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Managing Urban Traffic and Road Network using GIS Facilities

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Abstract:
Modern GIS technologies use digital information, for which various digitized data creation methods are used. The most common method of data creation is digitization, where a hard copy map or survey plan is transferred into a digital medium through the use of a computer-aided design (CAD) program, and geo-referencing capabilities. With the wide availability of ortho-rectified imagery (both from satellite and aerial sources), heads-up digitizing is becoming the main avenue through which geographic data is extracted. Heads-up digitizing involves the tracing of geographic data directly on top of the aerial imagery instead of by the traditional method of tracing the geographic form on a separate digitizing tablet (heads-down digitizing). The use has been accelerated through the component technology, which simplifies the insertion of GIS components into a variety of applications-including administration. We describe the need of creating and upgrading of the information system for Romanian road administration: basic application user interfaces were enriched with a specialized GIS component, which enables a fast and clear (geo) graphical view of the data about the selected part of the road network. The simplicity of using this intelligent digital map (as we named this specialized component) makes it possible to effectively and clearly display the relevant information, which is so necessary in the process of decision making.

Keywords: Road administration, Geographic Information Systems (GIS), Road information, Digital map.

1. INTRODUCTION

Road controlling authorities put great effort and expense into collecting large quantities of data related to road asset management, including road safety related data. Data is the cornerstone of all road safety activity and is essential for the diagnosis of the road crash problem and for monitoring road safety efforts. Without ongoing, data-led diagnosis and management of the leading road injury problems, it is difficult to achieve significant and sustainable reductions of crash risk or the severity of crashes.

Traffic and road models demand large amounts of data – some of which are: traffic network topology, traffic network data, zone-data and trip matrices, etc. GIS is a natural tool for handling most of these data as it can ease the work process and improve the quality control. If we are asking what is a GIS maybe the answer can be this: A Geographic Information System, or GIS, is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyse, and display all forms of geographically referenced information. Or, in simple terms: a computer system capable of holding and using data describing places on the earth's surface.

The system will allow users to generate routes for multi modal transport networks, cycling and walking. It will be accessible from a wide range of devices ranging from web to mobile solutions. In order to generate routes that better reflect the users' preferences a flexible restriction mechanism allowing multiple options will be described. Upon generating each route, cost information will be displayed, as well as fuel savings as opposed to using a personal car, allowing users to calculate statistics for daily, weekly, monthly or yearly savings. The major advantage of a GIS is that it allows you to identify the spatial relationship between map features. A GIS does not store a map in any conventional sense; nor does it store a particular image or view of a geographic area. Instead, a GIS stores the data from which you can draw a desired view to suit a particular purpose. The heart of any GIS is the database through which questions such as what a feature is, where it is, and how it relates to other features can be answered. The Digital map library can be designed to allow any user on the GIS network to view county wide geographic data from a common source. The map library also provides an efficient and secure means of maintaining the database. Concluding, geographic information system (GIS) is an information system specializing in the input, management, analysis and reporting of geographical (spatially related) information. Among the wide range of potential applications GIS can be used for, transportation issues have received a lot of attention (Figure 1).

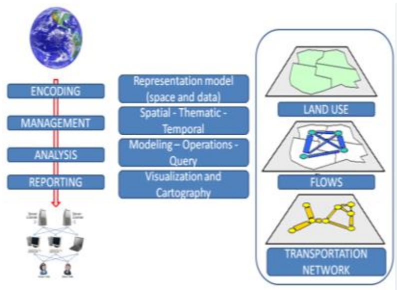

Figure 1. The four major components and layers (GIS)

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2. COMPONENTS OF TRANSPORT GIS

The four major components of a GIS according Figure 1 are encoding, management, analysis and reporting, have specific considerations for transportation:

Encoding. Deals with issues concerning the representation of a transport system and its spatial components. To be of use in a GIS, a transport network must be correctly encoded, implying a functional topology composed of nodes and links. Other elements relevant to transportation, namely qualitative and quantitative data, must also be encoded and associated with their respective spatial elements. For instance, an encoded road segment can have data related to its width, number of lanes, direction, peak hour traffic etc.

Management. The encoded information often is stored in a database and can be organized along spatial (by region, country, census units etc.), thematic (for highway, transit, railway, terminals etc.) or temporal (by year, month, week etc.) considerations. It is important to design a GIS database that organizes a large amount of heterogeneous data in an integrated and seamless environment such that the data can be easily accessed to support various transportation application needs.

Analysis. Considers the wide array of tools and methodologies available for transport issues. They can range from a simple query over an element of a transport system (what is the peak hour traffic of a road segment?) to a complex model investigating the relationships between its elements (if a new road segment was added, what would be the impact on traffic and future land use developments?).

Reporting. A GIS would not be complete without all its visualization and data reporting capabilities for both spatial and non-spatial data. This component is particularly important as it offers interactive tools to convey complex information in a map format. A GIS-UT (GIS for Transportation) thus becomes a useful tool to inform people who otherwise may not be able to visualize the hidden patterns and relationships embedded in the datasets (potential relationships among traffic accidents, highway geometry, pavement condition, and terrain).

