A New Approach for The Automation of Spatial Data Updates Using ArcGIS ModelBuilder for Provincial Planning in The Region of Nghe An, Vietnam

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Abstract

Timely updating of administrative boundaries in national spatial databases is a critical component of modern territorial management, especially in the context of administrative restructuring in many countries. Traditional updating methods in ArcGIS remain largely manual, involving multiple discrete steps that are time-consuming and error-prone. This study proposes a semi-automated spatial data updating model using ModelBuilder within the ArcGIS environment to streamline the process into a single workflow. A case study was conducted in Nghe An province, Vietnam, which is undergoing commune-level administrative mergers. The proposed model reduced processing time by 70% while maintaining spatial accuracy in compliance with the VN-2000 coordinate system and current technical standards. The study has processed a large amount of spatial data that was collected from 2010 to 2024 in Nghe An province, Vietnam. The model was further piloted in three additional provinces and a regional planning project involving 14 northern midland and mountainous provinces, demonstrating its scalability and potential for integration into national and subnational planning databases. This approach provides a replicable solution for other countries facing similar administrative restructuring, supporting efficient and accurate spatial data management. The model also directly supports the integrated provincial planning process for the 2021–2030 period and beyond.

1. Introduction

Efficient spatial planning is critical for the sustainable management of natural resources, the coordination of socio-economic development, and the implementation of infrastructure projects in harmony with environmental objectives [1]. In recent years, integrated spatial planning has emerged as a strategic approach to sustainable development, particularly in regions undergoing rapid urbanization, administrative restructuring, and increasing demands for digital and data-driven governance frameworks [2, 3]. Geographic Information Systems (GIS) have become foundational tools in this process, facilitating spatial analysis, land-use planning, infrastructure management, zoning, and environmental impact assessments [4, 5].

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In Vietnam, the rollout of the national integrated planning framework for the 2021–2030 period underscores the urgent need for accurate and up-to-date spatial data, especially at the provincial level [6]. Nghe An Province, the focus of this study, is one of the largest and most geographically diverse provinces in the country. It is currently undergoing significant changes due to commune-level administrative mergers and major infrastructure investments. These transformations have placed growing pressure on local authorities to maintain an accurate geospatial database to support planning activities.

Despite the capabilities of leading GIS platforms such as ArcGIS (developed by ESRI, USA), the process of updating geospatial data remains largely manual and fragmented. Tasks such as data entry, coordinate system transformation, attribute editing, spatial validation, and data export are often handled in isolation. This workflow not only consumes time and human resources but also increases the risk of inconsistency and human error—both of which can undermine the quality of planning outcomes [7].

To address these limitations, this paper proposes a semi-automated spatial data update model using ArcGIS ModelBuilder, applied specifically to Nghe An Province. The study focuses on two critical data layers: administrative boundaries and transportation infrastructure. By integrating discrete manual steps into a unified automated workflow, the model reduces processing time by up to 70% while ensuring compliance with the VN-2000 coordinate reference system and national technical standards.

The model was piloted and validated in Nghe An and further tested in other provinces with similar spatial dynamics. The results confirm its scalability and practicality for broader adoption. Moreover, the proposed approach contributes to the digital transformation of Vietnam's planning sector by enhancing data consistency, improving workflow efficiency, and supporting the creation of a unified digital platform for integrated provincial planning across the 2021–2030 period.

From a theoretical standpoint, this study contributes a generalized, rule-based model for automating spatial data updates within GIS environments, particularly applicable to regions experiencing administrative restructuring and rapid infrastructure development. Unlike prior research that treats spatial updates as ad hoc or static corrections, this model formalizes a sequential and modular geoprocessing workflow grounded in spatial topology, attribute integrity, and coordinate consistency. The framework is adaptable across diverse territorial contexts and provides a scalable foundation for advancing automation in geospatial data infrastructure—thereby aligning spatial planning theory with the evolving demands of smart and sustainable governance.

The rest of the paper is structured as follows. Section 2 reviews the significant methods related to the work. Section 3 describes the data preparation and methodology. Section 4 analyzes obtained results and Section 5 provides main conclusion of the paper.

