ISSN 2518-7325 (Online), ISSN 2306-1677 (Print)
Land Management, Cadastre and Land Monitoring
Received: 15.12.2025; Accepted: 14.01.2026; Published: 30.03.2026;
http://dx.doi.org/10.31548/zemleustriy2026.01.06

UDC 349.41:528.44

VALUATION-ORIENTED LADM PROFILE AND DATA INTEGRATION ARCHITECTURE FOR MASS APPRAISAL

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Abstract. *The article proposes an assessment-oriented national profile of the Land Administration Domain Model for Ukraine, which sets out a unified logic for integrating cadastral, legal, urban planning, and market information in a format suitable for mass assessment and taxation of real estate. The conceptual framework is based on the provisions of ISO 19152-1:2024 and ISO 19152-4:2025, and the subject area is structured in the form of a UML model with the definition of key entities and relationships between spatial units, legal statuses, and valuation results. To transition from disparate registries and cartographic materials to a coordinated valuation-ready dataset, an intermediate layer of semantic harmonization is justified, including unified identifiers, classifiers, and attribute normalization rules. A practical scenario for forming an MVP showcase for mass valuation with the fixation of data sources and quality control indicators (completeness of key fields, duplicates, spatial inconsistencies, price outliers) is described. The technological implementation of the profile is supported by an open stack of PostgreSQL/PostGIS, QGIS, and Python, which ensures the reproducibility of calculations, the auditability of decisions, and the possibility of scaling for the needs of communities and government agencies. The*

proposed approach forms the basis for conducting various types of assessments (regulatory, market, and mass) in a single information loop.

Keywords: *LADM, mass appraisal, land registry, data interoperability, CAMA, geospatial data, valuation profile*

Problem Statement. The current stage of land relations reform in Ukraine is characterized by growing demands for quality, compatibility, and openness of data used in land resource management, real estate valuation, and tax base determination. The functioning of the State Land Cadastre, the State Register of Real Rights, the Urban Development Cadastre, the Construction Register, and official databases remains fragmented, making it impossible to comprehensively reflect the legal status, spatial characteristics, and market dynamics of land plots. In such conditions, there is a growing need to create an interoperable model capable of combining different types of information sources into a single logical space..

The update of the international standard ISO 19152 (LADM) and the release of its fourth part, focused on real estate valuation, make this research even more relevant. The new provisions of LADM–Part 4 create the conceptual prerequisites for the formation of national valuation profiles, in which legal, spatial, and economic data are integrated into a single structure. This is particularly important for Ukraine in connection with the introduction of mass valuation, the need to develop transparent tax mechanisms, the development of the National Land Cadastre, and the transition of local communities to digital land management systems..

At the same time, the lack of a coordinated information model that would support the integration of cadastral data, urban planning regulations, regulatory and market valuation results, transaction information, and macroeconomic indicators hinders the development of a methodologically sound mass valuation system. The formation of an assessment-oriented LADM profile for Ukraine makes it possible to eliminate data fragmentation, ensure the reproducibility of assessment procedures, increase the transparency of decision-making, and create a reliable basis for a modern real estate taxation system.

Review of Recent Research and Publications. The issue of integrating cadastral, legal, and valuation data is actively discussed in the works of leading researchers who analyze the application of the international standard ISO 19152 (Land Administration Domain Model, LADM) and the prospects for its implementation in national land systems. The latest research on LADM Edition II emphasizes the need to build unified information models capable of combining the administrative, spatial, and economic characteristics of real estate objects [1], as well as the role of LADM–Part 4: Valuation as a conceptual basis for the formation of state valuation profiles [2, 3].

European and global research projects have devoted considerable attention to issues of cadastral data interoperability and registry harmonization, particularly through integration with urban planning, construction, and tax systems [4, 5]. A number of studies emphasize the importance of transitioning from fragmented cadastral structures to national land information infrastructures capable of supporting automated assessment procedures and spatial analysis [6, 15]. An important component of this direction is the use of open geospatial software (PostGIS, QGIS, Python), which ensures the reproducibility and transparency of assessment procedures [7, 8].

The issue of mass property valuation (CAMA) in contemporary literature is considered in the context of the development of tax systems, market transparency, and the introduction of machine learning. The World Bank, TEGoVA, and a number of research centers emphasize that the adequacy of the mass appraisal model largely depends on the availability of market transactions, the accuracy of spatial factors, and the consistency of the legal characteristics of objects [9, 10, 11]. A separate area of research is devoted to the application of GEOAI and spatial characteristics (accessibility, relief, environmental parameters) in the construction of market value models [12, 13, 14].

