



E-ISSN: 2707-8418

P-ISSN: 2707-840X

[Journal Website](#)

IJSSE 2026; 7(1): 11-16

Received: 05-04-2026

Accepted: 07-05-2026

Pham The Huynh

Faculty of Geomatics and
Land Administration, Hanoi
University of Mining and
Geology, 18 Vien Street, Dong
Ngac Ward, Hanoi 100000,
Vietnam

Specialization of field–office work and application of the Doubly Connected Edge List (DCEL) data structure in digital cadastral mapping in Vietnam

Pham The Huynh

DOI: <https://www.doi.org/10.22271/2707840X.2026.v7.i2a.67>

Abstract

In the context of modernizing land administration, improving the efficiency of digital cadastral map production and updating has become an urgent requirement to support the development of multipurpose land information systems. This study proposes a solution for enhancing the digital cadastral mapping process through a high degree of specialization between field and office operations, combined with the application of the Doubly Connected Edge List (DCEL) data structure. A key contribution of the study is the development of a mechanism for exchanging “visual information” between field and office teams to overcome information discontinuities during the surveying and mapping process. In addition, a land-parcel zoning method and the DCEL data model are employed to maintain topological integrity and effectively manage cadastral parcel changes. The study further proposes a remote data quality control approach by converting cadastral data into KML format and validating it on the Google Earth platform. Experimental results obtained in An Khanh Commune, Hoai Duc District, Hanoi City, demonstrate that the proposed workflow increases labor productivity by approximately 30–40%, enables the parallel implementation of cadastral surveying and cadastral record preparation, and ensures data consistency and standardization in accordance with current technical regulations.

Keywords: Digital cadastral map; Specialization; DCEL; Google Earth; Visual information; Land administration.

Introduction

Digital transformation in land administration has become an inevitable global trend. According to Enemark (2009), modern land administration systems should integrate legal, economic, and spatial information to support sustainable development ^[1]. In this context, cadastral maps are no longer merely surveying products but have become fundamental components of national spatial data infrastructures. Modern cadastral databases must maintain spatial integrity throughout their operation and updating processes. Changes such as parcel subdivision, parcel consolidation, land-use conversion, and administrative boundary adjustments all alter the spatial structure of cadastral data. Therefore, topological data models are increasingly preferred because they preserve spatial relationships among geographic objects ^[2].

In recent years, cadastral mapping technology in Vietnam has undergone significant development, gradually shifting from manual surveying methods to digital workflows supported by total stations, GNSS/GPS technologies, and specialized mapping software such as MicroStation and AutoCAD. This transition has substantially improved the accuracy and efficiency of cadastral surveying. In Vietnam, cadastral mapping technologies have evolved from manual approaches to digital environments utilizing GNSS RTK, electronic total stations, and specialized software packages. However, practical production processes still face several limitations, particularly regarding the interdependence between fieldwork and office-based processing. Surveyors are often required to participate directly in data editing because they possess field information that cannot be fully represented by coordinate data alone. This situation reduces opportunities for labor specialization and limits the scalability of production activities ^[3].

Current cadastral mapping practices continue to exhibit significant organizational shortcomings. Most notably, field personnel are frequently required to undertake part of the

Corresponding Author:

Pham The Huynh

Faculty of Geomatics and
Land Administration, Hanoi
University of Mining and
Geology, 18 Vien Street, Dong
Ngac Ward, Hanoi 100000,
Vietnam

office-based editing process to ensure the accurate representation of parcel geometry. Such an arrangement decreases the level of labor specialization, creates excessive workloads for field survey teams, and fails to utilize office-based technical personnel efficiently.

Furthermore, the continuous evolution of cadastral surveying and mapping regulations requires increasingly standardized and synchronized data management. Meanwhile, most existing software systems still rely on the Spaghetti data model, which, despite its simplicity, suffers from several disadvantages, including geometric data redundancy, limited topological management capabilities, and poor preservation of data consistency during parcel changes. Numerous mapping systems continue to store spatial objects independently, resulting in redundant datasets and difficulties in updating land records. Research on the Land Administration Domain Model (LADM) indicates that modern cadastral databases should maintain topological relationships and support lifecycle management of parcel changes [4,5].

