UTILIZING REMOTE SENSING AND GIS TO DESIGN A DATABASE OF ROAD TRANSPOTATION IN THANH HOA PROVINCE OF VIETNAM: A PILOT IN DONG SON AND THIEU HOA DISTRICT

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Abstract. It is necessary to construct a comprehensive and accurate road transport database for Thanh Hoa province, a large province in the North Central region, which ranks third in population and fifth in area of Vietnam. This database will provide an essential overview of the transport infrastructure, enabling effective and precise management. The study utilizes remote sensing in conjunction with GIS technology to develop the road transport system database, with a pilot project focused on Dong Son and Thieu Hoa districts. The database has been successfully established and standardized to include traffic infrastructure objects, such as roads, bridges, signs, traffic signal systems, and lighting systems, for both Thieu Hoa and Dong Son districts. Using this well-structured framework, the road network management can easily expand data coverage to include the remaining districts within the province. In addition to the database creation, the study has developed three groups of tools to facilitate the management and maintenance planning for road infrastructure objects in the province. These tool groups consist of data management and updating tools, tools for generating statistical reports, and tools for planning and estimating maintenance costs. This road network database plays a vital role in providing essential spatial and non-spatial information to support various aspects, such as urban planning, environmental resources management, and more.

Keyword: *Sentinel-2A, Sentinel-2B, GIS technology, road transport database, Model Builder.*

1. INTRODUCTION

The transport system is a crucial component of any economy and serves as a fundamental tool for development. There exists a close relationship between the quantity and quality of transport infrastructure and the level of economic development. Efficient transport systems provide economic and social opportunities and benefits, enabling easy accessibility to markets, employment, and investments. On the other hand, deficient transport systems, whether in terms of capacity or reliability, can lead to economic costs, including reduced or missed opportunities and a lower quality of life [3].

Proper management, operations, and maintenance are essential for a transportation system to remain effective. Strict and systematic management of quantity, quality, condition, maintenance, and operational information is imperative. To achieve an effective and accurate management, it is crucial to build a complete and accurate database that provides an overview of the transportation infrastructure [9]

In developed countries, the use of remote sensing images has become common practice in urban planning. Currently remote sensing data is being used to create thematic maps and

base maps for urban planning, due to it's useful. Over the past few years, many successful applications have demonstrated the feasibility of using remote sensing techniques for traffic infrastructure monitoring purposes such as radar-based remote sensing techniques, interferometric synthetic aperture radar techniques, high-frequency ground-penetrating radar… High-resolution images are helpful for interpreting and monitoring structural changes in infrastructure [4], [8], [11].

Some other studies have aimed at integrating remote sensing and GIS focusing mainly on road feature extraction [19], road network analysis [1]. The application of remote sensing and GIS can be seen as a great support for effective planning, analysis and decision making especially for the development and growth of urban areas.

The above studies have focused on building a database on road traffic infrastructure, but it is not complete. Due to the use of raw data sources, the integration of data and forecast information were not fast, synchronous and timely. Therefore, research on remote sensing and GIS applications in road traffic infrastructure management which provide users with truly useful information, ensuring speed, synchronization and timeliness is an issue that needs to be addressed.

Over the years, remote sensing and GIS technologies have been developed in Vietnam and have made significant contributions in multi-sectoral, multi-field including the transportation industry [5]. It is a fact that in Vietnam, there are quite a lot of remote sensing image materials; from low and medium resolution satellite images such as MODIS, LANDSAT images to ASTER, SPOT 6/7, KOMPSat ... with high resolution covering the territory of Vietnam taken in different times. This is a great advantage of remote sensing data that needs to be exploited, applied well for a large space, reducing the cost of direct measurement of the field to ensure economic efficiency for managers. The use of remote sensing data, with features used by high spike frequency, extended range, multi-time, increasingly high resolution... including remote sensing data and research radar, combined with GIS and actual investigation results is a modern, highly effective method [21]. GIS is built using computer tools and application software to analyze and display on the map the spatial data related to the earth. GIS technology allows efficient integration of common database operations such as analysis, statistics and search functions, with special tools for geographic processing and visualization on maps [4].