2. Literature Review

2.1. History of Provincial Planning

Provincial planning history" refers to the development and evolution of regional or provincial land-use planning systems, policies, and legislation over time. This history varies greatly depending on the country and specific province or state [8, 9].

Provincial or state planning typically has the following periods:

• In the early development (Pre-20th Century), the informal land was used. The planning was largely guided by local or colonial authorities.

• In the formalization (Early to Mid-20th Century), planning acts or land-use policies were introduced. The influence of industrialization and urbanization developed in the period.

• In the modernization and expansion (Post-WWII to 1980s), rapid urban growth prompted more structured zoning and infrastructure planning. We focused on transportation, housing, and economic development.

• In sustainability and smart growth (1990s–Present), greater emphasis on environmental protection, heritage preservation, and sustainable development have been proposed and investigated. Regional growth strategies, greenbelts, and climate adaptation plans have significantly developed.

Vietnam's provincial planning history reflects the country's transition from a centrally planned economy to a more decentralized and market-oriented system[10]. In 1986, reforms of country aimed to liberalize the economy and reduce state control. The planning process became more responsive to local conditions, though still aligned with national socio-economic development strategies. The adoption of the Law on Planning (2003) and Law on Construction (2003) enhanced legal frameworks for spatial and socio-economic planning. The Law on Planning was introduced in 2017[11]. Provinces are actively preparing and approving provincial master plans for the period 2021–2030, with a vision to 2050.

2.2. Applications of GIS and Information Technology in Urban Planning

Information technology (IT) provides efficient solutions in urban planning . Various IT applications: Participatory Planning GIS, 3D models, communication platforms and computer games have applied in provincial planning. Technology helps us to work remotely and collect large database [12, 13].

Computer applications have efficiently supported urban planning and management over the last three decades [14]. Moreover, the rapid advances of IT and AI tools not only support the contemporary components of smart cities but also help adding another dimension to urban planning for managing socio-economic transformation in the cities with several effective tools and techniques [15, 16] .
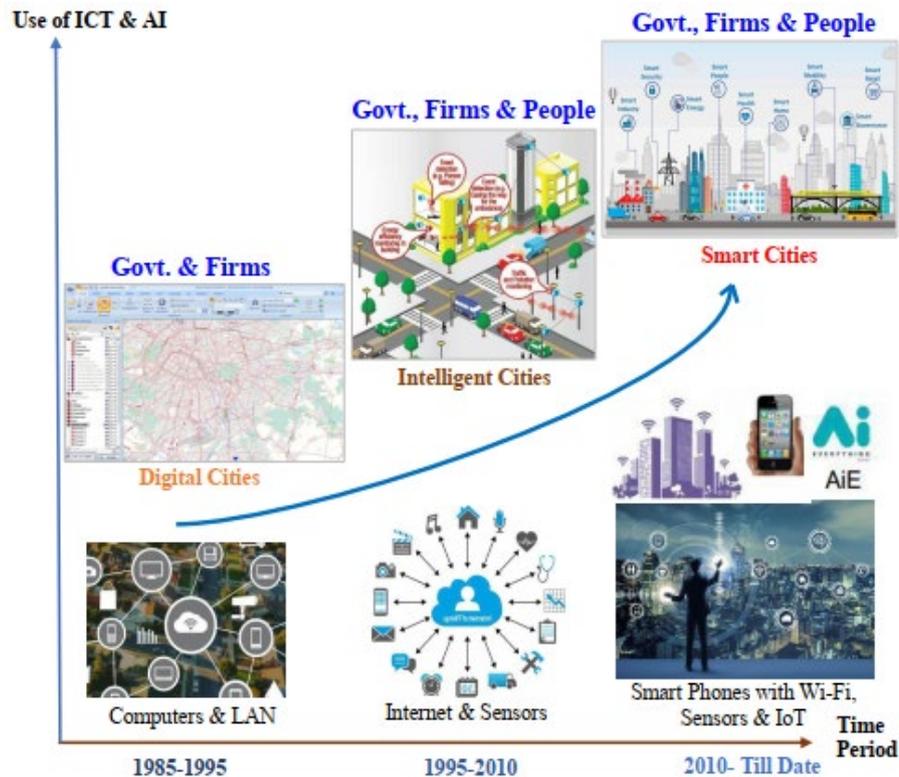
Fig. 1 *IT Applications that are widely used in urban planning during time [11]*