In Ukrainian practice of developing a cadastral registration ecosystem and data for real estate taxation, the key issues remain the fragmentation of sources, different object identifiers, and the lack of agreed classifiers. This complicates the development of transparent and reproducible procedures for mass valuation and quality control of the tax base. The LADM-UA Valuation Profile proposed in the article, in combination

with the requirements of ISO 19152-1:2024 and ISO 19152-4:2025, forms a standardized framework for semantic harmonization and integration of registries within the NIGD, and the use of an open geospatial stack (PostGIS/QGIS/Python) lowers the barrier to implementing CAMA prototypes at the community and government levels [1, 2, 7, 8, 15].

At the same time, the issue of forming a comprehensive assessment-oriented LADM profile for Ukraine, which would cover legal, spatial, market, engineering, planning, and macroeconomic characteristics, has not been addressed in scientific works. Particular attention should be paid to the problem of integrating the official results of mass appraisal, data from the State Property Fund of Ukraine, market offers, transactions, and urban planning regulations into a common information model that would simultaneously comply with the international LADM standard and be able to function on the basis of open source software. It is this scientific gap that determines the relevance and necessity of the research, the results of which are presented in this article.

The aim. The aim of the study is to develop and scientifically substantiate an assessment-oriented LADM profile for Ukraine that is capable of integrating legal, spatial, urban planning, market, and official assessment data into a single information environment. Such a profile should ensure the interoperability of state registers, support mass appraisal procedures, and form a transparent tax base based on open source software (PostgreSQL/PostGIS, QGIS, Python). An additional goal is to build a technological architecture that allows the proposed profile to be implemented in practical applied solutions for the needs of local self-government bodies and state institutions.

Materials and Methods. The material basis of the study is normative and publicly available information on the structure and functioning of Ukraine's national cadastral and registration systems, including the State Land Cadastre, the State Register of Property Rights, urban planning documentation, construction and address registers, as well as official databases of assessment results. The analysis covers the types of data

contained in the relevant information systems, their attributive composition, principles of formation, and regulatory requirements for their maintenance..

The methodological basis of the study is the conceptual model ISO 19152:2023 (LADM) and its updated fourth part, dedicated to real estate valuation. Based on regulatory documents, international standards, and the structure of existing national registries, a systematic analysis of their information compatibility, classification of entities, logical connections, and integration capabilities in a single data space was carried out.

As part of the work, conceptual UML diagrams were developed using LucidChart, which reflect the logical relationships between legal, spatial, urban planning, valuation, and market data in accordance with the requirements of LADM Core and LADM–Part 4: Valuation. During modeling, the types of data contained in state registers and databases were compared with the entities and attributes necessary for performing mass valuation and forming a valuation profile.

The systematic analysis method was used to determine the structure of the national assessment profile and to form a generalized data architecture. Semantic grouping of entities made it possible to identify key information blocks — legal, spatial, urban planning, valuation, market, and macroeconomic — and establish logical connections between them within the conceptual model of LADM-UA Valuation. Thus, the research results are based on a conceptual synthesis of regulatory, spatial, and valuation information without the actual loading of data into software environments.

Results and Discussion. The analysis of the international standard ISO 19152:2023 and the national cadastral and registration systems of Ukraine made it possible to form a conceptual model that reflects the interrelationships between legal, spatial, urban planning, and assessment data in a single logical structure. Based on the provisions of the basic LADM package (LA_Party, LA_RRR, LA_BAUnit, LA_SpatialUnit, LA_SpatialUnitGroup) and the updated part of LADM–Part 4: Valuation, a UML diagram was constructed that represents a valuation-oriented LADM profile for Ukraine. The model combines the legal status of the object, spatial

characteristics, valuation results, market indicators, and auxiliary national data (UA extension), ensuring the consistency of entities and their semantic integration.