Today, the need for planning and development of urban and residential areas is rapidly increasing, leading to the development and expansion of traffic infrastructure and also posing new requirements and challenges in urban traffic infrastructure management, especially database system management. Several studies have, provided database solutions and technical infrastructure solutions to build suitable software for road traffic management [6], [7], [15]… However, these systems only focus on managing the current state of road traffic, not providing much support for network planning management. The system's road traffic has not yet been published on the Internet, some research is only theoretical and implementation requires a very high capital source [6],[15].

In Vietnam today, facilities directly managing transport system mainly store transport system database records on paper, some discrete data on computers and some data are digitized using GIS technology, image files.... However, this digitized data is scattered, incomplete and inaccurate, and not updated regularly. Storage, updating, searching, and

statistics still face many difficulties [12]. Therefore, digitizing and building a database of the current state of road traffic infrastructure is very necessary, supporting effective exploitation and improving management.

Figure 1. *Geographical site map of Dong Son and Thieu Hoa districts, Thanh Hoa province*

Thanh Hoa is a significant province located in the North Central region of Vietnam, boasting the third-largest population and the fifth-largest area. Alongside Hanoi, Hai Phong, and Quang Ninh, it serves as a major center for various industries, including energy, processing, and manufacturing. The province also excels in high value-added agriculture, logistics, tourism, education and training, specialized medical services, as well as cultural and sports offerings. As part of the northern development quadrangle of Vietnam, Thanh Hoa represents a new growth pole, contributing significantly to the region's advancement [13].

With a long history of development, Thanh Hoa province now boasts a dense and extensive transportation system to cater to its large population. To effectively support the transportation needs and overall development of the region, there is a pressing need for a modern, up-to-date, and accessible transport database system. Hence, the primary objective of this paper is to construct a comprehensive database for managing road transportation infrastructure in Thanh Hoa province, utilizing a combination of remote sensing and GIS technology through a pilot study in Dong Son and Thieu Hoa districts. The resulting dataset holds potential for practical application, serving as a platform not only for transportation databases but also for other fields, such as natural resources and environment, construction, and agriculture.

2. MATERIAL AND METHODOLOGY

2.1. Material

Study area: Dong Son and Thieu Hoa, two districts situated in the center of Thanh Hoa province, can be found in specific coordinate regions. Dong Son's coordinates lie between 19°43’ to 19°51’ north latitude and from 105°33’ to 105°45’ east longitude, while Thieu Hoa's coordinates range from 19°51' to 12°50' north latitude and from 105°35' to 105°48' east longitude (Figure1). These districts were chosen as study sites due to their well-established and developed road networks. Both Dong Son and Thieu Hoa boast major national highways traversing through them. National Highway 45 runs from Thanh Hoa city, cutting across the north of Dong Son district, passing through Rung Thong town, and extending to Thieu Hoa district. Similarly, National Highway 47 starts from Thanh Hoa city, crosses the north of Dong Son district, goes through Rung Thong town, and reaches Trieu Son district. Additionally, a trans-Vietnam railway passes through both districts, facilitating economic and cultural exchanges with other localities in the country.

Data: - Remote sensing image data serves to build a geographic database: The Sentinel-2A MSI taken on July 7, 2023; Sentinel-2B MSI taken on July 12, 2023 1 radar satellite images taken on December 21, 2017 and Landsat – 8 OLI/TIRLIGT taken on July 7, 2023 in Thanh Hoa province were used in this study.

- Spatial data and attribute data on road transport system in Dong Son and Thieu Hoa districts of Thanh Hoa province.

2.2. Methodology

This paper used the following methods:

***Collect data:** Spatial data and attribute data in the article are collected from 2 sources:

- Collection of Spatial data is maps from the Department of Surveying and Mapping or the Department of Transport of Thanh Hoa province.

- Attribute data is collected from survey work, collecting locations and characteristics of objects in the field.

