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THEMATIC ELECTRONIC MAPS FOR INTELLIGENT TRANSPORTATION SYSTEMS IN CITIES

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Abstract
This article highlights the role and importance of thematic electronic maps in the effective management of intelligent transportation systems in cities. It analyzes the possibilities of monitoring, managing, and modeling traffic flows through electronic maps created based on modern GIS (Geographic Information System) technologies. The paper also examines issues related to optimizing urban infrastructure, improving road traffic safety, and reducing environmental impacts with the help of electronic maps. In addition, the crucial role of information and communication technologies in the development of intelligent transportation systems is emphasized. The research results serve as a basis for developing recommendations aimed at modernizing urban transportation systems.

Keywords: Intelligent transportation systems, thematic electronic maps, urban infrastructure, transport logistics, digital mapping, traffic management, GIS technologies, urban planning, transport flow modeling.

Introduction

In modern cities, the rapid increase in the number of vehicles and the growing complexity of traffic flows have led to intensified problems such as traffic congestion, road accidents, and negative environmental impacts[1]. **Intelligent Transportation Systems (ITS)** play a crucial role in addressing these issues. ITS are integrated systems aimed at the efficient real-time management of transportation through the use of advanced electronic, information, communication, and sensor technologies. The components of ITS include **adaptive traffic lights, traffic monitoring cameras, safety sensors, and electronic toll collection points**. These elements make it possible to monitor and manage traffic, as well as collect data on traffic flows, thereby creating opportunities for more efficient and safe transportation management.

Due to the diversity and spatial distribution of data in the transportation network, **Geographic Information Systems (GIS)** play a key role in managing and analyzing this information. Through GIS, the locations and operations of ITS facilities in the city can be mapped and visualized in direct connection with real-time data streams. **Thematic electronic maps** are designed to display data related to a specific topic—such as congestion levels, safety risks, or the status of toll collection points—within a geographic context (Figure 1). These thematic maps make specific aspects of the transportation system more “visible,” allowing for an

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intuitive understanding of problem areas and effectively conveying this information to decision-makers.

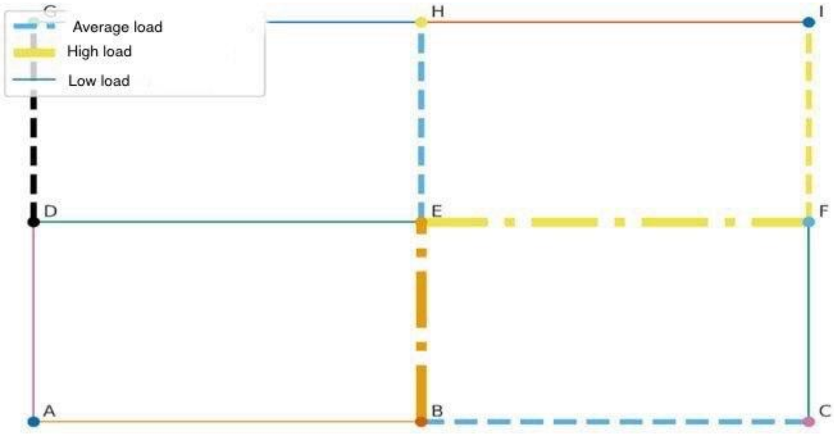

Figure 1. Schematic representation of congestion levels

In managing the spatial aspects of ITS components and integrating them, **GIS technology** serves as an indispensable tool. The field known as **GIS-T** (GIS for Transportation) focuses on collecting, storing, analyzing, and visualizing transportation-related spatial data, representing an adaptation of general GIS to the transportation sector[1]. Research indicates that GIS has become a powerful decision-making tool for assessing the condition of transportation infrastructure, modeling traffic flows, and planning transportation policies. Through GIS, **various data sources**—such as real-time data from sensors, GPS tracking, and historical congestion records—can be integrated to create **multi-layered maps** of the transportation network. These maps enable engineers and planners to instantly identify areas with high congestion or frequent accidents, providing valuable insights for efficient traffic management and infrastructure development.

The analysis of the literature shows that **presenting spatial information in the form of thematic maps is an innovative and effective approach** for the successful implementation of ITS. This approach is based on modern methods such as GIS technology, real-time data collection from IoT devices, rapid analysis of big data, and the use of artificial intelligence algorithms (Figure 2).

