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Land Guard: An Open-Source Enterprise GIS for Cadastral Parcel Mapping in Iran

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ABSTRACT:

This paper presents the design and implementation of *Land Guard*, an open-source enterprise GIS system developed to improve cadastral parcel map production and management in Iran. The research addresses the limitations of the existing TAM–Transpoly workflow, which relies on fragmented tools, lacks real-time validation, and depends on proprietary formats. Using a Design Science Research Methodology, the system was developed with Python, PyQGIS, PyQt, and PostgreSQL/PostGIS. Land Guard integrates spatial and descriptive data entry in a single interface, performs real-time topological and administrative boundary validation, and stores data directly in an enterprise spatial database with role-level access control. A usability evaluation with 10 surveyors showed a 50% reduction in workflow time and a 40% reduction in user interactions compared to Transpoly. While not fully LADM-compliant, the system's conceptual schema is mapped to LADM schema. The findings demonstrate that free and open-source GIS technologies can deliver scalable, secure, and user-friendly cadastral systems, supporting digital transformation in land administration.

1. INTRODUCTION

Land information systems (LISs) are parcel-based information systems that record data related to land parcels, including rights, restrictions, and responsibilities and their relation to people (Espada, 2010). Cadastre is a dynamic and precise part of a LIS that ensures the continual updating and maintenance of land parcel information (Österberg, 2014). Typically, such systems rely on the geometric description of parcels such as their location and boundaries and integrate this spatial information with legal data (e.g., ownership types, rights holders, and land-use restrictions), as well as physical characteristics and property valuation (Espada, 2010). The existence of accurate maps and reliable registration records is essential for conducting legal land transactions. This fundamental requirement is precisely what a cadastral system fulfils by providing official maps and formally documenting property rights (Pullar, 2009). Accurate cadastral information underpins secure land tenure, transparent property markets, and sustainable land management (Williamson et al., 2010). Traditional cadastral systems in many developing countries, however, remain fragmented, paper-based, and difficult to maintain.

A nationwide, systematic implementation of cadastral surveying in Iran began in the 1990s through the adoption of photogrammetric methods. During this period, the National Cartographic Centre (NCC), in collaboration with the Iranian Deeds and Properties Registration Organization (DPRO), produced base cadastral map at a scale of 1:2000 for urban areas. These maps were primarily generated through aerial photography and manual drafting techniques. Designed to delineate property boundaries, formalize ownership, and provide a technical foundation for parcel subdivision and property transactions, these maps nevertheless lacked integrated descriptive and legal information. Moreover, in the absence of a mechanism for incremental updates, they functioned more as static technical maps rather than comprehensive cadastral documents (Hajiheidari et al., 2024, Mehrzad, 2016). Many workflows still rely on outdated methods and proprietary tools that hinder efficiency and data integration.

The SHAMIM platform was established to enable precise coordinate collection using GPS receivers; SHAMIM is an acronym for Integrated Cadastral Positioning Network (Real Estate Registration Organization of Iran, 2024a). In order for the collected data to be usable within Iran's cadastral system, the Transpoly (Transform Polygon) software was developed as a bridging tool. In this workflow, surveyors collect a land parcel's boundary using GPS, and process the data through a series of desktop and web applications before the data being integrated into the central cadastral database. This workflow can be seen as a solution for continuous updating of Iran's digital cadastral map (Shafiee et al., 2021, Shafiee et al., 2020). Unfortunately, it lacks the state-of-art GIS technology and the current chain of desktop and web applications is cumbersome and sub-optimal both from the user and system design perspectives. In the current workflow, validation only occurring at the final stage. This fragmented workflow increases the likelihood of errors, prolongs processing times, and creates challenges for integrating cadastral data into a modern digital infrastructure.

Internationally, the adoption of free and open-source GIS (FOSS) solutions has gained momentum in cadastral modernization due to their flexibility, cost-effectiveness, and alignment with open standards such as the Land Administration Domain Model (LADM) and OGC interoperability specifications (Lemmen et al., 2015, Steudler, 2009). Several pilot implementations in Asia, Africa, and Latin America have demonstrated the potential of open-source enterprise GIS platforms for improving cadastral workflows, yet localized adaptations remain essential to ensure usability, security, and institutional uptake.

This paper introduces *Land Guard*, an enterprise GIS system specifically designed for cadastral parcel management in Iran. The system seeks to answer the research question: Can an open-source enterprise GIS provide a more efficient, user-friendly, and standards-oriented alternative to the TAM–Transpoly workflow? The study contributes to the literature by (1) developing a FOSS-based cadastral application with integrated spatial-descriptive validation, (2) empirically comparing its

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performance against the official system, and (3) exploring its alignment with international cadastral standards and future integration into Iran's digital land administration infrastructure.