The great appeal of GIS stems from their ability to integrate great quantities of information about the environment and to provide a powerful repertoire of analytical tools to explore this data. The example displayed in this paper contains only a few map layers pertaining to urban transportation planning. The layers included would be very different if the application involved modeling the habitat of an endangered species or the environmental consequences of leakage from a hazardous materials site.

Imagine the potential of a system in which dozens or hundreds of maps layers are arrayed to display information about transportation networks, hydrography, population characteristics, economic activity, political jurisdictions, and other characteristics of the natural and social environments. Such a system would be valuable in a wide range of situations – for urban planning, environmental resource management, hazards management, emergency planning, or transportation forecasting, and so on. The ability to separate information in layers, and then combine it with other layers of information is the reason why GIS hold such great potential as research and decision-making tools.

Reliable and detailed data help road safety practitioners accurately identify problems, risk factors and priority areas, and to formulate strategy, set targets and monitor performance as shown in Figure 2.

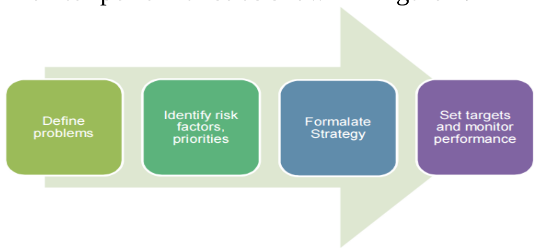


Figure 2. Data Flow in Road Safety Management

3. GIS-UT DATA REPRESENTATIONS

The road safety database is a spatial referenced database with all data modeled as spatial objects (point and line) and encoded in geospatial format, which stores all safety related data in a centralized location, provides functionalities to perform spatial query and spatial analysis and integration with other spatial database. It all provides tools to convert locations between linear referencing system and spatial referencing system. Figure 3 shows a screenshot of the safety database.

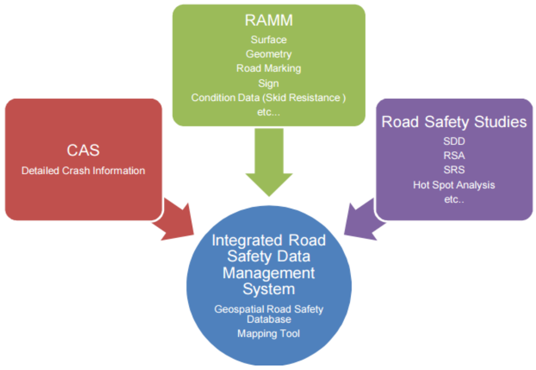


Figure 3. Structure of Integrated Road Safety Data Management System

In recent years, developments of enterprise and multidimensional GIS-UT data models also received increasing attention. Successful GIS deployments at the enterprise level (e.g. within a state department of transportation) demand additional considerations to embrace the diversity of application and data requirements. An enterprise GIS-UT data model is designed to allow "each application group to meet the established needs while enabling the enterprise to integrate and share data". The needs of integrating 1-D, 2-D, 3-D or webGIS, and temporal data in support of various transportation applications also have called for the implementation of multidimensional (including spatio-temporal) data representations.

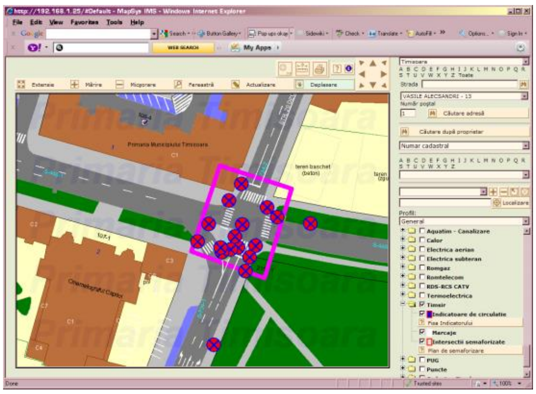
In short, one critical component of GIS-UT is how transportation-related data in a GIS environment can be best represented in order to facilitate and integrate the needs of various transportation applications. Existing GIS data models provide a good foundation of supporting many GIS-UT applications. However, due to some unique characteristics of transportation data and application needs, many challenges still exist to develop better GIS data models that will improve rather than limit what we can do with different types of transportation studies.

