A Database-Driven Architecture for Integrating and Serving 3D Condominium and Cadastral Information: The CondoMaps Platform

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***Abstract*—Three-dimensional condominium information systems require more than visual building models: spatial objects must be constructed from authoritative plans and linked consistently to cadastral, registration, building, unit, parcel, and juristic-person records. This study presents CondoMaps, a database-driven architecture for constructing, organizing, and serving 3D condominium information in Thailand. The workflow transforms verified floor plans and cadastral references into georeferenced LOD2 building and unit geometries, assigns persistent project–building–floor–unit identifiers, stores administrative and legal attributes in a normalized relational database, and publishes the integrated objects through controlled map, scene, query, and REST services. The accepted production snapshot contains 7,150 condominium projects, more than 180,000 units, over 650 LOD2 buildings, at least 6,500 contextual LOD1 buildings, 194,304 spatial features, and 457,936 linked attribute records. The combined database and file repository occupies approximately 6 TB and supports 48 published services across 22 land-office branches. Quality checks on the accepted snapshot found complete mandatory documentation and fields, no duplicate normalized keys, and no orphan records in the reported integrity tests. Linkage rates of 100% apply only to the specified sets of 7,150 evaluated records or objects and are not estimates for all units. Horizontal RMSE values of 0.0775 m and 0.031674 m were obtained in two four-control-point plan rectification cases; they are case-level results, not evidence of repository-wide positional accuracy. A browser implementation demonstrates retrieval of associated unit, juristic-person, coordinate, title-deed, and parcel-survey information from a selected 3D building. The contribution is the traceable end-to-end linkage among source documents, normalized records, identifiable 3D objects, and governed web services rather than visualization alone. Performance and formal security benchmarks remain future work.**

Keywords*—3D Condominium model; spatial database; 3D cadastre; data integration; web GIS; service-oriented architecture; CondoMaps

I. Introduction

Condominium information management requires the integration of heterogeneous sources that describe the same property from legal, physical, spatial, administrative, and institutional perspectives. A project may be represented by scanned plans, cadastral parcels, building and unit geometries, registration records, juristic-person information, taxation attributes, and territorial references. Because these sources originate from different institutional and technical workflows, they often differ in format, identifier structure, coordinate reference, completeness, and update frequency. When maintained in disconnected systems, the relationship between a physical condominium object and its authoritative records becomes difficult to trace, validate, and maintain.

The problem is particularly significant for vertical property. Condominium units may overlap horizontally while remaining distinct by floor, elevation, internal boundary, ownership status, and associated rights. Three-dimensional cadastre and BIM–GIS research has improved the representation of vertically subdivided legal spaces and the association of building geometry with structured property information [1]–[5]. Condominium-oriented BIM/IFC studies have further incorporated ownership boundaries, legal semantics, and rights, restrictions, and responsibilities into 3D building models [6], [7], while web-based prototypes demonstrate the value of interactive access to legal spaces [8].

Complementary research has advanced building and indoor-space reconstruction from point clouds, photographs, sketches, reusable components, and orthographic drawings [9]–[13]. Service-oriented geospatial platforms have also demonstrated reusable delivery of 3D GIS, property, environmental, land-use, and enterprise information [14]–[18]. These developments provide the geometric and service foundations required for 3D property systems. However, geometric construction and service publication do not by themselves ensure that an individual 3D building or unit remains uniquely connected to its authoritative cadastral, governance, and administrative records.

The central computer-science problem is therefore how to preserve stable identity and traceable relationships throughout the complete information lifecycle. Authoritative documents must be validated, plans spatially rectified, records normalized, geometries assigned persistent identifiers, relational constraints enforced, and accepted objects published through controlled map, scene, query, report, and REST services. The architecture must also permit geometry, legal attributes, administrative information, and service configurations to be updated independently without breaking their relationships.

Existing studies have progressively connected 3D cadas-

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tre, dynamic BIM, semantic building models, browser-based GeoBIM, and cadastral digital-twin frameworks [19]–[24]. Nevertheless, production-scale evidence remains limited for an architecture that preserves a deterministic identity chain from source documents to normalized records, from records to 3D objects, and from those objects to governed service responses. Cross-country assessments of BIM and geoinformation likewise identify semantic conversion, georeferencing, harmonization, policy, and institutional capacity as continuing barriers to operational integration [25].

This study presents CondoMaps, a database-driven architecture for integrating and serving 3D condominium and cadastral information in Thailand. The study examines how verified plans and cadastral references are transformed into georeferenced 3D models, how a persistent project–building–floor–unit hierarchy binds these objects to normalized relational records, and how the integrated information is retrieved through governed geospatial and REST services.

