DEVELOPMENT OF THE METHODOLOGY FOR CREATING A DATABASE OF MULTI-APARTMENT RESIDENTIAL BUILDING DATA BASED ON THE EXAMPLE OF A SEPARATE RESIDENTIAL SECTION IN THE REPUBLIC OF ARMENIA

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Abstract: *This article analyzes the existing challenges in the management and data coordination of multi-apartment residential buildings in Armenia. Special emphasis is placed on the absence of a comprehensive, digital, unified database on multi-apartment buildings, which creates significant obstacles to urban planning, socio-economic development, and the improvement of quality of life. The seismic resistance of buildings is a primary concern, a fact underscored by the 1988 Spitak earthquake. Yet, no information source exists in Armenia that documents the seismic resilience of each building. The lack of technical monitoring of the housing stock, as well as insufficient cooperation and fragmented data among relevant authorities, further complicates the effective management of the housing sector. Under these circumstances, the collection and centralization of comprehensive digital information in a single repository has become especially urgent. The primary aim of this research is to develop a scientifically grounded methodology for the creation of an architectural and technical database of multi-apartment buildings in Armenia. To achieve this, the study examines international experience and synthesizes both local and global approaches to collecting spatial and technical data on multi-apartment buildings. The current state of residential buildings is analyzed, unique challenges are identified and classified, and principles and patterns for architectural and technical analysis in the database are proposed. The methodology is further elaborated through the modeling of the database based on a case study of a distinct residential segment. The article employs methods such as the collection and summarization of archival materials and documents, systemic and situational analyses, and the study of government decisions related to the topic. The proposed methodology can serve as a foundation for creating a unified and digital repository of architectural and technical data on multi-apartment buildings in Armenia, with wide application in urban planning, technical assessment of the building stock, and the enhancement of public safety.*

Keywords: *multi-apartment building, architectural and technical database, Armenia, digital inventory, mapping, data collection methodology.*

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Introduction

The management of residential buildings in Armenia continues to face substantial challenges due to the absence of a unified, digital building database. Fragmented responsibilities among government agencies, insufficient monitoring, and the lack of technical documentation undermine effective decision-making in housing policy. As highlighted in recent research, the Armenian housing stock reflects both the legacy of Soviet-era standardized construction and the urgent need for modernization, yet no centralized mechanism exists to document structural conditions, energy efficiency, or seismic resilience.

The importance of creating such a repository is underscored by historical precedents: the catastrophic 1988 Spitak earthquake revealed the vulnerability of Armenia's multi-apartment stock, yet more than three decades later, no comprehensive registry tracks seismic resistance or building condition on a nationwide scale. Current housing management remains reactive rather than proactive, relying on partial surveys or scattered municipal archives.

Against this backdrop, the present study aims to develop a scientifically grounded methodology for the establishment of a unified architectural and technical database of multi-apartment residential buildings in Armenia. The research focuses on the following key objectives: to examine international experience and identify effective models for the management of multi-apartment residential buildings, to synthesize international and local practices in the collection and systematization of spatial and technical data on residential building stocks, to analyze the current state of multi-apartment buildings in Armenia, identify existing challenges, and develop a classification based on their defining characteristics, to establish principles and regularities for the architectural and technical analysis of residential buildings within a unified database, to develop a scientifically grounded methodology for the creation of a comprehensive residential building database, to model and test the proposed methodology through a pilot case study using a selected residential area as an example. Drawing on international experience and through the comparative analysis of residential building databases from nine countries: Germany, Spain, the Netherlands, Russia, the United States, France, Estonia, Kazakhstan, and Japan [1-41], local research addressing the necessity of residential building modernization [42-45], and the analysis of sector-specific legal acts and regulations, this research aims to define the structure, scope, and functional framework of comprehensive residential building data. The methodology is demonstrated through a pilot case study in Yerevan's Davtashen district, where a digital inventory and mapping exercise illustrate how centralized data collection could serve urban planning, technical assessment, and public safety.

Materials and Methods

The study was conducted through a comprehensive analysis of published and archival sources related to both international and Armenian experience. It examined scientific articles, reports, legal acts, regulations, and records of realized and unrealized projects, complemented by original research data. Using scientific methods of analysis and generalization, the research applied a systemic approach and situational analysis, synthesizing archival materials and evaluating relevant government decisions of the Republic of Armenia concerning housing management and building stock modernization. Furthermore, remote-sensing and LiDAR data were employed to identify potential building footprints, while geospatial (GIS) technologies supported spatial analysis, data integration, and visualization. The classification scheme for building information was developed to ensure the consistency and interoperability of the collected data.

Armenian Experience in Residential Building Databases

Standard-design residential construction in Armenia began to develop in the 1950s, amid a severe housing shortage throughout the Soviet Union. During this period, large-scale mass housing programs were launched based on pre-designed standard projects, aiming to provide affordable dwellings rapidly and efficiently. In Armenia, early standardized housing primarily consisted of five-story buildings constructed from stone and monolithic structures, widely implemented not only in Yerevan but also in regional cities. The largest segment of Armenia's multi-apartment housing stock was created during the Soviet decades, particularly between the 1950s and 1980s, when thousands of panel buildings were erected in Yerevan and other cities to accommodate the rapidly growing population [42]. Following independence, new housing construction nearly came to a halt due to the economic crisis. Over the past two decades, especially in Yerevan, modern multi-apartment residential complexes have emerged, reflecting a shift toward new architectural typologies and investment-

driven urban development. Today, multi-apartment buildings in Armenia represent not only functional housing units but also the material expression of the country's social and historical transformations, embodying both the legacy of the past and the challenges of the future.