Fig. 1 shows the IT applications in planning during time [11]. Information system and artificial intelligence (AI) has focused primarily on providing rich information for decision making and more intelligent. Moreover, effective solutions have been designed for urban issues by integrating data from various sources using modern and promising technologies.

3. Research Design and Methodology

3.1 Study Area

Nghe An is the largest province in Vietnam by land area, located on the East–West Economic Corridor that connects Myanmar, Thailand, Laos, and Vietnam via National Highway 7, terminating at Cua Lo Seaport. Administratively, it comprises 21 second-level units, including Vinh City—the provincial capital and a regional center for politics, economy, and culture.

In 2010, Nghe An had 412 commune-level administrative units and in 2023, this number had increased to 460 due to boundary changes and commune mergers. These administrative changes, alongside rapid infrastructure development, have caused substantial spatial shifts, especially in rural and peri-urban areas.

Given these dynamic conditions, Nghe An was selected as the pilot site for this study to evaluate the proposed GIS data update model's feasibility, efficiency, and scalability in a real-world setting.
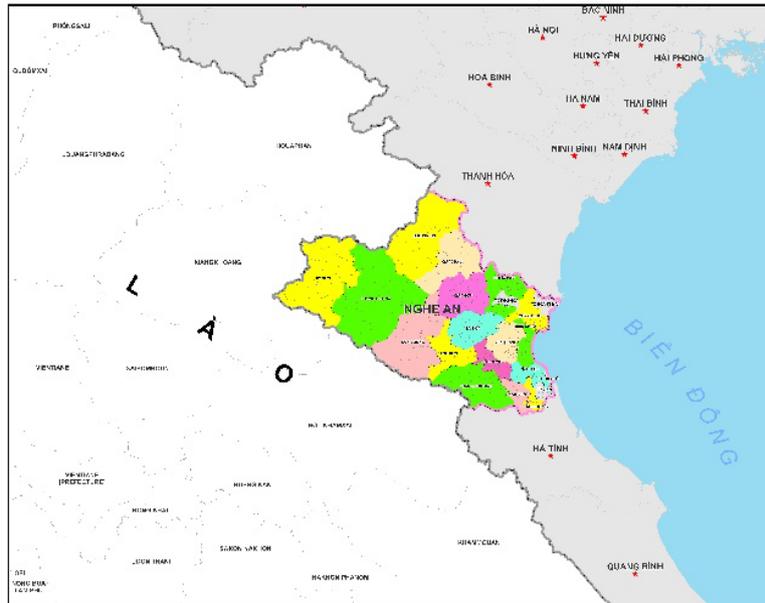
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Fig. 2 *Geographic location and administrative boundaries of Nghe An Province*

3.2 Data Preparation and Processing

The data used in this study were collected and processed based on the technical requirements set out in Vietnam's Planning Law (2017) [12] and related guidelines for building map databases to support spatial planning. For Nghe An Province—the largest in Vietnam by area—the base map at a scale of 1:100,000 was selected to match the province's size and administrative structure. This map served as the foundation for analysis and the creation of thematic maps in the provincial planning process for the 2021–2030 period.

The main data sources include:
- (i) the national geospatial database at 1:100,000 scale created in 2010,
- (ii) an updated topographic map at the same scale from 2023,
- (iii) the 2021 Statistical Yearbook of Nghe An,
- (iv) satellite images and spatial data from Google Earth, used to visually verify recent changes.

