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# Developing an LADM Valuation Information Model for Mongolia

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**Abstract:** Modern land/property valuation practice requires three-dimensional (3D) valuation, which is crucial to better valuate and assess values of property units. However, conventional land/property valuation systems primarily exist in 2D form, which hinders the accurate valuation of buildings, condominiums and land. The present study introduces the first step toward establishing an advanced land/property valuation system in Mongolia, where it is urgent to meet such requirements. We examined relevant Mongolian geospatial standards and documents, those related to land valuation (i.e., cadastral parcels and buildings), and a valuation information model, which is based on the ISO 19152:2012 Land Administration Domain Model (LADM), with the aim of developing an LADM Valuation Information Model country profile for Mongolia. After the in-depth analysis of the data model of both the LADM Valuation Information Model and the national geospatial relevant standards, we proposed the LADM Valuation Information Model country profile as a conceptual model. Our study results demonstrate how the LADM Valuation Information Model can be adapted to the Mongolian land administration system. Our findings can be used to serve a reference data model to construct 3D land/property valuation systems for efficient valuation of land (e.g., mass appraisal) and taxation purposes.

**Keywords:** Land Administration Domain Model (LADM); ISO 19152; LADM Valuation Information Model; immovable property valuation; Mongolian LADM Valuation Model country profile

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## 1. Introduction

Land administration encompasses the processes of recording and disseminating information about the ownership, value and use of land and its related resources. These processes indicate the determination (i.e., adjudication) of rights and other attributes of the land, the surveys and their description with detailed documentation and the provision of associated information in support of land markets [1]. Land administration systems (LASs) deal with the social, legal, economic and technical frameworks, which facilitate the implementation of land policies in both developed and developing countries. The LAS as a crucial infrastructure supports efficient land markets and land administration as a natural resource toward sustainable development. Operational LAS—which can simultaneously be considered as a multipurpose cadastral system—encompasses land administration functions, including the areas of land tenure (e.g., securing and transferring rights in land), land value (e.g., valuation or assessment and taxation of land and properties), land use (e.g., planning and control of the use of land) and land development (e.g., implementing utilities, infrastructure and construction planning) [2].

While the design of appropriate systems in the areas of land tenure and value should support the establishment of an efficient land market, that in the areas of land-use control and development should lead to an effective land-use management. The integration of efficient land market–land-use management should establish the basis for economic, social and environmental sustainable development [2,3] (Figure 1).

Meanwhile, the International Organization of Standardization (ISO) in 2012 established an ISO 19152 Land Administration Domain Model (LADM) standard to facilitate the implementation of these types of LASs [4]. The LADM yields a conceptual model for land administration and cadastral information concerned with rights, responsibilities and restrictions affecting land (or water) and geometrical (geospatial) components based on people–land relationships. Moreover, LADM provides a reference model that aims to support an extensible basis for the development and improvement of efficient and effective land administration (cadastral) systems based on a model-driven architecture (MDA) and enables involved parties, both within a single jurisdiction and among different jurisdictions, to communicate with the shared ontology implied by the model [4].

To further extend the standard's scope and inclusion of land-related information, the current version of the standard (ISO 19152:2012 LADM, which is regarded as LADM I) was extended to LADM Edition II (LADM II) as a multipart standard, which is currently under review. The LADM II incorporates six parts: land administration fundamentals (Part 1), land registration (Part 2), marine space (Part 3), land valuation (Part 4), spatial planning information (Part 5) and implementations (Part 6) [5]. Figure 1 illustrates the scope of LADM I and II and its relation to the four land administration functions.

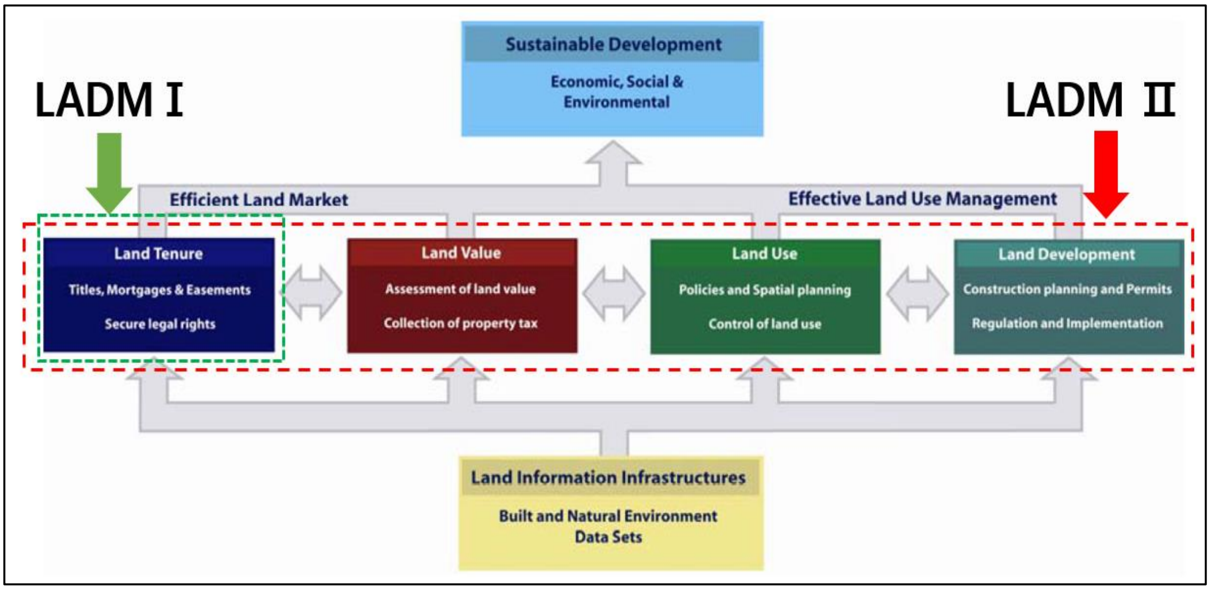


**Figure 1.** Land administration functions considering the scope of LADM I and II. Adapted from [3,6].

The Mongolian cadastral system supports the LAS from the legal and fiscal perspective with the aim of realizing a multipurpose cadastre, which is achieved through the implementation of well-functioning LAS. Recently, the government of Mongolia published the document "Vision 2050" [7], which defines the nation's long-term development policy (vision) by multiple sectors. The document partly deals with issues pertinent to the improvement of LAS the land valuation. Moreover, activities relevant to the land valuation and LADM standard can be derived as follows:

- Establishing a smart integrated land cadastre system and improving the availability of citizen-centered state services.
- Establishing a digital land stock exchange within the competence of the state administrative organization in charge of land issues and creating an integrated system of land and immovable property.
- Creating and developing an integrated system of land cadastre of three and four dimensions (D).

- Establishing a land evaluation system, payment, tax and stock exchange based on artificial intelligence and blockchain technology.
- Promoting a 3D system of land and immovable property based on advanced technology.
- Introducing internationally recognized standards and creating innovations and partnerships to implement effective land governance and management for ensuring economic, social and environmental sustainable development.

Furthermore, strategic implementation of the "Vision 2050" involves three primary phases: Stage I (2021–2030), Stage II (2031–2040) and Stage III (2041–2050). One of the general objectives in the first phase mentions an item closely related to land valuation, stating "introduce an integrated land exchange and multipurpose cadastral system and streamline a state monitoring arrangement of the unified land database and its use" [7].

To address the existing challenges, national geospatial standards addressing systematic and efficient management of geodata in the context of developing LAS have been established in Mongolia. The standards involve 18 independent thematic standards, such as cadastral, land-use management and buildings underpinning spatial data collection, management and dissemination to support national land administration activities [8]. These geospatial standards are crucial to overcome the existing challenges.

However, the current local geospatial standards lack in explicitly modeling and representing land/property valuation information, as can be noted in the upcoming version of the LADM II. These standards only deal with certain relevant land valuation information with their "cadastral parcels" standard [9]. Therefore, it is crucial to adequately represent land valuation information to enable multipurpose cadastral system and the well-functioning of LAS. Moreover, introducing the LADM standard to the local system means enabling the representation of cadastral and land administration information in 3D or 4D, and this fundamental capability of the standard will be extremely essential for implementing the relevant challenges mentioned in the "Vision 2050".

To meet these challenges and requirements, it is crucial to solve the lack of standardization of land/property valuation in the current land administration system of Mongolia.

Therefore, we examined relevant Mongolian geospatial standards and documents, those related to land valuation (i.e., cadastral parcels and buildings) and a valuation information model, which is based on the ISO 19152:2012 LADM, with the aim of developing an LADM Valuation Information Model country profile for Mongolia.

The remainder of this paper is organized as follows: Section 2 presents the related studies in the field. Section 3 describes methods used in this study. Section 4 briefly introduces Mongolian LAS from the perspective of land valuation and national geospatial standards (spatial data infrastructure). Section 5 presents the study results, development of the LADM Valuation Information Model country profile for Mongolia, with its subsections dealing with analysis of the data model of the LADM Valuation Information Model, and national geo-standards. Finally, Section 6 provides a discussion of the study and presents the primary conclusions.