The proposed architecture combines document validation, spatial rectification, normalized data management, identifier-based object enrichment, database-resolvable 3D queries, and controlled service publication. Its implementation is evaluated using a production snapshot containing 7,150 condominium projects, more than 180,000 units, over 650 LOD2 condominium buildings, at least 6,500 contextual LOD1 buildings, 194,304 spatial features, 457,936 attribute records, and 48 published services. The evaluation covers documentary completeness, normalized-key uniqueness, object–record linkage, spatial rectification, geometry validity, relational integrity, and functional retrieval.

The principal contribution is an end-to-end object–relational–service architecture that preserves identity from authoritative documents to normalized database entities, from database entities to identifiable 3D objects, and from those objects to governed client responses. The novelty lies not in a new rendering algorithm or database engine, but in the deterministic and traceable integration of these components within an operational condominium information lifecycle.

II. Related Work and Research Gap

The literature relevant to CondoMaps can be analyzed through three technical capabilities: service-based information delivery, semantic representation of vertical property, and geometric reconstruction. These capabilities are complementary, but they solve different parts of the overall information lifecycle.

Service-oriented geospatial systems separate repositories, processing functions, and client applications to support information reuse across institutional workflows [14]–[18]. Their architectural strength lies in interoperability at the application level, but their service contracts are usually defined around datasets, layers, or administrative records. They rarely specify how the identity of a selected unit or building component is preserved across geometry, normalized records, authorization rules, and service responses.

Three-dimensional cadastre and BIM–GIS research provides a richer representation of vertically subdivided property. Existing approaches support visualization of legal spaces, standards-based spatial planning, integration of BIM and geospatial information, strata-title modeling, and 3D property master plans [1]–[5]. Condominium-specific BIM/IFC research extends these approaches by representing ownership boundaries and legal semantics [6], [7], while web-based prototypes demonstrate interactive access to modeled legal spaces [8]. Their principal limitation is the limited documentation of operational maintenance across project, building, unit, parcel, juristic-person, territorial, and audit entities.

Geometric reconstruction research addresses another component of the lifecycle. Point-cloud segmentation, image- and sketch-guided modeling, component-based construction, orthographic conversion, and automated generation of cadastral solids improve the efficiency and geometric quality of 3D model production [9]–[13]. These methods provide the spatial objects required by a 3D property platform, but geometric validity does not inherently establish authoritative cadastral identity.

Table I compares the principal research streams and shows that the gap is not the absence of visualization, cadastral databases, reconstruction methods, or web services individually. It is the absence of a persistent integration contract that governs the transitions among them.

TABLE I. Comparison of Related Research Streams

Stream	Strength	Typical Limitation	Requirement Addressed by CondoMaps
Service-oriented GIS	Reusable services and distributed access	Dataset-, layer-, or record-oriented contracts	Persistent resolution from 3D objects to authorized relational records
3D cadastre and BIM–GIS	Vertical-space and legal-semantic representation	Limited synchronized operational maintenance	Project–building–floor–unit identity linked to cadastral and governance entities
Geometric reconstruction	Efficient generation of structured 3D geometry	Geometry does not establish authoritative identity	Identifier assignment and relational validation before publication
Conventional cadastral databases	Authoritative legal and administrative records	Weak vertical representation and 3D interaction	Database-resolvable 3D objects linked to existing records

The resulting research gap is a deterministic identity chain that remains valid through four transitions: source document to normalized entity, normalized entity to 3D object, 3D object to governed service, and service response to client interaction. The same identity must support both spatial selection and attribute-based search and remain stable when geometry, descriptive attributes, governance records, or service permissions are revised independently.

III. CondoMaps Architecture and Workflow

A. Layered Architecture

The deployed architecture combines data, GIS-service, and application tiers. As shown in Fig. 1, Database Server 1 maintains condominium attributes, unit-related records, and LOD1–LOD2 building datasets, while Database Server 2 supports property-tax data exchange. A cleansing and validation layer mediates data movement into the condominium repository. SuperMap iServer and iPortal provide map, scene, query, and portal functions, and mobile and web applications consume the published services. The 77-province component represents a planned expansion target rather than completed production coverage.