Despite the absence of a unified residential building database, several legal acts and government regulations have been adopted in Armenia to govern housing management, building maintenance, and urban development. These documents collectively define the institutional and legal framework for the sector and can serve as the foundation for developing an integrated building information system[1,2,3,4,5].

In various normative legal documents of the Government of the Republic of Armenia, there are both direct and indirect references to multi-apartment residential buildings, their management, and control mechanisms. However, these references are at times inconsistent and, from a technical and programmatic perspective, lack clarity. In addition, multiple data-exchange systems exist between various public and private institutions. Nevertheless, information related to multi-apartment residential buildings, including data formats, storage practices, and standards, differs across governmental bodies and is not uniformly regulated by sector-specific normative and legal acts.

International Experience in Residential Building Databases

Germany

Germany has led the creation of standardized, methodologically robust building-stock databases, beginning with TABULA/EPISCOPE's European typology framework that included Germany as a key case [4], later expanded with cadastral integration, machine-learning methods, and life-cycle benchmarks [1-5]. A nationwide set of ~29 million buildings (≈19 million residential) was function- and type-classified from OpenStreetMap and auxiliaries with only 3.6% deviation from official stats [1]. Using census grids plus morphological/socio-economic features, XGBoost predicted building size and construction year, mapping each to a TABULA archetype with 97.4% and 73.9% accuracy [2]. By harmonizing cadastral building footprints (HU-DE), address registers, and land-use data, researchers generated a nationwide dataset comprising approximately 51 million building polygons in its raw form, reduced to about 48 million polygons after preprocessing (removal of overlaps, small and atypical objects). Based on the classified residential buildings, around 62% were identified as detached houses [3]. TABULA/EPISCOPE groups dwellings into representative model buildings by size, age band, and energy parameters for consistent European comparison [4]. Using DGNB certification data, researchers proposed LCA benchmarks and stressed standardization with automated quality checks [5]. Openness varies: TABULA and archetype resources are open [4], ML datasets appear in academic repositories [1,2], while cadastral access is partly license-bound [3] and DGNB-based LCA remains proprietary [5]. Overall, Germany's databases show high rigor, national coverage, and validation [1,2], with TABULA enabling cross-country comparability [4], but fragmentation persists and access to cadastral and DGNB-based datasets is limited [3,5].

[1] Law of the Republic of Armenia "On State Registration of Rights to Property", HO-295. Available at: https://www.arlis.am/hy/acts/109181

[2] Order of the Minister of Urban Development of the Republic of Armenia dated 31 March 2014 "On Approval of Construction Norms RA CN 31-01-2014 'Residential Buildings. Part I. Multi-Apartment Residential Buildings'", No. 93-N. Available at: https://www.arlis.am/hy/acts/90112

[3] Decision of the Government of the Republic of Armenia dated 8 April 2021 "On Approval of the Strategic Program for the Establishment of an Integrated Cadastre", No. 505-L. Available at: https://www.arlis.am/hy/acts/151578

[4] Order of the Chairman of the Urban Development Committee of the Republic of Armenia dated 31 January 2022 "On Approval of the Rules for the Maintenance, Operation, and Modernization of Multi-Apartment Buildings (Including Energy Efficiency and Energy Saving)", No. 02-N. Available at: https://www.arlis.am/hy/acts/159909

[5] Decision of the Government of the Republic of Armenia dated 6 October 2022 "On Approval of the List of Basic and Thematic Spatial Data and Guidelines for Their Standardization within the Framework of the National Spatial Data Infrastructure of the Republic of Armenia", No. 1569-N. Available at: https://www.arlis.am/hy/acts/169336

Spain

Spain has developed residential building stock datasets mainly from Energy Performance Certificates (EPCs) and cadastral or open geospatial data. Early studies used EPC samples to define national energy baselines and identify inefficiencies [6], later integrating EPC, cadastral, and socio-economic data for urban-scale analyses and decision-making [8-10]. EPC data characterize national energy performance patterns and inform retrofit policy design [6]. A typological and climate-based framework defines representative dwelling archetypes (1980-2007), and tests retrofit scenarios across 13 climate zones, showing major energy-demand reductions from envelope upgrades [7]. At the city scale, EPC indicators linked with socio-economic data in Valencia reveal spatial inequalities and retrofit priorities [8]. In Barcelona, cadaster and field diagnostics identify priority neighborhoods such as Raval, Carmel, and Besòs-Maresme for rehabilitation [9], while Bilbao applies a QGIS-based workflow using open cadastral data to extract building-envelope geometry and thermal parameters by construction year, supporting energy modelling [10]. Cadastral and open-data layers in Barcelona and Bilbao are publicly accessible and GIS-compatible, enabling reproducible stock characterization [9,10], whereas EPC data remain aggregated and regionally incomplete [6,8]. Overall, Spain's EPC-based research provides a strong national evidence base for building-energy analysis [6-8], and the cases of Barcelona and Bilbao show advanced integration of cadastral, EPC, and socio-economic data through open-GIS workflows for efficient diagnosis and prioritization [9,10].