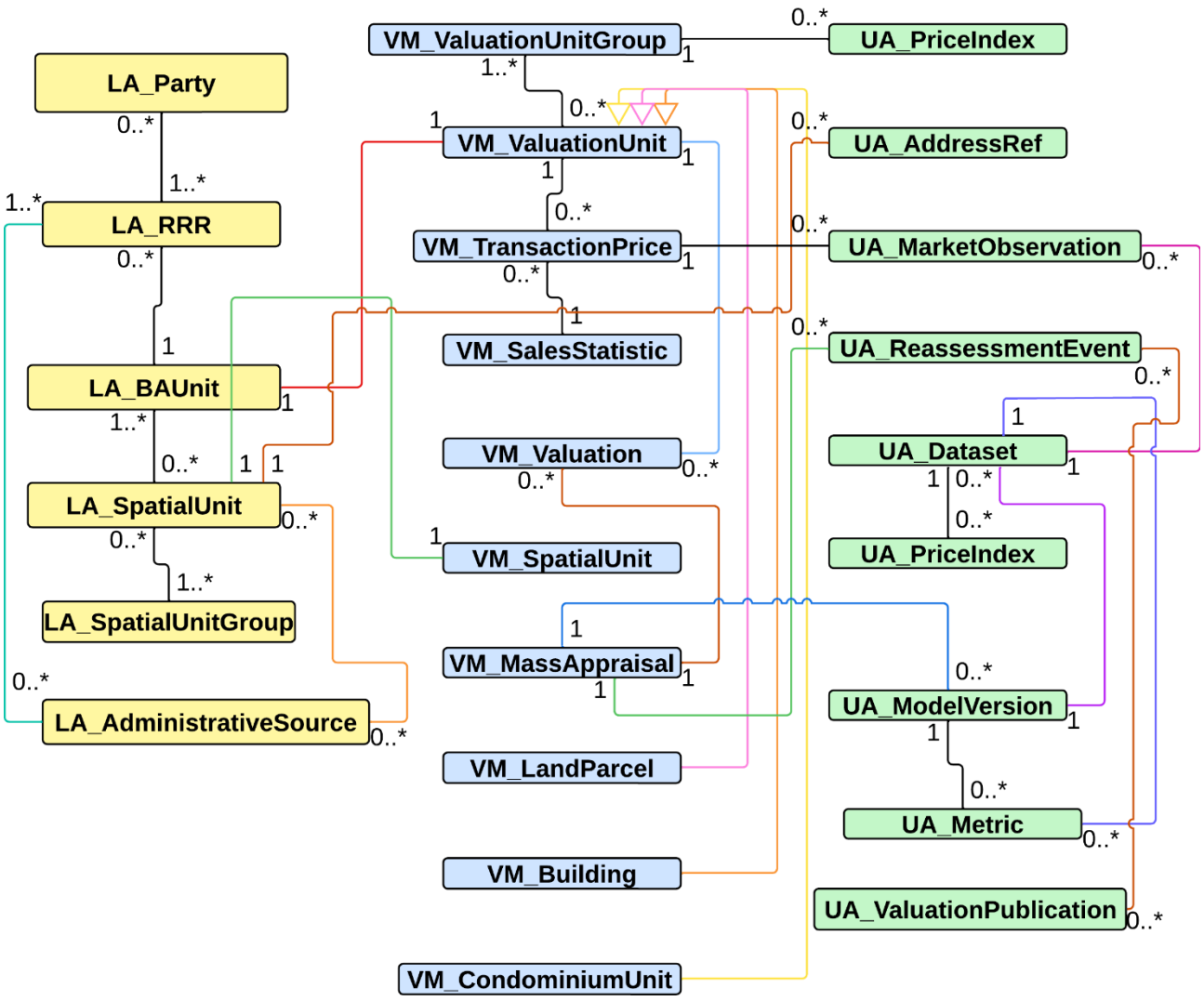

Figure 1 - Conceptual UML model of Ukraine's valuation-oriented LADM profile, built on the basis of LADM Core and LADM–Part 4: Valuation using national extensions UA-Core.

Developed by the author

The proposed model demonstrates the structural logic of interaction between legal, spatial, and evaluative components and defines the place of each class in the construction of a unified evaluation environment. The LADM Core blocks reflect the formation of legal relations, the relationship between entities, rights, and spatial units, which is the basis for any further valuation. The LADM–Part 4 package provides the representation of valuation units, valuation results, transaction prices, and statistical indicators necessary for building mass market models. Ukrainian UA-Core extensions allow for the specifics of national registries to be taken into account, in particular address data, metrics, indices, and model versions..

The alignment of these three groups of entities within a single UML model ensures conceptual data compatibility and creates the basis for building a complete information architecture for mass appraisal. This approach allows not only to describe the structure of data used in valuation processes, but also to clearly identify which aspects of legal, spatial, and market characteristics are critical for the accuracy of value modeling and the formation of the tax base.

The constructed UML model shows the logic of interaction between entities within the LADM profile, but for the practical application of such a model in the context of real estate valuation, it is necessary to define the principles for coordinating external data sources and the mechanisms for organizing them. At this stage, a three-level integration scheme is justified, covering external cadastral, registration, urban planning, construction, appraisal, and market systems, an intermediate level of harmonization, and the final conceptual level of LADM. This structure allows us to show how different types of data sets are semantically and structurally consistent with each other and how they can be transformed into LADM-compatible entities without losing their content.