## 2. State of the Art

Land and/or property valuation is the process of assessing the value of a land or–property at a specific time, and it holds great importance in decision-making for land administration. Moreover, land valuation is beneficial in facilitating 3D land valuation, which will help overcome the limitations of conventional cadastral systems in providing mostly two-dimensional (2D) legal and geometric description about property units by better estimating and assessing values of property units [10].

LADM II deals with the land valuation information with its part 4 (land valuation). Moreover, the LADM Valuation Information Model (Conceptual data model) is originally based on the ExtValuation class of LADM I and has been extended further by some researchers. An initial design of the LADM Valuation Information Model (Fiscal extension module) was developed for specifying database values in immovable property valuation and taxation [11]. Immovable property valuation-related concepts, including valuation object and activity, were developed [12]. Subsequently, some classes and code lists of LADM-based Valuation Information Model were updated for the specification of inventories and databases used in the valuation of recurrently levied immovable property taxes [13].

The purpose of the LADM Valuation Information Model is to define the semantics of valuation registries, which is held by public authorities, and specify its relationship with other land administration registries and databases [5,10]. In particular, the LADM Valuation Model conceptual schema provides the recording of data concerning parties involved in valuation practices, valuation units that are objects of valuation (e.g., cadastral parcel, building and condominium) and their features, and input and output data used and produced based on single and mass appraisal processes [5,11,13].

LADM Valuation Model can be used to construct information systems for immovable property valuation and taxation; additionally, it offers a data exchange option. Immovable property valuation includes the identification of properties, assessment of properties through single or mass appraisal procedures, recording transaction prices, generation and representation of sales statistics and appeals [11,13,14]. Figure 2 demonstrates classes of the LADM Valuation Information Model in green with their association to the classes of the LADM I (in gray).

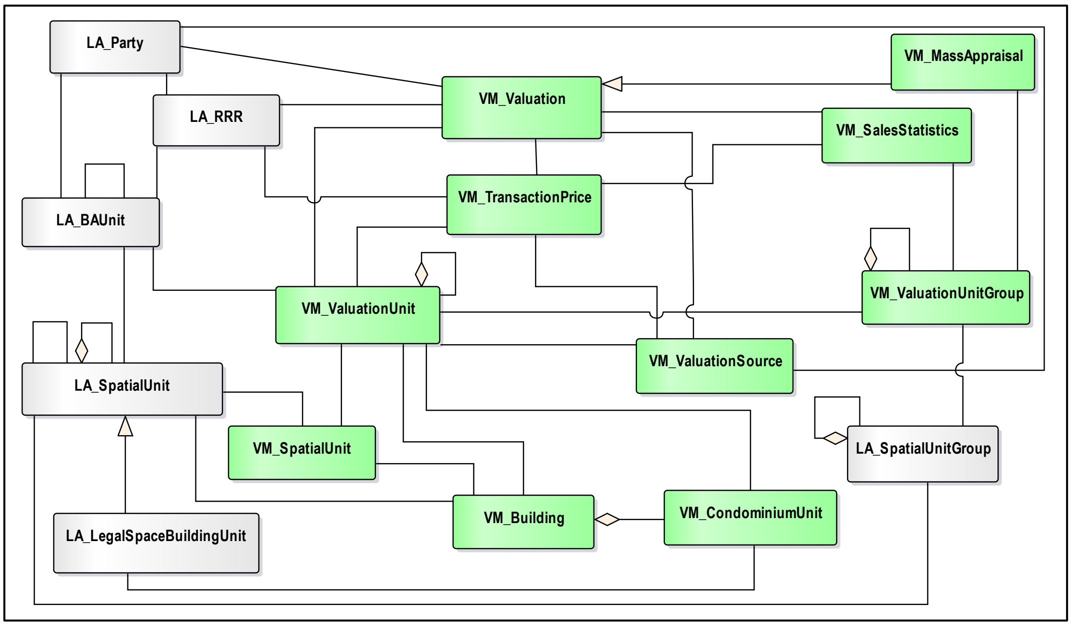


**Figure 2.** LADM Valuation Information Model and its relationship to LADM I. Adapted from [14].

Implementation of LADM II Valuation Information Model and its applications have been identified in several countries. In the case of Turkey, earlier valuation models were developed as a country profile of LADM Valuation Information Model covering immovable property valuation conducted for taxation purposes, i.e., annually levied recurrent property taxes (e.g., land or building tax) in Turkey [15]. Subsequently, the LADM Valuation Information Model of Turkey was evaluated by populating the database on prototypical basis [16]. More recently, this model has been updated to address the Turkish case with the inclusion of more classes and attributes with some real-world application using prototype development [14].

Moreover, the Netherlands country profile of the LADM Valuation Information Model was developed based on the public property valuation system and practices and relevant data sets and sources for property valuation. It covered transaction prices, parties and market analysis information relevant to valuation procedures [17].

In this direction, Tomić et al. further proposed an international valuation information model extending the ISO 19152:2012 LADM for identifying the semantics of valuation registries maintained by public authorities in Croatia. They assessed the availability of existing data from land and other public authoritative registries as a basis of mass property valuation and suggested the application of UML use case and class diagrams to facilitate possible data integration [18].

Furthermore, the Serbian LADM country profile was extended to cover property valuation information. The valuation model was developed based on the previously developed Serbian country profile while considering national laws and bylaws. The study presented examples of specific valuation procedures and expected that the proposed model would be further used for single and mass valuation [19].

As evident from the literature, some countries have already begun to review application of the LADM Valuation Information Model considering their local needs–systems. Therefore, considering the current requirements and needs of cadastral system advancement, the present study examines how LADM Valuation Information Model can be applied to the Mongolian land administration system.

## 3. Methodology

According to the LADM standard, the actual use of the LADM requires the implementation of an application schema, i.e., a country profile. To implement it under test, the association/relationship (or mapping) between the LADM and data model needs to be determined [4]. Further, to enable this procedure, we explored the relevance of national geospatial standards, particularly to a land valuation, and LADM Valuation Information Model. For national geospatial standards (i.e., geo-standards), we employed the data model of primarily two standards, namely, cadastral parcels [9] and building construction [20], with their dependent standards, i.e., boundary [21], address [22] and geographical name [23] as an input to the country profile. Additionally, for the LADM Valuation Information Model, we identified and used 10 Unified Modeling Language (UML) classes along with their datatypes and code lists based on the relevant literature. Therefore, based on the in-depth analysis of data model of both LADM Valuation Information Model and national geospatial relevant standards, we identified the corresponding classes from each data model. This process is also referred to as a schema matching technique [18], which involves semantic mapping between the classes of the two data models and is widely used in conceptual modeling. The mapping of data models was done based on manual process owing to having a relatively few classes and attributes in our study data. Based on these processes, we aimed to develop an LADM-based Valuation Information Model country profile for Mongolia on the conceptual level in the UML class diagrams using MDA supported tools, i.e., Enterprise Architect.

## 4. Land Administration System in Mongolia

### *4.1. Current State of Land Valuation*

In Mongolia, the legal foundations for cadastre have been well-established to provide land tenure security and basis of taxation. According to the Law on Cadastral Mapping and Land Cadastre (Cadastral law) [24], cadastral activities primarily consist of two parts, recording of a unified land database and state land registration. The unified land database is divided into six major categories: agricultural land; land of cities, villages and other settlements; land under roads and networks; land with forest resources; land with water resources; and land for special needs [25]. Recording of the unified land database involves activities of cadastral mapping, cadastral surveying, assessment of land quality and economic assessment of land.

Regarding land valuation, land quality assessment encompasses activities involving the compared assessment of land using the indices to examine its condition and quality, and economic assessment of land encompasses activities involving the compared assessment of land using the indices to examine the potential of land and economic return. Moreover, land registration activities comprise cadastral mapping and registration of land rights. Figure 3 describes the overall cadastral activities that eventually contribute to the construction of national land information system and database.

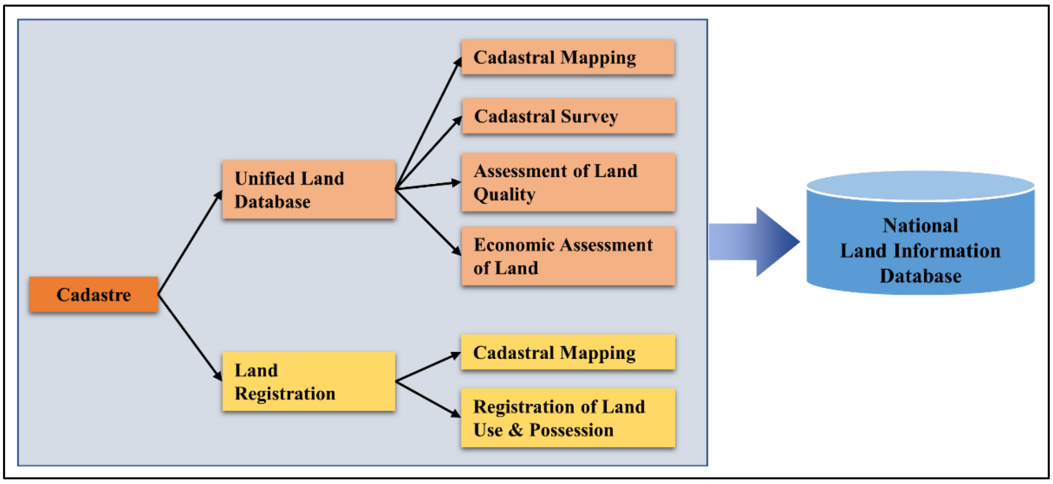


**Figure 3.** Cadastral activities in the context of land administration.

In 1997, Mongolia passed the Law on Land Fees [26], which regulates levying land fees on citizens, business entities and organizations for possessing and using state-owned land and paying the fees to the state budget. Primarily, the act is closely related to land valuation in terms of basic land evaluation. Basic land valuation is determined by the government and is settled on the characteristics of land, i.e., land grade, location, utility, socio-economic and environmental condition and land-use purpose [26]. Furthermore, some relevant land fee (e.g., land possession or use) is determined based on basic land valuation.