Netherlands

The Netherlands operates one of Europe's most comprehensive national building and address registries, Basisregistratie Adressen en Gebouwen (BAG), managed by Kadaster, the national Cadastre, Land Registry, and Mapping Agency. Established by law in 2009 as part of the Dutch Base Registries, BAG integrates data collected by municipalities and maintained nationally by Kadaster, ensuring consistency and legal reliability [11]. Over time, it has become a core element of the national Spatial Data Infrastructure, supporting urban planning and public administration [11-13]. BAG's governance model includes municipalities as primary data providers, Kadaster as the central coordinator, and the Ministry of the Interior overseeing the framework. It records key attributes such as building footprints, official addresses, construction year, and functional use [11]. Kadaster applies Linked Data and semantic web principles to connect BAG with other national datasets, enabling automated data exchange and analysis [12]. The Kadaster Knowledge Graph (KKG) links BAG with cadastral, demographic, and topographic data, creating a unified semantic structure for research and innovation [13]. All BAG data are publicly accessible via the PDOK platform, compliant with the INSPIRE Directive, and promoting transparency and reuse [12]. Overall, the BAG system provides nationwide coverage, legal authority, and continuous updates under a strong governance model. Its integration into semantic web and open-data infrastructures makes it one of Europe's most advanced building data systems, though effective use still demands technical expertise and interoperability management [11-13].

Russia

Russia operates several large-scale information systems for managing the residential building stock. The core platform, the State Housing and Utilities Information System (ГИС ЖКХ), consolidates data on multi-apartment buildings, utilities, and management companies, while the **"**Reform of Housing and Utilities**"** (Реформа ЖКХ) platform and regional programs collect information on building conditions, renovation needs, and funding for capital repairs [14,15]. These systems aim to centralize housing data and enhance transparency for both authorities and residents. Both ГИС ЖКХ and Реформа ЖКХ register construction year, number of apartments, ownership type, management company details, service contracts, tariffs, and repair schedules, functioning as nationwide housing registries [14,15]. Russian legislation also requires technical building passports containing structural and engineering characteristics and condition assessments, crucial for renovation planning [16,17]. Research introduces models for capital repair fund monitoring, linking financial

flows with building registers to improve accountability [18]. Recent studies highlight BIM-based monitoring for continuous condition tracking and digital twin creation, enhancing maintenance and safety management [19]. Other works connect building data to risk management systems, aligning with national GOST and international ISO 31000/14001 standards [20]. While ГИС ЖКХ provides open access to basic building information such as address, construction year, and management company, detailed technical and financial data are restricted to registered users [15]. Building passports remain accessible mainly to municipal and housing authorities, limiting transparency. Overall, Russia achieves nationwide housing coverage through ГИС ЖКХ and Реформа ЖКХ [14,15], with legally mandated technical passports ensuring documentation of all multi-apartment buildings [16,17]. The integration of financial monitoring enhances transparency [18], and the adoption of BIM enables modern digital monitoring tools [19], though openness, interoperability, and regional data quality remain limited, and risk management systems are still developing [17,20].

United States

In the United States, residential building data systems are shaped by federal, state, and city initiatives. The U.S. Department of Energy (DOE) Buildings Performance Database (BPD) is the largest open dataset of empirical building energy performance and characteristics, supporting market analytics and retrofit decision-making [21,22]. Complementing it, the Standard Energy Efficiency Data (SEED) Platform is an open-source tool enabling jurisdictions to manage benchmarking and Building Performance Standards programs through consistent taxonomies and cross-source data alignment [23]. At the city level, open-data portals and benchmarking ordinances, such as those in New York City and Chicago, provide localized datasets for policy analysis and building-stock characterization [24-26]. The BPD aggregates over 750,000 anonymized building records, harmonizing descriptors and energy-use data for benchmarking and savings estimation, with peer-group analytics, quality control, and validation [21,22]. The SEED platform supports consistent data taxonomies, cross-dataset matching, and audit trails, addressing local governments' staffing and data-quality challenges [23]. Comparative studies using open data from ten U.S. cities show that open-data models outperform national baselines (CBECS) in predicting building energy performance, with building area, property type, conditioned area, and water use as key predictors [24]. Analysis of six years of NYC benchmarking data (2011-2016) identifies two performance clusters, one improving in energy intensity and another stagnating or increasing, revealing varied policy outcomes and the need for targeted measures [25]. The ZoLa platform integrates zoning, land-use, and tax-lot data, offering regulatory and spatial context for linking with energy datasets to enhance urban-scale modeling [26]. The BPD provides open, anonymized records and analysis tools [21,22], SEED is fully open-source for adoption by cities and states [23], and many city benchmarking datasets (e.g., NYC, Chicago) are publicly available, while platforms like ZoLa provide authoritative geospatial layers for integration and policy applications [24-26]. Overall, the United States has built a multi-layered data ecosystem that combines federal big-data infrastructures (BPD), jurisdictional frameworks (SEED), and city-level open benchmarking systems [21-26], enabling empirical analysis, compliance tracking, and policy design, though data completeness, uneven coverage, and linkage issues between buildings and tax parcels remain challenges that SEED continues to address [23,24].

France

France has developed the national buildings database BDNB by merging multiple official sources, land-tax "fichiers fonciers," IGN BD-TOPO, and ADEME EPC/DPE records into a unified, building-centric schema to support stock analysis and policy design [28]. A recent study links geolocated EPC data in BDNB to "Danube" archetypes to quantify renovation levels by age band and housing type, showing post-war dwellings with the highest activity and single-family houses undergoing more extensive roof works than collective housing [27]. The same study outlines BDNB fields such as construction year, height, use, and location, and notes biases in EPC data (e.g., certificates tied to transactions) that may overestimate renovation rates when used

independently [27]. In Île-de-France, a component-based "TyPy" workflow enriches BDNB to estimate material stocks and demolition waste at the building level, supporting circular economy planning and designed for replication across French regions [28]. France also participates in the ECCABS archetype-aggregation framework, enabling European-level comparability, national energy demand modeled within this framework differs from statistics by only -6% to +2% [29]. The BDNB integrates public datasets and EPCs into an interoperable, updatable system suitable for building-level analysis, while EPC microdata remain partially restricted, though the methods and regional applications are publicly documented [28,27]. Overall, BDNB offers an integrated foundation for EPC-archetype renovation analysis with known limitations, component-level material and waste modeling in Île-de-France, and harmonized archetype modeling within a European framework [27-29].