Figure 2 shows the generalized architecture of information exchange and structuring for valuation purposes. External systems are presented as autonomous sources that form the legal, spatial, functional, market, and macroeconomic characteristics of real estate objects. At the intermediate level, they are analytically

grouped, key attributes are identified, formats are normalized, and information is organized according to logical blocks: legal (RRR), spatial (SU), functional and urban planning (zoning), valuation (valuation inputs), market (market), and macroeconomic (metrics, indexes).

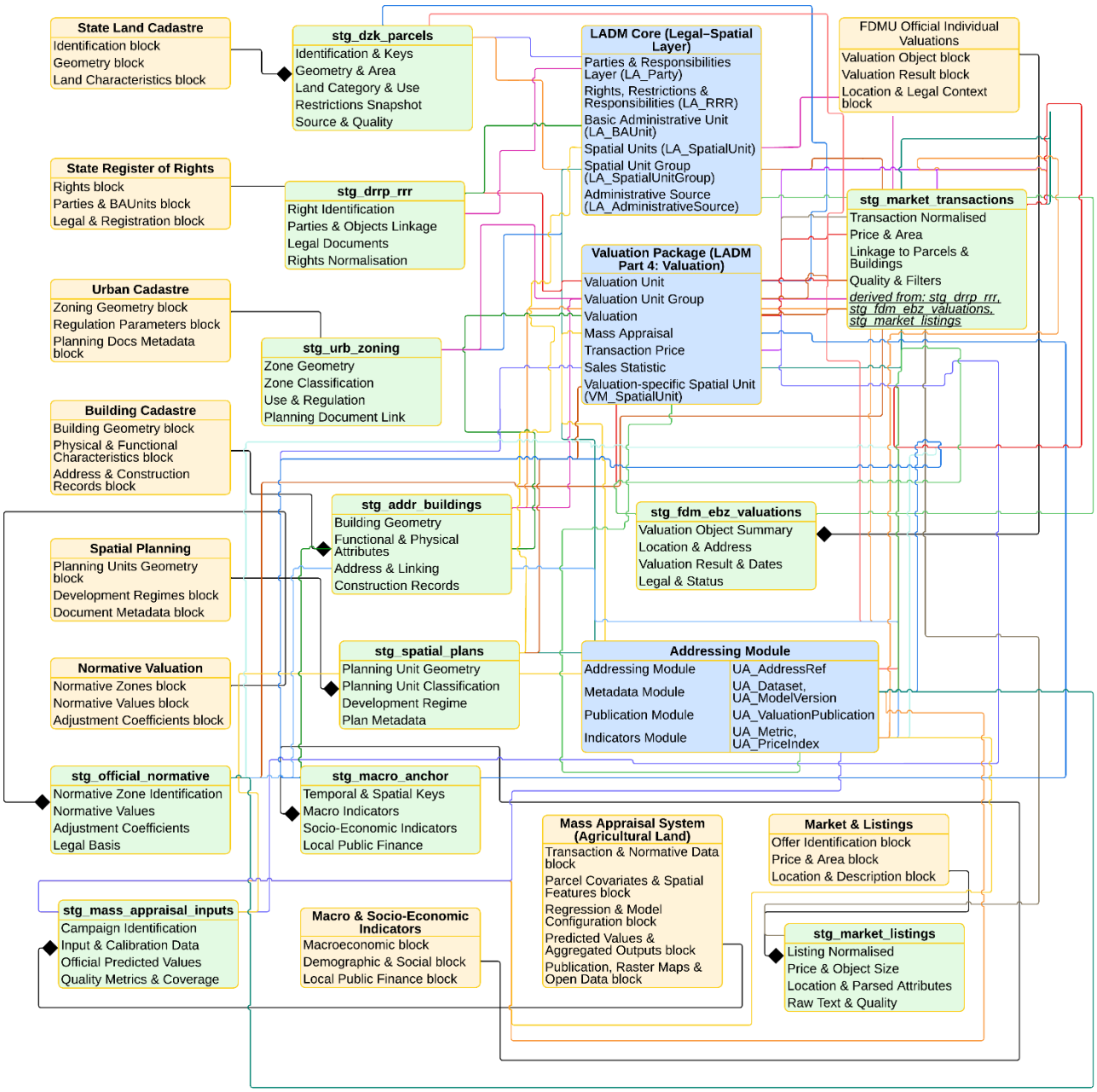

Figure 2 - Generalized scheme of integration of external cadastral, registration, urban planning, appraisal, market, and macroeconomic data with their semantic harmonization for further conversion into LADM-UA Valuation Profile.