Furthermore, in June 2018, methodical instructions for land economic assessment were approved by the government resolution No.181; methods determining land valuation zones, grades (regions), basic valuation of land and the methodical instructions for land payment amounts were approved by the government resolution No.182. The resolution No.181 has an appendix of methodical instructions for land economic evaluation [27], which consists of 15 articles covering provision of general methodological flow of evaluating each major land category from its preparation stage to the last primary stage.

Based on these legal frameworks, the land assessment system was developed and implemented as a part of the development of the cadastral assessment system (i.e., Computer Assisted Mass Appraisal, CAMA) for land payments and taxation. The system can calculate each of six major categories of the unified land classification (database) using the factors affecting the valuation and land market price automatically [28]. Additionally, it has been completely implemented across the country—21 provinces, 330 sums (administrative subunit), capitals and districts. The system utilized 14 factors from engineering, environmental and social infrastructures affecting land price and a total of 21,738 parcels in cities, villages and other settlements were evaluated for land market; a mass valuation was conducted for 880,504 parcels using the obtained results [8]. Moreover, a multiple regression analysis (MRA) was conducted to verify its applicability to the model of the CAMA system in Mongolia [29].

### *4.2. Overview of National Geospatial Standards (Spatial Data Infrastructure)*

The country involvement and selection by one of the six countries in the project of "Strengthening geospatial information management in developing countries toward implementing the 2030 Agenda" [30], which is in line with the Integrated Geospatial Information Framework by United Nations Initiative on Global Geospatial Information Management, provided major motivation to implement the national geoportal. The national geoportal system ensures interorganizational coordination and generates and utilizes spatial data in accordance with unified standards to ensure no overlapping budget, innovation and reliability of information [31].

Along with the geoportal and project implementation, 18 basic spatial data models (geo-standards) for spatial data collection, management and efficient use were defined. The purpose of the national standards was to completely define the structure, content and technical specifications of the database to be followed for the entry and formation of location-based spatial data infrastructure (SDI) into the integrated information system and regular updating and information exchange. Currently, all data related to national standards are being collected and processed according to the standards and disseminated through geoportals [8].

Data model of the standards is defined using the UML class and was approved by the government and Department of Standards and Metrology of Mongolia in 2021. The specification of standards is derived from the INSPIRE (Infrastructure for Spatial Information in Europe) and ISO TX 211 (ISO/TC 211-Geographic information/Geomatics) ISO 19100 series standards and requirements; moreover, national relevant standards, documents (norms, rules, regulations) and content and classification of SDI based on the UML were also considered [8].

The geoportal system is linked to the Integrated Management System of Unified Land Database, which is introduced to all the administrative units of the country, to exchange spatial data and information through the database and services to create a unified database [8]. Figure 4 demonstrates an overall architecture of the geoportal with its relation to SDI and unified land database.

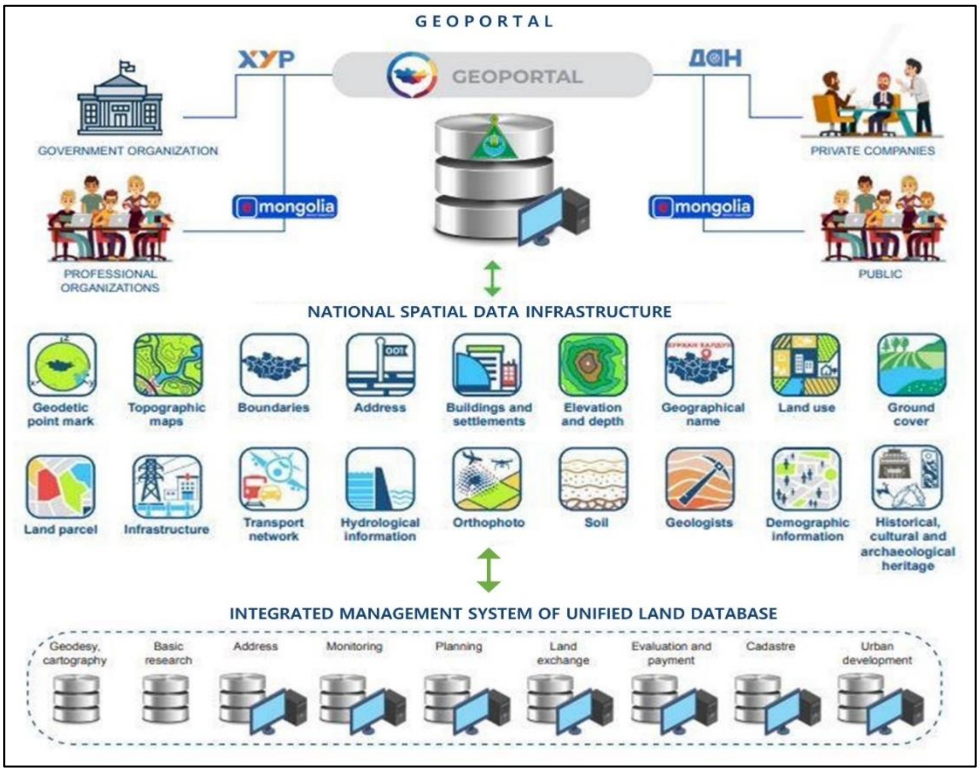


**Figure 4.** National geo-standards and their relation to geoportal and SDI. Adapted from [32].

## 5. Developing the LADM Valuation Information Model for Mongolia

The LADM Valuation Information Model country profile was developed through three parts, analysis of both the UML classes of the LADM Valuation Model and national geo-standards and development of the country profile based on these analyses. In particular, this section first deals with the LADM data model, which is the primary model on which the country profile is based; the second part copes with the national geo-standard data model, which is a sub-model supporting the LADM Valuation Information Model country profile; and lastly, the third part presents the developed country profile (conceptual data model to be implemented afterwards), which comprises 20 classes—each 10 classes from the LADM and national geospatial standards.

### *5.1. Analysis of Classes of the LADM Valuation Information Model*

In this study, we analyzed and organized the 10 classes of LADM Valuation Information Model based on previous studies [5,10,11,14], which are described as follows: VM_ValuationUnit class provides information about objects of valuation unit for fundamental recording of land and improvements (buildings), which can only be land, building or land and improvements together as land or condominium property. It consists of three code lists: VM_ValuationUnitType, which specifies possible types of valuation units such as parcels, buildings and property; VM_NeighborhoodType, which is used to indicate where the valuation unit is located (e.g., urban and rural); and LA_UtilityNetworkType, which originally originated from the LADM I that represents utility services available to valuation units (e.g., gas, electricity and heating).

VM_ValuationUnitGroup class is for grouping or zoning valuation units, such as administrative, economic and market zones that indicate similar characteristics or functions of valuation units (e.g., commercial, residential and agricultural). VM_SpatialUnit class represents land as a subject of valuation, e.g., a cadastral parcel and demonstrates characteristics for current and future land use. VM_Building and VM_CondominiumUnit classes represent physical information of buildings and building parts and condominium units with their characteristics in valuation activities. VM_Building demonstrates characteristics relating to specifications of buildings, such as construction material, energy performance and heating system. Different types of building use, i.e., residential, office and industrial are registered according to the BuildingUseType code list. The VM_Building may represent buildings that are considered as complementary parts of parcels but may be valued separately from the parcels on which they are present. Moreover, it may represent a building enclosing condominium units. The VM_Building consists of zero or more condominium units. The purpose of the class VM_CondominiumUnit is to record the primary physical condominium unit information, such as accessory parts (e.g., garage, shop), floor number, rooms and shares in joint facilities.

The VM_Valuation class is an improved form of the ExtValuation external class of LADM I and specifies output data yielded during a valuation process. The class demonstrates attributes, such as value type, assessed value, valuation purpose and approach, and status of appeals to valuation. Notably, the valuation approach characteristic includes VM_ValuationApproach code list that deals with three primary types of valuation methods, namely, sales comparison, income and cost methods dominant in practice, with each method involving separate data types. In particular, VM_SalesComparisonApproach includes contents of adjustments of time, location and physical ones with estimated value. The VM_CostApproach covers cost-related characteristics, such as cost type (e.g., replacement or reproduction cost), cost-related attributes, chronological and effective age of building and obsolescence. The VM_IncomeApproach involves income information, such as gross, effective and net income and operating expenses and capitalization rates characteristics.