Previous studies have primarily focused on improving surveying accuracy or developing individual geometric algorithms, while insufficient attention has been given to ensuring information continuity between field and office operations. In response to this gap, the present study proposes a new specialization framework based on standardized visual information exchange and the DCEL data structure to preserve geometric, attribute, and topological information throughout the development and management of cadastral databases.

Today, digital cadastral maps are not only products supporting land registration but also core components of national spatial data infrastructures. According to Dale and McLaughlin [6], modern cadastral systems must simultaneously support land tenure administration, real estate market operations, and information provision for planning and socio-economic development. Williamson *et al.* [7] emphasize that sustainable land governance must be built upon digital cadastral databases capable of integrating spatial, legal, and economic information. Within the Fit-for-Purpose Land Administration framework, FIG [8] also

highlights the central role of cadastral databases in the digital transformation of land administration.

In Vietnam, the implementation of the national land database and the enforcement of the 2024 Land Law [16] have further intensified the need for standardized and synchronized cadastral data. This challenge requires not only higher surveying accuracy but also the development of data models that ensure topological integrity, facilitate the updating of land changes, and enable data sharing among specialized information systems. Under these circumstances, investigating new production models combined with advanced topological data structures represents a highly relevant scientific and practical research direction.

2. Methodology and Data used

2.1. Land Parcel Zoning and Specialization of Field–Office Work

In traditional cadastral production in Vietnam, field personnel typically conduct data editing in addition to surveying activities. Although this approach helps reduce field identification errors, it adversely affects labor efficiency [3].

To improve production organization, this study proposes dividing survey areas into parcel blocks based on stable and easily identifiable linear features, such as transportation routes, irrigation canals, or natural boundaries. Within each block, land parcels are managed using a unique identifier system with the structure MX.SL.ST, corresponding to Commune Code, Block Number, and Parcel Number.

Based on this approach, the production workflow is reorganized toward greater specialization. Field teams focus exclusively on detailed surveying, collection of existing land-use information, preparation of field sketches, and acquisition of site photographs. Office teams receive survey data along with associated visual information to perform point connectivity, map compilation, and data quality assessment. This approach eliminates dependency between surveyors and editors while facilitating the simultaneous execution of multiple production stages. The workflow is illustrated in Figure 1.