Developed by the author

The diagram shows that a formal comparison of attributes between different registers is not sufficient to build a conceptually coherent assessment profile. It is necessary to create an intermediate logical structure within which semantic alignment of terminology, identification of duplicate elements, determination of key links between legal and spatial entities, and formation of common classifiers and groups of attributes are carried out. This approach allows for the unification of information from different sources, regardless of differences in formats, standards, or registry structures.

The result of this stage is the creation of a harmonized information base that can be integrated into the LADM profile without violating the internal logic of the model. The alignment of external data sets with LADM conceptual classes enables further modeling, the formation of spatial and economic indicators, the analysis of market activity, and the development of a national mass appraisal system based on a standardized, transparent, and reproducible information architecture.

To reinforce the applied nature of the conceptual model (Fig. 2), the paper clarifies the correspondence of data from state registers and cartographic sources to specific classes and attributes of LADM and the assessment module (ISO 19152-4), and describes the format for their storage and exchange within the MVP mass assessment. Data from several state registers are used to populate the national profile model LADM-UA, with each set of attributes imported into the corresponding model classes and linked through common identifiers (primarily the cadastral number) and spatial relationships. Below is a list of what information is received from each source, in what format it is received, and how it is reflected in the LADM-UA structure:

The data from the State Land Cadastre (SLC) directly corresponds to the LA_SpatialUnit class and forms the spatial component of the Valuation Unit. Attributes such as cadastral number, land plot geometry, area, land category, and intended use are transferred to this class. In technical implementation, this data is stored in a spatial database in the form of vector objects with Polygon geometry and a related attribute table. The exchange is carried out through standard geospatial formats (GeoPackage, GeoJSON), service interfaces (WFS), or as tables (CSV/PostGIS),

which ensures interoperability between systems. The cadastral number of a plot is used as its primary identifier when uploading to the LADM-UA database and provides a link to data from other registries.

The State Register of Real Rights (SRPR) data corresponds to the LA_RRR and LA_BAUnit classes and is integrated with the valuation unit through common object identifiers (cadastral number, address identifier). The model receives attributes such as type of right, existence of restrictions and encumbrances, date of registration, and term of validity. This data can be obtained through XML/JSON message exchange or in the form of tables linked by cadastral number. In the LADM-UA model, ownership is represented by an instance of the LA_Right class (subclass of LA_RRR) with the rightType attribute, the value of which corresponds to the type of right. The form of ownership of a plot is indirectly reflected through the connection of the right with the corresponding party: the LA_Party class contains a record about the owner. For private property, this is a conditional record of a natural person (without disclosure of personal data), for communal property – a record about the community or local self-government body, for state property – about a state body or institution. The link between rights and land plots is ensured through a common plot identifier: the LA_RRR record contains a foreign key to the basic administrative unit (LA_BAUnit or the LA_SpatialUnit profile itself), identified by the same cadastral number. This ensures that each right is linked to the correct real estate object in the model.

The State Address Register ensures the alignment of address attributes between spatial, legal, and market data. Address records correspond to auxiliary national classes (UA-Address) and are used as additional linking keys for geocoding market observations and verifying the correctness of the spatial location of the valuation unit. In exchange processes, address data is used in tabular format and via REST interfaces.

The urban planning cadastre and cartographic materials, such as the cartographic part of the Kyiv Master Plan, form a separate set of spatial classes, which within LADM-Valuation are considered as external regulatory layers related to the valuation unit. Cartographic materials undergo the stages of georeferencing, vectorization, and semantic description, after which they are stored as thematic vector layers (functional

zones, land use restrictions, development parameters). These layers are stored in PostGIS table format and attached to the valuation unit using spatial join operations.

The estimated data and normative indicators of the State Property Fund of Ukraine correspond to the VM_Valuation, VM_ValuationUnit, and VM_ValuationInput classes. Attributes characterizing previous valuation results, base rates, zone coefficients, and valuation dates are transferred to the valuation unit. In the model, this allows you to store several types of valuations for a single object (regulatory, market, mass) in the form of separate records with a clear indication of the type of valuation and the input data used.

Data exchange between these blocks is implemented through a unified layer of semantic harmonization, which ensures that attributes are brought into line with agreed classifiers, formats, and identifiers. As a result, a valuation unit is formed as an integration node that combines spatial, legal, address, urban planning, cartographic, and valuation information into a single structure suitable for further use in mass valuation models and tax base analytics.