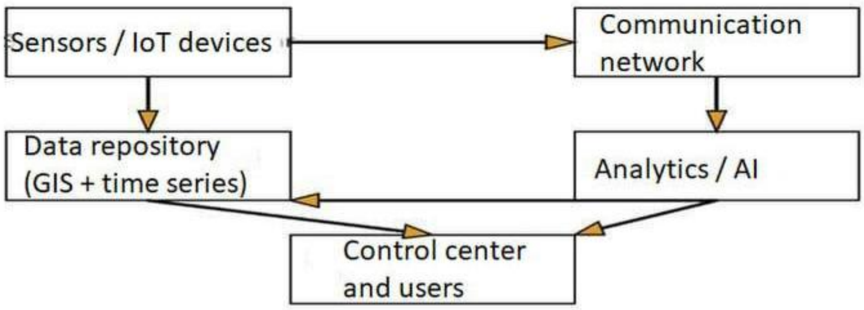

Figure 2. Components of Intelligent Transportation Systems

Methodology: Creating Thematic Maps for ITS Facilities

The development of thematic electronic maps related to ITS requires a multi-stage approach. Within the framework of this study, the following methodology is proposed:

1. Data Collection and Preparation (Analysis of the Transportation System):

First, the current state of the urban transportation system and the **needs of ITS** are analyzed. For this purpose, data is collected from various sources:

- **Infrastructure and facility data:** A geo-database is created containing information about the city's existing traffic lights (including adaptive traffic lights), the locations of traffic monitoring cameras, safety sensors, electronic toll collection points, and other ITS devices. A catalog is developed for each facility, including its coordinates, type, model, and operational parameters.
- **Traffic flows and performance indicators:** Data is collected on indicators such as congestion levels, average vehicle speed, delay times, passenger transport volume, and accident statistics. This information can be obtained from traditional stationary sensors (e.g., inductive loops installed under the road, traffic counters from surveillance cameras) as well as from **Floating Car Data (FCD)**—that is, GPS-equipped taxis and buses, or through drivers' mobile applications.
- **Analysis of problems and needs:** Based on the collected data, a map of the city's transportation issues is created. For example, intersections and road segments with high congestion are identified, a map of "black spots" with frequent accidents is developed, and public transport routes with significant delays are highlighted.

2. Designing the Structure of the Thematic Map: The next stage involves developing a strategy for visually presenting the collected data. At this step, a multi-layer electronic map is designed using **GIS tools**:

- **Basemap:** A clear and detailed representation of the city's road network, settlements, districts, and key landmarks is prepared. For this purpose, open cartographic data sources (such as OpenStreetMap) or digital map databases from the city's master plan are used.
- **ITS facilities layer:** All cataloged ITS facilities (traffic lights, cameras, sensors, toll collection points) from the previous stage are placed on the map as points or icons. Different colors and symbols are assigned based on the type of facility (e.g., traffic lights – green/circle icons, cameras – camera icons, etc.). This layer visually represents the spatial distribution of the ITS infrastructure across the city.
- **Thematic indicators layer:** Depending on the theme of the map, the most important indicators are displayed in spatial distribution. If the theme is traffic congestion, the average speed or **saturation level of road** segments (vehicles per hour) is visualized using color-coded lines (e.g., green – free flow, yellow – slowdown, red – congestion[2]). At **intersections**, indicators such as average waiting time or throughput can be shown to optimize traffic light settings, especially when the goal is to determine the need for installing adaptive traffic lights. In this way, by presenting selected indicators in their geographic context, the exact **locations of transportation problems** become clearly visible.
- **Additional layers:** If necessary, contextual data such as public transportation lines, population density, and the locations of key facilities can also be added to the map. These data

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serve as supporting factors in planning transportation solutions. For example, if congestion issues are observed only during working hours and near office areas, an appropriate solution might involve adjusting working hours or improving access to public transportation.

3. Data Integration and Real-Time Updates: One of the key challenges in creating thematic maps is **ensuring the continuous flow of real-time data**. In modern cities, dozens of different sensors and sources transmit data every second. This project envisions the development of a dedicated **unified platform** to integrate these data streams. The GIS map server must include a robust data integration system, which functions as follows:

- Data flow from various sensors: Information transmitted from different sensors (road detectors, cameras, IoT devices) is received by the central database **via API**. For example, data on vehicle speeds and travel times are connected to the GIS system through software interfaces, allowing this information to be displayed on the **thematic map in real time**[3].
- Filtering, merging, and aggregating raw data streams: Mechanisms are applied to **filter, merge, and aggregate** incoming raw data. For instance, if multiple sensors are installed on the same road segment, their readings are combined to produce an average value for that segment, while abnormal "noise" data—such as incorrect values sent by a malfunctioning sensor—are identified and removed.
- Linking and automatic updating of map layers: The cleaned and processed data in the database is linked to GIS map layers, ensuring **automatic updates of the map**. For example, if a new incident (such as a traffic accident) occurs or congestion suddenly increases in a specific area, the corresponding map element (icon or road color) is updated instantly. This updated information is then delivered to both the **ITS operations center** and end-users through mobile applications or web-based maps (Figure 3).