VM_MassAppraisal class represents mass appraisal-related information and inherits from VM_Valuation class. It demonstrates characteristics, such as mathematical models, sample sizes and mass appraisal analysis types (e.g., multiple regression, artificial neural network, time series). Moreover, it presents a performance indicator characteristic described in VM_MassAppraisalPerformance datatype, which contains the date of performance analysis, sample size, appraisal level, measures for appraisal level (e.g., mean and median) and the measure of appraisal uniformity (e.g., coefficient of dispersion and variation). VM_TransactionPrice specifies the information related to property transactions, including the date of contract or declaration, transaction price and type of transaction (e.g., open market or forced sale, inheritance, family transfer). Moreover, transaction information recorded in a land registration database can be generated and updated periodically based on the information of contracts or declarations by the involved parties (i.e., buyer and/or seller) in transactions. VM_SalesStatistic class represents sales statistics produced through the analysis of transaction prices for monitoring price trends. Such analysis can be based on spatial (e.g., condominiums in a municipality) or thematic clusters (e.g., condominiums used for residential purposes). The class VM_SalesStatistic contains characteristics that indicate calculated average transaction prices per square meter of valuation units, price index value, base price index value and their exact dates.

To record property valuation-type sources (e.g., valuation report, sale contract and rental contract), they are documented within the class VM_ValuationSource, which inherits from the class LA_Source. LA_Source class includes acceptance, document availability status, life span stamp information and other necessary characteristics required for the recording (c.f. real-world time—valid time) of the source. Moreover, exceptionally, the VM_ValuationSource is the only class that does not inherit from the VersionedObject class of LADM, with all valuation model classes inheriting Versioned Object class. Figure 5 illustrates LADM Valuation Model core classes with their attributes, as described in this section. Additionally, Figure 9 presents data types and code lists as a part of the country profile, and some attributes are added accordingly.

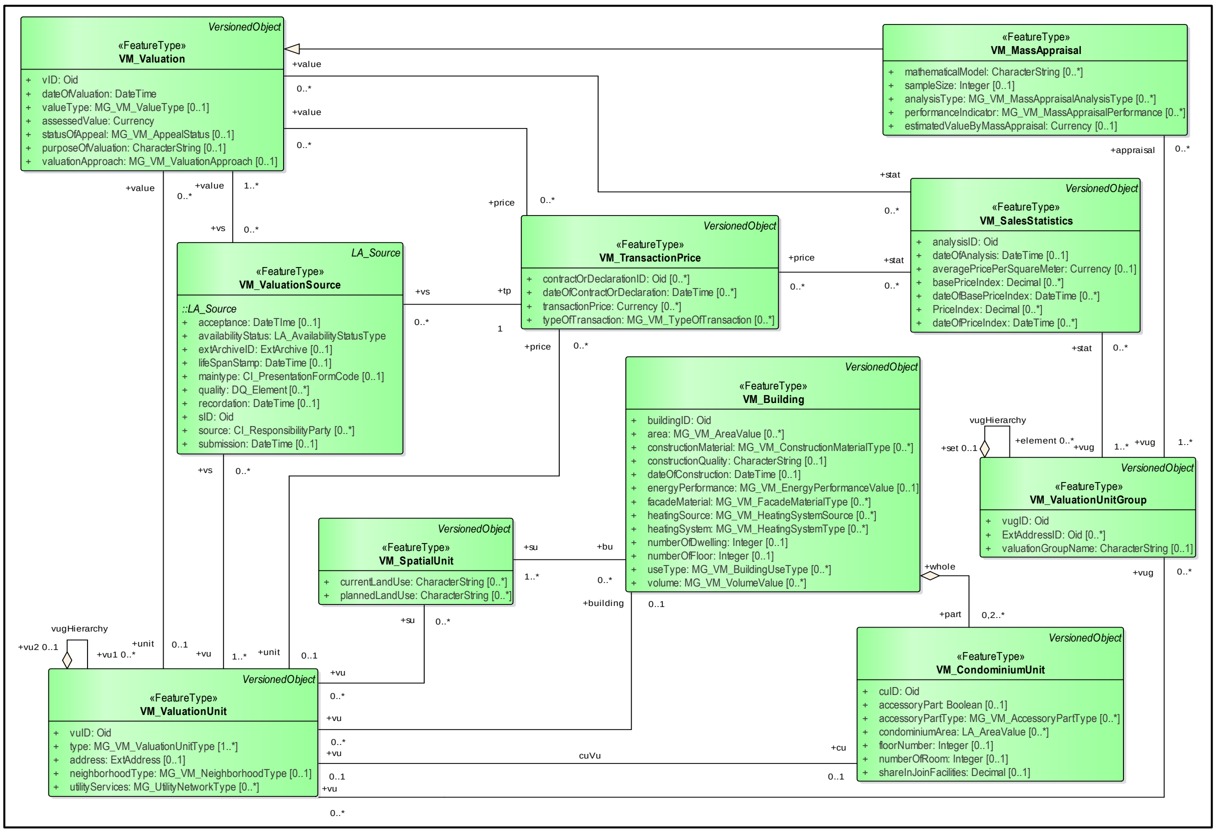


**Figure 5.** LADM Valuation Information Model.

## *5.2. Analysis of Data Model of National Geospatial Standards*

In this study, data models of national standard, cadastral parcels and building construction are considered for developing the Mongolian LADM Valuation Information Model country profile. Both these standards are dependent on other existing standards; in particular, they are commonly dependent on address and geographical name, but the cadastral parcels are additionally dependent on boundary.

All the standard models consist of classes, data types and code lists. Cadastral parcels include six classes and datatypes with their corresponding code lists. Figure 6 presents the

UML data model of the cadastral parcel standard, and their brief description is provided in Table 1.

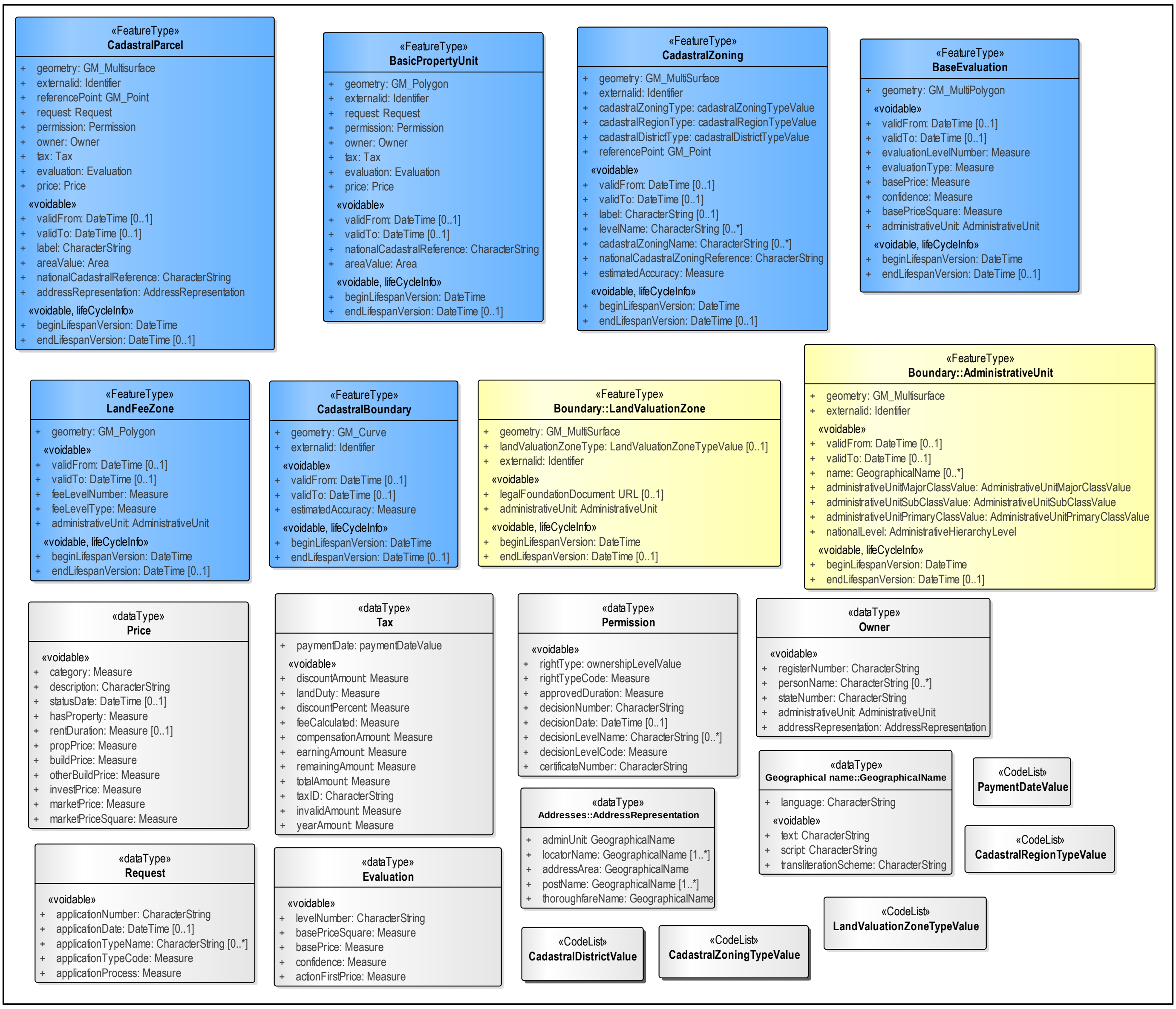


**Figure 6.** Data model of cadastral parcels standard.

Cadastral parcel standard includes classes of CadastralParcel, BasicPropertyUnit, CadastralZoning, BaseEvaluation, LandFeeZone and CadastralBoundary. All classes of cadastral parcels include common attributes of begin and end LifespanVersion to record changes in data.