2. RESEARCH METHODOLOGY

This section provides a detailed account of the research methodology and system design. Subsection 2.1 begins with a comparative analysis of various open-source GIS platforms to justify the selection of the core technologies. Subsection 2.2 then presents the overall research framework, which is grounded in the Design Science methodology. Next, Subsection 2.3 delivers a requirements analysis of the existing traditional system (TAM–Transpoly) to identify its shortcomings. TAM is a Persian acronym for a property parcel map production; Transpoly is an acronym polygon transformation. The workflow and the three-tier architecture of the proposed Land Guard system are elaborated in Subsection 2.4. Subsequently, Subsection 2.5 describes the database design and the conceptual data model, while Subsection 2.6 details the security mechanisms and access control implemented in the system.

2.1 Comparison of Open-Source GIS Platforms for Cadastral Applications

In the software landscape, several general-purpose desktop GIS applications are available, encompassing both commercial and open-source solutions. The commercial group includes AutoCAD, ArcGIS, SuperMap, NetCAD, and Bentley MicroStation, whereas open-source platforms comprise QGIS, gvSIG, GRASS GIS, and OpenJUMP. In the cadastral domain, specialized systems are typically implemented as extensions *or* plugins within these platforms. Examples include UP-parcel and UP-mysam in Iran, developed as add-ons to Bentley Map and AutoCAD. Likewise, open-source initiatives such as STDM and LADM-Colombia operate as plugins on QGIS, enabling land-administration workflows in different regions (Jenni et al., 2017, Lemmen, 2010).

Beyond these host-dependent environments, there also exist versatile open-source libraries such as GeoTools and GDAL that allow the development of stand-alone applications independent of commercial desktop systems. The programming language underlying each library largely defines the software development environment of a GIS or land-administration system. Libraries written in C/C++ can generally be accessed from multiple programming languages, while the reverse is not always true. For instance, GDAL is written in C++, and GeoTools depends on it but is bound to the Java ecosystem; therefore, any system relying on GeoTools must be implemented in Java. A notable example is SOLA, a Java-based application built using the GeoTools and GDAL libraries capable of operating independently without relying on any off-the-shelf desktop GIS such as OpenJUMP (Food and Agriculture Organization of the United Nations, 2010). Similarly, the present research adopts a comparable architectural principle, employing PyQGIS and PyQt libraries to develop an independent, domain-specific platform for cadastral parcel management.

A major distinction among these systems lies in their conceptual domain model. Most commercial GIS software employ proprietary data models such as the Parcel Fabric Model in ArcGIS which are not globally transferable and lack interoperability across jurisdictions (Meyer, 2004). In contrast, several open-source cadastral systems are designed fully in accordance with the LADM international standard, ensuring semantic consistency, data interoperability, and institutional integration at both national and international levels. All commercial and open-source GIS software are technically capable of accommodating these standardized models.

Regarding operating systems and database management, commercial GIS products are predominantly restricted to Microsoft Windows, which limits their deployment on Linux or MacOS environments. Open-source platforms, by contrast, are generally cross-platform and support all major operating systems. Most commercial GIS software integrate seamlessly with enterprise databases such as Oracle, PostgreSQL/PostGIS, Microsoft SQL Server, and occasionally MySQL. Open-source GIS applications primarily rely on PostGIS for advanced spatial operations, offering partial interoperability with other databases through libraries like GDAL.

While commercial applications provide more sophisticated user interfaces and tighter integration with established enterprise workflows forming significant market share worldwide (e.g., SuperMap across Africa, Europe, and Asia) open-source approaches demonstrate that high-scale, standards-based, and nationally adaptable cadastral systems can be effectively developed using free and open technologies. These solutions eliminate vendor lock-in (Cheraghi, 2018), support localization, comply with international standards, and reinforce the principles of Fit-For-Purpose Land Administration (Enemark et al., 2014). Given the demonstrated potential and maturity of open-source solutions such as LADM-Colombia, STDM, and SOLA, the subsequent analysis in this research will focus primarily on this family of open cadastral software.

