



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 7, July 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

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Review of Geographical Information System in Transportation Planning

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ABSTRACT: India has a vast road network spanning over 3.01 million kilometers, comprising 34608 km of National Highways, 128622 km of State Highways, and an unofficial network of 2737080 km. These roads operate in a wide range of social, economic, and climatic conditions. National and local levels have been the main venues for the planning and administration of the nation's massive network. While local level planning is problem-specific and limited to the area around a few major cities, national level planning in the nation is broad based and uses some macro level data like area, gross domestic product, etc. Adopting the country's travel demand requirements-based road network planning would not be sufficient.

The absence of a substantial amount of data necessary for this purpose can be blamed for the major planning in several areas of the road network. The next issue is how to manage and access the data, even if it is made available. Important information about the current transportation infrastructure is dispersed across the nation at various organizations. Planners rarely make effective use of the attribute data of the NH, SH, and MDR networks, which is available in fragments across various state level system organizations. Currently, no data from the current network can be used for any exercise assessing the network's sufficiency in a regional context or for creating national plans for major networks like expressways. Consequently, practically speaking, the current

I. INTRODUCTION

India has a vast road network spanning over 3.01 million kilometers, comprising 34608 km of National Highways, 128622 km of State Highways, and an unofficial network of 2737080 km. These roads operate in a wide range of social, economic, and climatic conditions. National and local levels have been the main venues for the planning and administration of the nation's massive network. While local level planning is problem-specific and limited to the area around a few major cities, national level planning in the nation is broad based and uses some macro level data like area, gross domestic product, etc. Adopting the country's travel demand requirements-based road network planning would not be sufficient.

Highway networks are experiencing deterioration as a result of inadequate funding for infrastructure. Utilizing recently developed technologies, like Geographic Information Systems (GIS), can enhance this sector's decision-making process and make better use of the scarce financial resources available. In transportation planning agencies, Geographic Information Systems (GIS) are becoming increasingly popular, particularly in metropolitan transportation organizations. The management of highway maintenance is becoming a crucial issue in many developed nations. The increased overfriendliness of GIS and declining costs have made it possible for many more authorities to use it for transportation management and highways. Transport planners can store and analyze data on land uses, travel patterns, population densities, etc. using GIS. The primary goals of utilizing GIS are display and mapping.

GIS is widely used in transportation-related applications. Route planning, traffic modeling, accident analysis, highway maintenance, and environmental evaluation of road schemes are examples of common applications. The majority of transportation GISs require a structured road network as a basic prerequisite. To fully assess the effects of construction, more data on general topography, land cover, and land use are necessary. One ongoing issue is the lack of relevant data

for GIS. Geographic Information Systems (GIS) use longitudes, latitudes, and other projection systems made up of a hierarchical structure of graphical objects to describe the world. A typical GIS shows a map of the entire world. Creating and managing a database, choosing and updating hardware and software, and utilizing the technology are the main needs and concerns related to GIS management technology.

The paper thus reviews the suitability of Geographical Management System (GIS) technology for managing the transport infrastructure in the country.

II. OBJECTIVES

Transport planners can store and analyze data on land uses, travel patterns, population densities, etc. using GIS. The integration of data and map/display are the two main goals of using GIS. GIS is widely used in transportation-related applications. The use of location as the foundation for information system structure is a key component of the Geographic Information System (GIS), which represents a new paradigm for information organization and system design. Because transportation-related data is primarily spatially distributed and requires a variety of network level analysis, statistical analysis, and spatial analysis and manipulation techniques, the application of GIS is relevant to the transportation industry. The majority of the effects of transportation are spatial.

III. GIS IN TRANSPORTATION

The primary benefit of utilizing GIS is its capacity to retrieve and examine geographically dispersed data in relation to its true spatial location superimposed on a base map of the coverage area, a capability not offered by other database management systems. The primary advantages of utilizing a GIS extend beyond its intuitive visual access and display. These advantages also include the capacity for spatial analysis and the application of standard GIS functionalities, which include thematic mapping, charting, network-level analysis, simultaneous access to multiple data layers and their overlay, and the ability to interface with external software and programs for data management, decision support, and user-specific functions (Vonderohe, 1993).