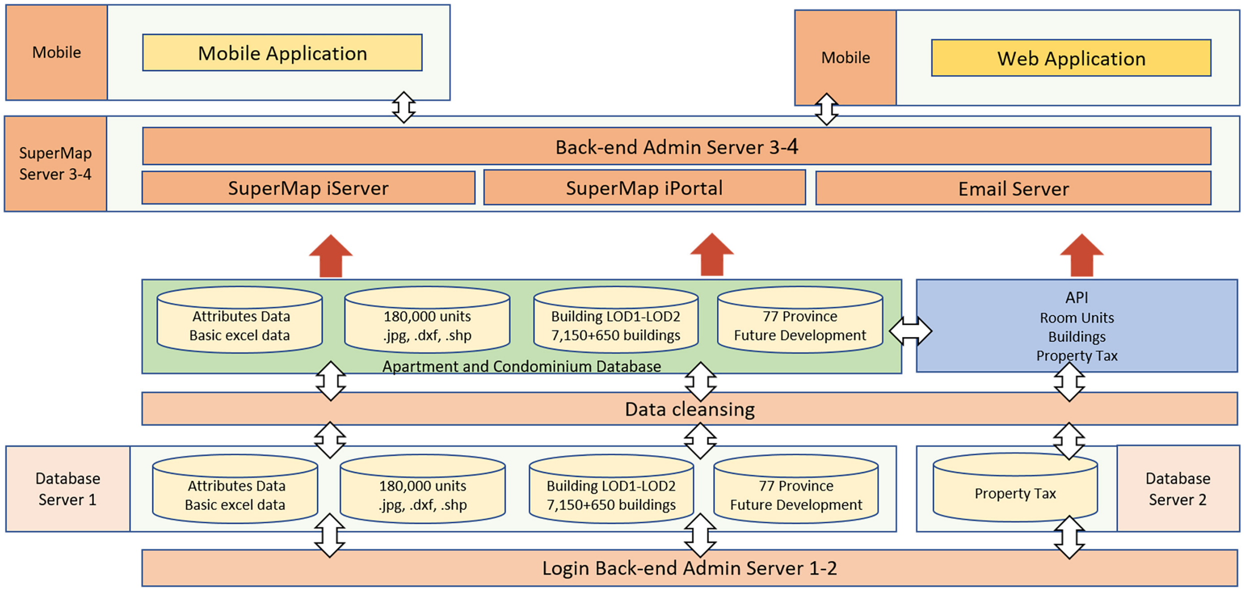


Fig. 1. Physical deployment and data-flow architecture of CondoMaps.

B. Relational Model and Object Identity

The production database contains 16 operational and reference tables. These tables are grouped into core condominium, cadastral, governance, administrative, and system domains. Table II summarizes the functional role of each domain, while Fig. 2 presents the core relationship among condominium projects, buildings, units, unit properties, and 3D object identifiers.

TABLE II. FUNCTIONAL DATA GROUPS

Group	Representative Tables	Role
Core condominium	TB_REG_CONDO, TB_REG_CONDO_BLD, TB_REG_CONDOROOM	Stores project, building, floor, unit, area, dimensions, and linkage identifiers
Cadastral	TB_REG_PARCEL	Stores parcel, survey, UTM reference, registration, area, and ownership attributes
Governance	Corporate, committee, agent, and common-property tables	Represents juristic persons, responsible actors, governance history, and shared property
Administrative	Region, province, amphur, tambol, and land-office tables	Normalizes territorial and responsible-office references
System	Log and information tables	Supports authentication traces, record status, audit history, and portal content

The extended cadastral relationship is shown in Fig. 3. It connects condominium records to parcels, land offices, and normalized territorial references. Governance and audit tables follow the same foreign-key principle and are therefore described in text rather than repeated as separate figures.

The identifier hierarchy is expressed as:

$$I_o = (I_c, I_b, I_f, I_u), \tag{1}$$

where, I_c, I_b, I_f, and I_u denote condominium, building, floor, and unit identifiers. In the current database, I_u is implemented through the room identifier. A building object uses (I_c, I_b), while a unit object uses the complete tuple. Parcel, juristic-person, and administrative records are resolved through foreign-key relationships rather than geometric proximity.

For example, the illustrative tuple $(1987, 1, 12, 1208)$ denotes unit 1208 on floor 12 of building 1 in condominium project 1987. When this object is selected, the query service uses the tuple to resolve the associated project, building, unit, parcel, land-office, and juristic-person records. The example illustrates the resolution mechanism and is not presented as a verified production identifier.

C. Document-to-Model Workflow

The workflow begins with completeness checking of registration documents, floor plans, parcel references, and supporting attributes. Accepted plans are scanned, assigned project identifiers, and rectified using control points. The horizontal residual for control point i is:

$$e_i = \sqrt{(x'_i - x_i)^2 + (y'_i - y_i)^2}, \tag{2}$$

And the reported horizontal RMSE is:

$$RMSE_{xy} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}. \tag{3}$$

Two supplied rectification evaluations each used four control points. Case A produced a horizontal RMSE of 0.0775 m and a maximum residual of 0.077744 m; Case B produced a horizontal RMSE of 0.031674 m and a maximum residual of 0.040204 m. The cases were not selected through a repository-wide probability sampling design. They therefore demonstrate the rectification calculation and the results for the two evaluated plans only; they do not characterize positional accuracy across all projects, buildings, or units.