CadastralParcel class expresses an estate (parcel), object or a part of it, with an identification number and certain boundaries, with the same owner, user, possessor and land-use purposes. BasicPropertyUnit class represents basic property unit, which is the fundamental unit of property rights, i.e., a land allocated to enterprises, organizations and citizens for land use and possession according to the land law. It consists of one or more contiguous parcels or geographically separate ones. CadastralParcel and BasicPropertyUnit have similar characteristics, and their main attributes include label (parcel address), reference point (corner points), area, national cadastral reference (official parcel ID) and address representation. Moreover, these classes contain common datatypes of request, permission, owner, tax, evaluation and price.

**Table 1.** Short description of UML class, datatype and code list of the cadastral parcel standard.

| No. | Class Name | Stereo Type | Description | Standard |
|---|---|---|---|---|
| 1 | CadastralParcel | Feature type | A piece of land or a lot that has an owner | Cadastral |
| 2 | BasicPropertyUnit | Feature type | A basic unit of ownership established by law | Cadastral |
| 3 | CadastralZoning | Feature type | Possessors, users and owners have common land use purposes, and land use type is restricted zone. | Cadastral |
| 4 | BaseEvaluation | Feature type | Land basic valuation | Cadastral |
| 5 | LandFeeZone | Feature type | Land payment zone | Cadastral |
| 6 | CadastralBoundary | Feature type | Boundary containing parcels that do not overlap each other | Cadastral |
| 7 | LandValuationZone | Feature type | Determine the basic price of land and the amount of payment | Boundary |
| 8 | AdministrativeUnit | Feature type | The country and self-administered territorial units | Boundary |
| 9 | Request | Data type | Application information | Cadastral |
| 10 | Permission | Data type | Rights information | Cadastral |
| 11 | Owner | Data type | Owner and possessor information | Cadastral |
| 12 | Tax | Data type | Payment information of a parcel | Cadastral |
| 13 | Evaluation | Data type | Parcel evaluation information | Cadastral |
| 14 | Price | Data type | Market price information of a parcel | Cadastral |
| 15 | AddressRepresentation | Data type | All address elements necessary to identify spatial objects | Address |
| 16 | GeographicalName | Data type | Geographical names | Geographical |
| 17 | CadastralZoningValue | Code list | Classification of cadastral zones | Cadastral |
| 18 | CadastralRegionValue | Code list | Classification of cadastral regions | Cadastral |
| 19 | CadastralDistrictValue | Code list | Classification of cadastral districts | Cadastral |
| 20 | PaymentDateValue | Code list | Classification of payment term/period | Cadastral |

CadastralZoning is a verbatim cadastral zoning that includes a zone with owners, possessors and users with the common land-use type where a certain use of land is restricted. This class has several characteristics with some code lists including cadastralZoningType (general classification of cadastral zoning), cadastralRegionType (second classification of cadastral zoning) and cadastralDistrictType (third/detailed classification of cadastral zoning). BaseEvaluation class denotes base evaluation of land, and main attributes of this class include levelNumber (land base price zone), levelType (type of land base price zone), basePrice (land price per square meter), confidence (initial auction price indicator) and basePriceSquare (first auction price per square meter of land).

LandFeeZone class represents a zone for land fee payment, and its primary attributes are levelNumber (type of land fee zone), AdministrativeUnit attribute, specifically indicating AdministrativeUnitSubClassValue code list, which denotes administrative subunits such as a sum (Mongolian provincial administrative subunit) and duureg (equals/equivalent to city districts) in the Boundary standard.

CadastralBoundary class is verbatim a cadastral boundary that contains parcels, which are represented without overlapping each other. This class uses GM_Curve as geometric value and has characteristics such as estimated accuracy to be measured.

LandValuationZone class from Boundary standard expresses land valuation zone to determine the basic price of land, amount of payment and land benefits. This class has landValuationZoneType code list, which represents a classification of land assessment zoning with zone numbers, zone names and administrative (sub-)units across the country.

AdministrativeUnit class from Boundary standard denotes state and self-administered administrative territories unit (country, province, capital, sum, district's border line and boundaries of the bag (subunit of sum) and khoroo (administrative subunit of duureg). This class has special characteristics: administrativeUnitMajorClassValue code list, which notes administrative and territorial units at the level of provinces and capitals (major level) based on "MNS 5641-1: 2006" national standard; administrativeUnitSubClassValue code list, which describes administrative and territorial units at the level of sum and districts (minor level) based on "MNS 5641-2: 2006" national standard; and administrativeUnitPrimaryClassValue code list, which denotes administrative and territorial units at the level of bag and khoroo (primary level) based on "MNS 5641-3: 2006" national standard. Moreover, nationalLevel attribute, which expresses administrative and territorial unit levels, has AdministrativeHierarchyLevel code list.

Two external datatypes used in Cadastral parcels are AddressRepresentation and GeographicalName. AddressRepresentation from Address standard serves the purpose of representing address of a spatial object that is used in external databases in a readable manner. It uses GeographicalName value from Geographic name standard for its type. Further, GeographicalName datatype is used for expressing verbatim geographical name with characteristics such as language, text and script with their specification for describing geographic names. Code list values are not depicted in Figure 6 owing to its length and include CadastralZoningTypeValue, CadastralDistrictValue and LandValuationZoneTypeValue; rather, these are referred to the original document [9].

The building construction standard mostly includes classes of building-related information rather than construction. Besides, the standard consists of packages of basic building information including UML classes, datatypes and code lists; with additional expression of geometry to the basic building information, 2D and 3D building packages are distinguished. Moreover, 3D building package includes classes for representing building elements such as wall, door and window. Therefore, we used classes of basic building package, namely Building, BuildingPart and BuildingAndBuildingUnitInfo, with one additional class, BuildingUnit, from 2D buildings. Figure 7 presents UML classes, code lists and datatypes of building construction standard, and their brief description is provided in Table 2. The Building is the main class of the building and construction standard and is defined in the standard as "a covered structure placed on above- or below- ground for the placement of people, animals, things or for use in the production of goods".

**Table 2.** Short description of UML class, datatype and code list of building construction standard.

| No. | Class Name | Stereo Type | Description |
|---|---|---|---|
| 1 | Building | Feature type | Above and underground (inhabitable and uninhabitable) facilities |
| 2 | BuildingPart | Feature type | Additional part of a building |
| 3 | BuildingUnit | Feature type | Indivisible, independent and separated from outside and public space (not from another building unit) |
| 4 | BuildingAndBuildingUnitInfo | Feature type | Additional attributes of buildings, building parts and building units |
| 5 | EnergyPerformance | Data type | Energy consumption of buildings or building units |
| 6 | EngineeringInfrastructure | Data type | Energy, water and sewage, roads facilities, transport and communication networks |
| 7 | OfficialValue | Data type | Official values and associated metadata |
| 8 | DateOfEvent | Data type | Construction started and completed date |
| 9 | HeightAboveGround | Data type | Height of the building measured or given |
| 10 | OfficialArea | Data type | Areal classification of buildings, building parts and building units |
| 11 | CurrentUse | Data type | Current use of the building |
| 12 | ExternalReference | Data type | Other information systems containing any information related to spatial objects |
| 13 | FireResistanceValue | Code list | Fire resistance |
| 14 | ConditionOfConstructionValue | Code list | Condition of the building |
| 15 | ConstructionInfrastructureTypeValue | Code list | Type of construction complexity |
| 16 | BuildingNatureClassValue | Code list | Initial purpose of the building with respect to main category |
| 17 | BuildingNatureSubClassValue | Code list | Initial purpose of the building by subcategory |
| 18 | MaterialOfStructureValue | Code list | Construction materials |
| 19 | OfficialAreaReferenceValue | Code list | Type of building area |
| 20 | PropertyTypeValue | Code list | Type of property |

