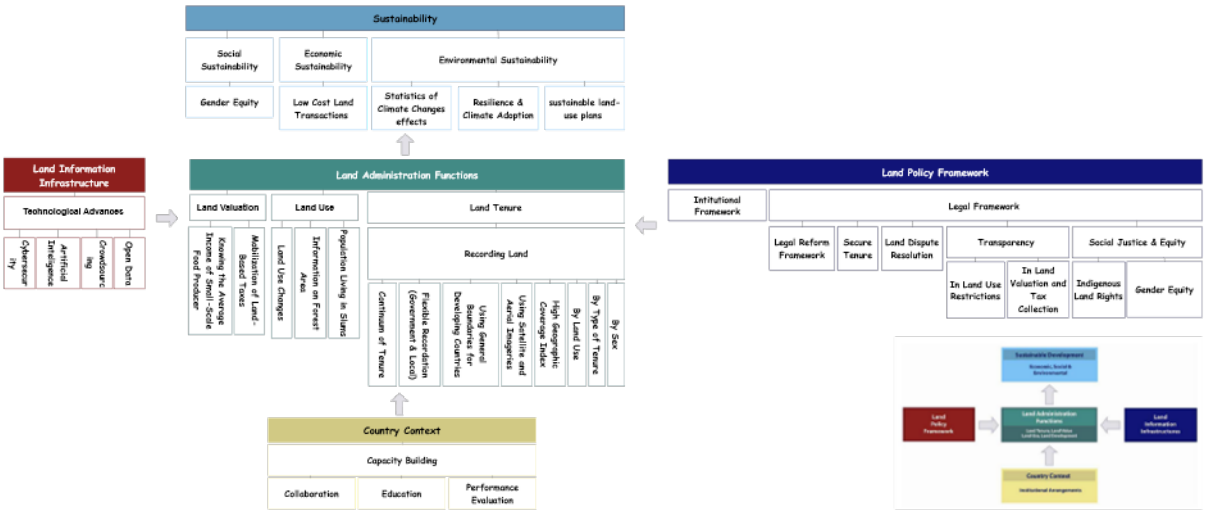

Figure 4. The Extracted Global Parameters for Advancing LAS (Jahani Chehrehbargh et al., 2024b)

Effective LAS is essential for resolving disputes and managing land conflicts. Online Dispute Resolution (ODR) systems offer viable solutions for land rights disputes by improving access to justice and overcoming barriers such as cost, time, and information imbalances. ODR includes various processes, such as negotiation, mediation, facilitation, arbitration, and other adjudication methods outside traditional physical settings, provided by entities like private enterprises, non-profit organizations, and governments (Salter, 2017).
This study outlines parameters that align with the land information infrastructure, addressing significant gaps in previously overlooked rights by land administration systems, such as women's rights, Indigenous land rights, informal rights, taxation, and land valuation. By focusing on the data model, crucial in the information infrastructure's data lifecycle, the study aims to align LAS with global trends, particularly for Indonesia.

4.1 Country-Specific Implementation for Indonesia

Indonesia is modernizing its land administration system to address challenges in land registration and construction permits (Jahani Chehrehbargh et al., 2024a). With millions of land parcels still unmapped, initiatives like the One Map Project, funded by the World Bank, aim to digitalize land services. Implementing the LADM for Indonesia could bring various benefits, including environmental protection and disaster management, along with potential cost savings. Adaptations and expansions are necessary, particularly in code lists to cater to local specifications. Some LADM classes align with existing Indonesian models, such as Person, Right, RegisterParcel, SurveyDocument, LegalDocument, Mortgage, SurveyPoint, GroupPerson, and Member class. However, classes like Responsibility, Restriction, and Serving Parcel, while supported by legal frameworks, await practical implementation (Sucaya, 2009).

The study adopts the basic classes of LADM Edition II (as shown in Figure 5) and extends them based on parameters derived from global initiatives, focusing on women, Indigenous and informal rights, valuation, and taxation.

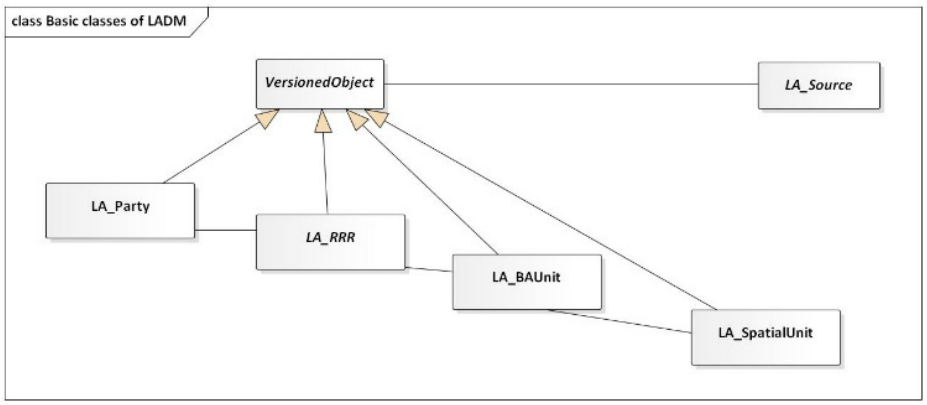

Figure 5. Basic classes of the core LADM Edition II (Lemmen et al., 2021)

4.1.1. Gender Equality

The initial step in securing women's land rights involves identifying the gender of parcel owners. The original LADM does not include a gender attribute in the LA_Party class. To make LAS gender-sensitive, this research proposes adding a gender attribute to the LADM, allowing for the collection of gender-specific data. Unger et al. (Unger et al., 2023) introduced gender as an attribute in the LA_Party class, using the ISO/IEC sex type code list. It is essential to differentiate between sex and gender: sex refers to biological traits, while gender involves societal roles and expectations, and gender identity refers to an individual's internal sense of their gender (World Health Organization, 2023).