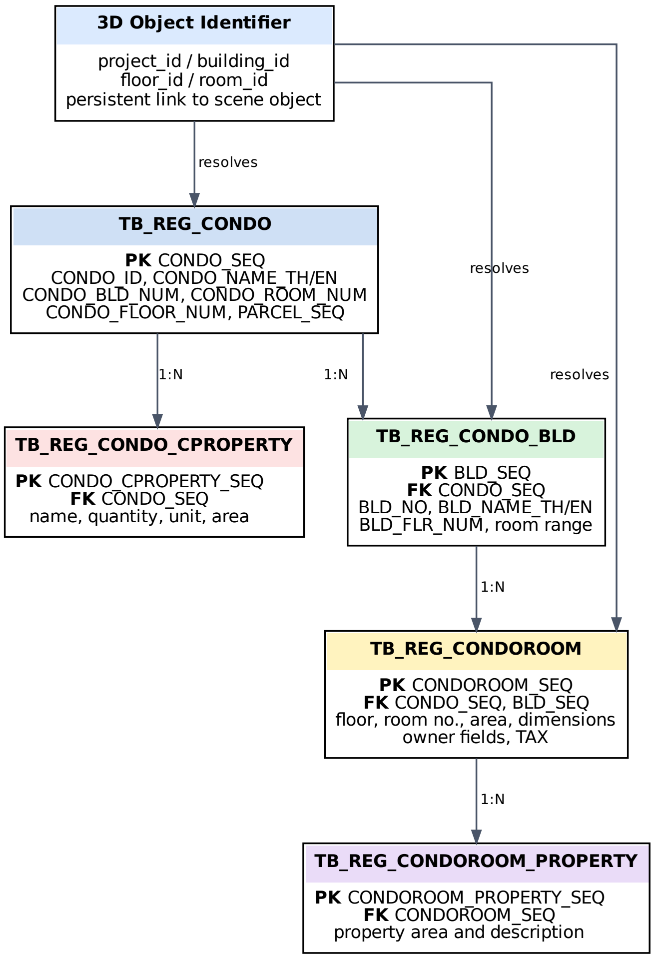


Fig. 2. Core relational structure linking condominium projects, buildings, units, unit properties, and 3D object identifiers.

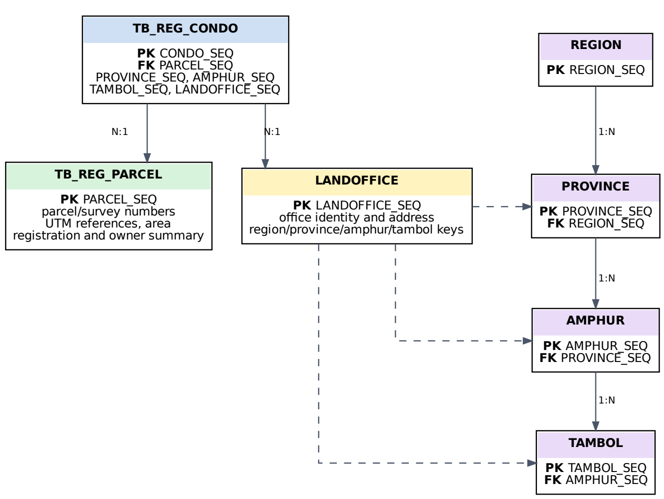


Fig. 3. Cadastral and administrative linkage among condominium records, parcels, land offices, and territorial references.

Rectified plans are digitized into floor boundaries, unit polygons, circulation spaces, and common areas. Repeated floors are generated from verified templates, while exceptional floors are modeled separately. Building envelopes are then constructed at LOD2, positioned in the geospatial reference system, and enriched with persistent identifiers. The main construction stages are illustrated in Fig. 4.

After geometric construction, project, building, floor, and unit identifiers are validated against the relational database. An object is published only when its parent entities resolve successfully, mandatory fields pass validation, and geometry satisfies the production rule. The integration procedure therefore consists of source validation, rectification, geometric construction, key normalization, parent resolution, object enrichment, duplicate and orphan checks, permission registration, and service publication.

D. Service Publication and Query

The service layer publishes 2D maps, 3D scenes, attribute queries, reports, and REST endpoints. Identity and authorization rules determine which services and fields a user may access. Audit fields record creation, modification, status, and user activity.

The available implementation records contain two independent API examples. They are reported separately because the identifiers in one request–response pair cannot be used to infer a relationship with the other operational case.

Listing 1: Example A: parcel-oriented query request.