Estonia

Estonia maintains a centralized Estonian Building Registry (EHR), one of Europe's first national 3D building databases, covering all registered buildings and supporting national energy modeling, digital twin development, and decarbonization strategies [33]. However, several studies highlight data incompleteness, particularly for technical attributes such as wall materials and thermal properties, prompting efforts toward registry enrichment and quality improvement [30-32]. Analyses of the EHR revealed extensive missing data fields, a combined enrichment approach using rule-based expert systems and machine learning models successfully reconstructed attributes like external wall materials, improving completeness and analytical usability [30]. Using EHR and Level of Detail geometry data, researchers developed neighborhood-scale digital twins for energy simulations, showing the potential of registry-based datasets for urban-scale energy and emissions modeling [31]. Comparative studies indicate that both expert-rule and machine-learning enrichment improve EHR data quality, with machine learning offering automation and scalability, while expert methods ensure interpretability and contextual reliability [32]. National-scale decarbonization modeling combined EHR-based archetypes with energy scenarios to estimate life-cycle greenhouse gas mitigation potential, projecting up to a 95% reduction in annual emissions by 2050 if renovation and energy-supply decarbonization progress as planned [33]. The EHR is a publicly maintained national database with open access to basic information (address, year, footprint), while detailed data are restricted to authorized users, academic collaborations have enabled extended access for developing enrichment and digital-twin methodologies [30-33]. Overall, the EHR forms the foundation of Estonia's building-stock research and decarbonization modeling. Ongoing enrichment efforts [30-32] and integration into life-cycle frameworks [33] underscore its scientific and policy significance, though incomplete technical data and limited public accessibility remain major challenges.

Kazakhstan

Kazakhstan does not have a unified national open building register comparable to those in Western Europe. Instead, building stock data are incorporated into regional exposure databases for Central Asia and national statistical reports. International projects (NHESS studies 2021-2024) have produced harmonized, high-resolution datasets on residential building distribution and population exposure, while recent architectural research addresses the legacy and modernization challenges of Soviet-era housing [34-37]. A 2021 seismic risk exposure database compiled by Patel et al. integrated census and housing statistics at 500 m resolution, generating spatialized estimates of residential building counts and population distribution essential for seismic risk modeling [34]. Scaini et al. (2024) refined this approach by combining population density, building typologies, and structural replacement costs, improving regional comparability across Kazakhstan and neighboring countries [35]. Complementary research expanded coverage to infrastructure and non-residential assets, creating a comprehensive framework for regional exposure assessment [36]. In parallel, Sarzhanov and Schurch [2023] analyzed Soviet-era housing typologies, construction methods, and modernization issues,

adding a qualitative socio-technical perspective to the statistical datasets [37]. Most Kazakhstan-related building data originate from international collaborations rather than national open registries [34-36]. These datasets are available through open-access scientific publications but not as official government-maintained databases, while national statistics remain aggregated and lack spatial detail. The Soviet housing analysis [37] is openly published yet qualitative. Integration into regional harmonized exposure databases has enabled cross-country comparability and high-resolution spatialized data at 500 m grid scale, supporting disaster risk and urban planning [34-36]. However, Kazakhstan still lacks a dedicated open building register and depends on external projects. Existing exposure datasets primarily serve disaster risk modeling rather than energy or renovation analysis, and no public GIS interface currently provides nationwide building-level accessibility for researchers or citizens.

Japan

Japan has developed multiple building databases and monitoring systems, ranging from official GIS-based inventories in Tokyo to high-resolution 3D city models under Project PLATEAU, as well as specialized registries for historical housing in Kyoto. These initiatives combine advanced digital technologies such as 3D and LiDAR with efforts to document and preserve traditional housing, reflecting Japan's integration of building data into urban planning, disaster risk reduction, and heritage conservation [38-41]. In Tokyo, the official GIS building database includes floor plans, story counts, total floor area, and usage classifications; these attributes were used to estimate station-area population and employment, demonstrating the value of detailed building data for transport-oriented planning [38]. Project PLATEAU, launched in 2020, created standardized 3D city models in CityGML format covering about 18 million buildings across 150 cities. Supporting applications in planning, disaster preparedness, and public engagement, it stands as one of the most comprehensive open digital building inventories globally [39]. In Kyoto, research on Kyo-machiya (traditional wooden townhouses) established a GIS-based monitoring system using PDA mobile GIS tools to georeference, photograph, and assess each house's condition and features, producing a longitudinal database for conservation and heritage-sensitive planning [40]. Earlier studies in Tokyo proposed LiDAR-based updating of urban building inventories to overcome photogrammetric limitations in dense areas, automating updates of building footprints and heights, especially in the Roppongi district, an essential step for seismic risk and damage assessments [41]. Japan's building data systems vary in accessibility: Project PLATEAU is fully open and standardized [39], Tokyo's administrative GIS data are research-accessible but not public [38], Kyoto's heritage GIS serves mainly local authorities [40], and LiDAR datasets require technical processing for broader use [41]. Overall, Japan's building data ecosystem is technologically advanced, integrating 3D and LiDAR systems with both modern and historical housing records. While Project PLATEAU exemplifies national-scale openness, fragmentation persists between municipal, national, and heritage datasets, and technical barriers still limit the full public application of LiDAR-based methods.