To develop a comprehensive gender-sensitive system, it is necessary to recognize a broad spectrum of gender identities. By incorporating these identities under the attribute "LA_GenderType," the system can accurately reflect an individual's gender. Figure 6 shows the proposed gender attribute and its code list, with green boxes indicating modified classes, yellow boxes highlighting new elements and blue boxes for Indonesia's profile.

4.1.2. Indigenous Rights

Indigenous peoples, often referred to as first peoples, aboriginal peoples, native peoples, or autochthonous peoples, have deep-rooted connections to specific regions, maintaining unique traditions and cultural aspects tied to their territories. Recognizing these distinctions is crucial for developing inclusive policies and preserving cultural diversity (IPBES, 2018). Protecting their rights supports sustainable development and social justice, as emphasized by ILO Convention 169 (ILO, 2003), and the UN Declaration on the Rights of Indigenous Peoples (UNDRIP) (Paixao et al., 2015). Integrating these rights into land administration data models ensures their recognition and protection.

Indonesia's indigenous population is diverse, comprising numerous ethnic groups with distinct cultural identities and ancestral ties to specific regions. The government recognizes 1,331 ethnic groups, but many more people self-identify or are considered indigenous by others. The Aliansi Masyarakat Adat Nusantara (AMAN), the national Indigenous peoples'

organization, estimates between 50 and 70 million Indigenous peoples in Indonesia (IWGIA, 2023). Indigenous communities are referred to by terms such as "komunitas adat terpencil" and "masyarakat adat". Recent legislation reflects an implicit recognition of their rights, such as the Basic Agrarian Regulation and laws on human rights, coastal management, and the environment (Mamo, 2020). This study recommends including “masyarakat adat” in the party type classification and listing the 31 most populated ethnic groups in the Indigenous group codes for Indonesia (Na'im & Syaputra, 2010).

Indonesia faces persistent violence and criminalization against Indigenous Peoples, often related to infrastructure projects and dams. For example, in the Ngada district, a reservoir project in Rendu Indigenous territory sparked conflicts that escalated to violence in 2016. President Joko Widodo's 2017 regulation on Land Tenure Settlements in Forest Areas suggests relocating communities unless they prove longstanding habitation before the area was designated as forested (IWGIA, 2023). These challenges highlight the need for comprehensive approaches to protect indigenous land rights.

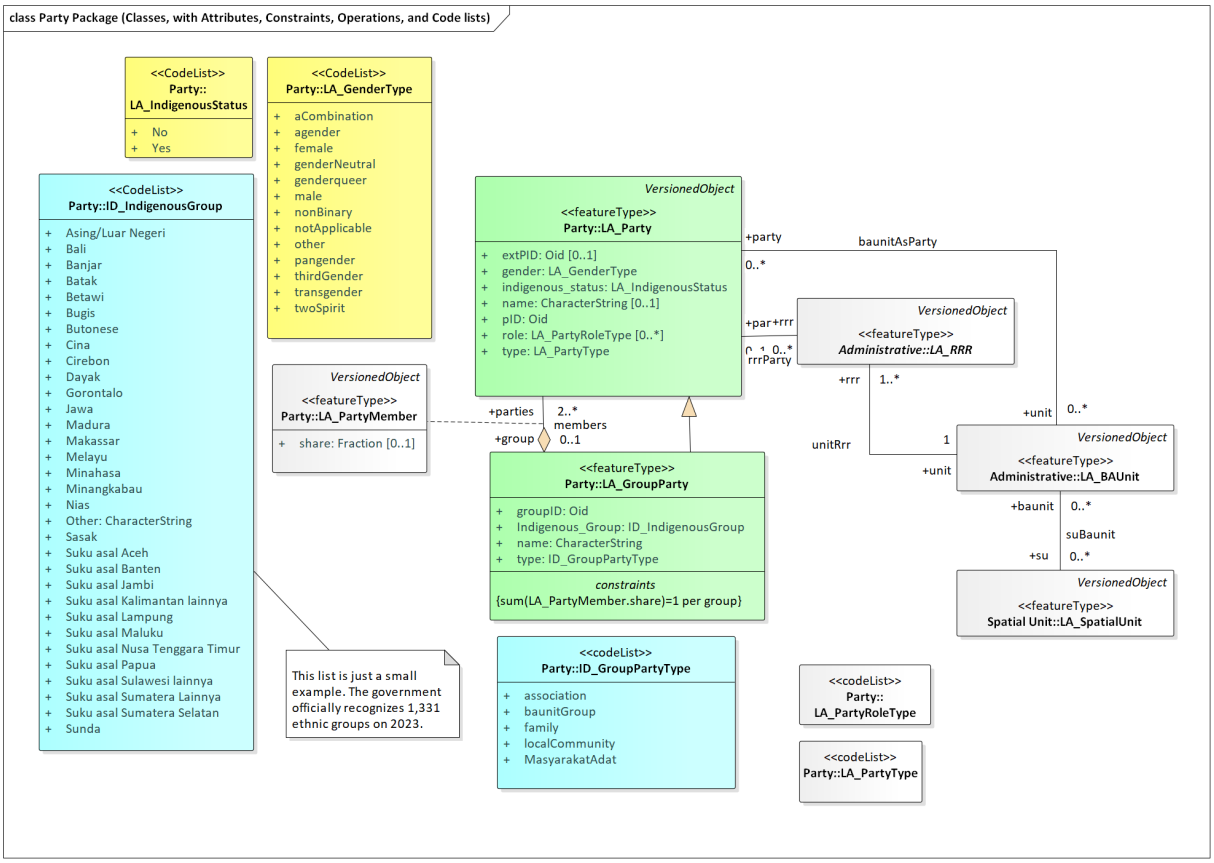

Figure 6. Extended LADM party package for Indonesia

This study introduces the attribute “Indigenous_status” within the LA_Party class of LADM to mark individuals or groups as belonging to Indigenous communities. This binary attribute (Yes/No) simplifies implementation and strengthens the foundation for recognizing Indigenous land rights. Building on Silvane et al.'s research on Indigenous land rights in

Brazil (Paixao et al., 2015), this study expands LADM to include attributes like "Indigenous group" and "Indigenous group type" (local community or Indigenous people). The administrative package of LADM also includes Indigenous unit types in the LA_BAUnitType code list and Indigenous rights in the LA_RightType, ensuring a nuanced understanding of Indigenous land rights within LADM, as shown in Figure 6.