We needed to choose a DBMS (database management system) and a desktop GIS platform. PostgreSQL and MySQL were among our DBMS choices. PostgreSQL, often referred to as Postgres, is an open-source object-relational database management system (ORDBMS). It combines the features of a relational database, using Structured Query Language (SQL) for data manipulation, with object-oriented capabilities, allowing for the definition of custom data types and complex objects. While MySQL is a powerful DBMS but it falls behind in advanced features like row level security (RLS). In addition, PostGIS, the Postgres spatial extension, outperforms MySQL in terms of support for advanced spatial queries and geographic coordinate reference system. Based on the comparative analysis presented in Table 1, QGIS was ultimately selected as the core GIS platform for the proposed cadastral map management system. This decision was grounded in QGIS's extensive capabilities, high flexibility, and strong support for open standards. In addition to its modern graphical user interface and customizability, QGIS offers seamless integration with PostgreSQL/PostGIS, as well as direct interoperability with other open-source tools such as GRASS GIS and SAGA GIS. These features provide a robust, user-friendly, and extensible foundation for the development of enterprise-level geospatial systems tailored to cadastral applications (Steudler and Törhönen, 2010). Most of these features are accessible through its API (PyQGIS) and it enables us to develop standalone custom GIS without the requirement of running QGIS itself. We avoided using QGIS application itself, because many of the surveyors are not GIS specialist and learning QGIS might be an overkill for them. The simplified GUI of Land Guard can be learnt in a few hours.

In contrast, while alternative open-source GIS platforms such as GRASS GIS, gvSIG, and OpenJUMP demonstrate competency in specific technical domains, they exhibit limitations that reduce their suitability for the cadastral enterprise context. GRASS GIS, for example, excels in analytical geoprocessing and offers development libraries like PyGRASS, yet its steep learning curve, cumbersome interface, and focus on scientific and ecological applications render it less accessible for nontechnical users in administrative or land registry settings (Espada, 2008). Although its recent versions have a streamlined interface. Likewise, gvSIG and OpenJUMP, though modular and extensible, fall short in terms of active community support, up to date documentation, and full native integration with relational spatial databases such as PostGIS (Steudler and Törhönen, 2010). These findings further reinforce the selection of QGIS as the most appropriate platform for building a scalable, maintainable, and user-oriented cadastral system.

Key Feature	QGIS	GRASS GIS	gvSIG	OpenJUMP
Graphical User Interface	Modern and intuitive	Complex and technical	Moderate	Basic and outdated
Suitability for Cadastre	Highly suitable	Technical/ research-oriented	Limited	Rarely used
PostGIS Support	Full support	Supported	Supported	Limited
Community and Maintenance	Very active	Academic -focused	Declining	Low activity
Organizational Customization	High	Difficult	Moderate	Limited
Ability to launch a standalone custom GUI application	Yes	Yes, but very difficult	Yes, but in java	Yes, but in java

Table 1. High-level comparison of selected open-source GIS platforms for cadastral applications adapted from (Steudler and Törhönen, 2010, Espada, 2008).

The system was developed entirely with a suite of free and open-source technologies, centred around the Python programming language, PyQGIS for spatial processing, a PostgreSQL/PostGIS database, and the PyQt framework for the user interface. This FOSS-based approach ensures vendor independence, high customizability, and reduced long-term development and maintenance costs.(QGIS Development Team, 2024, PostGIS PSC (Project Steering Committee), 2024, PostgreSQL Global Development Group, 2024, The Qt Company, 2024, Python Software Foundation, 2024)

2.2 Overall Framework and Research Approach

This study adopts an applied, design-oriented research approach aimed at producing a tangible software artifact in response to the growing demand for reliable and cost-effective solutions in the field of land management (Hevner et al., 2004). The iterative nature of this approach was a key factor in its selection, as it enables continuous refinement and improvement of the system throughout the development cycle. The research process explicitly follows the six core steps of the Design Science Research Methodology (DSRM), the details of which are outlined in Table 2.

2.3 Requirements Analysis of the Existing System

The design and implementation of the Land Guard were grounded in a comprehensive evaluation of one of the operational systems currently used by Iran's cadastre administration, following established principles of needs assessment and requirements analysis for enterprise GIS (Harmon and Anderson, 2003). At this stage, functional requirements were extracted, and technical shortcomings were identified through direct observation and reverse engineering techniques.

DSRM Stage	Implementation in This Research
Problem Identification	Inefficiencies and limitations of the workflow based on Transpoly software
Definition of Objectives	Designing the alternative application (Land Guard) to streamline the process
Design and Development	Building the Land Guard application using open-source technologies
Demonstration	The developed software serves as a tangible prototype of the proposed solution
Evaluation	Comparative analysis of Land Guard and Transpoly to assess advantages
Communication	Dissemination of research findings through this article

Table 2. Mapping the research process onto the design science research methodology (DSRM) framework.