3.3 Methodology

The research methodology combines the use of existing geospatial datasets with the development of a semi-automated update workflow using ArcGIS. The core of this approach is the application of ModelBuilder, a built-in tool in the ArcGIS ecosystem, which allows users to integrate multiple geoprocessing steps into a unified, repeatable model. This design significantly reduces manual operations and enhances consistency in data processing.

The process begins with the preparation and standardization of input data, including topographic maps, administrative boundaries (from 2010 and 2023), transportation networks, and attribute tables. All datasets are converted to a national coordinate system (VN-2000) and standardized in GIS.

3.4 ModelBuilder Workflow Design and Implementation

The ModelBuilder workflow (Figure 2) consists of six key stages.

This semi-automated approach reduces dependency on operator skill, minimizes errors, and shortens update time by up to 70% compared to traditional manual methods. Furthermore, the model can be easily adapted for other provinces with similar administrative or spatial planning needs.
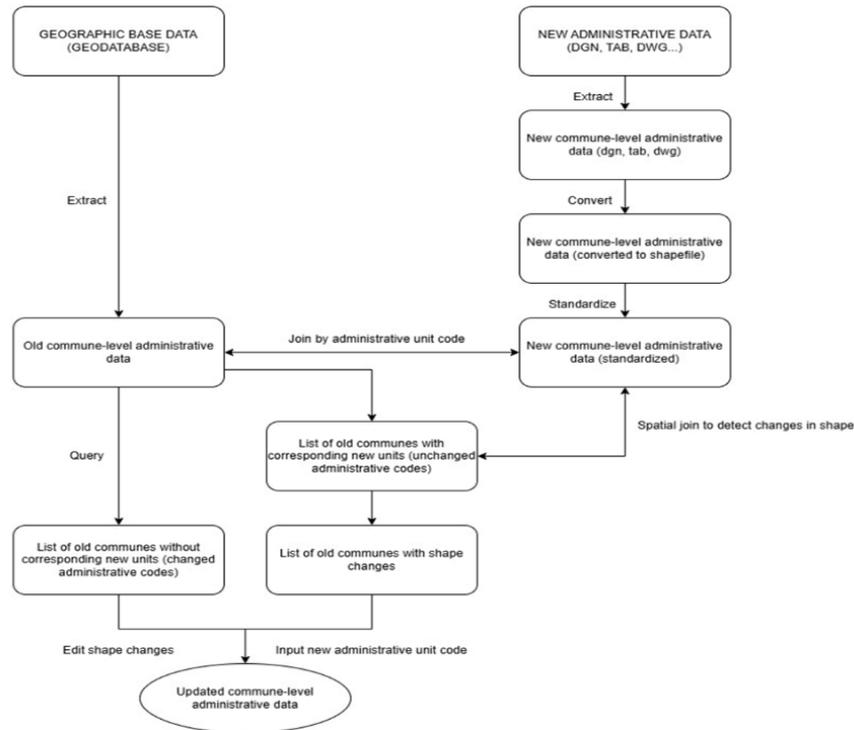
Fig. 3 *Workflow of our solution*

One of the key steps in the workflow is the spatial update of the polygon layer representing commune-level administrative boundaries in Nghe An Province. Under traditional methods, this task typically requires GIS technicians to manually execute multiple separate operations in ArcGIS such as Join Attributes from a Table, Select by Attributes, Feature to Point, and Table to Excel. This approach increases processing time and introduces the risk of errors during data transformation and attribute linking.

To address this limitation, the research team developed a semi-automated data processing model using the ModelBuilder tool within the ArcMap environment. The model was designed to consolidate all individual steps—data import, attribute joining, feature selection, field updates, and data export—into a single streamlined workflow. This integration not only reduces execution time but also ensures repeatability and ease of reuse for future updates or application in other provinces.