4.1.3. Informal Rights

Land tenure encompasses various forms of ownership, including private, communal, open access, and state-held rights (Paasch et al., 2013). It can be formal (officially recognized) or informal (lacking official recognition and protection). Urbanization has significantly increased informal settlements, with about 25% of the global urban population living in slums as of 2015 (Jones, 2017). Addressing this requires comprehensive data collection and understanding of informal settlements, aligned with SDG indicator 11.1.1 (Berisha et al., 2022).

Traditional land information systems often fail to account for informal and customary tenures. The Social Tenure Domain Methodology (STDM), a specialization of LADM, addresses this gap by enabling the recording of various land rights, including informal land use and diverse property objects or spatial units (Kalogianni et al., 2022).

The LADM standard acknowledges different types of rights, such as ownership and customary rights, allowing flexibility in land administration practices. However, there hasn't been any approach that integrates informal social tenure relationships like informal occupation, tenancy based on non-formal and informal rights, and customary rights into the LADM (Paasch et al., 2013). To enhance international harmonization and facilitate a better understanding of the diverse types of rights, restrictions, responsibilities, and mortgages, it is essential to define and publicize these tenure categories.

According to Paasch et al. (Paasch et al., 2013), extending the LADM to support informal land rights involves careful consideration of hierarchical structuring and the incorporation of definitions and relationships within code lists. Inspired by initiatives like EULIS and the European Environment Agency's GEMET, an approach involving hierarchical coding and broader/narrower relationships can be adopted. This structured approach enables the creation of a more comprehensive and nuanced understanding of informal land rights within the LADM framework. Semantic technologies like RDF and SKOS, along with an open-linked data approach, can further enhance the extension of LADM to support the complex landscape of informal land rights.

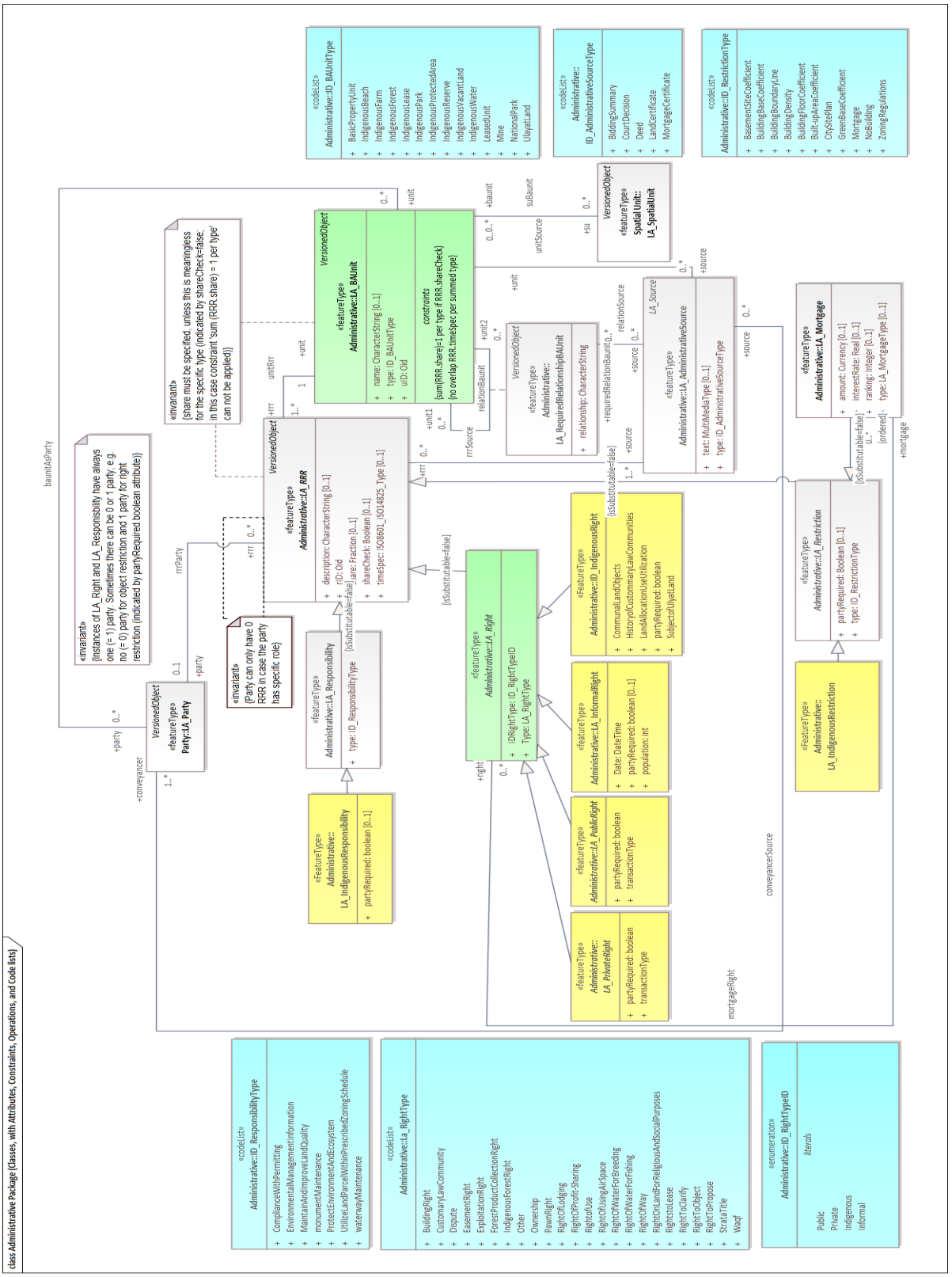

Figure 7. Extended LADM administrative package for Indonesia

The proposed approach can be put into practice, albeit with a slight increase in complexity and potential disruption to the existing LADM naming structure. To address this, as shown in Figure 7, this study recommends incorporating informal rights as generalizations under LA_Right, with attributes such as settlement types, population data, and recorded dates. The settlement type can be derived from the code list associated with the right types, allowing for clear differentiation between informal and formal settlements. Also as customary law in Indonesia requires registering land parcels of indigenous people as Ulayat Land, to avoid conflicts, both physical and juridical data should be verified. Different forms are used for registering land for indigenous people, so incorporating these forms into the data model ensures a comprehensive system, so we included them in the administrative package, information such as:

- **Management rights:** Details applicant information, land status, current use, and physical control of the land.
- **Land designation:** Requires details about the history of customary law communities, location, communal land objects, and land use plans.
- **Statement of physical control:** Confirms the land area and lack of conflicts.

As Figure 7 shows, the administrative package includes indigenous land rights and relevant information, along with code lists for types of rights, restrictions, responsibilities, units, and administrative sources specific to Indonesia.

4.1.4. Valuation and Taxation

United Nations guidelines highlight the importance of land management and property valuation in achieving Sustainable Development Goals (SDGs). Property valuation is essential for various processes, including property taxation, compensation for expropriation, and real estate transactions. Accurate and current property data are crucial for consistent and precise valuation. Efficient LASs should integrate valuation registries with other public registries like cadastre, land, address, and building registries (Cagdas et al., 2016).

In 2016, Cagdas et al. introduced an initial valuation model within LADM (Cagdas et al., 2016), expanding it to meet international taxation and valuation standards. This module facilitates all stages of property taxation, including identification, assessment through various appraisal methods, and management of tax collection, arrears, and appeals. The module records data related to parties and units involved in valuation and taxation, integrating legal information from cadastral systems with fiscal data.

In 2021, Abdullah et al. expanded this model, introducing features like VM_ValuationSource, VM_SpatialUnit, VM_Building, and VM_CondominiumUnit(Kara et al., 2021). This study incorporates additional valuation factors proposed by (Jafary et al., 2022), extending the LADM valuation class according to the latest models of valuation and taxation.

The extended features and attributes are as follows:

- **VM_Valuation:** Focuses on the input and output data utilized and generated within single or mass appraisal processes for property tax assessment.
- **VM_SinglePropertyAppraisal:** A subclass of VM_Valuation, detailing single property appraisal-related information through attributes such as SalesComparisonMethod,

valuationByCostMethod, valuationByIncomeMethod, and their corresponding data type classes.

- **VM_MassAppraisal:** Designed to organize mass appraisal-related information, describing mathematical models, mass appraisal analysis types, and the sample size of the analysis.
- **VM_TransactionPrices:** Includes attributes that characterize transaction contracts or declarations, encompassing details such as the date of contract or declaration, price, transaction date, and type (e.g., sale, heritage, forced sale, and rent prices).
- **VM_SalesStatistics:** Created for time series data generated through the analysis of transaction prices.
- **VM_ValuationUnit:** Serves as the basic recording unit in fiscal registries and is associated with LA_BAUnit, denoting the fundamental registration unit in cadastral systems.
- **VM_SpatialUnit:** Represents cadastral parcels, including sub-parcels that are divisions based on official land use for taxation purposes.
- **VM_Building:** Provides a set of common attributes shared by its sub-classes, encompassing details such as area, volume, type of use, building type, number of dwellings, and floors of buildings. It also includes construction and energy-related attributes, such as the date of construction, construction material, facade material, heating system, heating source, and energy performance.
- **VM_CondominiumUnit:** Records essential condominium unit characteristics necessary for valuation procedures, such as area, volume, use type, condominium type, floor number, and the count of rooms, bathrooms, and bedrooms.
- **VM_ValuationSource:** Introduced to record the type of valuation sources, such as valuation reports, sale contracts, rental contracts, and declarations. This class inherits from the LA_Source class, which includes acceptance and lifespan stamp characteristics, representing the real-world time (valid time) of the source.
- **TM_Taxation:** Dedicated to capturing specific taxation details related to immovable properties. This includes information such as the name or identifier of the property tax, fiscal year, assessed value of the fiscal unit, exemptions granted (including type and amount), assessment ratio, applied tax rates, assessed tax amount, due date for tax payment, as well as specifics about payments and appeals. Payment details like amount and date, appeal identification, appeal subject, and appeal status are recorded. Additionally, values for the attributes exemptionType and AppealStatus are provided by two code list classes, FM_ExemptionType and FM_StatusOfAppeal, respectively.

As part of the ongoing development of LADM, enhancing the existing code lists signifies a significant step forward. This study has introduced new enumerations to the code lists, including:

- **SpecificProperty and MassAppraisal:** Incorporated into the code lists of VM_ValuationApproach within the VM_Valuation class.
- **IncomeValue:** Added to the code lists of VM_ValuationType within the VM_Valuation class.

- Attributes within the **VM_Building** class, such as **designQuality**, **sunlightExposure**, **numberOfBedroom**, **numberOfBathroom**, **numberOfBalcony**, **numberOfCarspaces**, **numberOfStorage**, **Storey**, and **landScapeView**.
- **gymAndRecreation:** Included in the code lists of VM_AccessoryPartType within the VM_CondominiumUnit class.

The proposed valuation classes and attributes tailored to Indonesian conditions, emphasizing the need for such integration in national land management practices. The National Land Agency of Indonesia historically focused on land tenure and use, with land valuation incorporated only in 2006. Challenges persist in implementing mass valuation methods, particularly due to data collection issues in Indonesia's diverse market landscape. Since 2014, the Directorate of Land Valuation and Land Economy has emphasized the importance of land acquisition. Accurate land valuation is crucial given Indonesia's vast territory. Therefore, integrating comprehensive land management, including accurate land valuation, across all functions is essential. These additions are shown in Figure 8 and Figure 9.