After collected data will be analyzed, evaluated, and formatted. In this article, data will be built and stored in ESRI's Geodatabase standard.

- **Remote sensing data, in combination with GIS and actual investigation results method:** played a pivotal role in fulfilling various tasks, including input data provision, updating, analysis, querying, and information management. The road network extraction was achieved through the utilization of remote sensing data, alongside other essential background data such as boundary data, population statistics, topography, hydrology, and field data [2]. To construct the road transportation map, spatial data obtained from the satellite image database, coupled with measurement data from Dong Son and Thieu Hoa districts, were integrated using ArcGIS software. GIS technology facilitated the creation of electronic maps, seamless integration of information, visualization of scenarios, resolution of intricate problems, and the swift and efficient generation of innovative solutions [10], 20].

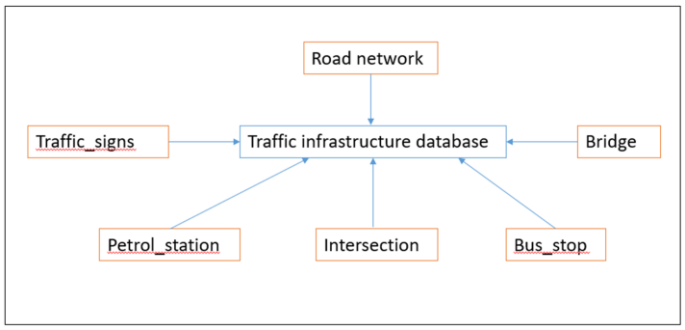


***Figure 2.** Traffic infrastructure database management model*

- **Field surveys**: were conducted to supplement and provide further spatial data and object properties.

- **Modeling method:** Model Builder in ArcGIS is used in this study. Models will be constructed based on data conversion between various formats consist of transportation database fields and surface overlays for mapping the road transport system, for example from Kmz format in Google Earth to Gdb spatial layers in ArcGIS. Similary, by passing the output of this model as input to next model, these models consist of a series of combined numerical tools that facilitate automated data processing in ArcGIS.

Based on the characteristics and management objects, propose a data structure design model as shown in Figure 2.

The process of building a road transportation database for Dong Son and Thieu Hoa districts, Thanh Hoa province is summarized in Figure 3 below.

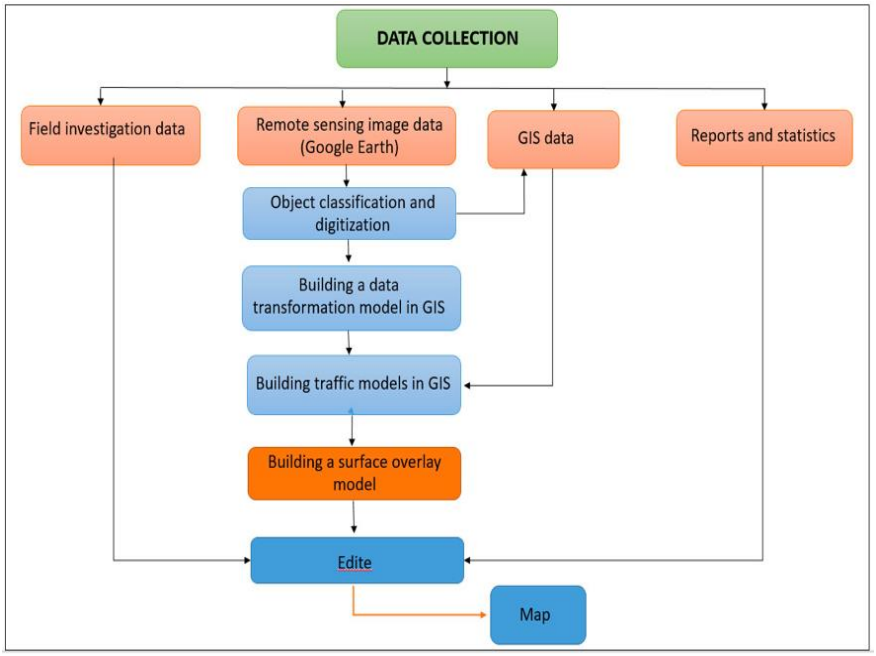


Figure 3. *Using remote sensing and GIS to design the database of road transportation database for Dong Son and Thieu Hoa districts, Thanh Hoa province*