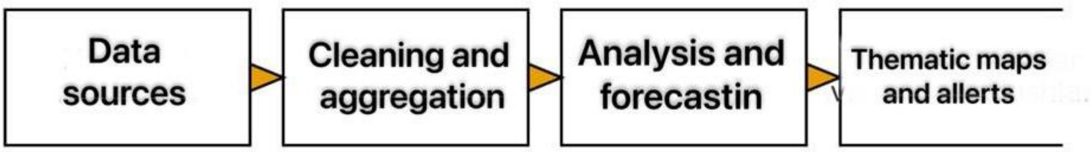

Figure 3. Real-time data flow

4. Automating Thematic Map Analysis: The map should not only passively display data but also serve as a tool for **analyzing and forecasting information**. In this regard, our methodology is based on integrating GIS analytical functions with artificial intelligence algorithms:

Results and Discussion: Practical Significance of ITS Maps

The thematic ITS maps developed based on the approach described above have a significant positive impact on the processes of transportation planning, management, and investment decision-making in cities. Below are examples of the **functional capabilities** and **value** of such maps, along with their **applications in advanced cities**.

Application in Planning and Management: Thematic ITS maps are a convenient tool for **comprehensively understanding** the urban transportation system. For example, with the help of an interactive map, city planners can monitor where congestion is currently intensifying and justify the need for constructing new roads or intersections in the future. Management authorities, on the other hand, can use the map to assess the situation in real time and implement **adaptive measures** accordingly.

Public Information and Community Services: Another important aspect of thematic ITS maps is **providing transportation-related information to the public**. This is considered an integral part of ITS, as drivers and passengers can adjust their routes based on real-time data. For example, in Singapore, mobile applications and web maps such as **MyTransport.SG** and **OneMotoring** provide drivers with information about current traffic speeds on highways, road closures, accidents, and even toll rates at collection points [4].

To gain a clearer understanding of the functional capabilities described above, we examine **advanced global experiences**. Below, the ITS maps and smart transport management practices are presented using the examples of Singapore, Amsterdam, Seoul, and London.

Singapore. Singapore is a global leader in implementing ITS solutions. The iTransport integration platform connects all ITS elements into a single "central brain," continuously receiving data from adaptive traffic lights, cameras, GPS information from vehicles, and more. This platform filters raw traffic data collected from underground sensors and transforms it into actionable information for analysis and planning [5]. As a result, Singapore maintains a **dynamic**, **real-time view** of the city's transportation situation, enabling highly efficient traffic management and planning.

Amsterdam. In recent years, the city of Amsterdam in the Netherlands has been recognized as one of the leading innovators in **sustainable and technological transport solutions**. Amsterdam has established the **MRA Smart Mobility** platform to improve data exchange on a regional scale – this platform brings together government, business, and scientific communities to make transport data open and useful [6]. As a result, a number of projects and startups have been implemented in Amsterdam, such as a **smart charging infrastructure** for electric vehicles, **autonomous boat taxis (Roboat)** on the city's busy canals, and local **smart parking hubs (Buurthub)** for public bicycles.

Seoul. Seoul, the capital of South Korea, is one of the major megacities that has widely implemented the "**smart city**" concept. Here, a city transportation management center called **TOPIS (Transport Operation and Information Service)** operates [7]. TOPIS is essentially the "**digital control tower**" of the entire city's transportation system, collecting and integrating real-time data on road traffic, bus intervals, and subway operations. This center unifies all sources, including footage from hundreds of CCTV cameras installed throughout the city, GPS sensors on buses and taxis, road sensors, and reports from citizens, continuously updating a **single status map** 24 hours a day.

London. The city of London has been implementing various innovative ITS measures for many years to efficiently manage its complex transportation system. **Transport for London (TfL)** is the organization responsible for managing London's transport network. TfL is working on a system that applies **AI algorithms** to numerous road sensors installed across the city, enabling automatic recognition of vehicles and drivers. Through this system, for example, it becomes possible to monitor in real time which districts have a high flow of trucks or where traffic violations by drivers are more frequent.

The above analyses confirm that the approach of creating thematic electronic maps based on ITS objects in cities is proving to be effective. With the help of such maps:

- The actual state of the urban transportation system is displayed in a clear **visual form**, making problem diagnostics easier.
- **Evidence-based** foundations are established for planning and investment decisions – decisions are made not only based on intuition or political interests, but also by relying on the data visible on the maps.
- The operational efficiency of transport management increases: real-time maps make it possible to quickly detect incidents and respond promptly (in particular, immediately dispatching services to accidents, taking measures to eliminate congestion, etc.).
- An open data environment is created for citizens and businesses – which helps build trust in ITS and increases the efficiency of transportation use.

Strategies and Recommendations for Developing ITS Based on Electronic Maps.