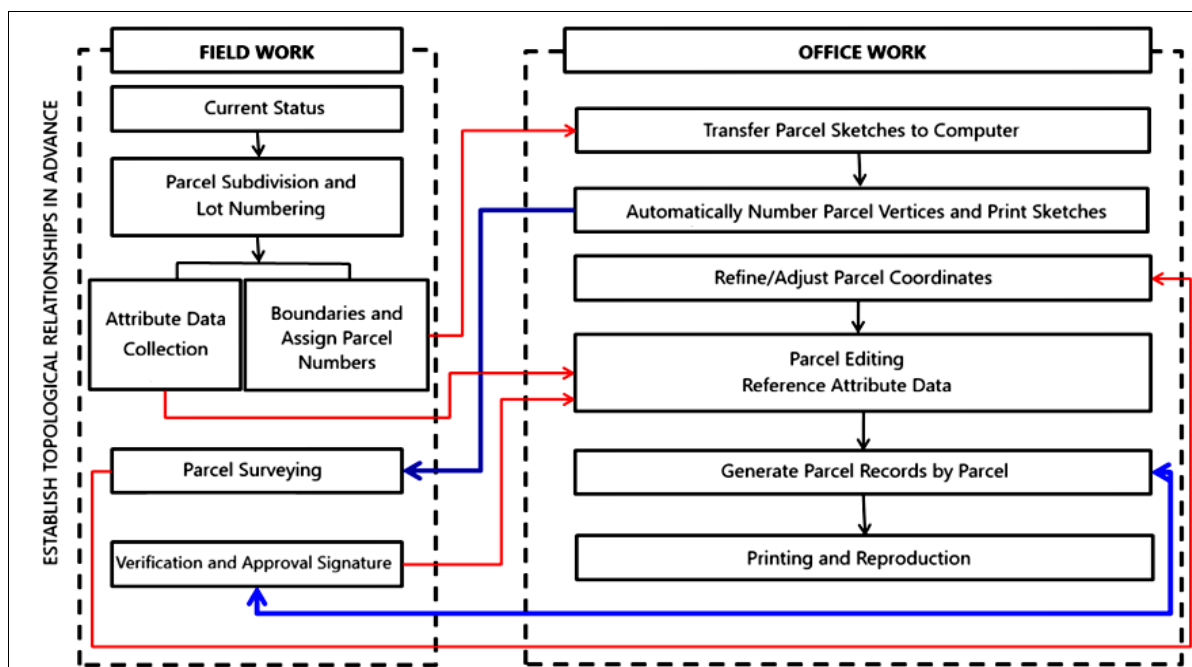


Fig 1: Specialized workflow for field and office operations.

To facilitate effective information exchange between field and office personnel, the study proposes standardizing a package of visual information accompanying each survey dataset. Each parcel block is associated with site photographs, location sketches, descriptions of land-use boundaries, information on structures located on the land, and additional notes regarding land management and land-use conditions. These datasets serve as a contextual information layer, enabling office staff to accurately identify cadastral objects without direct participation in field surveys.

This organizational model is particularly suitable for large-scale cadastral mapping projects. Once a survey area has been divided into independent blocks, multiple survey teams and editing teams can work simultaneously on the same project while maintaining data consistency. Consequently, project scheduling is improved, human resources are optimized, and project completion times are reduced.

2.2. Application of the Doubly Connected Edge List (DCEL) Data Structure

To overcome the limitations of conventional data models, this study adopts the Doubly Connected Edge List (DCEL) data structure for cadastral information management. DCEL is an efficient topological data structure that stores both spatial objects and their topological relationships.

DCEL is widely used in GIS and computational geometry applications. Each edge is represented by two oppositely directed half-edges. Each half-edge stores information about its origin vertex, twin edge, next edge, previous edge, and the face located to its right [9]. Through this structure, topological relationships can be retrieved directly without the need for complex spatial computations, which is especially important in cadastral databases that frequently require parcel updates.

The DCEL model consists of three fundamental

components:

- **Vertex Table:** Stores point coordinates and references to associated half-edges.
- **Half-Edge Table:** Stores information on origin vertices, twin edges, previous edges, next edges, and adjacent faces.
- **Face Table:** Represents land parcels or spatial regions enclosed by edges.

This data organization enables rapid retrieval of adjacency relationships between neighboring parcels without reconstructing the topology of the entire map. Such capability is highly beneficial for common cadastral operations, including parcel subdivision, parcel consolidation, and land record updating.

One notable advantage of DCEL is its support for land-change management. During parcel subdivision, only new vertices and corresponding half-edges need to be added, while related Face entities are updated accordingly. Similarly, during parcel consolidation, common boundary half-edges can be removed or restructured without affecting other spatial regions. As a result, cadastral data maintain topological consistency following each update.

The DCEL structure also integrates effectively with the Land Administration Domain Model (LADM) standardized under ISO 19152 [5]. Within this framework, DCEL manages geometric and topological relationships, whereas LADM handles legal information, land rights, landholders, and administrative relationships [4]. The integration of these two models provides a robust foundation for the development of multipurpose land administration databases. The DCEL model allows adjacency relationships among land parcels to be queried instantaneously without reconstructing topology for an entire map sheet. Figure 2 illustrates a DCEL representation of neighboring land parcels.