3. RESULT AND DISCUSSION

3.1. The process of building a road network system database for Dong Son and Thieu Hoa districts, Thanh Hoa province

The Model Builder process was chosen to convert kmz format to gdb format data in ArcGIS
due to its agility and convenience [18]. The road transport database of Dong Son and Thieu Hoa districts is conducted as follows:

Step 1: add the boundary layer of Dong Son and Thieu Hoa districts to Google Earth using the Add Path tool to digitize roads. The scope is national highways and provincial roads belonging to two districts (Figure 4).

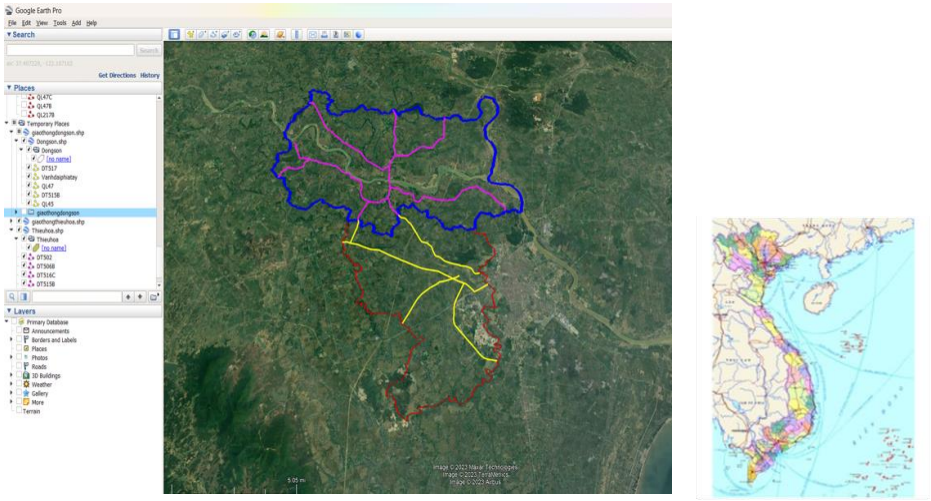


Figure 4. *Digitizing roads on Google Earth.*

- Step 2: After the data is generated as a KMZ file, build a builder model in ArcGIS to convert multiple KMZ files into spatial layers (Figure 5 and Figure 6).

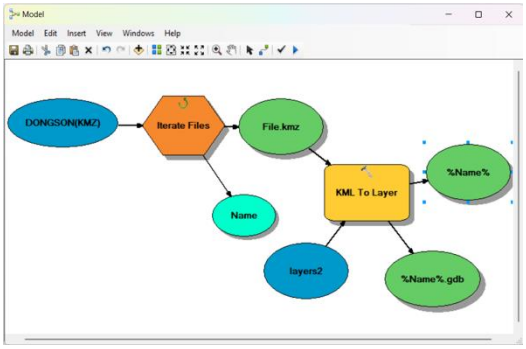


Figure 5. *Build Builder Model converting KMZ file in ArcGIS for Dong Son district.*

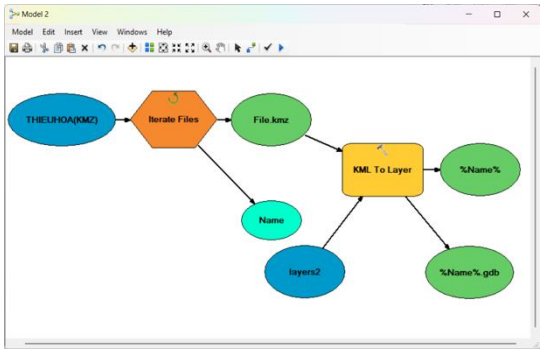


Figure 6. *Building Builder Model to convert KMZ file in ArcGIS for Thieu Hoa district.*

- Step 3: Build a transportation database model (Figure 7 and Figure 8).