Comparative Summary of Country Analyses through Tables

Based on the preceding country analyses, the following comparative table has been compiled. It summarizes which key attributes are included in residential building databases across different countries, such as address, year of construction, building use type, number of apartments, technical data, renovation information, and ownership details. The table provides a structured overview of the findings from all examined cases (Table 1).

Table 2 summarizes the main systems and tools used to manage residential building databases in different countries. It provides an overview of whether building footprints are available, which national databases are in place, what mapping tools are applied, the primary data sources, and the general level of openness. This comparative perspective complements the attribute-based analysis by focusing on institutional and technical infrastructures.

Table 1. Availability of Key Attributes in Residential Building Databases by Country

Country	Address	Year of Contraction	Building use type	Number of Apartments	Technical data	Renovation data	Ownership info
Germany	+	partial	+	-	partial	partial	-
Spain	+	+	+	Partly via tex registers	partial	-	-
Netherlands	+	+	+	-	partial	-	-
Russia	+	+	+	-	partial	-	-
USA	+	+	+	Partial (e. g. NYC PLUTO dataset)	partial	-	-
France	+	+	+	-	partial	-	-
Estonia	+	+	+	-	partial	-	-
Kazakhstan	+	+	+	+ (aggregate only)	-	-	-
Japan	+	+	+		- (only footprints and year)	-	-

Table 2. Main Systems, Tools, and Data Sources for Residential Building Databases by Country

Country	Building footprint	Main database/ system	Mapping tools	Data sources	Openness
Germany	(GeoBasis-DE, INSPIRE)	TABULA / DE typology + national building inventory	GIS (ArcGIS, QGIS), national statistics	EPC data, census, cadastre	Partial
Spain	(Catastro)	*Catastro Inmobiliario* (national cadastre)	Cadastre GIS viewer, ArcGIS	Parcel and building registry, tax databases	Portal
Netherlands	(BAG viewer)-	BAG (*Basisregistratie Adressen en Gebouwen*) + Kadaster	BAG viewer (PDOK), 3D BAG model	Municipal data, national cadastre, GIS	Open
Russia	(Rosreestr map)	Rosreestr (EGRN) - Unified State Register	Public cadastral map	Parcel and building registry, technical passports	Restricted
USA	(city open data)	Buildings Performance Database (BPD), state and city-level databases (e.g., NYC PLUTO, LA GeoHub)	GIS (ArcGIS/QGIS), city open-data portals	Building permits, tax data, EPC	Partial
France	(IGN Geoportail, BatiParis)	BDNB (*Base de Données Nationale des Bâtiments*) + IGN BDTOPO	Geoportail, BatiParis map	Integration of 30+ government registries, national statistics, EPC	Partial
Estonia	(xGIS Maaamet, EBR)	EHR / Estonian Building Registry + ADS (Address Data System)	xGIS Maaamet viewer, QGIS	Cadastre, building permits, energy certificates	Partial
Kazakhstan	(no public map)	Housing Stock Statistics (National Bureau of Statistics)	Statistical reporting (no public map)	Census, national statistics	Restricted
Japan	(NLNI datasets, shapefiles)	National Land Numerical Information (Building Data)	GIS datasets (shapefiles), e-Stat Japan	Local government building data, census	Partial

Taken together, comparative work highlights that effective international benchmarking must consider more than "which parameters are present or absent." Equally important are the institutional settings**,** data governance frameworks**,** technological approaches **(**e.g., GIS, digital twins, LiDAR), and accessibility conditions (open, restricted, or partially aggregated). By situating Armenia's case within such a comparative framework, the present study not only identifies missing data categories but also clarifies which methodological and institutional choices may be most transferable. This provides the basis for a nuanced comparative table in the following section.

Summary of Lessons for Armenia

The comparative review of international experiences highlights a set of transferable principles that are directly relevant to the Armenian context. Although Armenia currently lacks a unified building database, the synthesis of lessons from Germany, Spain, the Netherlands, Russia, the United States, France, Estonia, Kazakhstan, and Japan provides a structured pathway for designing such a system.

A first recurring insight concerns the importance of standardized typologies and archetype models. Germany has shown how layering cadastral data with archetype frameworks and machine learning enrichment can provide reliable and comprehensive stock characterizations [1-5]. Spain has demonstrated the potential of combining EPC datasets with cadastral registers and simulating retrofit potential across climatic zones using archetype models [6-10]. France further illustrated how EPC-archetype linkages can be expanded to monitor renovation progress, while standardized archetype frameworks ensure comparability across European contexts [27-29]. These cases emphasize that Armenia should establish a typology-based framework for its residential stock, which will form the backbone of the proposed national database.

Secondly, the governance and institutional framework is critical. The Netherlands' BAG register illustrates how a centralized, authoritative system can serve as the backbone of national spatial data infrastructures, with local authorities responsible for updates and validation [11-13]. Russia underscores the importance of legal mandates such as technical passports for multi-apartment buildings, ensuring that documentation is systematically produced and maintained [14-20]. Armenia can draw on these models by establishing clear legal requirements and institutional responsibilities for maintaining the database, supported by mechanisms of accountability.