The system under review is the Transpoly software, developed for converting survey files in DXF format into an intermediate format with a .TRP extension (an acronym for Transpoly). In this workflow, users manually input descriptive data after uploading the DXF file, then submit the resulting TRP file to the TAM portal, an official web-based platform operated by the DPRO (Real Estate Registration Organization of Iran, 2024b); The process involves map processing, data validation, and, upon acceptance, integration into the national cadastre database. We call the whole system as TAM-Tranpoly in the rest of this paper. The traditional workflow is a complex; multi-stage process distributed across several actors and systems. It begins when a new cadastral request is dispatched from the TAM system to the surveyor. Upon receiving a text notification and logging into the TAM system, the surveyor reviews the request and contacts the landowner to coordinate the required documents and schedule the field survey. After completing the fieldwork, the surveyor drafts the parcel map as a DXF file in CAD software, which is then imported into the Transpoly application. There, the surveyor enters the necessary attribute information to produce the intermediate .trp file.

In the next stage, this file is uploaded again into the TAM system, which subjects the data to validation. The TAM system then validates the data and produces a PDF document that includes both the parcel map and the validation report. If no errors are detected, the data are integrated into the central database and the process successfully concludes. However, if errors are identified, the workflow enters one of three distinct feedback loops, depending on the error type: 1) In the case of topological errors, the process returns to the CAD stage for correction of the DXF file. 2) In the case of attribute errors, the process returns to the Transpoly application for data correction. 3) If the GPS points are invalid, the workflow reverts to the surveyor, who must repeat the field measurement. In all three cases, once corrections are made, the subsequent stages must be repeated, culminating in revalidation within the TAM system.

Despite its operational functionality, several critical limitations were identified in this software and its surrounding system. One key challenge is the requirement to "explode" polylines into individual line segments to determine adjacency relationships. Moreover, the absence of a unified graphical interface that links spatial and descriptive data, as well as the lack of real-time spatial-descriptive validation, increases the likelihood of user errors and complicates the workflow.

The findings from this analysis led to the definition of a new set of requirements, including: support for open formats such as Geopackage (Open Geospatial Consortium (OGC), 2014); the establishment of internal linkages between spatial and descriptive data; enhanced graphical capabilities for editing and quality control; and reduced dependency on proprietary tools.

Assessing the computer proficiency of users and planning appropriate training constitute a critical step in the successful implementation of a spatial information system (Harmon and Anderson, 2003). In line with this, the Land Guard system was developed with the explicit aim of minimizing the need for extensive specialized training. The primary prerequisite for its operation is only a general familiarity on the part of the surveyor with modern graphical environments such as Windows or macOS. By contrast, the conventional workflow required users not only to master specialized CAD software, but also to become proficient in the operational procedures of two additional, independent platforms Transpoly and TAM.

Ease of use in Land Guard is achieved through the integration of what was previously a three-stage process into a single, unified interface that provides immediate, visually intuitive feedback. This design substantially reduces the cognitive burden on users by eliminating redundant steps and intermediate files, thereby streamlining operations. As a result, the system renders the workflow accessible even to surveyors who may not be advanced GIS professionals, while maintaining clarity and efficiency.

Beyond user-centred considerations, a cost-benefit assessment was also adopted as a guiding principle in justifying the implementation of the system (Harmon and Anderson, 2003). While the primary expense of the project lay in development time, the adoption of free and open-source software (FOSS) effectively eliminated the upfront costs of licensing. The design objective, in turn, was to secure both quantitative benefits such as reduced processing time and improved error correction and qualitative benefits, including enhanced data integrity, reduced uncertainty, and strengthened support for informed decision-making. These benefits are evaluated in the Results section.

2.4 Workflow and Architecture of the Land Guard

The workflow of the Land Guard outlines the overall data flow and the interaction among core system components involved in cadastral information management. In this process, users enter spatial and descriptive data related to land parcels via a user-friendly interface. Once submitted, the data are processed and structured by a designated processing module within the system. The processed output is then visualized in a graphical environment, allowing users to assess the accuracy and quality of the data. Finally, validated data are transferred to a structured database, enabling long-term storage, efficient querying, and future spatial analysis. The workflow diagram is presented in Figure 1.