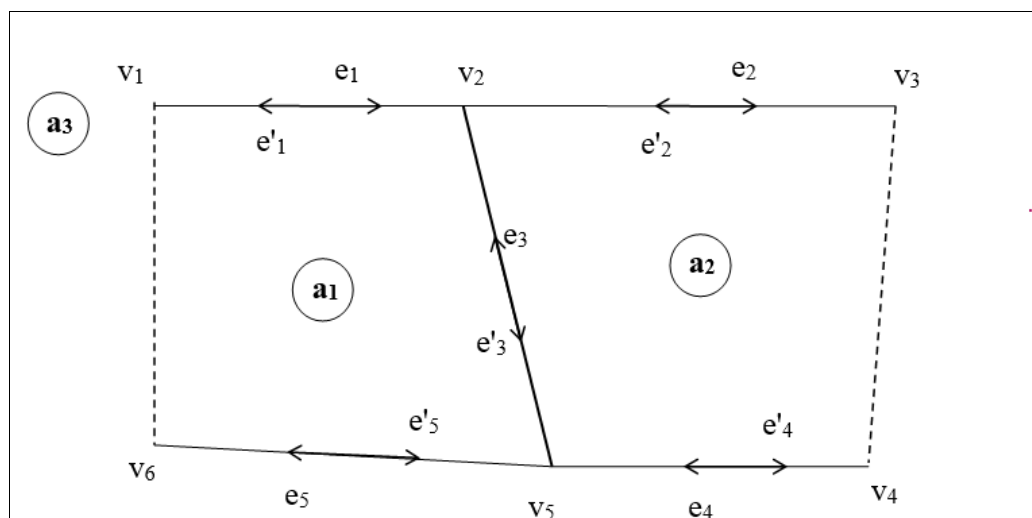


Fig 2: Doubly Connected Edge List (DCEL) structure.

2.3. Overlay Algorithm and Visual Quality Control

This study develops a spatial overlay algorithm based on the principle of tessellating each area of a source map layer with corresponding areas from a target map layer. The method preserves attribute information while ensuring data integrity following overlay operations. To support quality

assessment, cadastral data are transformed from the VN-2000 coordinate system to WGS-84 and exported to KML format. These datasets are subsequently displayed in Google Earth and compared with satellite imagery to rapidly identify errors introduced during surveying or map editing. In addition to visual inspection using Google Earth, the

system may be extended to support automated quality-control procedures. Validation rules include detecting overlapping regions, identifying topological gaps, verifying polygon closure, and evaluating area discrepancies before and after cadastral updates.

Furthermore, advances in remote sensing technologies and unmanned aerial vehicles (UAVs) create opportunities for integrating high-resolution imagery into cadastral validation and updating workflows [10]. Such datasets can facilitate rapid detection of land-use changes, new construction activities, and boundary modifications, thereby enhancing digital land administration.

3. Results and Discussion

The experimental system was developed using Visual Basic 6.0. To enhance computational efficiency, geometric processing algorithms were compiled as Dynamic Link Libraries (DLLs), and the compilation process was optimized by customizing the Link.exe configuration to support the /DEF parameter.

The study area consisted of Digital Cadastral Map Sheet No. 24 at a scale of 1:500 in An Khanh Commune, Hoai Duc District, Hanoi City. Due to rapid urbanization and frequent land-use changes, this area represents a suitable environment for evaluating the proposed approach.

Experimental results demonstrated that parcel subdivision and consolidation operations were performed accurately while fully preserving existing topological structures. When changes occurred, only the affected components required updating, leaving the remaining cadastral database unaffected. This significantly improved the efficiency of cadastral data maintenance and management.

The experiments confirmed that the proposed solution not only increases cadastral mapping productivity but also strengthens data quality control, preserves topological structures, and supports efficient management of land changes, thereby establishing a foundation for modern and sustainable land information systems. Figure 3 illustrates parcel subdivision operations conducted within the software without disrupting the existing DCEL structure.