Third, data quality, enrichment, and integration with advanced technologies emerged as another common theme. Estonia provides a clear example of using expert rules, machine learning, and digital twins to enrich incomplete registry data and to support neighborhood-level energy and decarbonization modeling [30-33]. Japan offers longer-term perspectives through Project PLATEAU, demonstrating the added value of 3D city models and LiDAR for continuously updating inventories [38-41]. Armenia can adopt a phased approach, beginning with GIS-based registries, then progressively integrating enrichment techniques and advanced modeling as institutional and technical capacities grow.

Fourth**,** transparency, openness, and usability are indispensable. Open-access platforms such as BAG in the Netherlands [11-13], BPD in the United States [21,22], and Project PLATEAU in Japan [39] have shown that accessible datasets stimulate innovation, academic research, and civic participation. At the same time, countries like Russia illustrate the drawbacks of limited openness, which constrains research and reduces the potential for broad policy uptake [14-20]. Armenia should balance openness with necessary restrictions, ensuring accessibility for research and planning while protecting sensitive information.

Finally, contextual and historical dimensions should not be overlooked. Kazakhstan highlights the importance of documenting Soviet-era mass housing typologies and their modernization challenges [37]. This resonates directly with Armenia's own housing legacy, where much of the stock consists of standardized series requiring systematic evaluation and renewal. Armenia should therefore integrate historical documentation with forward-looking data collection, ensuring both preservation of context and planning for modernization [34-37].

Beyond these lessons, the comparative analysis highlights emerging opportunities for a national residential-building database in Armenia. Rapid advances in open-data technologies and international cooperation in spatial and building information systems can be leveraged. Partnerships with European and Asian actors, participation in regional data-harmonization efforts, and adaptation of open-source tools (e.g., SEED, BAG-inspired models) provide a practical basis to accelerate digitalization of the housing sector. Armenia's compact urban structure also enables phased rollouts and pilot testing to refine methods before nationwide deployment.

Concurrently, several risks must be addressed to ensure long-term sustainability. Institutional fragmentation, limited technical capacity, and scarce financial resources could impede implementation and inter-agency coordination. The absence of a legal mandate for technical building passports threatens data completeness and continuity. Privacy and cybersecurity constraints may curtail openness, limiting research and policy utility. Without sustained government support, strong data governance, and long-term funding, the initiative risks remaining a short-lived project rather than a durable national platform.

Results and Discussion

The proposal of a phased approach to database implementation is driven by the need to reduce risks associated with database development and to ensure system stability.

The proposed phased implementation approach consists of five consecutive stages, each with clearly defined objectives and outcomes.

Phase 1. Selection of a pilot residential area and boundary definition

- Select a representative residential area (neighborhood or microdistrict), taking into account building typology, construction period, and urban planning characteristics.
- Define the boundaries of the area and identify the buildings within it.
- Outcome: a spatially defined pilot zone and a list of database objects.

Phase 2. Development of the data system and model

- Develop a unified system of building characteristics (technical, spatial, functional, and operational indicators).
- Establish the logical structure of the database (tables, attributes, and relationships).
- Outcome: an approved data model and a defined set of indicators.

Phase 3. Initial data collection and verification

- Collect available archival, cadastral, and design documentation.
- Conduct field surveys to verify missing or unreliable data.
- Perform cross-validation of data across different sources.
- Outcome: a verified and reliable dataset for the pilot area.

Phase 4. Database population and functional testing

- Enter the verified data into the database.
- Test data retrieval, updating, and analysis functionalities.
- Identify methodological and technical shortcomings.
- Outcome: an operational pilot database and a refined methodology.

Phase 5. Dissemination and scaling

- Refine the methodology based on pilot results.
- Develop normative and methodological guidelines for nationwide implementation.
- Gradually extend the database to other residential areas, municipalities, and regions.
- Outcome: a scalable framework for a national multi-apartment residential building database.

The proposed multi-stage methodology enables incremental improvement, reduces the likelihood of errors, and ensures alignment of the database with the institutional and information environment.

Within the framework of this research, a methodology for creating a database of multi-apartment residential buildings was developed and proposed (Appendix 1). Although formulated using multi-apartment housing as

the primary example, the methodology can also be applied to the creation or integration of databases for public and industrial buildings in different cities or individual urban areas.

The methodology comprises the following main stages:

I. Data collection
II. Multi-factor data analysis
III. Data classification
IV. Data integration
V. Application of results

I. Data Collection

The primary data sources include the Cadastre Committee of the Republic of Armenia, municipal or local authorities, up-to-date cartographic and topographic datasets, and residential building management companies. Data collected from these official sources are complemented by resident surveys and observations using Google Earth Street View.

The data collection methods include field (in-situ) surveys, analysis of online sources, automated data acquisition via a GIS platform, and structured questionnaires.

During the collection and examination of multi-apartment building data through the GIS platform, the following processes are carried out: address classification, cadastral linkage, building identification, and geometric delineation. Based on building geometry, standard-design residential buildings are detected and classified. Through the analysis of address data and cadastral maps alone, it is possible to identify the building's location, address, land parcel information (functional and designated land use), and geographic coordinates. The determination of building coordinates is essential for the verification stage, as it enables field-based validation and correction of inaccurately delineated or misclassified buildings.

II. Multi-Factor Data Analysis

During data validation and filtering, the completeness and accuracy of the collected information are verified. Duplicate or unreliable entries are removed, while missing data are supplemented using alternative verified sources.

To enhance the quality of results obtained through the GIS platform, datasets are cross-referenced with satellite imagery, and clearly low-quality or non-applicable images are excluded from the analysis. Comparative analyses are conducted between data obtained from official sources and GIS-derived results. In cases of inconsistency, data verified through field surveys serve as the primary basis for validation.