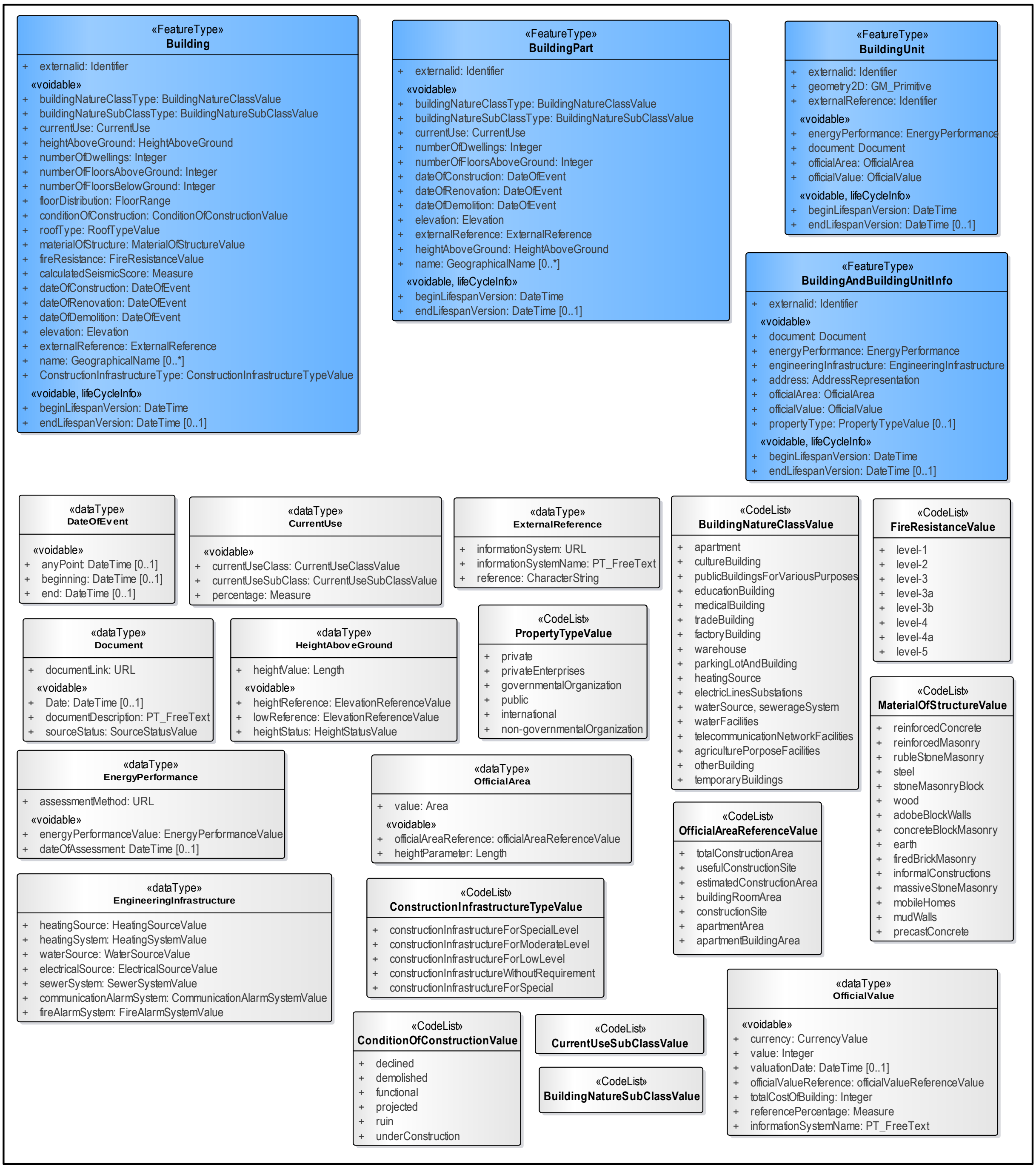


**Figure 7.** Basic data model of building construction standard.

Building class includes various attributes describing characteristics of a building. Therefore, it has characteristics, such as external reference information with ExternalReference datatype; building nature class types—buildingNatureClassType, which notes the major category of the initial purpose of the construction by BuildingNatureClassValue code list; buildingNatureSubClassType, which remarks the minor category of the initial purpose of the construction by BuildingNatureSubClassValue code list; height above ground character noting height reference values with its corresponding datatype; condition of construction indicating the status quo of construction and is expressed in ConditionOfConstructionValue code list; material of structure describing types of building structure materials with MaterialOfStructureValue code list; fireResistance indicated fire resistance values with FireResistanceValue code list; construction infrastructure type showing type of construction complexity with its corresponding code list ConstructionInfrastructureType-Value; and GeographicalName value for the building name.

BuildingPart class is used for recording an additional part of the building, which possesses the same but less attributes than Building class. It represents a subdivision of a building (i.e., building unit), which is indivisible; independent; can be sold, leased, bequeathed separately; and has its own space and is separated from outside and public space (not from another building unit). It demonstrates characteristics, such as energyPerformance, which indicates energy performance indicating energy efficiency of the building; building part; building unit; and document which uses Document datatype; and the same for officialArea OfficialArea datatype, and officialValue OfficialValue datatype.

BuildingAndBuildingUnitInfo class is an abstract spatial object type for registering additional characteristics of buildings, building parts, and building units. Therefore, it demonstrates characteristics such as engineering infrastructure expressing heating, water, electricity, and sewer with its code list EngineeringInfrastructure; property type remarking a type of property, i.e., private, public by its PropertyTypeValue codelist. Codelist values, those are not described in Figure 7 owing to its length, such as CurrentUseSubClassValue and BuildingNatureSubClassValue are referred to the original document [20].

### *5.3. LADM Valuation Information Model Country Profile*

The first mention regarding the valuation-related model for Mongolia was made in the country profile, which was developed as one of our earlier works [33], wherein the LADM country profile was extended by ExtValuation & ExtTaxation classes; however, classes and attributes were not sufficient to adequately represent the valuation model of the country. As the Valuation information model is an extension of the LADM I, a part related to the LADM I is dealt with in our previous works [33,34], and readers are specially referred to the recent one [35]. Thus, herein, only Valuation Information Model-related classes are considered and described for generating the country profile.

According to the LADM standard, an actual use of the LADM requires an application schema, that is, a country profile. To examine the application schema or the country profile under test, presentation of a linked (inherited) structure between the LADM and data model of the country profile, or a mapping of elements between each data models (classes), is required [4]. Therefore, based on the identification of the corresponding classes from the LADM Valuation Information Model and classes from national geo-standards (cadastral parcels and building construction), we modeled and developed the LADM Valuation Information Model country profile for Mongolia. As the valuation information model is the primary model, classes from the local standard to the country profile are modeled as a supporting (sub) model to the valuation information model. In the proposed model, the "MG_" prefix denoting Mongolia was used for presenting country profile.

Classes of LandFeeZone, BaseEvaluation and LandValuationZone were modeled as an association relationship to the MG_VM_Valuation class. In general, VM_Valuation class specifies output data produced by a valuation process. When the valuation is performed for taxation purposes, characteristics of MG_VM_LandFeeZone, i.e., land fee zone, can be referenced. MG_VM_Valuation can have zero or one [0 . . . 1] MG_VM_LandFeeZone. Land valuation-related data can be produced by referencing to MG_VM_BaseEvaluation class, where basic price for land (e.g., one square meter) can be considered. Moreover, valuation for basic price of land can be performed using corresponding attributes of MG_VM_BaseEvaluation. Considering the relationship, zero or more [0 . . . *] MG_VM_Valuation is associated to zero or one MG_VM_BaseEvaluation.

LandValuationZone is used for determining land valuation zone to define the basic price of land and amount of payment. When valuating land for basic price or land fee, payment zero or one MG_VM_LandValuationZone class can be referenced. It specifies land valuation zone where a specific code is provided as a valuation zone type.

MG_VM_LandValuationZone class is associated with MG_SpatialUnit class, which is not presented in the profile but in the LADM I profile.

MG_VM_ValuationUnit is a key class in the model. VM_ValuationUnit class is responsible for recording units of the valuation, such as parcels, buildings or combinations of them. Four of the Mongolian cadastral classes, including CadastralParcel, BasicPropertyUnit, BuildingUnit and BuildingAndBuildingUnitInfo, are modeled to this class. MG_VM_CadastralParcel and MG_VM_BasicPropertyUnit are related to only land and parcels (no improvements), whereas MG_VM_BuildingUnit and MG_VM_BuildingAndBuildingUnitInfo are concerned with building information for valuation activities. Considering their relationship, zero or one cadastral parcel and basic property unit can be referenced when the valuation unit is set to a parcel. Whilst zero or one building unit and building and building unit information can be referred when a valuation unit is selected as a building (improvements). Additionally, classes of CadastralParcel, BasicPropertyUnit and BuildingUnit are also linked to the MG_VM_SpatialUnit class. They are represented in one or more [1 ... *] spatial unit, which is associated to the LA_SpatialUnit that could support 2D or 3D representation of spatial units.

VM_Building class is used for providing physical information of buildings and building parts and condominium units required in valuation activities. Both MG_Building and MG_BuildingPart classes specify building-related attributes in detail, such as building use types and purposes. MG_Building and MG_BuildingPart classes corresponded directly to the VM_Building class. Thus, MG_VM_Building and MG_VM_BuildingPart classes are modeled as subclasses of VM_Building class by inheriting all its attributes. Moreover, duplicating attributes of these classes to the MG_VM_Building class were removed. When valuating buildings, these classes can be referenced.

MG_VM_CadastralZoning is linked to the VM_ValuationUnitGroup class, which groups together valuation units by its similar characteristics or functions. MG_VM_ValuationUnitGroup references zero or more MG_VM_CadastralZoning, which contains characteristics, such as cadastral zoning types (e.g., region, district). In addition to the LADM Valuation Information Model, valuation units can be grouped together by their cadastral zoning. MG_VM_CadastralZoning is represented in spatial units and can be directly related to MG_SpatialUnit, which is not explicitly expressed in the model.