The construction of the model began with creating a custom toolbox in ArcMap, followed by logically organizing the required processing tools within the ModelBuilder interface (Figure 3). Once finalized, the model was saved and deployed as a standardized tool for spatial data updates. Users can execute the full update process by running the model once, without needing to perform each step manually.
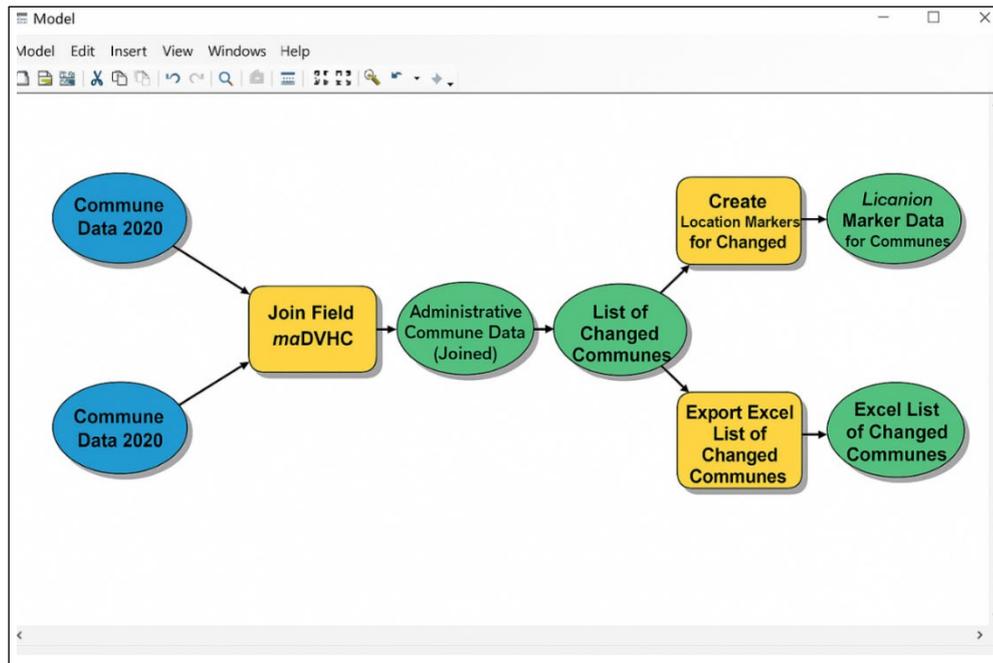
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Fig. 4 *Model builder in ArGIS*

After constructing the model using ArcMap's geoprocessing tools, each component in the ModelBuilder interface was arranged in a logical sequence to ensure clarity in data flow and ease of use (Figure 4). Once finalized, the model was saved as a custom tool in ArcToolbox and is now ready to serve as a standardized workflow for automating the spatial update of administrative boundaries.

The model starts by connecting commune-level boundary datasets from 2010 and 2023 based on their administrative codes (maDVHC). It then filters unmatched features—indicating changes or discontinuities—and generates a list of affected communes. Subsequently, the model creates spatial marker points for visual identification and exports the results as an Excel report (Figure 5). This fully automated process ensures data consistency, minimizes manual errors, and reduces update time significantly.
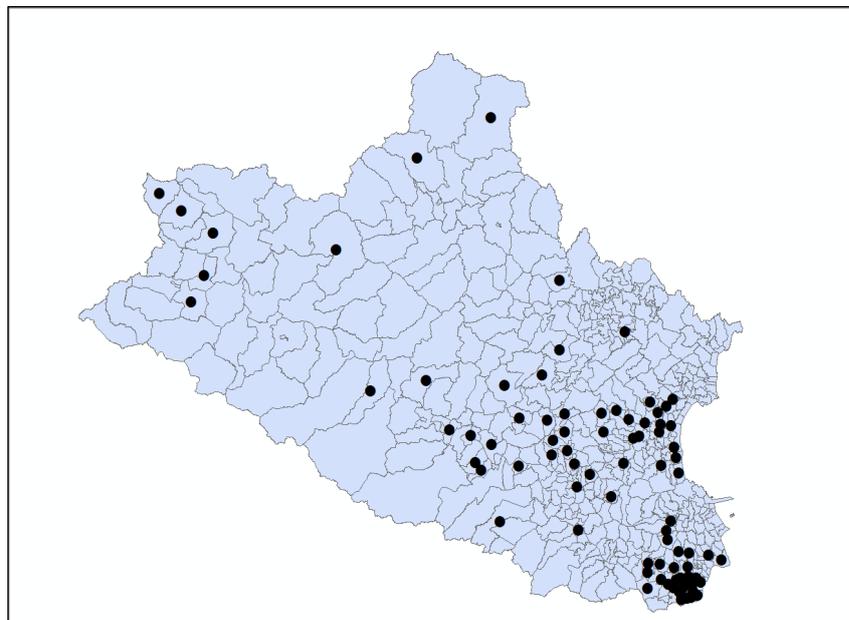
Fig. 5 *Spatial points generated for analysis*