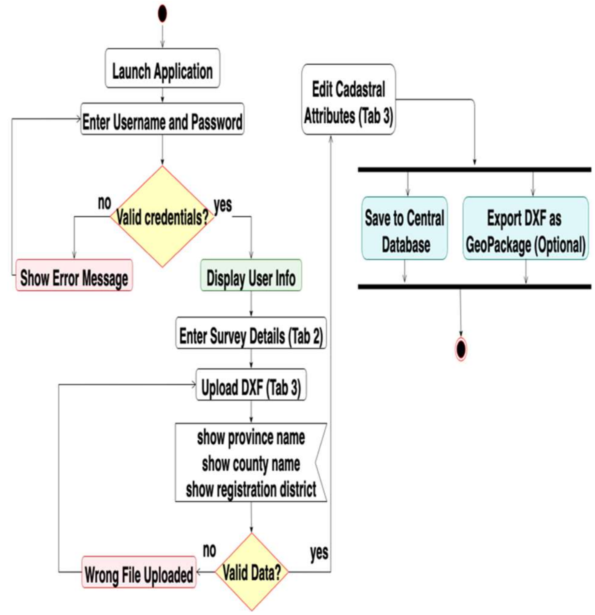
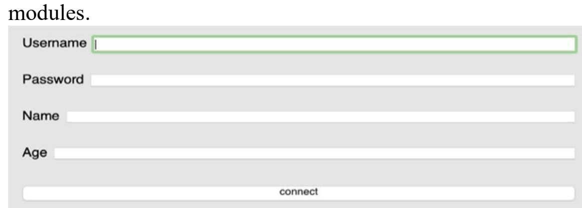


Figure 1. Workflow diagram of the Land Guard.

The architecture of the Land Guard has been designed based on a three-tier approach, comprising the presentation layer, logic layer, and data layer (Bass et al., 2003). This structure facilitates a clear separation of responsibilities and enables independent maintenance, development, and testing of each component, as illustrated in Figure 4. We preferred a direct database connection over an OGC web service connection for its flexibility and advanced DBMS features such as RLS. These features are not available in a web service like WFS (Web Feature Service). Direct connections between desktop GIS clients and PostGIS create a powerful environment for real time data editing, in which every change is immediately recorded as a transaction within the central database (Obe and Hsu, 2021). Our system adopts this model by employing the psycopg2 library to establish a live, bidirectional link between the PyQt user interface and the PostGIS database. This approach eliminates the need for intermediate files, enhances data integrity, and supports a genuinely multi-user organizational setting a clear advantage over file-based workflows or less flexible web service-oriented architectures.

In the presentation layer, the graphical user interface is developed using the PyQt library. This layer enables direct user interaction with various tabs, allowing for data entry processes such as uploading, viewing, and editing through an integrated map interface and attribute table.

The graphical user interface of the Land Guard is presented in Figure 3, greatly aids in understanding the system's operational workflow. As previously mentioned, this interface has been developed using PyQt and is integrated with spatial processing modules.



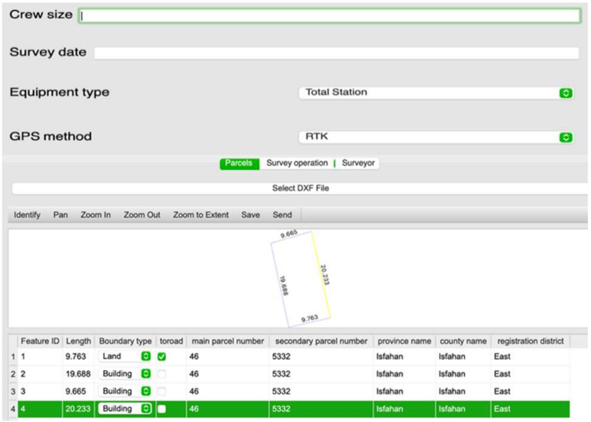


Figure 3. Graphical user interface of the Land Guard.

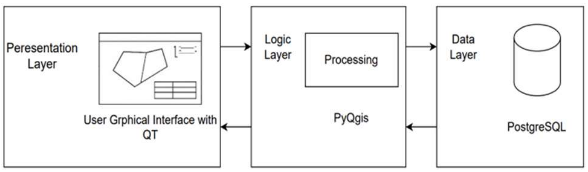


Figure 4. Architecture of the Land Guard. 3-tiers architecture separates responsibilities and enables independent maintenance, development, and testing of each component

In the logic layer of the application implemented in Python using the PyQGIS library the core processing operations of the software are executed (QGIS Development Team, 2024, Python Software Foundation, 2024). Once the user uploads a DXF file, the software automatically performs an explode operation to convert polylines into individual line features, preparing the environment for the user to define boundaries and identify adjacent parcels; this operation is called "casting" of a polyline to lines in a DBMS. The map is displayed within a graphical canvas, with each edge labelled by its corresponding length. Simultaneously, related attribute data are shown in a table beneath the map, where users can edit the entries as needed. This interactive structure linking spatial and attribute data within a GIS framework enables more rigorous quality control and reduces the likelihood of human error.

Another challenge was to provide a GUI for the user to select a date in Jalali calendar. We used *jdatetime* Python package for that purpose.

2.5 Database Design and Conceptual Model

The conceptual model designed for the cadastral software consists of four primary tables that are logically interconnected, adhering to principles of data integrity (Figure 5).