Analytical reports may be generated to assess data completeness and interlinkages. The final validated datasets are confirmed through expert discussions and agreements with relevant institutions.

III. Data Classification

The collected data are classified into the following main groups:

General information: address, year of construction, building type, cadastral number, identification code, land parcel area, managing authority.

Architectural and spatial data: number of floors, number of apartments by type, number of entrances, staircases, elevators, building footprint area, basement area, attic area, technical floor area, total residential floor area, area of public or commercial spaces, total floor area, floor height, maximum elevation point, site coverage ratio, and floor area ratio (density coefficient).

Structural system: type of structural system, external wall type, foundation type, roof type, thermal insulation of external walls, and overall technical condition.

Engineering systems: roof drainage, sewage, cold and hot water supply, ventilation, gas supply, heating, electrical supply, fire protection systems, and their technical condition.

Main renovations: information on the type, scope, and year of implementation of renovation or reconstruction works (Appendix 2).

IV. Data Integration

Based on the validated datasets, the systemic structure of the database is formed. Data are standardized into a unified format and organized by region, city, administrative district, and building series.

V. Application of Results

The structured and systematized data on multi-apartment residential buildings can serve as a foundation for urban planning and policy-making, public awareness and information dissemination, strategic planning of renovation and reconstruction programs, risk assessments (including seismic resilience and energy efficiency), socio-economic analyses, preparation of investment programs, and modeling of spatial development strategies.

Example of Residential Building Database Mapping in the Davtashen Administrative District

This study includes a pilot application conducted in the Davtashen administrative district of Yerevan, which contains multi-apartment buildings of diverse typologies, from Soviet-era prefabricated panel structures to newly built residential complexes. Each multi-apartment building was identified based on orthophoto boundaries, address data, and cadastral information. Identification through address databases alone often leads to inconsistencies related to property registration and population records. Therefore, to minimize these discrepancies, the research team developed a combined dataset integrating cadastral and address data, ensuring higher accuracy and completeness.

The addresses were linked to cadastral data (Fig.1), enabling geometric delineation and spatial verification of buildings. During the study, buildings were classified, geocoded, and verified through multiple stages, address classification, cadastral linkage, geometric isolation, and analytical verification.



Fig. 1. *The address has been linked with cadastral data*

As a result, several non-residential structures were filtered out, and a total of 334 buildings were identified within the Davtashen district, 195 of which were classified as multi-apartment residential buildings (Fig. 2).

Field verification and satellite imagery were used to validate the data and eliminate errors. Low-quality or outdated images were excluded, and site visits were performed when necessary to confirm building typologies.

This mapping allowed for the creation of a pilot residential building database map for the district, which visually illustrates the distribution and typological diversity of multi-apartment buildings. The spatial analysis confirms that many of these buildings, despite architectural variations, can be categorized as standard-design residential buildings based on their geometric and functional characteristics. Figure 3 presents an illustrative map of residential buildings in Davtashen, demonstrating how cadastral and address data integration can support the development of a comprehensive urban database.

Figure 4 illustrates the detailed information displayed for an individual building when selected on the database map. The interface shows key architectural, structural, and technical attributes, such as the building's address, construction year, number of floors and apartments, structural type, and condition, demonstrating how the proposed system enables building-level data visualization.