Road network is a linear reference system in GIS. Both districts have two levels of road network, the national dataset and the provincial dataset. For this study, provincial and national road networks are used, the unique identifier for route reference in the road network is the segment ID. There is also the type of road, route (primary direction starting and ending) and the length of the road segment. For other objects such as bridges, transport signs, intersections, petrol stations and bus stops the same procedure is applied to the road layer.

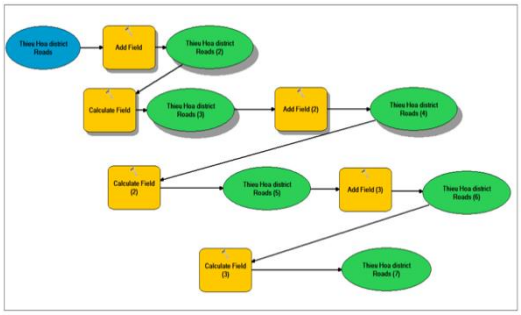


Figure 7. *Construction of Builder Model for transportation in Thieu Hoa district.*

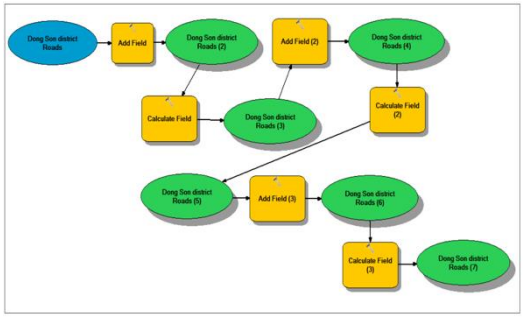


Figure 8. *Construction of Builder Model for transportation in Dong Son district.*

The structure of the road layer attribute database is presented in table 1.

Table 1. The structure of the road layer attribute database

Data layer name	Content interpretation	Data style
ID	Object class classification code	Short Interger
Name	Road names	Text(50)
NameOther	Another name for road	Text(50)
RoadClass	Road classification	Short Interger
WidthRoad	Road width	Float
FirstPoint	The first point of the route	Text(50)
FinalPoint	End point of the route	Text(50)
SurfaceTyp	Road surface material	Text(50)

- Step 4: After construction of the Geodatabase, enter spatial and non-spatial data for road layers such as design, edit and present maps, and obtain a database of road layer maps for research areas.