Below is an example of data integration for a specific plot of land, namely the plot with cadastral number 8000000000:75:815:0021 (Kyiv, Sviatoshynskyi district) in the consolidated LADM-UA model, which contains all available open attributes linked to each other. The State Land Cadastre provided its area of 0.0658 ha (658 m^2) and boundaries, which are stored as LA_SpatialUnit.geometry and the area attribute. The intended use of the plot – code A.01.05 (“for gardening”) in the category of agricultural land – is reflected in the model through the code value of the type of land use associated with this LA_SpatialUnit. The form of ownership – private – is imported from the SRPR and reproduced as a right of the ownership type (LA_Right object with rightType=ownership), associated with a conditional owner subject (LA_Party) of the “natural person” type. The official address of the plot, “Kyiv, 8 Sadova Street, plot 21,” has been added to the LA_SpatialUnit attributes for precise location. There is no normative monetary valuation for this plot — there is no NMO value in the open data (the plot has no recorded value), so the model does not contain a VM_ValuationInput record with a normative approach for this plot. At the same time, the plot can be

compared with the city master plan layer: it can be noted that it is located, for example, in a residential area according to the master plan — this would be entered as LA_Restriction with a reference to the master plan. All of the above data is linked by a unique cadastral number and other keys: the cadastral number is the main identifier assigned to the object. All of the above data is linked by a unique cadastral number and other keys: the cadastral number is the main identifier assigned to the LA_BAUnit/LA_SpatialUnit object and is duplicated in all related tables (rights, assessments, etc.) as a foreign key, ensuring the link between tables. Spatial links (via coordinates) ensure correspondence between the plot object and planning zones. This approach to data transformation allows for the formalized, but not overly complicated, combination of scattered registry information into a single LADM-UA structure, demonstrating a complete set of characteristics of a real estate object in a single model.

Pilot testing on real data showed that the key challenge of integration is not so much the construction of a UML structure as the harmonization of classifiers, administrative codes, and address directories between registries. Using the example of land plot 8000000000:75:815:0021, the following typical problems critical for the formation of a valuation-ready dataset were identified.

1) Inconsistency of the intended use with the current classifier (national land use purpose classification / national land use code list). In the State Land Cadastre of Ukraine (SLC) and State Register of Property Rights to Immovable Property (SRPR), the intended use is represented by the text value “For personal subsidiary farming, gardening, horticulture, haymaking, and grazing livestock,” which does not correspond to the current structure of the classifier codes used for modern analytical and evaluation procedures. When normalizing under the current classifier, there is a need to form an updated (harmonized) value — for example, 01.05 “For individual gardening.” To avoid loss of raw data and ensure auditability, it is advisable to store two representations of one attribute within LA_SpatialUnit (or national spatial unit extension) in LADM-UA: landUse_raw / purpose_raw — raw text value from the source (SLC/SRPR) + sourceSystem, sourceDate; landUse_code / purpose_code — normalized classifier code (01.05) + codeListVersion, mappingRuleId. Thus, the

model simultaneously maintains a “single source of truth” for the primary record and an analytically consistent value suitable for mass assessment.

2) Discrepancies in administrative codes and address classifiers when obtaining information/indicators from the State Property Fund of Ukraine (SPFU). For the specified plot, the cadastral number determines its location in the Svyatoshinsky district, but when generating information from the SPFU, the administrative code KOATUU 8038600000 is used. Additionally, it was found that 8th Sadova Street is not included in the SPF classifier, which makes it impossible to correctly match addresses. In LADM-UA, this is solved by allocating a master-data layer for administrative and address normalization, where administrative affiliation is stored as a set of parallel codes with a crosswalk table, and the address is stored as an official address_id from the State Register of Addresses, as well as address_raw from sources (SLC/SRPR). This makes it possible to exchange data between registries not by address line but through stable keys (address_id, administrative unit codes) and, if necessary, through geometry/coordinates as a fallback mechanism (spatial matching).

3) Significant difference between the SPF valuation and market offers. The value of the land plot was estimated at UAH 342,365.76, which is significantly lower than market offers for similar land plots. In practice, this means that there are different “value signals” in the system, which are of different nature: normative valuation (for fiscal and regulatory purposes) and market evidence — for calibrating mass valuation models and adequacy control. In LADM-UA, it is advisable to reflect this as several valuation records for one valuation unit in the valuation package. VM_Valuation (normative/administrative) — normative/official valuation value, date, source (SPF/reference), aggregation level (district/zone), methodology used. VM_MarketEvidence / VM_TransactionPrice — market observations (offer/transaction price, date, area, source of announcement, coordinates/address, geocoding quality). For quality control and further analytics, a quality gate normative/mass vs. market is introduced (for example, ratio/deviation from the market median by district/zone), which does not “cancel” the normative/mass assessment, but

allows you to identify areas/segments with a high gap and correctly explain this in the model (type of assessment, approach, source, date).