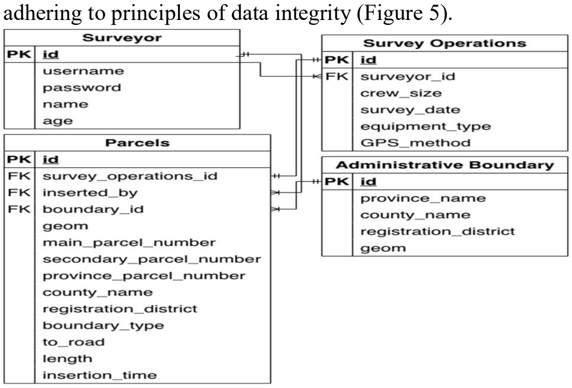


Figure 5. Entity-Relationship (ER) diagram of the Land Guard.

The Surveyor table stores the personal and identification details of each surveyor (such as name, age, username, and password) and is linked to the Survey Operations table through a one-to-many relationship, as each surveyor may conduct multiple survey tasks. Passwords are stored using secure hashing.

The Survey Operations table captures technical details of each survey activity, including crew size, survey date, equipment type, and the GPS method used. Each survey operation is further associated with a corresponding cadastral parcel, which encapsulates the spatial, descriptive, and graphical information related to the surveyed parcel. To ensure data integrity, predefined value domains have been established for fields such as Equipment type (with options such as 'Distometer' and 'Total Station') and GPS method (with options such as 'RTK' and 'Static'). These constraints are enforced in the user interface through dropdown lists (Combo Boxes).

The third table, Parcels table, is designed to store the spatial information of each land parcel along with the parcel's main and secondary identifiers. The system then automatically performs a vector overlay operation with Administrative Boundary layers for province, county and registration district to extract and assign the appropriate registration information to each parcel. This approach not only simplifies the database structure and reduces the data entry burden for users, but also enhances accuracy, increases automation, and improves alignment with GIS standards in the cadastral domain.

The streamlined and centralized design allows for fast processing, simplified data management, and seamless integration with the additional software modules. Moreover, by incorporating time stamps and user identity logs, the system lays the foundation for enforcing database-level security policies, which have been implemented accordingly.

The system's database has been designed to align, in most cases, with the classes defined in the LADM (Table 3). Intuitively, each field used in our database tables has been mapped to its corresponding class and attribute within the LADM class hierarchy, and these relationships are presented clearly in a tabular form. In this mapping framework, each target class in LADM can be regarded as a separate table within the database schema. In Table 3, in some of the rows the values of "Src table" and "Src field" fields are empty indicating the upper row mapping triggers insertion into two targets.

Our Surveying_Operation table is an adaptive entity: depending on its recorded value, different target classes are triggered for data insertion. For instance, when the value of this table is distometer, a corresponding row must be added to the distanceObservation class. For the parcels table, it is important to note that LADM is fundamentally a legal and administrative model; it does not directly represent physical or virtual boundaries. Therefore, the boundaryType field must be complemented through integration with a physical modeling standard such as CityGML to support spatial representation. The Administrative_Boundary table, on the other hand, is non-cadastral and external to our system. It is imported solely to facilitate positional verification of parcels through spatial overlay analysis, without exercising any control over its internal structure.

The global cadastral community has shifted its focus from traditional cadastral mapping toward data model-based approaches. Consequently, the development of a comprehensive data model has become essential. The ISO standard introduced a fully consistent framework known as the LADM, which this study adopts to ensure legal and conceptual conformity within the proposed system. In parallel, the Open Geospatial Consortium (OGC) has proposed the LandInfra model, which extends beyond the legal domain of LADM by incorporating CityGML and IFC standards to represent the physical boundaries of land parcels. However, in Iran, cadastral operations are still predominantly conducted through conventional cadastral mapping, and a substantial transition period will be required before a data-model-oriented approach can be effectively implemented.

Src table	Src field	Target attribute	Target attribute	Target codelist value
Surveyor	name	LA_Party	name	-
-	-	LA_Party	PartyRoleType	licensedSurveyor
Surveying_Operation	Surveyor_id	LA_Party	pID	-
Surveying_Operation	id	LA_Source	sID	-
Surveying_Operation	GPS_Method	LA_GNSSObservation	LA_GNSSSurveyType	RTK
-	-	LA_GNSSObservation	systemType	GPS
Surveying_Operation	supp_equipment_type = Distometer	DistanceObservation	-	-
-	supp_equipment_type = TotalStation	TPSObservation	-	-
Parcels	geom	LA_Point	originalLocation	-
-	-	LA_BFS	geometry	-
Parcels	parcel_number	LA_SpatialUnit	suID	-
Parcels	parcel_number	LA_SpatialUnit	-	-
Parcels	boundaryType	-	-	-
Parcels	to_road	LA_LegalSpaceCivilEngineeringElement	type	road
Administrative boundary	geom	BFS	geometry	-

Table 3. Mapping Land Guard database schema to the LADM.