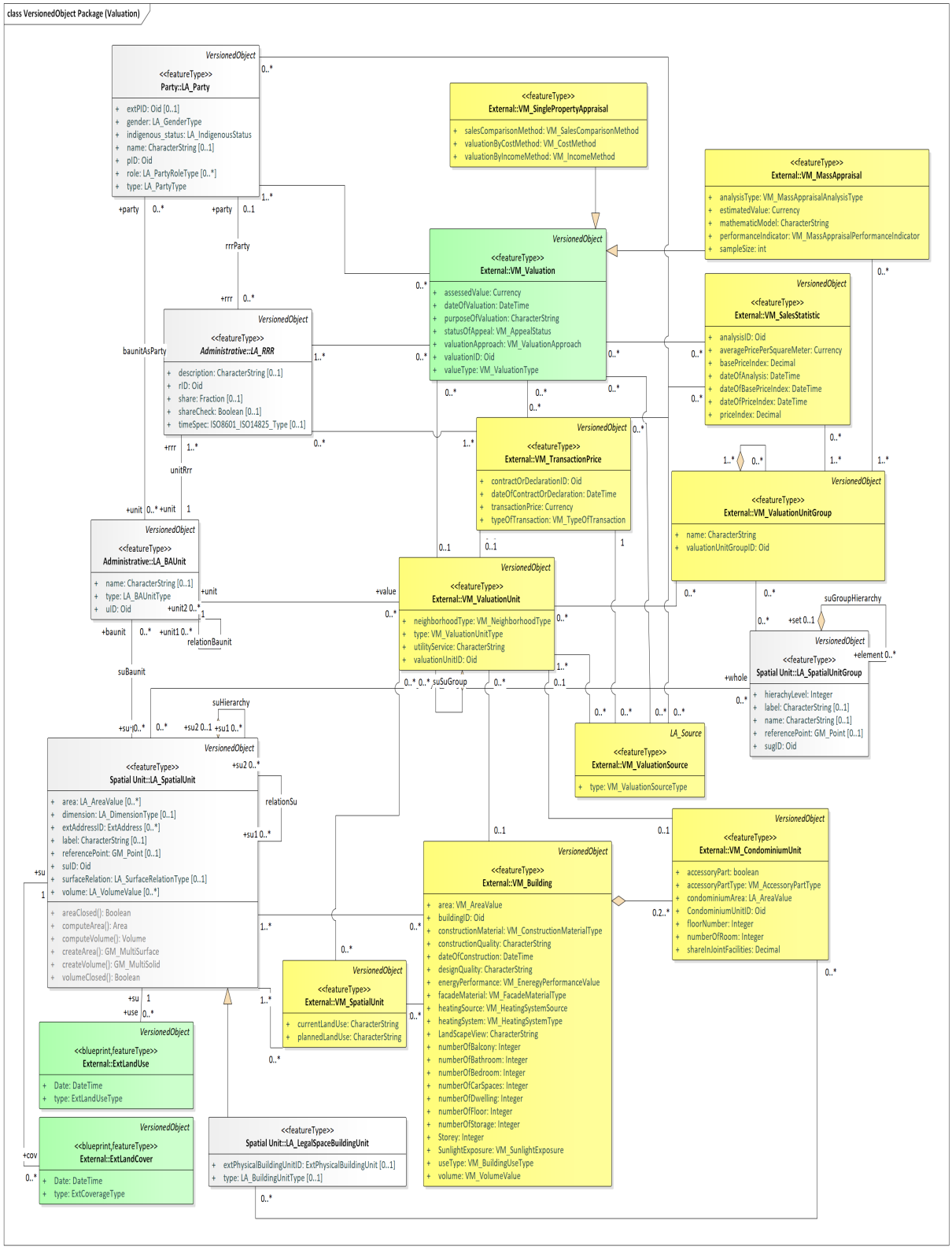

Figure 8. Extended valuation class within the versioned object package of LADM

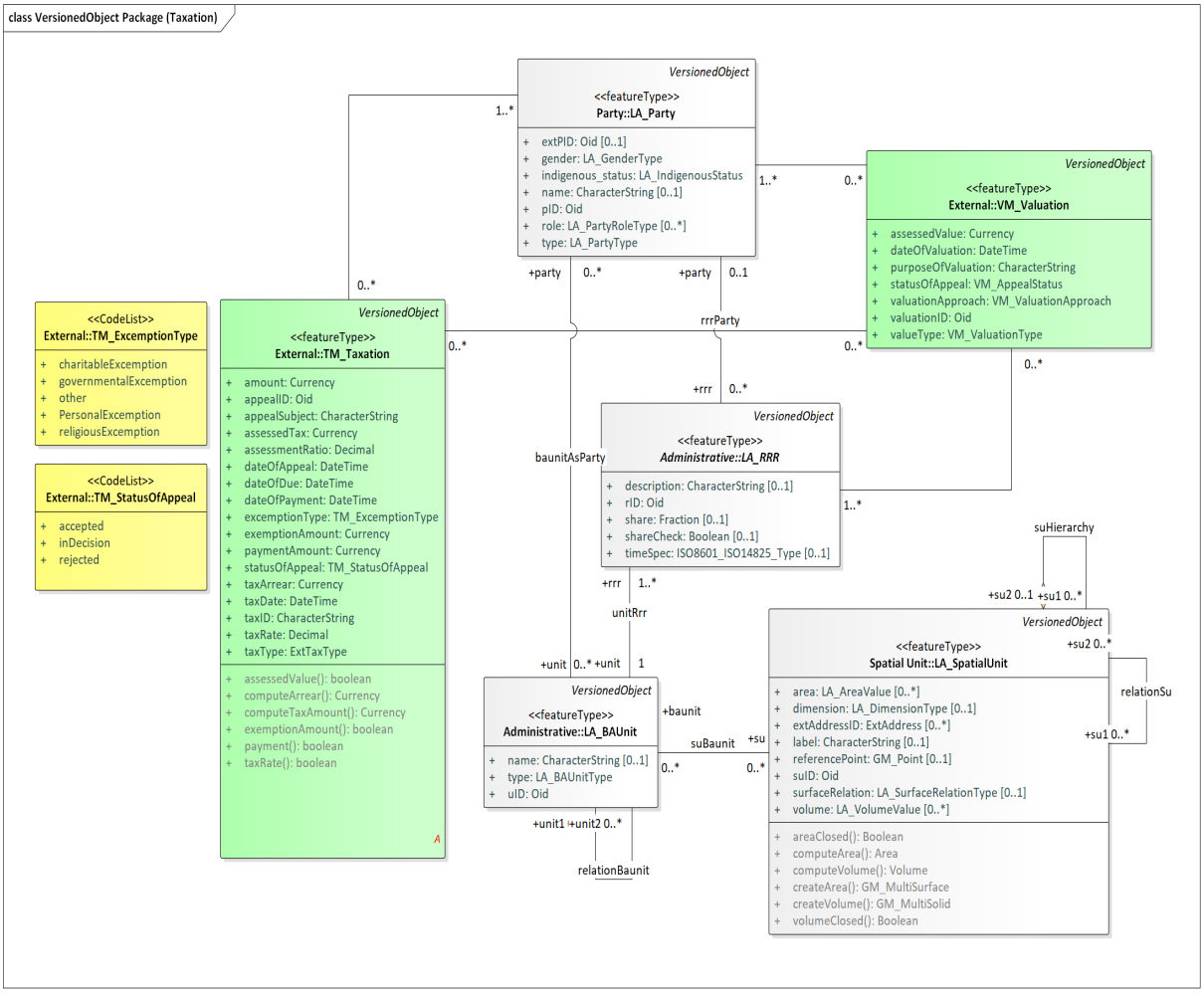

Figure 9. Extended taxation class within the versioned object package of LADM

4.2 Physical Data Model Implementation

The existing Land Administration Domain Model (LADM) is primarily a conceptual model, which lacks detailed guidance for practical application, making it difficult to translate into a physical model for production systems. While conceptual models can be interpreted differently depending on the perspective, a physical model offers a clear and consistent representation that reduces ambiguity (Shahidinejad et al., 2023). Physical models are crucial as they define the semantic and spatial information for various urban structures, such as buildings, roads, tunnels, and bridges (Olfat et al., 2021).

This chapter outlines the physical implementation of the extended LADM, focusing on the inclusion of previously ignored rights such as women's rights, Indigenous land rights, informal rights, taxation, and land valuation.

The physical model is constructed based on SQL codes. The process of creating the physical model from the UML in EA to the implemented physical model in PostgreSQL involves several key steps:

- **Utilize the Extended Logical Model:** Start by using the extended logical model within Enterprise Architecture (EA) software as the foundation for the physical model.
- **Convert UML to DDL:** Transform the Unified Modeling Language (UML) diagrams into Data Definition Language (DDL) within the EA software, establishing the initial blueprint for the database structure.
- **Modify Relationships in DDL:** Refine and adjust the relationships within the generated DDL to accurately reflect the intended data architecture.
- **Convert DDL to SQL:** Convert the refined DDL into SQL code, making it ready for implementation in the database system.
- **Refine SQL in pgAdmin:** Further modify the SQL in pgAdmin (Specifically primary and foreign keys) to resolve any issues and to finalize the database structure.