Based on the above research and analysis of advanced global experiences, we propose the following strategic recommendations for implementing and developing ITS in cities through thematic electronic maps:

1. stablishing a unified integration data platform: The foundation of ITS success lies in the integration of all transport-related data. Therefore, the first step is to create a unified **GIS database** and a **real-time data platform** at the city level. This platform should enable data sharing between the transport authority, traffic police, public transport operators, weather services, and even navigation companies.

2. Defining priority areas based on thematic maps: In developing the city's transport system, resources and time are limited. Therefore, it is crucial to **determine which areas or directions should be prioritized**. For example, a "congestion index" map helps identify the most congested areas, a "safety map" reveals locations with frequent accidents, and a "public transport service quality map" highlights bus routes with long waiting times. Subsequently, project proposals for specific ITS solutions are developed for these identified areas and routes.

3. Utilizing digital modeling and "digital twins": To assess the impact of large-scale projects on transportation in advance, using **digital models** of the city is highly beneficial. Currently, such digital modeling methods are well-developed — by integrating GIS data with software like **PTV Visum, SUMO, and MATSim**, it is possible to create simulations that closely reflect real-world situations. Strategically, every major city should have a **digital transport laboratory** where decisions are virtually tested, and the most optimal solutions are selected before implementation in real life. This approach helps save resources and improve outcomes.

4. Open data and collaboration with the private sector: The development of intelligent transport systems should not remain solely the responsibility of government agencies. If thematic maps and data are made as open as possible to the public and the private sector, an ecosystem of innovative solutions will emerge.

5. Human resources capacity and institutional cooperation: Implementing ITS based on electronic maps requires highly qualified specialists – a team consisting of GIS engineers, developers, transport engineers, and analysts must work together. Therefore, city transport administrations should invest in training and capacity building for such personnel.

6. Financial and legal strategies: Developing ITS and their maps requires significant funding, but it brings long-term economic benefits. According to a study by Juniper Research, smart transport management could generate $277 billion in savings for cities by 2025. Therefore, cities should view these expenses as **investments** rather than costs. As a financing strategy, it is advisable to use the public-private partnership (PPP) model, which allows combining public resources with private sector expertise and funding.

Conclusion

This scientific research has comprehensively examined the role and importance of **thematic electronic maps** in the implementation and development of Intelligent Transport Systems (ITS) in cities. The research findings draw the following conclusions:

- **A methodology for mapping ITS objects has been developed.** It integrates the exact locations and parameters of objects such as adaptive traffic lights, traffic surveillance cameras, safety sensors, and electronic toll collection points into a GIS map. By combining this layer of objects with transport flows and indicators, the state of the city's transport system is visually represented. The map ensures continuous updates of information on each object and each road segment.
- **The study confirmed the importance of selecting the map theme based on an analysis** of the transport system's condition and ITS needs. Each city has its own specific issues — congestion in some areas, safety in others, or pressing environmental problems. Before creating the map, an analysis should be conducted to determine which theme should take priority.
- **The functional capabilities of ITS maps** have been shown to be extensive in supporting planning, management, and investment processes. Interactive maps allow the identification of trends within the transport system, spatial analysis of problems, evaluation of "if-then" scenarios, and prioritization of investment projects. GIS-based visualizations serve to present complex information to decision-makers in a simple and understandable format.
- **Automating map analysis based on GIS, IoT, real-time data streams, and artificial intelligence** elevates transport management to a new level. The study examined technical solutions for integrating real-time data into GIS maps: acquiring sensor data via APIs, cleaning the data stream and detecting anomalies using artificial intelligence, and continuously updating the map.

The analysis of advanced global experiences examined how ITS maps provide practical benefits in cities such as Singapore, Amsterdam, Seoul, and London. In Singapore, the real-time traffic map and integrated management platform help maintain congestion at one of the lowest levels in the world. In Amsterdam, various smart transport projects are coordinated through a single data platform, contributing to the city's sustainable mobility goals. In Seoul, 3D digital maps and real-time monitoring systems work together to organize public transport services efficiently and enable rapid response to incidents. London has implemented smart

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sensors and AI to monitor transport flows and support strategic planning even in a large urban environment.

Based on the above conclusions, the synergy of ITS and GIS technologies offers cities unparalleled opportunities to optimize transport infrastructure, enhance convenience for citizens, and achieve economic efficiency. Thematic electronic maps serve as the "visible face" of these technological solutions, allowing complex processes to be explained and managed in a simple and intuitive way.

In conclusion, it should be emphasized that the successful implementation of intelligent transport systems in cities depends not only on technical solutions but also on their proper management and planning. Thematic electronic maps are an integral part of this management and planning, enabling cities to approach transport problems as **visible, understandable, and solvable issues**. Ultimately, this contributes to safer streets, smoother traffic flow, a healthier environment, and an overall improvement in urban quality of life.

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