The data layer of the software is built upon a PostgreSQL database integrated with the PostGIS extension. Communication between the application and the database is handled via the psycopg2 library, through which all data insertion, querying, and storage operations are executed. PostGIS is employed to store exploded line features using the standardized WKB (Well-Known Binary) geometry format. Additionally, the use of the Geopackage standard as the primary storage format ensures compatibility with other GIS software platforms (Obe and Hsu, 2021).

In designing the database schema for the proposed software, spatial tables have been organized in a manner that ensures structured storage of geometric data, spatial attributes, and descriptive information related to land parcels. Dedicated and well-defined tables have been created within the database to manage this information systematically.

2.6 Security, Access Control, and User Management

To enhance the security of data stored in the database, the Row-Level Security (RLS) mechanism in PostgreSQL was employed. To facilitate this, tracking fields including insertion time and the user (inserted by) were added to the relevant tables. A security policy was then created to dynamically filter records based on the current database user (current user). This policy ensures that, in every query, the system only returns records where the value in the inserted by column matches the active user. By implementing this policy, the system guarantees that each surveyor can only view or modify the data personally entered. This restriction not only limits access to records submitted by other surveyors but also prevents accidental or unauthorized mass deletions, thereby significantly strengthening the overall security of the database (PostgreSQL Global Development Group, 2024).

We enabled RLS on the Parcels and Survey Operations tables and granted the necessary privileges (SELECT, UPDATE, INSERT, DELETE) to all surveyor roles. Meanwhile, the Administrative Boundary and Surveyor tables are maintained by the database system administrator and are read-only to a surveyor's user.

3. RESULTS AND EVALUATION

This section presents a comparative evaluation of Land Guard application against Transpoly software. The assessment emphasizes key differences in user interface design, workflow automation, data output formats, and data management capabilities, with the aim of highlighting the procedural and architectural advantages of the new system.

3.1 Comparative Analysis of User Interface and Workflow

From a user-interface perspective, Land Guard delivers significant improvements in usability compared with Transpoly. In Transpoly, the user can only view the co
ordinate points within a DXF file and is required to enter attribute information without the contextual support of a visual map. By contrast, Land Guard offers an integrated environment in which the user can simultaneously visualize the surveyed parcel and enter the corresponding descriptive information. This integration results in a far more intuitive and context-aware data entry experience.

In addition, Land Guard introduces a key automation feature that streamlines the workflow. In Transpoly, the user must manually input administrative data such as province, county, and cadastral district. Land Guard, however, automates this process. Once the DXF file is uploaded, the system performs a spatial overlay with the administrative boundary layers. The correct province and cadastral district are automatically identified and displayed alongside the map. This not only reduces manual effort but also enhances the validity of the parcel's administrative boundary.

3.2 Comparative Analysis of Data Output and Management

A fundamental architectural difference lies in the model of data output and management. Transpoly was designed to generate an intermediate, proprietary .trp file that can only be utilized within the TAM system. This approach creates a closed workflow and restricts the reusability of the data. In contrast, Land Guard replaces this intermediate file with the open-standard

Geopackage format, which is interoperable and compatible with virtually all modern GIS software.
Furthermore, Land Guard is designed to support the direct storage of data in a centralized PostGIS database, enabling persistent storage, multi-user access, and advanced data management capabilities. By comparison, the Transpoly application functions merely as a stand-alone conversion tool and lacks any native integration with a database environment.

3.3 Quantitative Workflow Evaluation

To quantitatively evaluate the functional differences between the two workflows, a usability test was conducted with ten real surveyor participants. In this experiment, two key metrics were measured: the total number of mouse clicks and the total time spent (in minutes) to complete the mentioned task. The average results are as follows: an average of 26 clicks was recorded in Transpoly workflow, whereas this figure was reduced to 16 clicks in Land Guard; the average time required to complete the process using Transpoly was 15 minutes, while in Land Guard this was reduced to 7 minutes. The system exhibits high performance in geometric, topological, and descriptive data accuracy. Parcel boundaries are surveyed using dual-frequency GPS receivers in RTK mode through Iran's SHAMIM network, enabling centimeter-level precision. Official tolerance limits set by the Iranian Registration Organization are 5 cm for planar coordinates, with linear thresholds of 3 cm for lengths less than 200 m and 6 cm otherwise. The system automatically detects and corrects topological errors such as dangling lines, self-intersections, and polygon closure anomalies while verifying adjacency by identifying parcel gaps or overlaps beyond 10 % of the shared boundary. Thematic attributes include boundary types (wall, trench, etc.) and contextual adjacent features like roads and neighboring parcels. All survey operations combine deed inspection and field observations to reconcile legal and spatial data consistency.