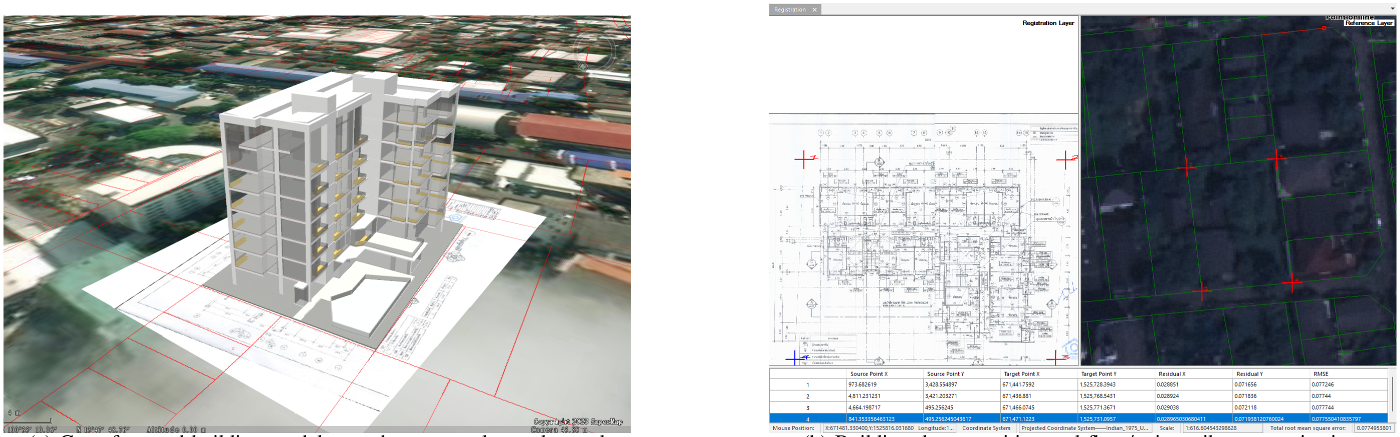
```
{
  ‘‘province”: ‘‘Bangkok”,
  ‘‘parcel_num”: ‘‘4149”
}
```

Listing 2: Example A: abbreviated response returned by the supplied API record.

```
{
  ‘‘code”: 200,
  ‘‘msg”: ‘‘success”,
  ‘‘condo_seq”: ‘‘1987”,
  ‘‘district”: ‘‘Phra Khanong”,
  ‘‘parcel_no”: [‘‘124149”]
}
```

The difference between the request value `4149` and returned parcel value `124149` reflects the supplied example. Because the available record does not document whether the first value is a search token, truncated identifier, or alternate parcel field, this example demonstrates API structure only and is not used as evidence of identifier equivalence.

In a separate operational example (Example B), project 1068 is associated with parcel numbers 41492 and 41493 and related corporate records. Fig. 5 shows the corresponding database-connected client workflow. Selecting a 3D condominium retrieves the project name and location, building, floor, and unit counts, juristic-person information, coordinates, title-deed numbers, and parcel-survey numbers. The illustrated project contains one building, 45 floors, and 494 units. Example B is independent of Example A.



(a) Georeferenced building model over the source plan and parcel context.

(b) Building decomposition and floor/unit attribute organization.

Fig. 4. Representative 3D condominium construction and enrichment stages.

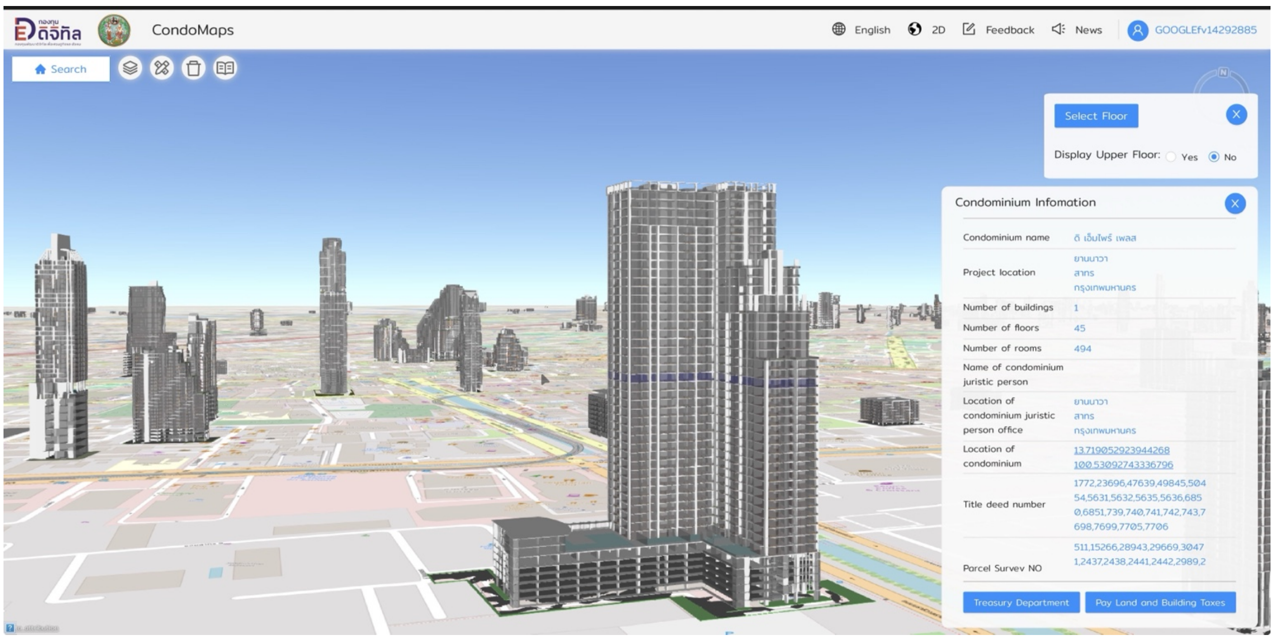


Fig. 5. Database-connected CondoMaps interface for retrieving integrated condominium and cadastral information.