- **Create Tables with Correct Relationships:** Create the database tables in pgAdmin, ensuring that all relationships are correctly established, completing the physical model.
- **Insert Data:** Populate the created tables with relevant data to operationalize the database.
- **Execute Queries and Connect to QGIS:** Perform queries to validate the model and connect the PostgreSQL database to QGIS for spatial data visualization and analysis.

The SQL insertions and query scenarios are utilized to demonstrate how these extensions are operationalized within a land administration system, specifically tailored for Indonesia.

4.2.1 Data Preparation and Input

The physical model of the extended LADM is built upon several core tables. These tables capture different aspects of land administration, including parties involved, rights associated with the land, addresses, and spatial units. Before executing queries and scenarios, it is crucial to prepare the data by ensuring that all necessary attributes are included and correctly structured within the database. The data used in this study pertains to 156 parcels located in Jakarta, each identified by a unique NIB (Nomor Identifikasi Bidang: Land Parcel Identification Number). The dataset includes information such as parcel areas, and other relevant attributes. However, to ensure that the database can handle queries and provide meaningful results, we need to create dummy data for attributes that are missing or incomplete. This involves adding necessary attributes such as gender, type of land rights, and any other relevant information that aligns with the objectives of the study. The dummy data will be used to populate the database tables, allowing for the execution of various scenarios and queries. For example, if the ownership details or gender information is not fully available in the original dataset, we would generate this data to ensure that all queries, especially those related to gender-based analysis, can be effectively run. Figure 10 show the original data in QGIS software.