The identified problems confirm the need for an intermediate layer of semantic harmonization embedded in the conceptual model: it ensures the preservation of primary values from registries (data lineage), the formation of normalized codes for analytics, the coordination of administrative and address identification, as well as the parallel maintenance of different types of assessments within a single valuation unit. It is this organization of data that allows us to obtain valuation_init (valuation inputs) as a ready-made, audited set of characteristics for mass valuation, where each indicator has a source, a classifier version, and normalization rules.

After forming a conceptual UML model and structure for integrating external data sources, the question arises of how to technologically implement the proposed profile in application systems. Given the priorities of openness, reproducibility, and accessibility, which are particularly important for local governments and state institutions, the LADM-UA Valuation model has been adapted to an architecture based on open source software and modern spatial analysis tools. At this stage, it has been determined which components of the information system ensure the semantic compliance of the model and which implement it in the form of a working environment.

Figure 3 summarizes the main technological levels that support the implementation of the assessment profile. On the left is a block of external systems that serve as sources of cadastral, legal, urban planning, construction, market, and macroeconomic information. The center shows the conceptual architecture of interaction between the LADM profile and technological tools that ensure data processing and integration. The model provides for the possibility of analytical processing, but without the need for actual loading or transformation within the scope of this study.

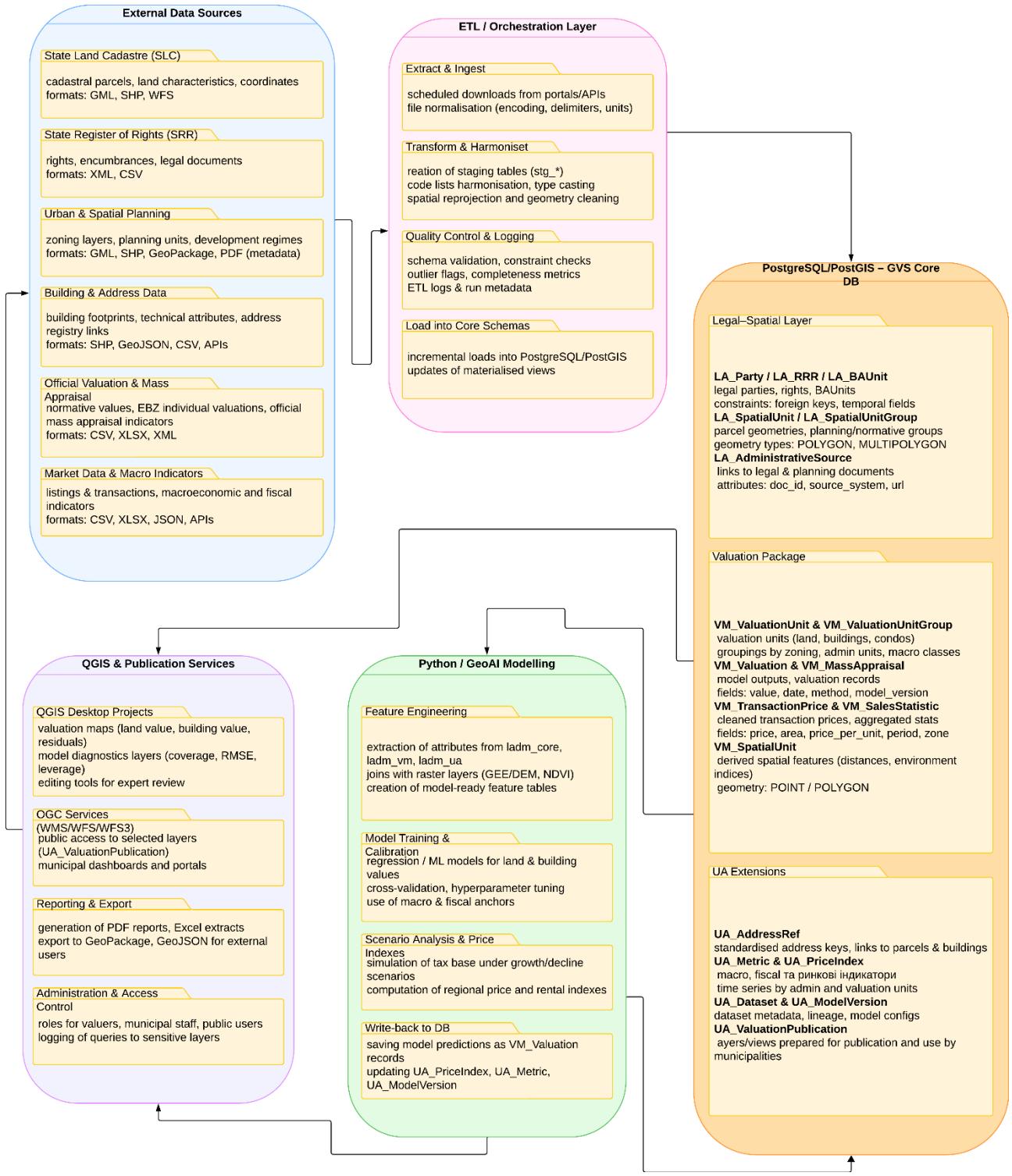

Figure 3 - Technological architecture for implementing the assessment-oriented LADM-UA Valuation Profile using open source software (PostgreSQL/PostGIS, QGIS, Python)ased on harmonized data from cadastral, registration, urban planning, assessment, and market systems.