IV. Implementation and Evaluation

A. Deployment Environment and Evaluation Design

The reported server-side deployment environment is summarized in Table III. These values document the production context but are not treated as a performance benchmark because client configuration, browser, benchmark tooling, and repeated workload measurements were not supplied.

The 1 TB value in Table III describes the locally provisioned storage of the reported server node, whereas the approximately 6 TB value in Table IV describes the combined logical inventory of the database and file repository used by the deployment. The latter is therefore not the capacity of the single server listed in Table III.

TABLE III. Server-Side Deployment Environment

Component	Configuration
Processor	Intel Xeon 6278C, 8 cores
Memory	64 GB
Storage	1 TB
Operating system	Microsoft Windows Server 2019 Standard
Database	Microsoft SQL Server 2019 Standard
GIS server/portal	SuperMap iServer 10.2.1; SuperMap iPortal 10.2.0
Web runtime	Apache Tomcat 8.5.70; JVM 1.8.0_256-b01
Network	100 Gbps (reported)

The evaluation uses five dimensions: production scale, documentary and attribute quality, positional accuracy, relational integrity, and functional retrieval. For a validation rule, the pass rate is:

$$Q = \frac{N_{pass}}{N_{tested}} \times 100\%, \tag{4}$$

where, N_{tested} is the assessed population or evaluation set and N_{pass} is the number satisfying the rule. Duplicate and orphan rates use the corresponding violation count in the numerator.

B. Production Scale

TABLE IV. PRODUCTION DATASET AND IMPLEMENTATION SCALE

Indicator	Value	Indicator	Value
Condominium projects	7,150	Land-office branches	22
LOD2 condominium buildings	>650	Contextual LOD1 buildings	≥6,500
Condominium units	>180,000	Operational SQL tables	16
Spatial features	194,304	Attribute records	457,936
Scanned documents	7,150	Spatial datasets	5
Published services	48	Repository size	6 TB

Table IV summarizes the frozen production snapshot dated October 18, 2023. The platform manages 7,150 projects across 22 land-office branches. The repository includes more than 180,000 condominium units, over 650 LOD2 buildings, at least 6,500 contextual LOD1 buildings, 194,304 spatial features, and 457,936 linked attribute records.

C. Quality, Integrity, and Functional Retrieval

The reported data-quality and relational-integrity results are summarized in Table V. The wording distinguishes full repository counts from evaluated records because several validation populations differ from the overall inventory.

Functional retrieval was verified through two paths. In the spatial path, the selected 3D object submits its identifier tuple and retrieves the associated project, building, unit, parcel, juristic-person, land-office, and territorial records. In the attribute path, a search by project name, province, district, parcel number, or license returns matching identifiers and scene objects. Both paths converge on the same normalized entities, which prevents separate 2D, 3D, and administrative applications from maintaining inconsistent copies.

The validation populations were defined by the scope of each archived check, not by a single common denominator. Repository-wide checks were executed on the accepted unit table (approximately 180,000 unit records) or the accepted attribute table (457,936 records), as indicated in Table V. The two linkage checks were available only as separate exports containing 7,150 evaluated records or objects. These exports contain one entry per condominium project, but the retained metadata do not establish a probability sampling procedure for selecting a unit or object within each project. Consequently, the reported 100% linkage rates describe only those archived evaluation sets. They must not be interpreted as population estimates for all 180,000 units. By contrast, the orphan-unit query was run against the complete accepted unit table and therefore has a different denominator.

V. RESULTS AND COMPARATIVE ANALYSIS

The implementation demonstrates that authoritative source documents, normalized relational entities, identifiable 3D objects, and governed web services can be connected within one operational workflow. The scale and integrity results show that the architecture has been applied beyond a small prototype, while the browser and API examples demonstrate database-resolvable retrieval.

Table VI positions CondoMaps relative to single-purpose systems. The proposed architecture is not claimed as a new rendering algorithm or database engine. Its originality lies in the integration contract that makes authoritative records, 3D objects, and services mutually resolvable.

The comparison is limited to capabilities explicitly described in the cited publications; absence from the table means “not reported for this comparison,” not necessarily that a capability is absent from the implementation. CondoMaps is differentiated by its persistent production identity chain and governed service publication, whereas the cited systems make distinct contributions in rights visualization, legal-space prototyping, and BIM/IFC semantics.