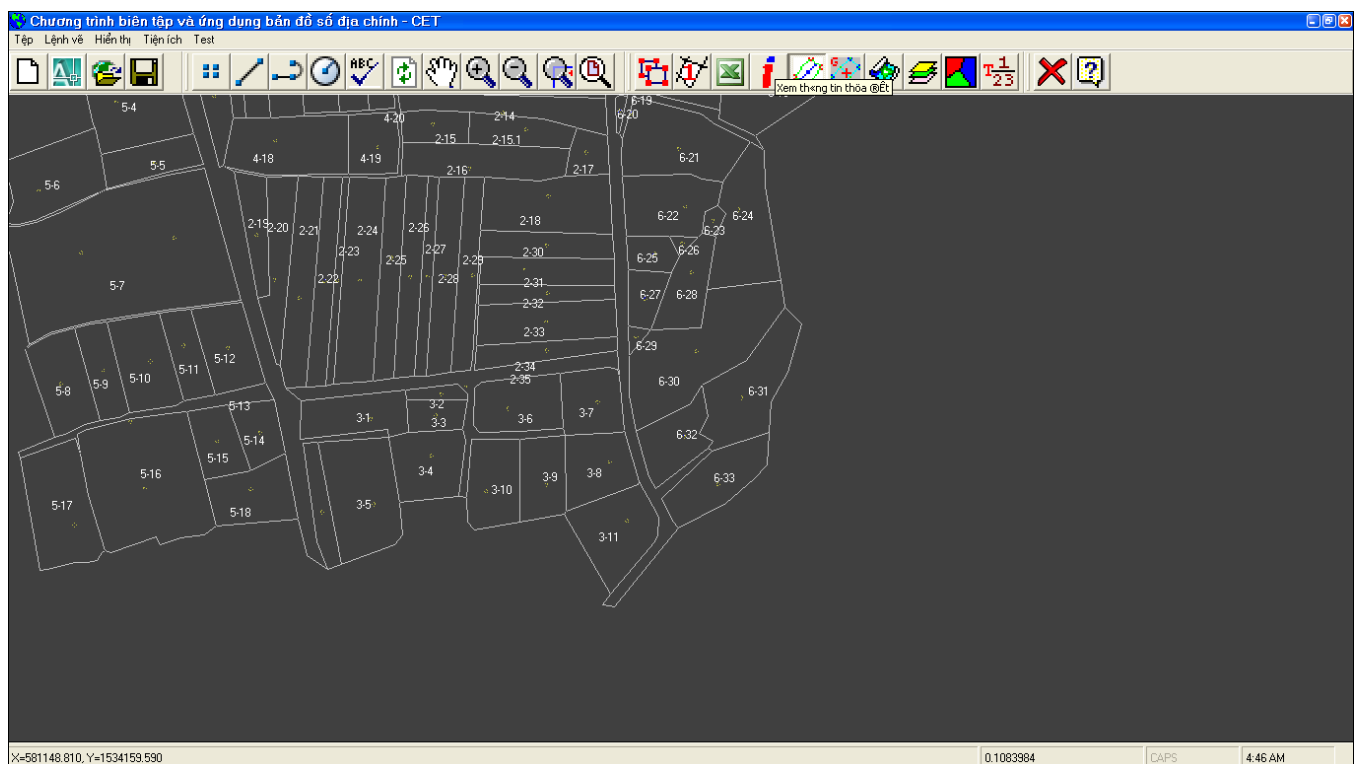


Fig 3: Experimental parcel subdivision results

Experimental results in An Khanh Commune indicate that the specialized field-office workflow combined with the DCEL data structure substantially improves productivity,

data quality, and land-change management capabilities. Key results are summarized in Table 1.

Table 1: Summary of Experimental Results

Evaluation Indicator	Result
Labor productivity increase	30–40%
Remote quality control	Achieved via Google Earth
Consistency with actual conditions	Parcel boundaries matched satellite imagery
Preservation of topological relationships	Maintained during parcel subdivision and consolidation
Processing time for subdivision/consolidation	Less than 0.2 seconds
Automation of map editing	Successfully implemented

The findings indicate that the proposed method not only improves cadastral map production efficiency but also aligns well with the development of national land databases. According to Williamson *et al.* [7], modern land information infrastructures should support integration of multiple data sources and facilitate information sharing among government agencies. Within this framework, maintaining stable topological structures is essential for ensuring long-term data consistency.

The DCEL-based model proposed in this study enables a transition from conventional map management toward dynamic cadastral database management. This development forms an important foundation for multipurpose land information systems supporting planning, construction, land finance, and smart urban governance.

Comparisons between cadastral data and Google Earth imagery revealed a high degree of correspondence between surveyed parcel boundaries and actual conditions observable from satellite images. This finding verifies data accuracy and enables timely detection of surveying errors, such as incorrect instrument station positioning or inaccurate representation of field objects.