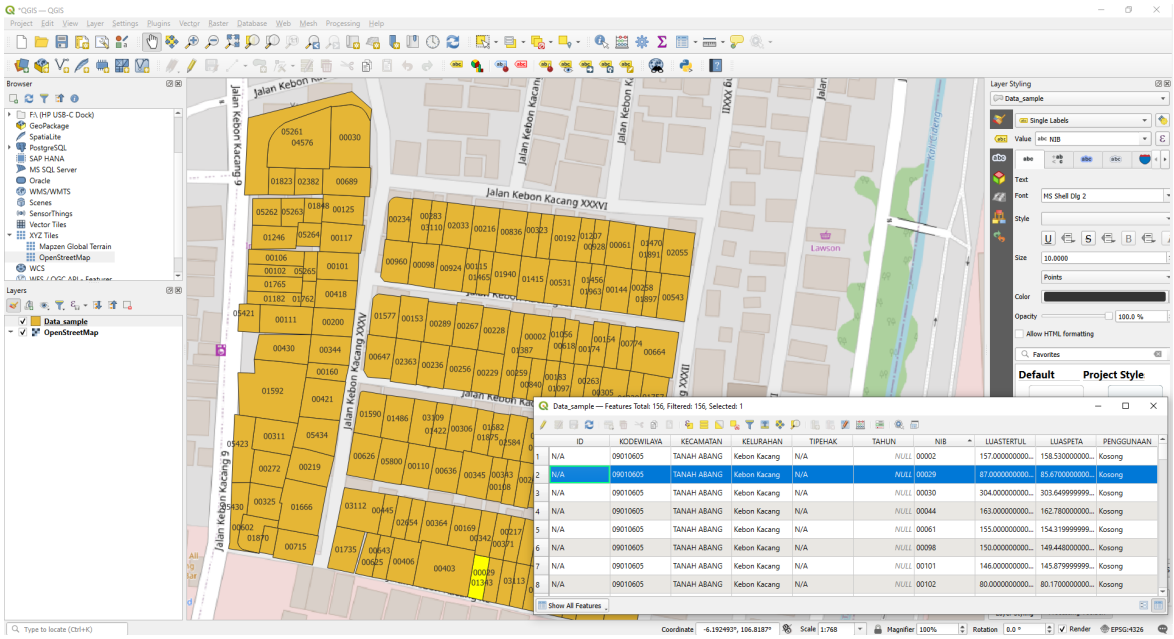

Figure 10. The provided data with related attributes in Bahasa language

4.2.2 Query 1: Identifying Women-Owned Parcels by NIB

Scenario Overview: In this scenario, the goal is to identify parcels owned by women within the study area by retrieving their corresponding NIB numbers. This information is crucial for assessing the distribution of land ownership based on gender and understanding the role of women in land ownership within the Jakarta region.

The earlier version of the LADM lacked the ability to directly answer this query because it did not include specific attributes related to the gender of parcel owners. Without this essential data, it was impossible to distinguish parcels based on ownership by gender, limiting the model's utility in conducting gender-sensitive analyses. This gap posed a significant challenge, especially in contexts where gender equality in land ownership is a critical metric for evaluating the effectiveness of land administration systems. The extended version of LADM, however, addresses this limitation by introducing a "Gender" attribute within the "La_party" class, which records the gender of the parcel owner. This enhancement not only improves the functionality of LADM in supporting local land administration but also aligns with global initiatives such as the United Nations Sustainable Development Goals (SDGs), particularly SDG 5, which emphasizes achieving gender equality and empowering women.

Query Execution: Figure 11 shows the query executed in pgAdmin software, with the result table displayed on the left side. Additionally, a visual representation of the query results, generated in QGIS, is shown on the right side of the figure, illustrating the spatial distribution of women-owned parcels across the study area. This visualization enhances the understanding of gender-based ownership patterns, supporting local policy-making efforts in land governance.

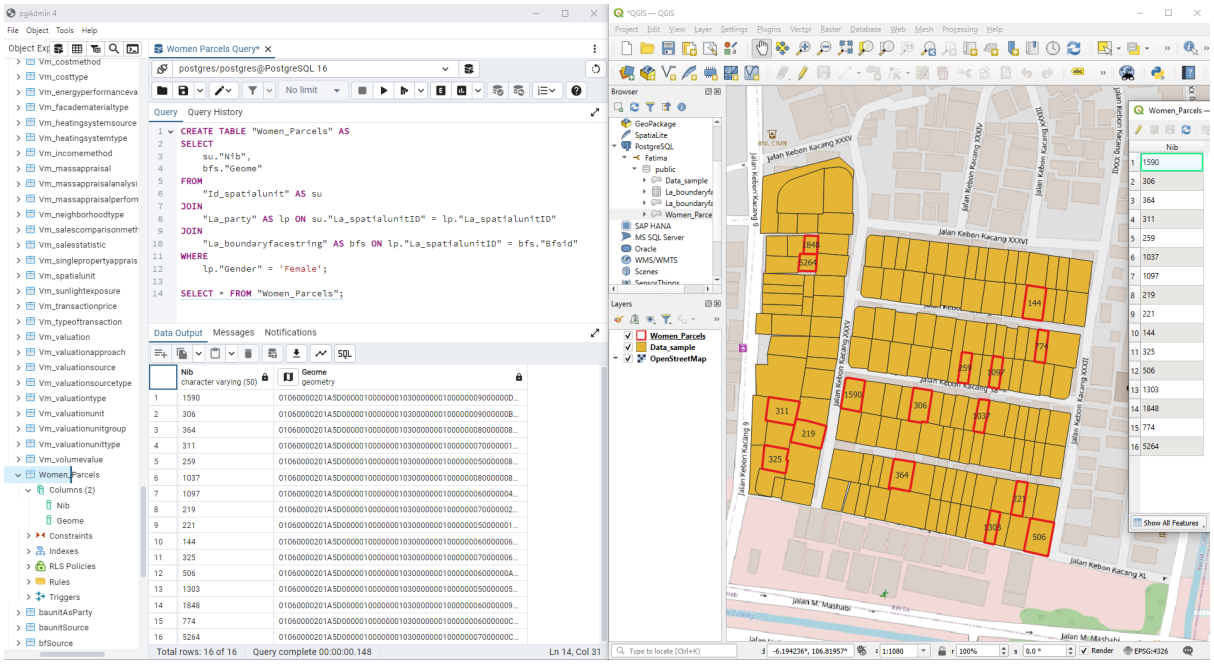

Figure 11. Women-owned parcels query execution in pgAdmin with the distribution displayed in QGIS

4.2.3 Query 2: Identifying Neighboring Parcels Within a 25-Meter Radius

Scenario Overview: In this scenario, the objective is to identify neighboring parcels within a 25-meter radius of a specific parcel (ID: 130) and record their ownership rights. These ownership rights include categories such as Informal, Indigenous, Private, or Public. This query is essential for understanding the spatial relationships between parcels and assessing the distribution of different types of land ownership within a specific area.