The results should nevertheless be interpreted within the available evidence. Dataset size demonstrates operational breadth but not workload-based scalability. The two rectification cases provide case-level positional evidence, not a population-wide accuracy estimate. The reported 100% quality results describe the accepted production snapshot after validation and should not be interpreted as the quality of all incoming raw submissions.

VI. DISCUSSION

The central contribution of CondoMaps is a persistent object–relational–service architecture that preserves the identity of a condominium entity across authoritative documents, normalized database records, 3D geometry, published services, and client interactions. Existing 3D cadastral platforms demonstrate the value of visualizing vertically subdivided rights [1], [4], [8], while BIM/IFC studies show how ownership boundaries and legal semantics can be represented within building models [6], [7]. CondoMaps complements these approaches by using a persistent project–building–floor–unit identifier hierarchy as the resolution key between a selected 3D object and its associated project, building, unit, parcel, juristic-person, territorial, and audit records. The contribution is therefore not visualization or semantic modeling alone, but continuity of identity throughout the operational information lifecycle.

This identity chain also addresses several recurring BIM–GIS and 3D land-administration challenges, including georeferencing, semantic conversion, data harmonization, and institutional coordination [2], [3], [25]. In the implemented workflow, these concerns are handled through normalized entities, persistent identifiers, validation gates, foreign-key constraints, and governed service publication. Geometry and descriptive records can therefore be maintained as separate technical resources while remaining mutually resolvable. This separation is important in a production environment because geometry, legal attributes, administrative references, and service permissions may change at different times and under different organizational responsibilities.

TABLE V. QUALITY AND INTEGRITY RESULTS FOR THE ACCEPTED PRODUCTION SNAPSHOT

Test	Evaluated population	Result	Scope of inference
Document completeness	7,150 accepted projects	100%	Mandatory documents in the accepted project snapshot
Duplicate normalized keys	457,936 accepted attributes	None	Accepted attribute table
Mandatory fields	457,936 accepted attributes	100%	Accepted attribute table
Unit–building linkage	7,150 archived linkage records	100%	Evaluated set only; not all units
Attribute–geometry linkage	7,150 archived object records	100%	Evaluated set only; not all spatial objects
Rectification case A	4 points; one plan	0.0775 m	Plan only; maximum residual 0.077744 m
Rectification case B	4 points; one plan	0.031674 m	Plan only; maximum residual 0.040204 m
Geometry validity	7,150 accepted geometries	100%	Evaluated accepted geometries
Orphan buildings	7,150 accepted buildings	None	Evaluated building records
Orphan units	Approx. 180,000 accepted units	None	Complete accepted unit table at snapshot date
Condominium–parcel linkage	7,150 accepted projects	100%	Accepted project records
Administrative hierarchy	457,936 accepted attributes	100%	Accepted attribute table

TABLE VI. CAPABILITY COMPARISON WITH REPRESENTATIVE PUBLISHED SYSTEMS

Capability	CadaSPACE [1]	Ilgar et al. [8]	Liu et al. [6]	CondoMaps
Primary emphasis	3D property-right visualization	Web legal-space prototype	BIM/IFC ownership model	Production data and service integration
Vertical legal/unit model	Yes	Yes	Yes	Yes
Browser-based 3D	Yes	Yes	Not central	Yes
Authoritative linkage	2D cadastral registry	Legal and BIM data	BIM/IFC semantics	Normalized cadastral and governance entities
Persistent identity chain	Not reported	Not reported	IFC-based semantics	Explicit project–building–floor–unit tuple
Governed service suite	Not reported	Prototype web delivery	Not central	Map, scene, query, report, and REST
Reported scale	Research platform	Building prototype	Case study	7,150 projects; >180,000 units; 48 services
Performance/security tests	Not compared	Not compared	Not compared	Not evaluated

For land administration, the architecture provides an explicit route from a physical or visualized building component to its registered context. This is particularly relevant to vertically overlapping property interests, which cannot be interpreted reliably from parcel footprints alone [1], [4], [6], [8]. The same resolution mechanism can support taxation, valuation, planning, and administrative reporting by connecting a spatial unit to its area, building, parcel, juristic-person, and territorial attributes. These uses should nevertheless be understood as supported application pathways rather than measured outcomes: the present study did not evaluate valuation models, tax calculations, planning decisions, or emergency-management performance.

The production snapshot demonstrates that the architecture has been applied at a scale substantially larger than a building-level prototype. However, the quality results must be interpreted according to their evaluation populations. All completeness, uniqueness, validity, and integrity metrics were calculated on the accepted production snapshot after validation gating; raw submissions that failed the acceptance rules were excluded. Consequently, the reported values describe the consistency of the filtered repository and do not measure the quality of incoming submissions or the overall data-acceptance rate. Likewise, the 100% unit–building and attribute–geometry linkage rates apply only to the two archived evaluation sets of 7,150 records or objects. They should not be generalized to the complete population of more than 180,000 units unless the original selection rule is recovered and shown to support such inference. By contrast, the orphan-unit test was executed on the complete accepted unit table at the snapshot date.