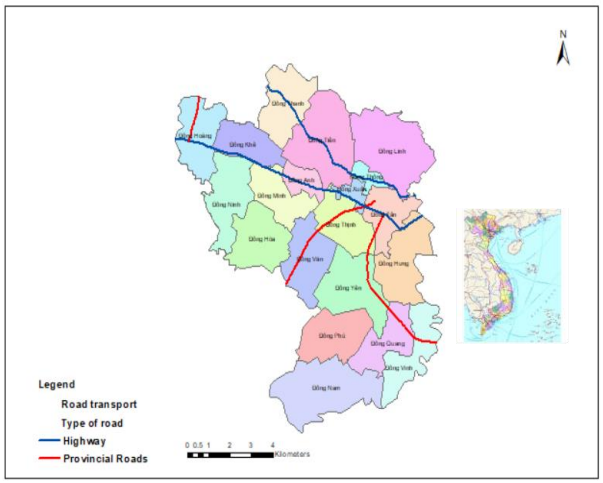


Figure 9. *Road layer after construction for Thieu Hoa district*

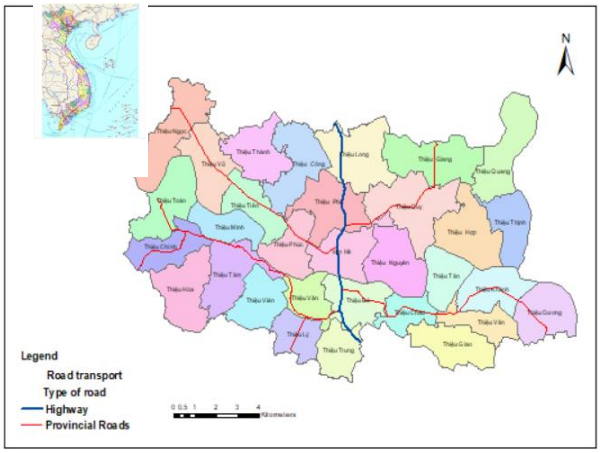


Figure 10. *Road layer after construction for Dong Son district*

3.2. The process of building database of bridges, traffic signs, intersections, gas stations, bus stations in Dong Son and Thieu Hoa districts, Thanh Hoa province

The process of building database of other objects such as bridges, traffic signs, intersections, gas stations, … is applied similar to the road layer. Spatial data of the above point objects is updated from excel files collected and located directly in the field. Attribute data is built based on the data structure for each object. After completing for building of Geodatabase database and entering spatial and non-spatial data for the remaining layers of the transportation infrastructure as designed, proceed to edit and present the map, obtain a road transport system map for the study area as in Figure 11 and Figure 12.

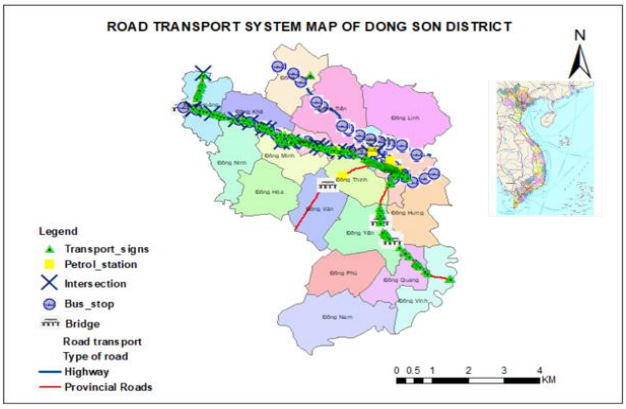


Figure 11. *Complete road transport system map for Thieu Hoa district*

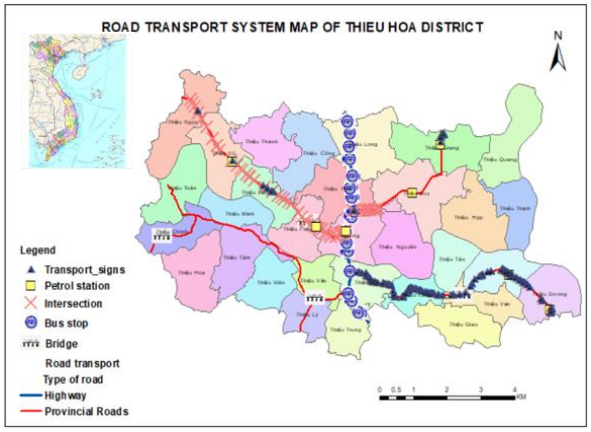


Figure 12. *Complete road transport system map for Dong Son district*

The regional road transport system database, stored as standard data in GIS is GeoDatabase based on applying standards in database construction: standard data format, standard project, standard topology and standard attribute data (Figure 13).