The user's ability to access, modify, and query the current database is restricted to very few options. The only query language available to the user is text; crossing attribute data cannot be selected or viewed in relation to topological or spatial relationships. The current database does not allow access to over-related data, including population, land use, and the characteristics of the local road network near the crossings. This GIS capability, in conjunction with the ultimate display of findings on a digital base map, will provide the user a clearer picture of the issue at hand, better decision-making capabilities, and a more comprehensive comprehension of the desired outcomes. Constructing conditional queries is possible.

Moreover, the majority of GIS programs' availability of numerous fundamental transportation models and algorithms might be helpful in some circumstances. Flexibility is further enhanced by the ability to interface with third-party software and procedures, which can access data stored in the GIS and display analysis results for viewing and then for the analysis. Geographic information systems (GIS) could be applied to the management of highway infrastructure in a manner akin to how they are currently used to land-based data. GIS processes offer a well-coordinated approach to consolidating a wide range of information sources under one visually appealing roof so that a broad range of users can access them. Technical and administrative specialists can benefit from the application of GIS tools.

Generally speaking, transportation planning consists of several distinct modules that are frequently used independently of one another. Roadside safety appurtenances, accident data, and traffic systems management (traffic operations management for traffic corridor analysis, highway construction-oriented rerouting, hazardous materials routing, incident management, and safety elements management) are some of the modules included in this category.

Thus, major applications for GIS in transportation planning includes

- The system of executive information.
- A system for managing pavement.
- Management of bridges.
- Management of maintenance.
- Management of safety.

- Forecasting travel demand; • Transportation system management (TSM)
- Protection of corridors and rights-of-way
- Management of construction
- Overweight/oversize vehicle routing; • Dangerous cargo routing.
- Value-capture analysis; land-side economic impact; environmental impact; accident analysis; and others

The combination of GIS and transportation information system (TIS) is known as GIS for transportation (GIS-T). The ability of GIS-T to integrate data is by far its greatest benefit to different transportation companies. The information referred to the transportation network and numerous other historical stand-alone databases, such as bridge inventories, traffic volume, other operational data, accident records, and signage locations. It is also possible to integrate data from other sources, including administrative, land use, demographic, environmental, resource, terrain, and subsurface data. Editing, displaying, measuring, overlaying, dynamic segmentation, surface modeling, raster display, analysis, routing, and connecting to other software are the primary features of GIS that are helpful in resolving transportation-related issues.

Pavement management, traffic engineering, planning and research, bridge maintenance, and field office support are among the fields where GIS applications are anticipated to be used. Additional planning applications include planning for evacuations in the event of hazardous material releases, creating new traffic analysis zones based on census tracts, and creating new urban highway networks.

When it comes to the analysis and design of transport routing networks, GIS is an invaluable tool. Because of its graphical display capabilities, one can see not only the various routes but also the order in which they are constructed, facilitating comprehension of the reasoning behind the routing network design.

The GIS technology is perfect for hazardous material, routing design, risk analysis, and decision making because of the way the transportation system interacts with its surroundings. Sophisticated mathematical models and search techniques can be combined with GIS to examine various management choices and policies.

IV. GIS IN HIGHWAY MANAGEMENT

GIS is a useful tool for managing highway maintenance, which is a crucial issue. Because of the advantages of decreased costs and increased ease of use, authorities in many developed countries are now actively using GIS for highways and transport management.