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4. Results and Discussion

4.1 Changes in Administrative Boundaries

Nghe An province has undergone significant administrative restructuring over the past decade. In 2010, the province consisted of 412 commune-level administrative units. By 2023, this number had increased to 460, as evidenced by comparisons between historical GIS data, government decisions, and the provincial statistical yearbook. These changes were mainly the result of mergers and the establishment of new administrative boundaries, driven by urbanization and infrastructure development. The spatial distribution of boundary changes is visualized in Figure 5, where each black dot represents a commune-level unit that has undergone administrative adjustment between 2010 and 2023. The map clearly shows that these changes are not evenly distributed across the province. Instead, they are concentrated in the southeastern and central regions—areas with higher population density, urbanization pressure, and more complex infrastructure networks. The analysis reveals a clear mismatch between the outdated 2010 administrative boundary data and the current administrative structure as of 2023. This mismatch, if not addressed, can lead to inaccurate spatial analysis and planning decisions. The findings demonstrate how critical it is to keep spatial and attribute data synchronized with ongoing administrative changes.

Figure 6 and Figure 7 illustrate the geographic shifts and attribute table discrepancies that necessitated updates. Changes were concentrated in the southeastern and central regions, reflecting areas with dense populations and developmental pressure. Spatial and attribute data inconsistencies highlighted the importance of a synchronized and up-to-date GIS database to support planning activities. Without these updates, planning decisions risk relying on obsolete information, undermining planning accuracy and credibility.

4.2 Performance and Efficiency of the Model

The proposed ModelBuilder solution consolidates the updating process into a semi-automated workflow. Traditional GIS workflows required multiple manual steps, each prone to errors and inconsistencies. By integrating operations such as attribute joins, feature selections, and spatial validations into a single tool, the new model improves reliability and efficiency.

By implementing the semi-automated model, this study shows that updates to complex spatial datasets—such as commune-level boundaries—can be performed more efficiently and accurately. Instead of relying on time-consuming, manual operations prone to error, the integrated workflow developed in ModelBuilder reduces processing time significantly, minimizes dependency on operator skill, and allows for easier data maintenance. These advantages are especially relevant for local authorities and planning agencies that require periodic updates across multiple layers of geospatial information.

Moreover, the model's ability to identify, isolate, and update only the changed features ensures that human and technical resources are focused where they are most needed. This targeted approach not only improves accuracy but also makes the data update process more transparent and easier to replicate in future planning cycles or in other provinces facing similar restructuring.

Performance assessments showed that the updated workflow reduced processing time by approximately 70% compared to traditional manual approaches. Moreover, automation reduced dependency on expert-level GIS skills, making the model more accessible to local agencies. The modular structure of the ModelBuilder also allows for easy adaptation to other layers, such as transportation networks or land use datasets, enhancing the overall flexibility of the system.

Fig. 6 *The attribute table of the geographic database*

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4.3 Implications for Planning Practice

Reliable spatial data is a cornerstone of effective spatial planning, particularly in contexts experiencing rapid change. By applying this model in Nghe An and extending it to 14 additional provinces, the study demonstrates the practicality and scalability of the approach. It supports timely updates, enhances coordination between local and national datasets, and ensures compliance with Vietnam's VN-2000 coordinate reference system and technical standards.