Implementation of the specialized workflow also produced substantial organizational benefits. Field teams could focus entirely on surveying and data collection, while office teams

performed centralized editing for multiple survey crews simultaneously. As a result, overall labor productivity increased by approximately 30–40% compared with traditional workflows.

From a technological perspective, the DCEL structure demonstrated significant advantages in managing land changes. Parcel subdivision and consolidation operations were executed almost instantaneously, with processing times below 0.2 seconds for complex topological operations. Furthermore, automation of land-use status mapping based on land-use attributes significantly reduced processing time and minimized human errors.

Experimental results also indicate that optimizing data types and compilation settings has a considerable effect on software performance, thereby meeting practical requirements for large-scale cadastral data processing.

The overlay of cadastral maps on Google Earth confirmed full correspondence between surveyed parcel boundaries and actual site conditions, enabling rapid identification of measurement errors without additional field verification. The KML conversion and overlay results for the An Khanh study area demonstrated close agreement between measured parcel boundaries and satellite imagery (Figure 4), allowing remote quality assessment by management agencies.



Fig 4: Experimental digital cadastral map displayed in Google Earth.

Despite these positive outcomes, several limitations remain. First, the experimental implementation was conducted only at the commune level and therefore does not fully reflect system performance within cadastral databases containing millions of parcels. Second, the experimental software was developed using Visual Basic 6.0 and did not fully exploit the capabilities of modern spatial database management systems. Future research should investigate implementation of the DCEL structure within PostgreSQL/PostGIS or other contemporary geodatabase platforms to evaluate performance under large-scale database environments.

4. Conclusion

This study demonstrates the feasibility and effectiveness of combining specialized field-office work with the DCEL data structure for the development and management of digital cadastral maps. The proposed workflow increases labor productivity by approximately 30–40%, enhances data quality control, and ensures the integrity of cadastral information despite frequent land changes.

The integration of Google Earth into the quality-control process provides an intuitive, convenient, and effective validation tool for both production units and management

agencies. In addition, the proposed solutions for data structure optimization and computational performance improvement create opportunities for developing highly competitive domestic cadastral software systems.

The research confirms the validity of combining workflow specialization with the DCEL data structure. The proposed approach not only addresses productivity challenges but also ensures the long-term sustainability of cadastral data in the face of continuous land changes. Incorporating Google Earth into the validation workflow enhances transparency and visual assessment capabilities. Optimization of computational performance through appropriate data-type selection and compilation strategies represents a significant contribution to the development of high-performance cadastral software.

In the future, the proposed solution may be extended to integrate planning databases, housing databases, technical infrastructure databases, and other sector-specific information systems, thereby contributing to the establishment of a national spatial data infrastructure supporting digital government and the digital economy in Vietnam. Further research is required to refine and standardize this workflow into a unified technical framework applicable nationwide, supporting the development of a modern, integrated, and multipurpose land information system for land administration in Vietnam.

References

1. Enemark S. Land administration systems. In: Map World Forum; 2009; Hyderabad, India.
2. van Oosterom P, *et al.* Cadastral information modelling. In: Best practices 3D cadastres: extended version. International Federation of Surveyors; 2018. p. 95–132.
3. Huynh PT. Research on the technology for cadastral digital map production and application under Vietnamese conditions [doctoral dissertation]. Hanoi: Hanoi University of Mining and Geology; 2015.
4. Lemmen C. A domain model for land administration. 2012.
5. International Organization for Standardization. Geographic information—Land Administration Domain Model (LADM). Geneva: International Organization for Standardization; 2012. ISO 19152:2012.
6. Dale PF, McLaren R. GIS in land administration. *Geographical information systems*. 1999;2:859–875.
7. Williamson I, *et al.* Land administration for sustainable development. Vol. 487.
8. Enemark S, *et al.* Building fit-for-purpose land administration systems. In: Proceedings of the XXV FIG Congress: Engaging the Challenges, Enhancing the Relevance; 2014. International Federation of Surveyors.
9. de Berg M, *et al.* Introduction. In: Computational geometry: algorithms and applications. Springer; 2008. p. 1–17.
10. Lillesand T, Kiefer RW, Chipman J. Remote sensing and image interpretation. John Wiley & Sons; 2015.