The visualization of data through maps is the primary goal of GIS use. Transport planners can quickly spot possible problems that can be resolved more cheaply and effectively than with the current approaches by using real-time data visualization. This information can be easily communicated to the public and decision makers through detailed GIS maps. For example, transportation maintenance and inspection teams can save time when gathering and updating data from remote locations thanks to Esri's mobile GIS technology. Field crews gather information from the field with precision using GPS and GIS-enabled devices, which they then use to update corporate databases in the office in real time. Officials can respond quickly to any situation that needs immediate attention by tracking resources and assets in real time using GPS and Esri technology. By instantly locating any work or inspection crew on a map, they can also more efficiently manage mobile resources and redistribute them as needed. Optimizing the scheduling and routing of maintenance and inspection teams can yield significant increases in productivity, which in turn leads to significant improvement.



Figure 1 GIS in road and highway

V. GIS GROUPED IN THREE CATEGORIES

5.1 GIS-T DATA REPRESENTATION

One of the main areas of GIS research is data representation. In a digital computing environment, data must be accurately represented before a GIS can be used to address real-world issues. The ability of GIS to integrate spatial and non-spatial data to support display and analysis needs is one of its unique features. For GIS, numerous data models have been created. Object-based data models and field-based data models are the two fundamental strategies:

Geographic space is viewed as being populated by distinct and identifiable objects in an object-based data model. Features are frequently shown as polygons, lines, or points.

In contrast, a field-based data model views geographic space as populated by continuously changing real-world features across space. Regular tessellations, like a raster grid, or irregular tessellations, like a triangulated irregular network (TIN), can be used to represent features.

Both object-based and field-based data models have been used in GIS-T studies to represent the pertinent geographic data. Certain GIS data model types are more appropriate for solving certain transportation-related issues than others. For instance, a network is usually represented as a collection of nodes connected by a set of links in network analysis based on graph theory. Therefore, the object-based GIS data model is a more suitable option for these kinds of transportation applications. There are other kinds of transportation data that call for adding to the standard GIS data models. Highway mileposts are one well-known example of linearly referenced data. The locations of features or events along transportation network links are frequently measured by transportation agencies (e.g., a traffic accident occurred at the 52.3 milepost on a specific highway).

Data of the origin-destination (O-D) flow kind are also commonly employed in transportation research. For analysis, such data have typically been represented as matrix forms, which are two-dimensional arrays. Unfortunately, most commercial GIS software does not offer sufficient support for handling matrix data due to the widespread adoption of the relational data model. Additional file formats and features have been developed by certain GIS-T software to enable users to work with matrix data in a GIS environment. Thus, traditional GIS techniques can be improved and expanded upon to better suit the requirements of transportation-related applications. The development and proliferation of GIS software add-ons is one way that particular techniques and models can be incorporated into pre-existing packages.

Enterprise and multidimensional GIS-T data model developments have also drawn a lot of interest. Enterprise-level GIS deployments that are successful (such as those in state departments of transportation) must take into account a variety of application and data requirements. "Each application group to meet the established needs while enabling the

enterprise to integrate and share data" is the goal of an enterprise GIS-T data model. Multidimensional (including spatio-temporal) data representations have also been required to support the integration of 1-D, 2-D, 3-D, and temporal data for a variety of transportation applications.

The Internet and mobile phones are two examples of modern information and communication technologies (ICT) that have revolutionized how individuals and businesses operate. Changes in spatiotemporal traffic patterns are a result of these shifting patterns of interaction and activity. Modern ICT has made the world more dynamic and mobile. Large-scale tracking data collection at the individual level is now both possible and reasonably priced thanks to the development of location-aware technologies (such as the Global Positioning System, cellular phone tracking system, and Wi-Fi positioning system). Thus, new research challenges for GIS-T arise from the question of how to represent and manage dynamic data of moving objects (people, vehicles, or shipments) in a GIS environment, particularly when dealing with Big Data issues. To put it succinctly, a key element of GIS-T is figuring out how to best represent transportation-related data in a GIS environment so as to facilitate and integrate the requirements of diverse transportation applications. Many GIS-T applications can be supported by the existing GIS data models. Nevertheless, there are still many obstacles in the way of creating more accurate GIS data models that will enhance rather than restrict the range of transportation research that can be conducted, given the particularities of transportation data and application requirements.