Overall, this section described the analysis of each class of the LADM Valuation Information Model and classes related to cadastre and buildings from national geo-standards. Based on this procedure, we developed and proposed the Mongolian LADM Valuation Model country profile. Figure 8 demonstrates our proposed model where newly added valuation-related classes are represented in blue and existing valuation model classes in green.

Considering the code list of the country profile, we adapted all code lists of the valuation information model, which was described in [13] to the country profile. However, some code lists have been adapted with some additional characteristics where necessary. In particular, some valuation unit types, e.g., apartment, bungalow and house were added to MG_VM_ValuationUnitType code list. Similarly, code lists of MG_VM_NeighborhoodType, MG_VM_AccessoryPartType, MG_VM_BuildingUseType and MG_VM_TypeOfTransaction were expanded. Moreover, existing code lists of the data model of cadastral parcels, building construction and other relevant geo-standards remained the same for the proposed model (refer to Figures 6 and 7). All code lists have "MG_" prefix with the same meaning as in the proposed model. Figure 9 presents code lists (in gray) and datatypes (in yellow) of the LADM Valuation Information Model country profile.

Based on our developed model, we created a UML object-instance diagram to demonstrate how our proposed country profile valuation model can be used in real case. Figure 10 presents a UML object-instance diagram for recording the process of mass appraisal-valuation as an example.

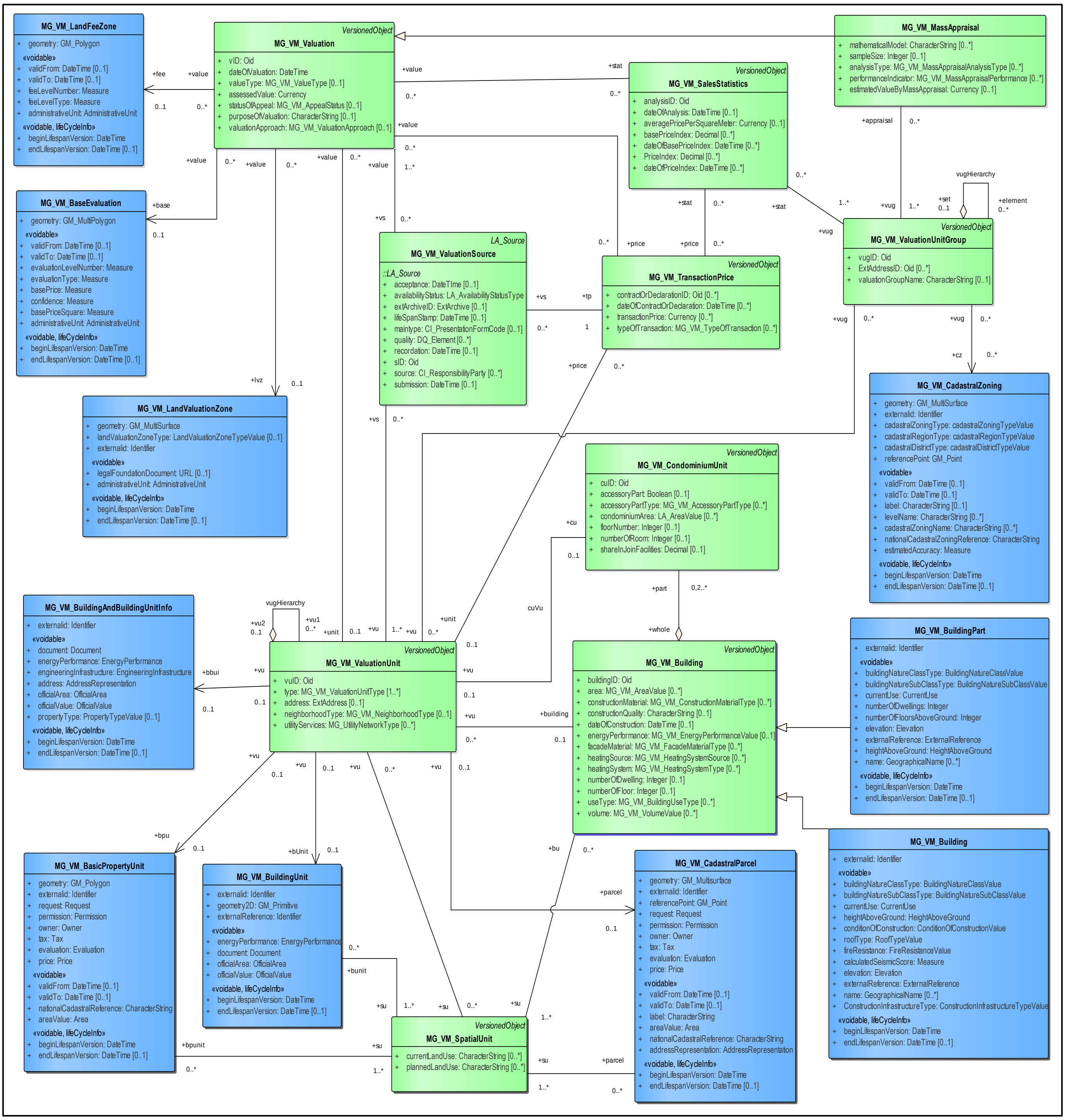


**Figure 8.** Mongolian LADM Valuation Information Model Country Profile (with basic valuation classes in green and newly added/extended classes in blue).

In Figure 10, MG_Party represents a person who is participating in the valuation process as a surveyor (actuator). In this case, valuation is done for appraising value of land price for per square meter. A valuation unit is set as a parcel in an urban area, and the parcel is provided by engineering utilities. Moreover, the valuation unit—parcel—is supported by the spatial unit, and its current and future land-use type is residential.

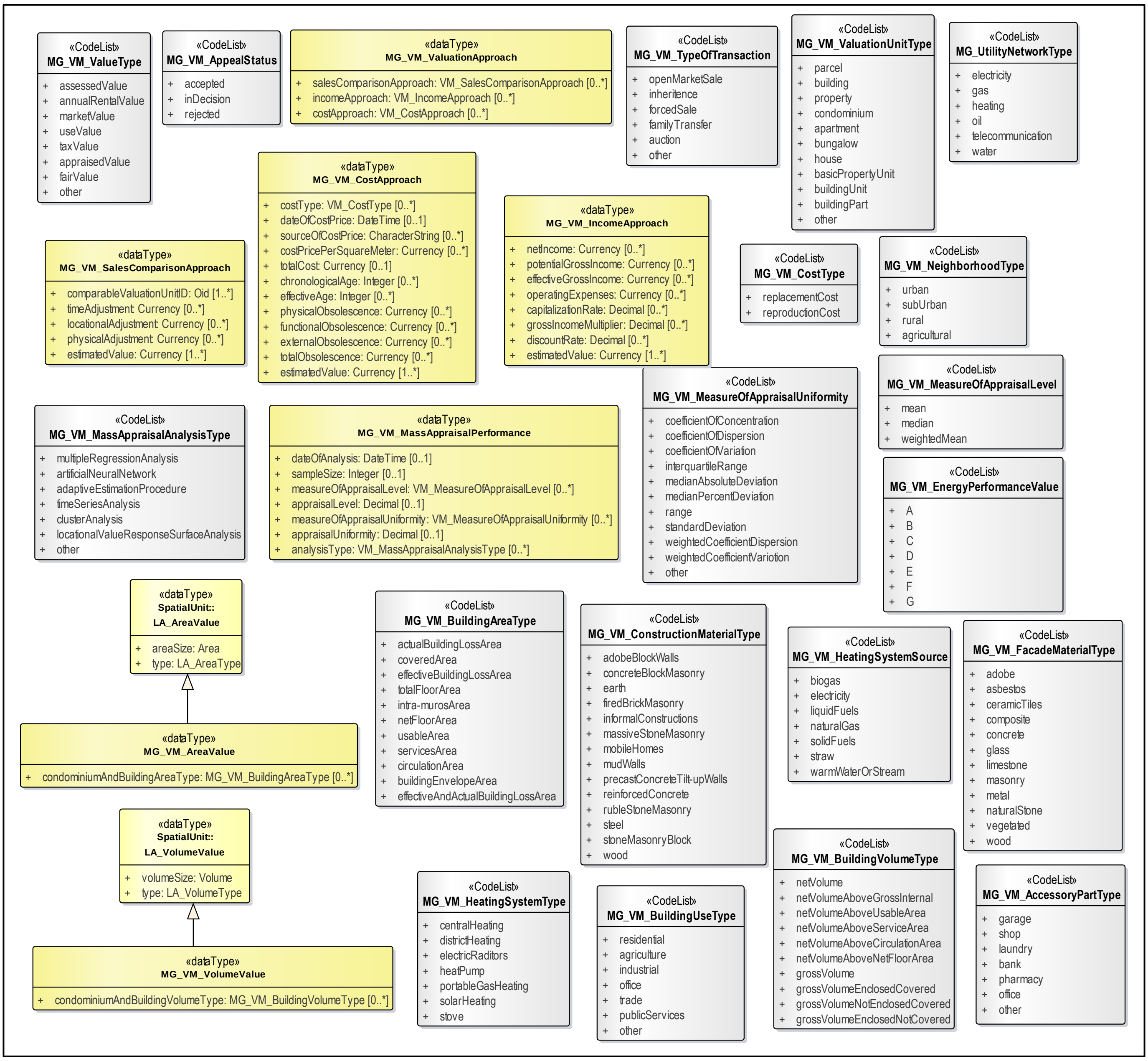


**Figure 9.** Code lists (in gray) and datatypes (in yellow) of Mongolian LADM Valuation Information Model Country Profile.