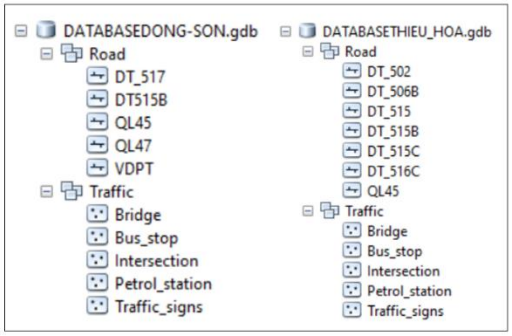
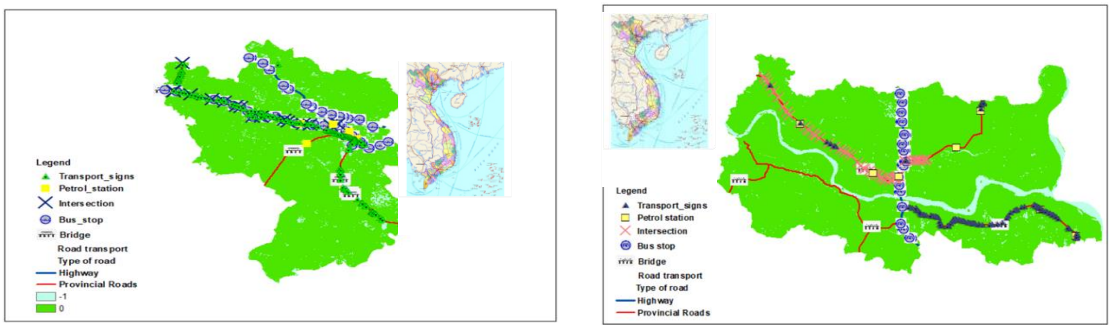


Figure 13. *Structure of road transport system database in 2 districts of Dong Son and Thieu Hoa, Thanh Hoa province*

3.3. Building a base layer database for road transport network maps

To add a base layer to the road transport network map, two methods were chosen. Two studied areas are both agricultural land, so the first method will build an NDVI base layer model for the map as shown in Figure 14 (a) and Figure 14 (b). Input data is from Sentinel - 2 image.



a) *b)*

Figure 14. *NDVI index of Dong Son district (a) and Thieu Hoa district (b)*

In oder to generalize the background layers for the map, Landsat 8 satellite images collected for input data of two districts to classify and improve the accuracy.

3.4. Exploit and use databases to serve road traffic infrastructure management.

Overlaying the GIS data layers, map of road traffic system in Dong Son and Thieu Hoa districts will be obtained (Figure 15).

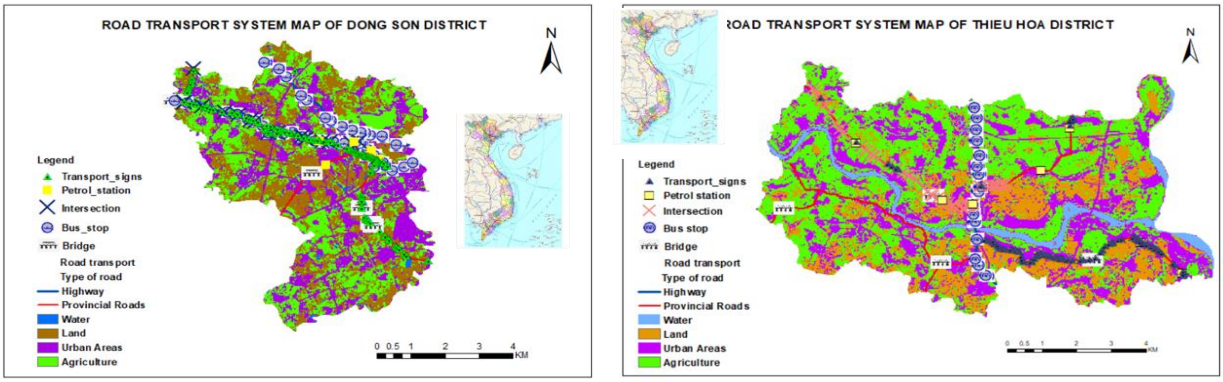


Figure 15. *A road network map of Dong Son district (a) and Thieu Hoa district (b)*

With the advent of geographic information systems (GIS), many studies on road traffic have been conducted in road traffic network analysis [14], [16], [17]. In which, GIS is a very effective approach for building databases, organizing geographical objects in the transportation network, including routes, auxiliary works and all information about the status of objects [22]. The road network database for Dong Son and Thieu Hoa districts has been successfully built and standardized, including the structure of many road infrastructure items, including roads, bridges, signs, traffic signal systems. This framework structure facilitates the effective expansion of data coverage for the remaining districts in the province, thereby benefiting the urban traffic management sector.