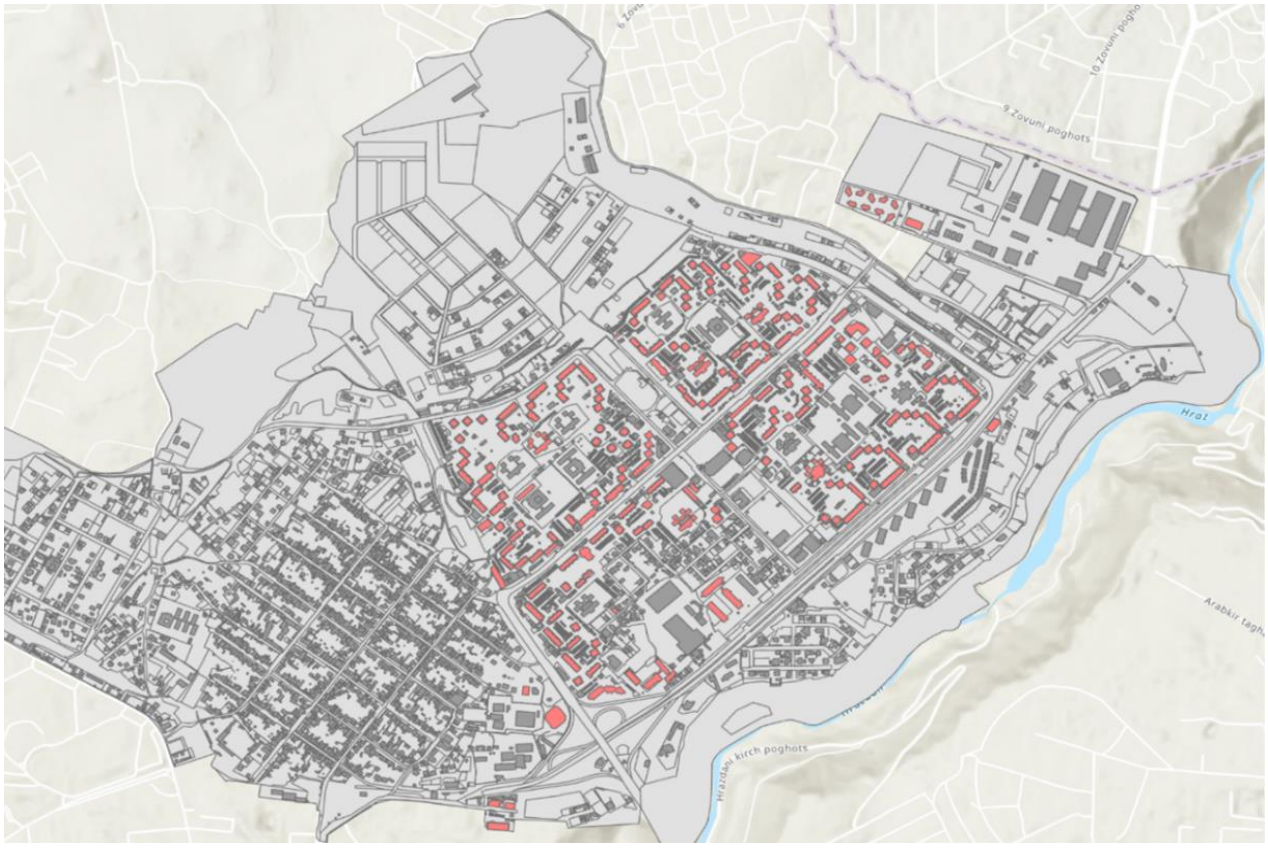


Fig. 2. *Isolated multi-apartment residential buildings*



Fig. 3. *Characteristic data of a multi-apartment building according to the proposed residential building database*



Fig. 4. *Preliminary example of the characteristic data and map of the residential building database map of the Davtashen administrative district*

Conclusion

As the study has shown, there exist a number of normative legal documents and scientific-practical projects developed at different periods concerning the collection of data on multi-apartment residential buildings, which reflect their management and control mechanisms. At the same time, a comprehensive and accurate dataset on the architectural and technical condition of buildings is still lacking in the form of a unified platform.

The analysis makes it possible to identify the main prerequisites for developing a database creation methodology for the Republic of Armenia. These include:

- A typological system of multi-apartment residential buildings, which will serve as the foundation of the database.
- Clearly defined legal requirements and institutional responsibilities for maintaining the database.
- Data quality, enrichment, and integration with advanced technologies, starting from a GIS platform and gradually incorporating enrichment techniques and advanced modeling.
- Limited data accessibility, ensuring availability for research and project development while protecting confidential information.
- A combination of historical documentation and ongoing data collection, maintaining contextual integrity while allowing for modernization.

As a result of the research, a methodology for the creation of a database of multi-apartment residential buildings has been developed and proposed, reflecting the fundamental principles and approaches underlying the database design. The methodology consists of the following main stages: data collection, analysis, classification, integration, and application of results.

The outcomes of this work can be applied in the formation or integration processes of databases for multi-apartment residential buildings, as well as for public and industrial buildings, both in various cities and in separate urban sectors.

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Conflict of Interest

The authors declare no conflicts of interest.

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DATABASE CREATION METHODOLOGY

APPENDIX 1

	PHASES	STEPS	
1	DATA COLLECTION	**RECEIVING SOURCES** • Cadastre Committee of the RA • Municipality or local authorities • Up-to-date cartographic and topographic datasets • building management companies • Resident surveys • Google Earth Street View observations	**COLLECTION METHODS** • Field (in-situ) surveys • Analysis of online sources • Automated data capture through a GIS platform
2	MULTI-FACTOR DATA ANALYSIS	**VALIDATION AND FILTERING** • Verify the completeness and accuracy of the data • Removal of unreliable data • Missing data are completed using alternative verified sources	**CONFIRMATION** • Expert discussions • Agreements with relevant institutions
3	DATA CLASSIFICATION	**CLASSIFICATION OF GROUPS** • General information • Architectural and spatial data • Structural system • Engineering systems • Technical condition of structural and engineering systems • Main renovations	
4	DATA INTEGRATION	**STANDARDISATION** • The collected and approved data are standardized in a unified format	**SEPARATION** • By region • By city • By administrative district • By building series
5	APPLICATION OF RESULTS	**DEFINING THE APPLIED AND PROSPECTIVE FRAMEWORKS** • Urban planning and policy-making • Public awareness and information-sharing • Strategic development of renovation and reconstruction programs • Risk assessments (including seismic resilience and energy efficiency) • Socio-economic and demographic analyses • Preparation of investment programs • Modeling of spatial development strategies	

ARRAGEMENT OF INCLUDED DATA

APPENDIX 2

SECTIONS	ITEMS			
1 DATA GROUPS	GENERAL INFORMATION	ARCHITECTURAL AND SPATIAL DATA	STRUCTURAL SYSTEM	ENGINEERING SYSTEMS
	• Address • Year of construction • Building type • Cadastral number • Identification code • Land area • Governing body	• Number of floors • Number of apartments by type • Number of entrances • Number of staircases • Number of elevators • Construction area • Basement area • Mansard area • Technical floor area • Total area of residential units • Area of public or commercial areas • Total area • Floor height • Maximum elevation point • Construction percentage and density coefficient	• Structural type • External wall type • Foundation type • Roof type • Thermal insulation of outer walls	• Roof drainage • Sewage • Cold water supply • Hot water supply • Ventilation • Gas supply • Heating • Electrical supply • Fire protection system
2 MAIN RENOVATIONS	TYPE OF WORK	SCOPE OF WORK	YEAR OF IMPLEMENTATION	
3 LOCATION ON THE MAP				
4 ASSESSMENTS / REPORTS				

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