Cadastral parcels are grouped as a cadastral district by valuation unit group, and its specific address information is expressed by ExtAddress class, i.e., the cadastral district is in Bayanzurkh district (addressID = 13301), Ulaanbaatar city. Moreover, in our case, the valuation process is performed using mass appraisal method and is based on 21,738 parcels (sample size); the currency is set to Mongolian tugrug (or tugrik). Mass appraisal is conducted using MRA method, which is most applicable among other methods.

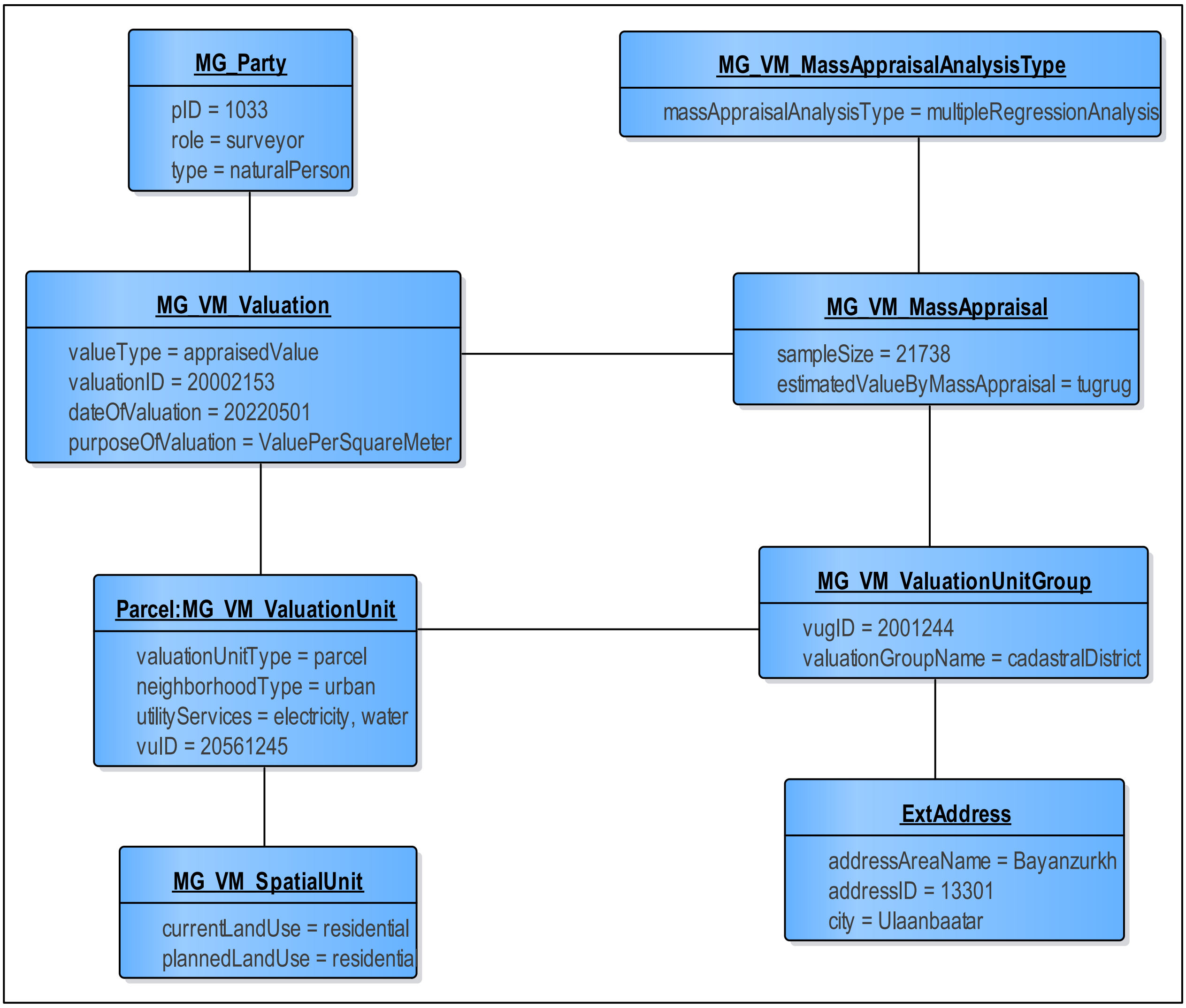


**Figure 10.** UML object (instance) diagram for recording the mass appraisal procedure.

## 6. Discussion and Conclusions

The present study examined how the national geospatial land valuation-related standards of Mongolia can be modeled to LADM Valuation Information Model to enable modern 3D land/property valuation in the country. This study aimed to overcome the lack of standardization of land/property valuation in the current land administration practice of Mongolia that exists despite standardization activities gaining momentum in the geospatial information domain. It also aimed to address the requirements and demands from the government project of "Vision 2050," which mentions an introduction of the integrated land exchange and a multipurpose cadastral system in its first implementation phase between 2021 and 2030. Moreover, the document mentions developing an integrated system of land and immovable property, promoting a 3D system of land and immovable property based on the advanced technology and introducing internationally recognized standards for implementing effective land governance and management.

The study explored relevancies of national geospatial standards, especially land valuation-related ones to the LADM Valuation Information Model. Herein we employed data model of two standards, cadastral parcels and building construction, with their linked/dependent standards (i.e., boundary). Therefore, based on the examination of the corresponding classes from each data model between the LADM and national standards, we developed LADM Valuation Information Model country profile for Mongolia. In particular, we extended LADM Valuation Information Model by adding five classes from cadastral parcels, four classes from building construction and one class from boundary standard. Building-related classes were added, as the LADM Valuation Information Model supports not only land as a parcel but also buildings, condominiums and combinations of these two as an immovable property to enable 3D land/property valuation. However, CadastralBoundary class from cadastral parcels data model could not be included in the proposed model because of its characteristics, which are suitable only for delineating cadastral boundaries and which may be appropriate and linked to the spatial unit package of LADM I country profile.

An object-instance diagram introduced herein showed how the developed model would work with some possible real scenarios involving mass appraisal process. Furthermore, we identified that mass valuation for determining parcel price is being implemented in the country. In this context, connecting existing land valuation-related models (standards) with the LADM Valuation Model not only at the conceptual level but also at the implementation level would greatly enhance the benefits of the LADM. This implies that the realization of the integrated system of land and immovable property in 3D context will be facilitated, which is in line with the government vision by involving the LADM-based approach.

Our study results demonstrated how the LADM Valuation Information Model can be adapted to the Mongolian land administration system. We believe that the LADM Valuation Information Model country profile for Mongolia will serve as the first step toward advancing land/property valuation system to enable well-functioning multipurpose cadastral system/LAS in the country. Furthermore, as the existing local (national) standards are being used for collecting and processing (inputting) data, if the LADM standard is adopted and referenced as a national standard, our proposed model can be adapted in practice with less effort. Moreover, existing land valuation-related information (taxation or assessment), including data model from building construction standard, can be organized systematically and efficiently, as the LADM typically provides it to support immovable property valuation system as a part of fully-functioning multipurpose cadastral system.

On the other hand, as we mentioned earlier in Section 2—related studies, only few countries have examined the implementation of the LADM Valuation Information Model by considering their local needs. As we used the local data model as input, the results may presently be applied only to Mongolia; however, similar to our study, the study results may be applied to the other region or country for improving their LASs based on their current available data and requirements. Furthermore, it is recommended that implementing LADM II-based LAS especially regarding the land tenure and value will benefit not only supporting the establishment of an efficient land market but also the integration of efficient land market and land use management to enable the basis for sustainable development.

However, the application of the LADM Valuation Information Model is limited, as it is yet to be approved by the standardization body and is underway to being effective as a part of the LADM II. Nevertheless, the authors believe that the primary idea behind the model will remain the same, but some of the revisions may occur at last. As our proposed valuation model country profile is at the conceptual level, its verification and evaluation as proof of concept remains. Moreover, the object-instance diagram presented herein is limited to provide such an evaluation.

Therefore, in future studies, a prototype for the proposed LADM Valuation Information Model country profile should be evaluated to determine whether the profile meets the requirements and needs of land valuation system in the country. Furthermore, it can refer to the existing prototypes with 3D visualization functions supporting the LADM valuation model as reported by [10,14,36].

**Author Contributions:** Conceptualization, methodology, and software, M.B.; investigation and data curation, M.B. and K.L.; writing—original draft preparation, M.B.; writing—review and editing, M.B., K.L. and W.L.; visualization, M.B.; supervision, funding acquisition, and project administration, W.L. All authors have read and agreed to the published version of the manuscript.

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