4. DISCUSSION

The evaluation results demonstrate that Land Guard provides substantial improvements over the TAM–Transpoly workflow in terms of usability, efficiency, and data integrity. The reduction in task completion time and number of user interactions reflects not only faster execution but also a significant decrease in cognitive load for surveyors. By integrating data entry, visualization, and validation into a single interface, Land Guard minimizes redundant steps and reduces opportunities for human error.

Equally important are the architectural innovations introduced by the system. The transition from a file-based, single-user model to a centralized, multi-user PostGIS database represents a fundamental re-engineering of cadastral data management. Real-time topological checks and automatic boundary matching at the point of entry address many of the weaknesses of the current process, where errors are often detected only during final validation. These improvements lay the foundation for a more robust and collaborative cadastral environment.

Beyond technical efficiency, the system introduces broader institutional benefits. The adoption of database-level user management and row-level security enhances accountability by linking each parcel entry to a verified surveyor. The use of open standards and formats (e.g., GeoPackage, PostGIS) ensures long-term interoperability with other GIS systems and national spatial data infrastructures. Together, these features align Land Guard with international best practices such as Cadastre 2014, LADM, and UN-GGIM recommendations on digital land administration.

Nevertheless, several challenges remain. Widespread adoption will require training programs for surveyors, institutional endorsement by the Iranian Registration Organization, and integration with existing cadastral services such as SHAMIM. Resistance to replacing established workflows and concerns about data governance may slow institutional uptake. Addressing these challenges requires not only technical refinement but also policy support, stakeholder engagement, and clear legal frameworks for digital cadastral operations.
This system offers an innovative contribution that fills a crucial gap both nationally and internationally. Although global FLOSS-based land administration platforms such as UN-Habitat, GLTN, STDM, and LADM Colombia exist, they do not necessarily support the full workflow of cadastral stabilization and mapping. Moreover, these systems must be tailored to suit the specific requirements of different jurisdictions. Even though conceptual-level standardization has been achieved within these FLOSS systems, their direct application across diverse contexts remains practically infeasible. In contrast, the proposed system is designed as a stand-alone application rather than a plug-in, offering several advantages in terms of simplicity, functionality, and purpose-driven design compliant with the Fit For Purpose (FFP) principles. Unlike conventional GIS software, it requires minimal training, allowing users to master the system within a very short timeframe. At the national level, the study addresses a significant gap in Iran, where the use of free and open-source software (FOSS) particularly in the geospatial domain is still highly limited. Most governmental institutions rely on commercial software, which often involves challenges such as data leakage, licensing constraints, and high operational costs. The innovation of this research lies in demonstrating the organizational reliability of open-source spatial technologies in the domain of land administration. To the best of our knowledge, this represents the first academic investigation of its kind within the Iranian jurisdiction.

5. CONCLUSION AND FUTURE RECOMMENDATIONS

This study introduced Land Guard, an open-source enterprise GIS application developed to overcome the limitations of Iran's TAM–Transpoly cadastral workflow. Built on Python, PyQGIS, PyQt, and PostgreSQL/PostGIS, the system integrates spatial and descriptive data entry, performs real-time topological and administrative validation, and implements database-level security controls. Comparative evaluation showed that Land Guard reduces workflow time by nearly 50% and lowers user interactions by 40%, demonstrating its potential to enhance efficiency, accuracy, and user satisfaction in cadastral mapping.

The key contributions of this research are threefold. First, it provides a working prototype that demonstrates the viability of using free and open-source software for enterprise-level cadastral applications. Second, it shows how real-time validation and centralized database integration can substantially improve cadastral workflows compared to file-based systems. Third, it positions Land Guard as a pathway toward compliance with international frameworks such as the LADM and OGC interoperability standards.

Looking ahead, future development should focus on incorporating advanced geometric editing and automated topological correction within the application, extending functionality to a web-based environment, and exploring the use of machine learning for error detection and change analysis. Importantly, full LADM compliance should be pursued to support standardized exchange of cadastral information nationally and internationally; this involves creation and utilization of relevant LADM schema instead of current schema with the provided mappings of this study.

By demonstrating how an open, secure, and scalable system can be implemented with local customization, this research contributes to the global discussion on digital land administration. Land Guard illustrates how developing countries can leverage open-source technologies to modernize cadastral systems, reduce costs, and improve service delivery, while building the foundations for integration into national and international spatial data infrastructures.

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