The positional results require a similarly limited interpretation. The horizontal RMSE values of 0.0775 m and 0.031674 m were obtained from two plan rectification cases, each containing four control points. These cases confirm that the rectification procedure can be evaluated quantitatively and document the errors obtained for the two selected plans. They do not characterize the distribution of positional error across all projects, buildings, floors, or units. A repository-level assessment would require a larger and explicitly defined sample covering different plan qualities, building forms, locations, and production periods, together with summary statistics and confidence intervals.

The current evidence also distinguishes deployment breadth from computational scalability. The approximately 6 TB combined repository, 48 published services, and deployment across 22 land-office branches show that the platform is used in an operational setting. These figures do not, however, establish API latency, throughput, concurrent-user capacity, error rate, scene-loading time, or browser rendering performance. No controlled workload benchmark was available for the reported snapshot. Claims about scalability must therefore remain limited to repository and deployment scale. A reproducible performance study should specify the server, client, browser, network, cache state, request mix, response size, number of repetitions, and concurrency levels, and should report at least median and tail latency, throughput, error rate, and scene-loading or frame-rate measurements.

Portability is another qualified property of the architecture. The deployed system depends on SuperMap iServer and iPortal for map, scene, query, and portal publication. The logical design can be adapted because its source, geometry, identity, database, service, and governance contracts do not depend on

Thai table names. Nevertheless, migrating the implementation to another spatial infrastructure would require exporting the spatial and 3D resources, reproducing identifier and referential constraints, mapping the service interfaces, translating roles and audit functions, adapting the web client, and regression-testing geometry, joins, permissions, and responses. The reusability claim therefore applies to the architectural pattern rather than to direct software portability. A comparative implementation using an alternative, standards-oriented spatial stack is required to quantify the effort and performance implications of migration.

The platform contains basic governance mechanisms: authenticated users are associated with permissions for published services and fields, and system tables retain creation, modification, status, and user-activity information. These controls support operational access management and auditability, but they do not constitute a formal security evaluation. The study did not include threat modeling, penetration testing, vulnerability assessment, encryption review, or privacy-risk analysis. This limitation is important because cadastral and juristic-person records may contain legally sensitive information. Future evaluation should address least-privilege roles, authentication and session controls, branch separation, encryption in transit and at rest, audit-log integrity, backup and recovery, incident response, retention policies, and minimization or masking of sensitive fields.

Finally, the architecture provides several prerequisites for future cadastral digital twins, including stable identity, normalized relationships, queryable 3D objects, and governed services [24]. The current platform should not, however, be characterized as a complete digital twin because it does not incorporate real-time sensing, predictive simulation, or automated state synchronization. Future work should prioritize reproducible validation queries, a broader positional-accuracy study, controlled service and browser benchmarks, formal security and privacy assessment, temporal versioning, standards-based semantic exchange, automated geometry and relational testing, and comparative deployment on an alternative spatial-data infrastructure.

VII. Conclusion

This study presented CondoMaps, a database-driven architecture for integrating, managing, and serving 3D condominium and cadastral information. The workflow transforms verified source plans and cadastral references into georeferenced building and unit geometries, assigns a persistent project–building–floor–unit identifier hierarchy, links the objects to normalized cadastral, administrative, and juristic-person records, and publishes the integrated information through governed map, scene, query, report, and REST services. By maintaining deterministic relationships among documents, database entities, 3D objects, and service responses, the architecture treats a published condominium object as a database-resolvable information entity rather than an isolated visual feature.

The accepted production snapshot contains 7,150 condominium projects, more than 180,000 units, over 650 LOD2 condominium buildings, at least 6,500 contextual LOD1 buildings, 194,304 spatial features, 457,936 attribute records, and 48 published services within an approximately 6 TB combined repository. The reported checks found complete mandatory documentation and fields, no duplicate normalized keys, and no orphan records within their stated accepted populations. The 100% linkage results apply only to the archived sets of 7,150 evaluated records or objects. The horizontal RMSE values of 0.0775 m and 0.031674 m apply only to the two evaluated four-control-point plans. The browser and API examples demonstrate functional retrieval between identifiable 3D objects and associated relational and cadastral records, but they are not performance benchmarks.

The principal contribution is the persistent object–relational–service integration contract that preserves identity throughout the condominium information lifecycle. The results provide evidence of operational breadth, consistency within the accepted snapshot, and functional retrieval; they do not establish the acceptance rate of raw submissions, population-wide linkage or positional accuracy, workload scalability, formal security assurance, or software-level portability. Addressing these limitations through reproducible sampling and validation procedures, broader spatial testing, controlled API and browser benchmarks, formal security and privacy assessment, temporal data management, standards-based exchange, and cross-platform implementation would strengthen CondoMaps as a reusable foundation for 3D land-information systems and future cadastral digital-twin applications.

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