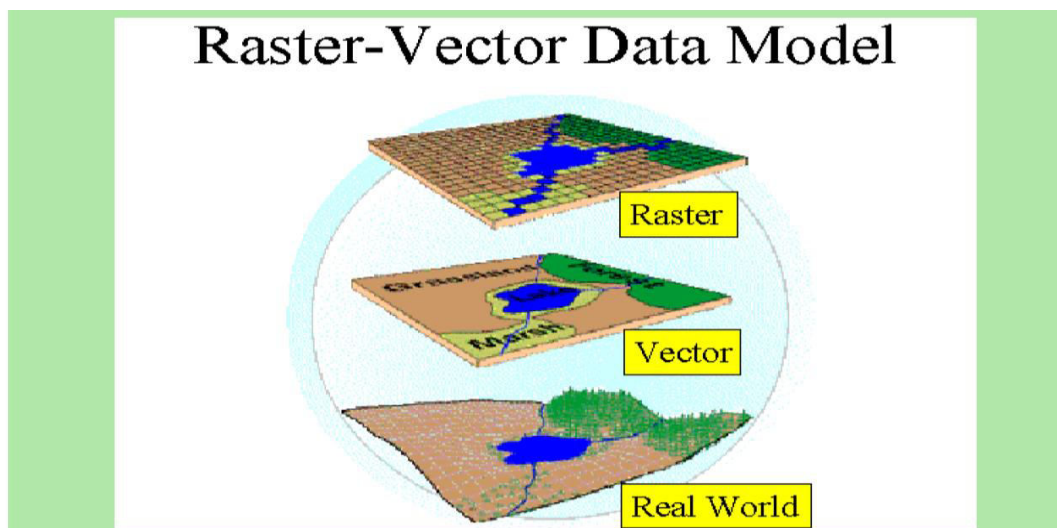


Figure 2

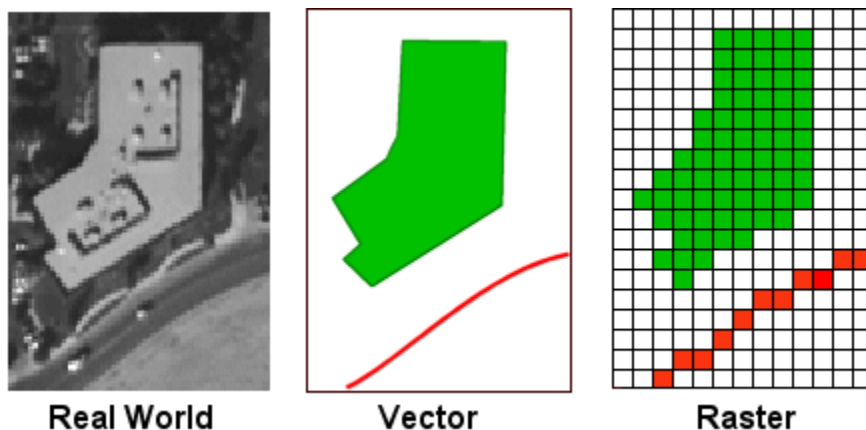


Figure 3

5.2 GIS-T ANALYSIS AND MODELING

Many of the common GIS functions (query, geocoding, buffer, overlay, etc.) have been useful for GIS-T applications to support data management, analysis, and visualization requirements. The transportation industry has created its own distinct models and analysis techniques, just like many other fields. Travel demand models (e.g. the four-step trip generation, trip distribution, modal split, traffic assignment models, and more recent activity-based travel demand models), 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-centres problem), and shortest path and routing algorithms are some examples.