The earlier version of the LADM was not equipped to handle this type of spatial query effectively, as it lacked the Indigenous and infomal rights. The extended version of LADM overcomes these limitations by incorporating spatial data capabilities and enhanced classification of right types.

Query Execution: Figure 12 shows the query executed in pgAdmin software, with the resulting neighboring parcels identified within a 25-meter radius of Parcel 130. The ownership rights of these parcels are then recorded in a new table, which is displayed on the left side of the figure. On the right side, a visual representation generated in QGIS illustrates the spatial relationship between Parcel 130 and its neighboring parcels, highlighting the different types of land rights. This visualization aids in understanding the proximity and distribution of various ownership categories, supporting local land management and planning efforts.

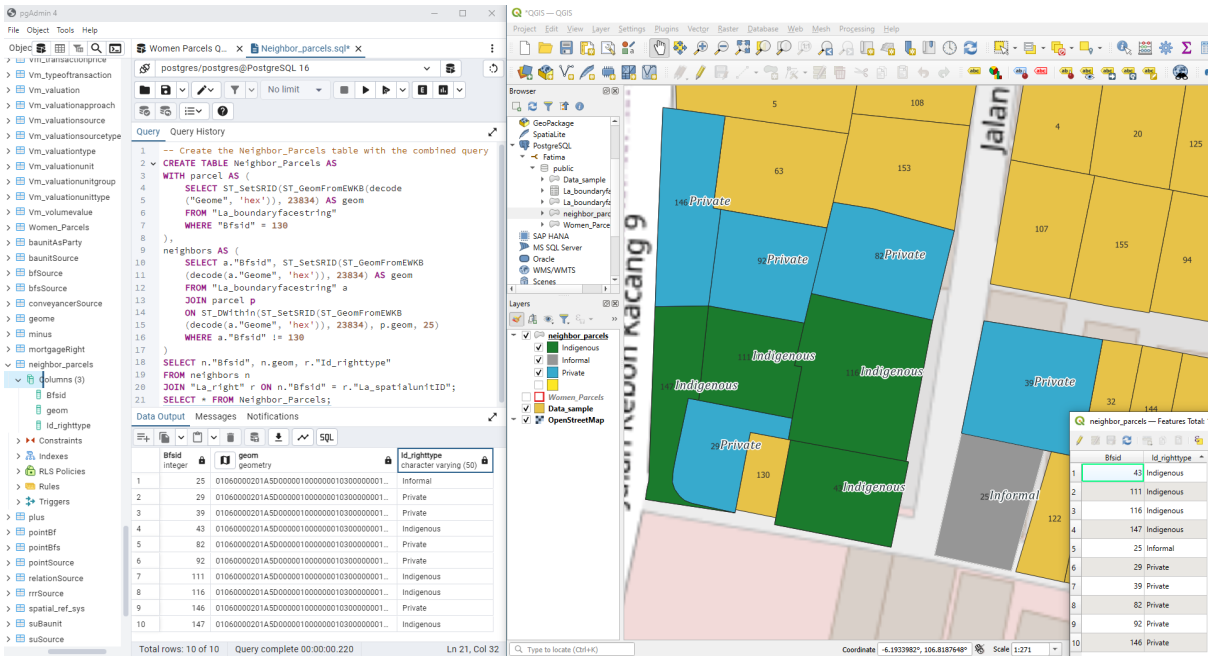

Figure 12. Neighboring parcels query execution in pgAdmin with the distribution and ownership rights displayed in QGIS.

5 CONCLUSION

This study has provided a comprehensive investigation into the enhancement of Land Administration Systems (LASs) by integrating key parameters from global initiatives into the Land Administration Domain Model (LADM). Recognizing that effective LASs are fundamental to economic stability, social equity, and environmental sustainability, this research addresses the pressing need to adapt these systems to meet contemporary global challenges such as population growth, disaster management, and resource scarcity. By extending the LADM to include women rights, indigenous rights, informal rights, and valuation and taxation, the study bridges a critical gap in the current literature, which often overlooks the integration of multiple global trends within a unified framework.

The research was grounded in a systematic methodology that included a continuous review of global initiatives, conceptual and logical model design, and the practical implementation of these extensions within a physical data model. Our study is unique and innovative as it not only presents a conceptual design but also implements a proof of concept through queries and practical application, something that has not been previously implemented in the context of LADM. The findings from this study highlight the significance of addressing spatial and administrative data aspects collectively to align with global sustainability goals, particularly in supporting vulnerable and marginalized communities such as women, Indigenous peoples, and those with informal land rights. The extended LADM framework not only advances theoretical discussions but also offers practical solutions tailored to the unique context of Indonesia, a country facing significant land governance challenges.

A key contribution of this research is the successful implementation of a physical model using PostgreSQL, which effectively operationalizes the extended LADM framework. This step was crucial in demonstrating the feasibility of the proposed extensions and validating their potential to support sustainable land management practices. However, the process of creating the physical model also presented several challenges. For instance, during the conversion of the UML to DDL in Enterprise Architecture (EA) software, extra columns were inadvertently created, requiring additional refinement. Additionally, the software sometimes assigned incorrect primary and foreign keys, leading to issues in establishing accurate relationships between tables. These challenges underscore the complexity of translating a conceptual model into a physical database, highlighting the need for careful validation and modification at each step to ensure the final model accurately reflects the intended design.

The physical implementation also underscores the importance of ongoing enhancement, validation, and integration of LASs to ensure they remain relevant and effective in a rapidly changing global environment. The extended LADM, now capable of addressing complex and nuanced land administration queries, is well-positioned to contribute to more equitable and sustainable land governance practices, both in Indonesia and globally.

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