Developed by the author

The architecture shown in the figure demonstrates that the implementation of a LADM-oriented evaluation profile does not require the construction of complex isolated software solutions, but can be based on well-standardized and accessible tools. PostgreSQL/PostGIS is considered as the core of the spatial database, within which LADM classes, UML structures, and logical relationship models defined in the conceptual part of the study can be implemented. Python provides the ability to perform assessment and spatial analysis, calculate indicators, and prepare attribute sets for mass assessment models. QGIS can perform visualization functions, verify the correspondence between spatial data and logical model classes, and create thematic maps and user interfaces.

Thus, the technological architecture not only confirms the practical feasibility of the proposed LADM-UA Valuation Profile, but also demonstrates that its implementation is possible on the basis of open and accessible solutions without significant financial and institutional costs. This makes the model suitable for use by local communities, government agencies, and research centers that need a transparent and structurally consistent basis for real estate valuation and taxation.

Conclusions and Recommendations. The study resulted in the development of a conceptual framework for a valuation-oriented LADM profile for Ukraine (LADM-UA Valuation Profile), which harmonizes legal (RRR), spatial (SU), urban planning, and market valuation data into a single information model. Based on ISO 19152-1:2024 and ISO 19152-4:2025, a UML diagram was developed that formalizes the relationships between valuation units, valuation inputs, market evidence, and basic LADM classes and supports the logic of mass valuation. It has been substantiated that effective CAMA procedures require comprehensive consideration of urban planning regulations, building characteristics, spatial accessibility, market activity, and macroeconomic indicators, and that the intermediate layer of semantic harmonization (classifiers, identification keys, normalization rules) is a critical element of end-to-end data integration between registries. The proposed technological scheme confirms the possibility of practical implementation of the profile based on open source software

(PostGIS/QGIS/Python) and forms a technical blueprint for local communities and state bodies for building transparent, standardized, and reproducible procedures for assessment and formation of the tax base. The scientific novelty lies in the development of an assessment-oriented LADM profile and an approach to inter-registry comparison through a mandatory intermediate level of semantic harmonization. The practical significance is determined by the possibility of using the model as a basis for prototyping CAMA processes, improving the quality of cadastral and tax information, and ensuring data interoperability in accordance with international standards.

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ОЦІНОЧНО-ОРІЄНТОВАНИЙ LADM-ПРОФІЛЬ ТА АРХІТЕКТУРА ІНТЕГРАЦІЇ ДАНИХ ДЛЯ МАСОВОЇ ОЦІНКИ

У статті запропоновано оціночно-орієнтований національний профіль Land Administration Domain Model для України, який задає єдину логіку інтеграції кадастрових, правових, містобудівних і ринкових відомостей у форматі, придатному для масової оцінки та оподаткування нерухомості. Концептуальну основу сформовано на положеннях ISO 19152-1:2024 та ISO 19152-4:2025, а структуризацію предметної області виконано у вигляді UML-моделі з визначенням ключових сутностей і зв'язків між просторовими одиницями, правовими станами та оцінювальними результатами. Для переходу від розрізнених реєстрів і картографічних матеріалів до узгодженого valuation-ready набору даних обґрунтовано проміжний шар семантичної гармонізації, що включає уніфіковані ідентифікатори, класифікатори та правила нормалізації атрибутів. Описано практичний сценарій формування MVP-вітрини для масової оцінки з фіксацією джерел даних і контрольних показників якості (повнота ключових полів, дублікати, просторові невідповідності, цінові викиди). Технологічна реалізація профілю підтримується відкритим стеком PostgreSQL/PostGIS, QGIS та Python, що забезпечує відтворюваність розрахунків, аудитованість рішень і можливість масштабування для потреб громад та державних органів. Запропонований підхід формує основу для ведення різних типів оцінок (нормативної, ринкової та масової) в єдиному інформаційному контурі.

Ключові слова: *LADM, масова оцінка, земельний кадастр, інтероперабельність даних, CAMA, геопросторові дані.*