4. GIS-T ANALYSIS AND MODELING

GIS-T applications have benefited from many of the standard GIS functions (query, geocoding, buffer, overlay etc.) to support data management, analysis, and visualization needs. Like many other fields, transportation has developed its own unique analysis methods and models. Examples include shortest path and routing algorithms (e.g. traveling salesman problems, vehicle routing problem), spatial interaction models (e.g. gravity model), network flow problems (e.g. minimum cost flow problem, maximum flow problem, network flow equilibrium models), facility location problems (e.g. p-median problem, set covering problem, maximal covering problem, p-centers problem), travel demand models (e.g. the four-step trip generation, trip distribution, modal split, and traffic assignment models), and land use-transportation interaction models. It is essential for both GIS-T practitioners and researchers to have a thorough understanding of transportation analysis methods and models. For GIS-T practitioners, such knowledge can help them evaluate different GIS software products and choose the one that best meets their needs. It also can help them select appropriate analysis functions available in a GIS package and properly interpret the analysis results. GIS-T researchers, on the other hand, can apply their knowledge to help improve the design and analysis capabilities of GIS-T.

One example of a functionally GIS data base is Timisoara City GIS (Figure 4).

A major objective of the Street Transportation Department of Timisoara city hall department is to provide a means for the integration of disparate right-of-way and street data. Using a variety of ESRI software products and these interfaces, the right-of-way objects and events are located relative to a position along the street network.



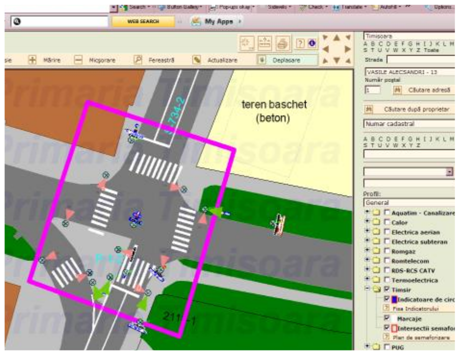


Figure 4. Interrogate model of Timisoara GIS-UT

Using this integration framework, applications can be developed to track department infrastructure and operations, as well as facilitate improved workflows and decision-making activities (Figure 5).

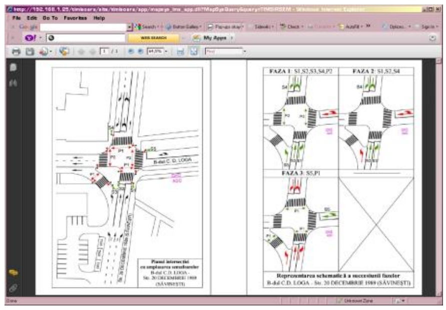


Figure 5. Design of traffic light junctions

The Street Transportation Department's and its integration with ArcIMS software makes spatial information accessible and useful to users across all companies and business areas of the department. This department-wide GIS is a collaboration of project, divisional, enterprise, and public access GIS implementations and is organized into five application areas including bridge management, street management, traffic signal management, storm drain management, and street lighting management. These application areas provide a general business context for accessing spatial data using the ESRI GIS functions (Figure 6).

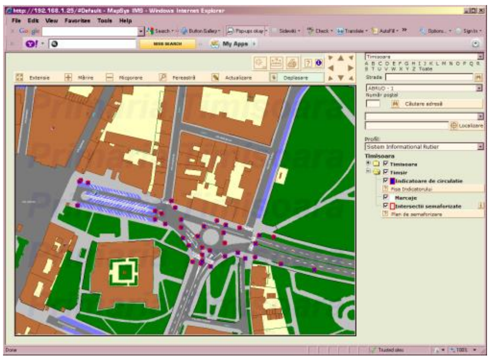


Figure 6. The model of road information system

5. CONCLUSIONS

The paper presents a method based on Geographical Information System (GIS) maps in making an efficient location service and routing protocols for in-road information networks. The main goal of this network is to transfer traffic data and improve the safety of the road transportation.

The aforementioned requirements are connected to the need for keeping the road cadastre up to date and effective. As in all census and cadastral operations, it is mandatory to have data structures and management software designed for easy updating, both by specialized engineers working directly on data structure with no need for a particular interface, and by public agencies employees, which do have analytic and management skills, but lack those needed for the management of the digital data base.

Implementing a collaborative system like the one described above offers advantages at multiple levels.

For individuals it offers a faster and cheaper transit solution without the hassles connected to complicated maps and diagrams. For public managers, the system will offer a reduction in car traffic as well as a reduction in the costs associated with road maintenance, allowing easier implementation and more flexibility in terms of varying public policies in the field of transport. Environmental advantages include reducing air pollution as well as limiting global warming emissions combined with reductions in the consumption of fossil fuels. On the theoretical level, it breaks the ice in utilizing GIS collaborative solutions for providing further than last-mile services to users.

GIS-UT is interdisciplinary in nature and has many possible applications. Transportation geographers, who have appropriate backgrounds in both geography and transportation, are well positioned to pursue GIS-UT studies.

It is clear that GIS can be used for a wide range of applications in the transportation sector. Merging GIS with telematics seems to open up a whole new array of possible real-time applications in the transportation sector.

What all these applications have in common is that GIS plays a major part, providing the spatial reference, but can the system still be called a GIS application? It may be argued that this system is no longer GIS, but a technology that dissolves GIS into something new. This is probably the largest potential for the future of GIS in transportation: GIS will no longer be a stand-alone product, but fully integrated with other business information systems.

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