More importantly, this tool facilitates the integration of updated geospatial data into ongoing provincial planning efforts for the 2021–2030 period. Planners can now incorporate real-time changes into land-use zoning, infrastructure development, and socio-economic forecasting, resulting in more resilient and data-driven planning frameworks. The improved transparency and repeatability of the process also promote trust among stakeholders and support long-term digital transformation in governance.
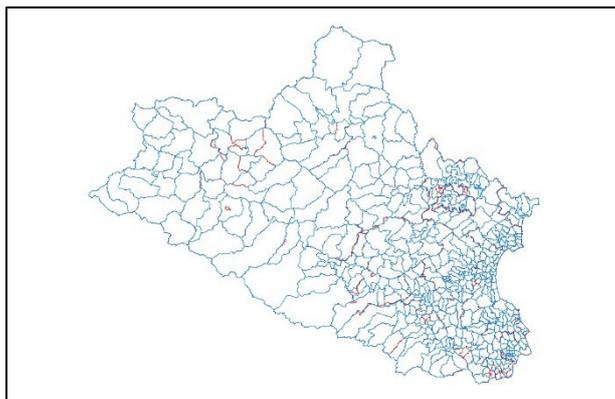

Fig. 7 *Updated administrative boundaries of Nghe An province 2023*

Figure 7 shows the updated administrative boundaries in 2023, the red polygons are new communes, included in the mathematical basis (VN 2000) of the geographic database, this is an important basis for integrating fields of provincial planning.

Recently, we have developed and applied the results for 14 northern midland and mountainous provinces in Vietnam. The results have shown the effectiveness of our proposed method in reality in Vietnam.

5. Conclusion

5.1 Summary of Key Findings

This study proposed a semi-automated GIS workflow using ArcGIS ModelBuilder to efficiently update commune-level administrative boundaries in support of integrated provincial planning in Vietnam. The model, applied to Nghe An province and expanded to other regions, proved effective in reducing processing time, increasing accuracy, and maintaining consistency with national standards. The study demonstrated how technological innovation can address the pressing need for up-to-date spatial data in rapidly changing administrative contexts.

5.2 Practical Implications

The research has several practical implications for provincial and national planning agencies. First, the tool developed offers a replicable model for improving spatial data quality in regions undergoing administrative restructuring. Second, the automation of traditionally manual GIS processes contributes to workforce efficiency and cost reduction. Lastly, by supporting the VN-2000 coordinate system and planning regulations, the model facilitates better compliance with legal and technical requirements in spatial planning.

5.3 Limitations and Future Work

While the study achieved significant improvements in spatial data processing, it has limitations. The model relies on the availability of high-quality, standardized input data, which may not be present in all provinces. Additionally, it was primarily tested on administrative boundaries and transportation layers; further work is required to extend its application to other thematic datasets. Future research should focus on incorporating machine learning for

automated anomaly detection and exploring the integration of real-time data sources such as IoT and remote sensing for continuous spatial monitoring.

This study presents a semi-automated GIS workflow using ArcGIS ModelBuilder to support the efficient and accurate update of commune-level administrative boundaries—an essential requirement for integrated provincial planning in Vietnam during the 2021–2030 period. Applied to Nghe An Province, the model reduced processing time by up to 70% while ensuring technical accuracy and compliance with the VN-2000 coordinate reference system.

Technically, the study led to the development of a reusable custom toolbox within the ArcGIS environment, allowing for the automation of previously manual geoprocessing steps such as attribute joining, change detection, and report generation. This significantly enhances the transparency, repeatability, and efficiency of spatial data management tasks, especially in contexts experiencing frequent administrative restructuring.

By simplifying the update process and minimizing operator dependency, the model improves workflow quality, supports the modernization of spatial databases, and strengthens the digital infrastructure required for sustainable construction and smart territorial governance. The proposed solution is not only scalable but also adaptable to similar spatial dynamics in other regions or countries, offering a practical contribution to the broader application of GIS in planning practice.

Acknowledgement

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** *Author Le Thi Minh Phuong;* **analysis and interpretation of results:** *Author Bui Hai Phong. All authors reviewed the results and approved the final version of the manuscript.*

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