Some transportation analysis models and procedures (like travel demand models) are only available in certain commercial software packages, but the majority of commercial GIS software includes the basic transportation analysis procedures (like shortest path finding). Fortunately, experienced GIS-T users have a better environment in which to create their own unique analysis procedures and models thanks to the component GIS design approach used by GIS software companies. A solid understanding of transportation analysis techniques and models is crucial for GIS-T practitioners as well as researchers. Such information can assist GIS-T practitioners in comparing various GIS software packages and selecting the one that best suits their requirements. Additionally, it can assist them in choosing the right analysis functions from a GIS package and in correctly interpreting the analysis's findings. Conversely, GIS-T researchers can use their expertise to enhance GIS-T's capacity for analysis and design. In recent times, there has been a notable focus on research on developing spatio-temporal GIS analysis functions to gain a deeper understanding of dynamic movement patterns, owing to the growing availability of tracking data that incorporates both spatial and temporal elements.

5.3 GIS-T APPLICATION

One of the most popular GIS application domains is GIS-T. Numerous transportation agencies and private businesses have deployed numerous GIS-T applications. Transportation safety analysis, travel demand analysis, traffic monitoring and control, public transportation planning and operations, environmental impacts assessment, intelligent transportation systems (ITS), routing and scheduling, vehicle tracking and dispatching, fleet management, site selection and service area analysis, and supply chain management are just a few of the many topics they cover in the broad field of transportation and logistics. These applications typically have different needs when it comes to data and analysis. For transportation planning and vehicle routing applications, for instance, it might be sufficient to represent a street network as centerlines. These various application requirements have a direct bearing on the problems with GIS-T analysis and modeling as well as data representation. What kind of GIS-T design would be suitable to support the modeling and analysis requirements of different applications when it becomes necessary to represent the transportation networks of a study area at different scales? A GIS-T data model that permits different geometric representations of the same transportation network is ideal in this situation. The goal of research on multidimensional and enterprise GIS-T data models is to address these crucial problems of improved data representations to support a range of transportation applications.

A growing number of Internet-based and wireless GIS-T applications are available due to the Internet's and wireless communications' rapid growth. The most popular commercial use of GIS-T is for driving directions. Global positioning system (GPS) navigation systems are primarily found as integrated applications in smartphones, but they are also available as portable devices and built-in devices in cars. When combined with wireless connectivity, these gadgets can deliver useful location-based services (LBS) and real-time traffic information. The increasing use of GIS-T in the private sector, especially for logistics applications, is another trend that has been noted in recent years. GIS-T can be a helpful tool for a range of logistics tasks since many businesses involve operations at geographically dispersed locations (e.g., supplier sites, distribution centers, retail stores, and customer location).

GIS-T is multidisciplinary by nature and has a wide range of potential uses. With their suitable backgrounds in both geography and transportation, transportation geographers are in a good position to conduct GIS-T studies and support GIS-T implementations that tackle practical issues.

VI. GIS IN ACCIDENT ANALYSIS

One of the more significant national and worldwide issues is traffic accidents, and the political, economic, and social aspects of a nation are all impacted by them. Information systems with analytical and accessibility capabilities to spatial and descriptive data are necessary for the management of traffic accident information. With the help of GIS's potent spatial analytics, authorities can analyze accidents and identify trends that provide them with more insight into traveler behavior. GIS greatly facilitates accident analysis and lowers the overall number of accidents on the roads. GIS enables more meticulous and precise data reduction, screening, and selection. Additionally, it permits a geographical examination of the pre- and post-processing outcomes. It makes it possible to create geographically-referenced spatial statistics. For example, a transportation company can identify major safety issues and pinpoint areas where action can be taken to lower the number of incidents by analyzing accident history. The user of GIS may also select two months' worth of accidents to compare. When illustrating a decline in accidents over time, the statistics can be helpful.