Thanh Hoa province is in strong development movement therefore the road network database is so important in providing essential spatial and non-spatial information. This valuable database serves a variety of purposes, supporting urban planning and environmental resource management, and many other purposes.

This study refers to the study management and data update tool group: These tools allow to access and update attribute information for each object of each data layer type. In addition, each object can be located and identified directly on the map.

This group of tools includes:

***Update attribute information directly via the attribute table (Figure 16)**

*** Use the Indentify tool (Figure 17)**

On the toolbar, click on the Indentify tool and click on the object need to look up information about. Then, click on the line layer object. The Identify Results windo wappears.

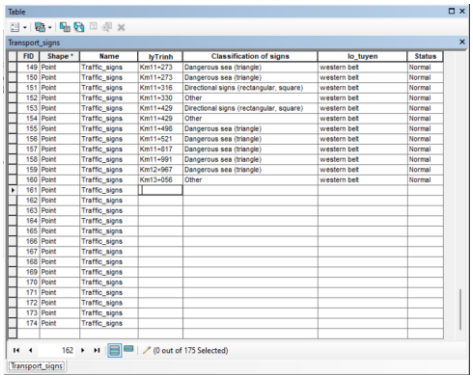


Figure 16. *Attribute table tool*

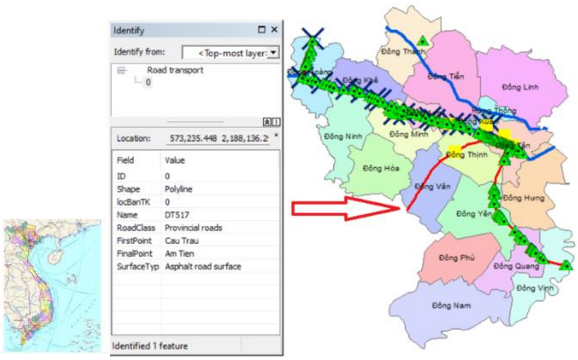


Figure 17. *Indentify information lookup tool*

*** Query objects on the Select by Attributes map:**

From the Menu toolbar, select Selection\ Select by Attributes. The Select by Attributes dialog box appears:

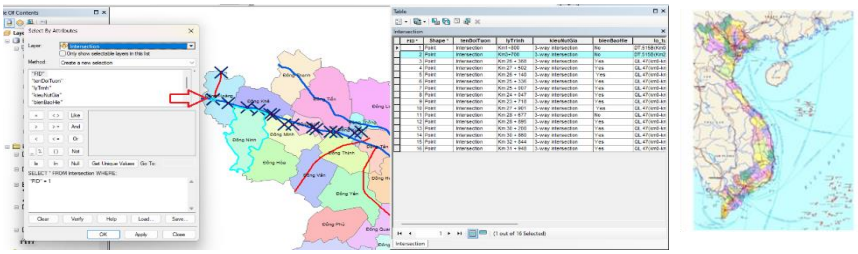


Figure 18. *Objects query tool on Select by Attributes map*

Based on the road transport system database that has been built, using ArGIS's specialized functions, additional functions such as extracting, updating, presenting data, and preparing reports can be provided. The report provides optimal solutions for the purpose of managing the road network of the remaining districts in the province and on a broader scale with other fields.

4. CONCLUSION

Effective transportation systems play a vital role in promoting economic growth and prosperity by enhancing the mobility of citizens and goods. Additionally, they exert significant impacts on road safety and social development. In this study, the database structure, encompassing various traffic infrastructure objects like roads, bridges, trees, signs, traffic signal systems, and lighting systems for both Thieu Hoa and Dong Son districts were successfully constructed and standardized. The framework structure facilitates seamless extension of the road network management data coverage to include the remaining districts within the province.

Furthermore, this study has developed three groups of tools to address the management and maintenance planning of road infrastructure objects in the province, which includes tools for managing and updating data, tools to generate statistical reports, and tools for planning and estimating maintenance costs. These tools contribute significantly to the efficient and effective management of the province's transport infrastructure, ensuring its smooth operation and supporting sustainable development.

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