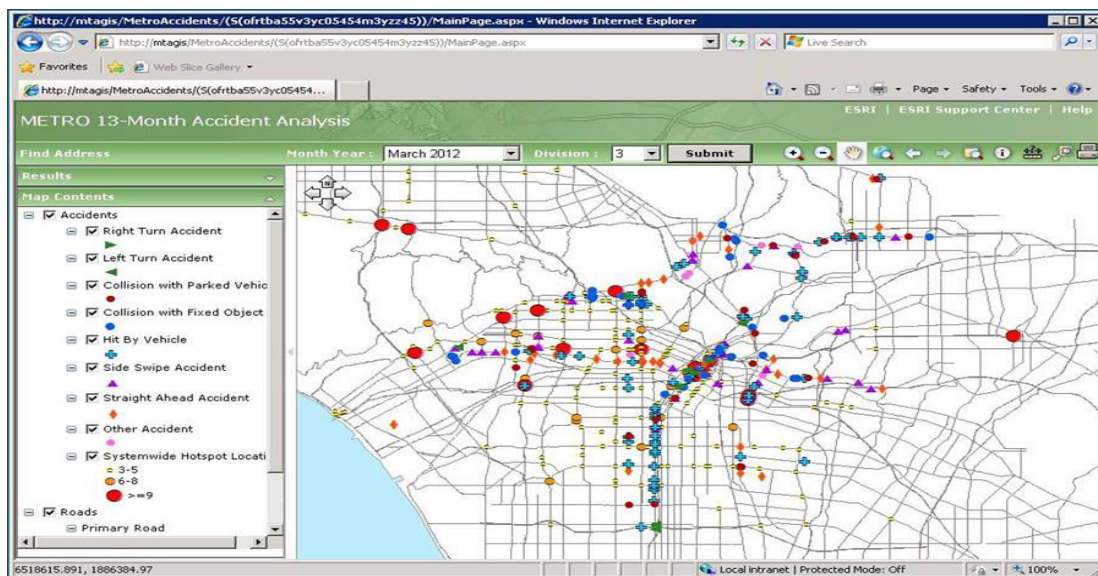


Figure 4

VII. PAVMENT MANTANANCE

The three main parts of the Pavement Management System (PMS) are data collection, analysis, and updating. Among the elements covered by data collection are:

Inventory: Specific pavement characteristics such as the quantity of lanes, dimensions, surface type, functional classification, and shoulder details.

History: Project information, including the kind of building, rebuilding, repairing, and maintaining Condition assessment: rutting, distress, friction on the pavement surface, and roughness of ride Traffic: amount, kind, and load information; and The elements being examined are as follows: Condition Analysis: surface friction, rutting, ride, and distress Pavement performance analysis and an approximation of the remaining service life. An estimation of network and project level investment strategies is called investment analysis. These comprise analysis over one and multiple years, and life cycle cost assessment should be taken into account.

Engineering analysis includes assessment of material, mix, design, construction, rehabilitation, and maintenance. Using GIS to manage this program makes sense because it allows for location-based maintenance of analysis of pavement section descriptions and pavement deficiencies gathered from pavement condition surveys. Funds for upkeep and resurfacing may also be distributed based on the number of lanes in a region and the corresponding ratings of

pavement condition. Thus, PMS based on GIS will provide a more visual tool for making such policy decisions and a more equitable distribution of funds.

VIII. CONCLUSION

The uniform environment provided by GIS allows data to be integrated for various planning purposes. The fundamental structure of an integrated highway information system is provided by GIS technology. When new information becomes available, it can be added to the developed database. As a result, the database is constantly changing and cannot be assembled all at once. The topological data found in GIS databases creates new avenues for the diverse purposes of data analysis pertaining to transportation. The various GIS features, including the spatial analysis functions and querying ability, are very helpful tools for the organizations in question to manage the road network on a daily basis. The management of highway infrastructure and the development of transportation information systems are significantly impacted by GIS technology. The decision-making process in transportation engineering will undergo a complete revolution if GIS technology is fully utilized. Globally, GIS is acknowledged as the most effective tool for integrating all forms of data required for the transportation industry. Planning, designing, building, maintaining, and managing the transportation system could make the most of the vast amount of information available about the nation's transportation infrastructure. It is imperative to arrange the current database in a way that is compatible with the GIS environment and to recommend a number of additional new data items that are thought to be helpful for improved management and planning.

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