Use of Geographic Information Systems in the Management of Transportation Systems

Geographic information systems (GIS) have helped to shape the evolution of transportation engineering and planning and now serve as an integral element in managing traffic and transportation systems. Given the complex multimodal and multijurisdictional issues that fall under the umbrella of traffic management, many GIS transportation applications have been designed for collection, analysis, and distribution of data. The ability to combine maps with extensive databases makes GIS ideal for considering spatial and temporal dimensions of traffic systems (Han et al., 2002). The ability to share, manage, model, and visualize data has and will lead to breakthroughs in gathering traffic data, disseminating travel information and advisories, increasing the safety of transportation systems, and optimizing transit.

Perhaps the most important aspect of traffic management, and certainly the foremost concern of Rhode Island’s Traffic Management Center, is incident management. This is largely accomplished through detecting incidents and relaying the appropriate information to facilitate as fast a response as possible. As it is not possible to canvas an entire roadway network with traffic cameras (nor is it possible to have enough people to view that many cameras), one must rely on traffic data such as speeds and volumes to assess performance of a system. Given spiraling congestion of traffic across the globe, this data is also necessary for analyzing and then optimizing transportation systems. Likewise, transit systems must also be optimized through sensitivity to demand and intelligent transportation planning. Finally, an optimized system will only perform as well as the motorists, who require information to make good decisions and who should be afforded a system that is safe. All of these needs may be effectively and efficiently facilitated through the application of open, compatible GIS platforms.

Travel times and speeds are the data traditionally used when assessing the level of service provided by a highway network. Unfortunately, the availability of this data is typically restricted to point sensor locations. Data may only be gathered where a sensor, such as a loop detector, is present, but cost of installation and maintenance, and the necessity to make cuts in pavement for installation, limit the number of sensors that can be installed. An appealing alternative to the traditional point sensor is the probe sensor, where a vehicle in the system relays speed and location data. Meaker and Horner (2004) explore an existing source for this probe data: the network of automatic position reporting systems (APRS) that have been established by amateur radio operators principally to serve mobile radio stations. These APRS systems collect location and speed data from mobile GPS receivers in probe vehicles, which then becomes available in real-time over the internet. Large amounts of this data are available in urban areas, particularly along the west coast and in the northeast. Since the location data is georeferenced, it may then be brought into a GIS as a layer of points for traffic assessment and analysis.

GIS may be used not only for estimating parameters of traffic, but also for estimating the parameters of specific traffic elements. Since heavy trucks account for a disproportionate share of incidents and resulting injuries and fatalities, these vehicles deserve special attention in traffic analysis and volume estimation. Unfortunately, state-of-the-practice commodity-based and vehicle-based modeling techniques tend to perform marginally at best. Using classification counts, socio-economic data, and statistical models, however, a GIS platform can be developed that provides more accurate truck volume, flow, and percentage estimates than can be derived from existing methods. Moreover, the platform may allow for automatic updates to reflect new data (Boilé and Golias, 2004).

Shifts and increases in population create new and complicated demands that existing transportation infrastructure is poorly equipped to accommodate. A large, dense population and issues of cost often mean that more highway lanes cannot simply be added or number of buses increased. Thus, it is necessary to make the best of existing infrastructure and optimize current and new additions to mass transit. This is the situation that much of India finds itself in on
account of huge urban population growth. Seeing a solution to Indian transportation issues through optimal use of public transportation through integrated transportation planning, Verma and Dhingra (2005) developed a GIS-based model for establishing an optimal rail corridor as part of the larger goal of creating an efficient demand-sensitive multimodal mass transit system. The model identifies transit demand and then uses an heuristic algorithm in TransCAD GIS software to identify an optimal rail corridor, which can then be displayed graphically.

Traffic performance may also be improved without expansion of the infrastructure by providing information to motorists. Many areas achieve this through advanced traveler information systems (ATIS) that use various technologies to provide pre-trip and en-route information. GIS-based ATIS are powerful tools for trip planning, route selection, mode choice, flow prediction, and traffic monitoring and analysis, on account of their ability to store and manipulate large amounts of information and display that information graphically. Kumar et al. (2005) succeeded in creating such a system for Hyderabad City, India in the form of a user-friendly GIS platform that can be used for route selection, finding facilities, getting transit details, and trip planning. The platform can be used from bus stops, train stations, airports, information centers, and personal computers, and with the right data can base its output on real-time information.

Naturally, traffic performance is at the mercy of any dangers to motorists that are present in the system. Traffic accidents stop or slow traffic in the direction of flow, create queues, slow traffic in the opposite direction (“rubbernecking”), and continue to adversely affect traffic flow well after they have been cleared. To make matters worse, these dangers may not be readily apparent when engaging in transportation planning or safety analysis. GIS can again be helpful in this regard, as demonstrated by Khattak and Shamayleh (2005). They first learned that GIS data visualization is successfully being used for transportation safety, public information relaying, and land use and transportation integration applications. They then succeeded in gathering light detection and ranging (LiDAR) data, inputting the data into ArcView, creating 3-D models, and visually identifying areas that contained obstacles to safe passing and stopping sight distances. Montufar (2002) demonstrated that the benefits of GIS could be extended to heavy truck safety analysis as it relates to road design, traffic engineering, and highway maintenance. GIS stands out from other techniques due to its ability to integrate collision, location, and traffic databases and conduct spatial analyses.

It is safe to say that traffic management and transportation systems have a great deal to gain from continued use of GIS. Spatial analysis and data visualization open new windows in transportation analysis and safety assessment. Graphical representations of data aid analysis and can be used to keep travelers informed and able to make intelligent decisions, whether on the road, at a transit station, or at home. Integrated GIS databases allow for effective, efficient, user-friendly data storage, management, and distribution. GIS-based modeling applications allow for a better understanding of the transportation system than was once possible and can be used to optimize existing or planned systems. Real-time traffic performance as determined by GIS can be crucial for traffic monitoring and incident management. These benefits apply to air, rail, and highway, typically cost little, and have global applications.

It seems inevitable that GIS will continue to take an increasingly vital role in the management of transportation systems. Development and implementation of GIS-based systems will help transportation engineers and planners to combat the transportation-related issues of today and tomorrow. Data sharing and interoperability limitations among GIS platforms and data sets with regards to accuracy, level of generalization, currency, completeness, differences in structure, and metadata (Han et al., 2002) have been, are being, or likely soon will be resolved. Research into GIS-based transportation solutions that may be adapted to many different situations continues to show superior results when held against traditional methods, thereby insuring widespread future use of GIS transportation applications.
ANOTATED BIBLIOGRAPHY


In light of inadequate state-of-the-practice techniques for truck trip estimation, this article presents a GIS-based estimation method using classification counts and socio-economic data. Heavy truck traffic has a strong impact on the transportation system, but commonly used commodity-based and vehicle-based modeling techniques for estimating this traffic are problematic. The proposed GIS tool allows for development of truck volume, flow, and percentage profiles for any highway in a region—New Jersey, in the case of this study. The steps that are followed, and largely automated, in this proposal are as follows: define the section of highway, input traffic and socio-economic data, select or create a statistical model, make model-based truck traffic predictions, and visualize the estimated and observed truck volumes. In New Jersey, this proposed modeling technique is shown to be more accurate than existing techniques. The proposed method is limited in terms of future predictions and hypothetical analysis. It does, however, allow for accurate “in house” truck volume estimation that automatically updates to reflect new traffic and socio-economic data. This seems like a highly worthwhile proposal considering its cost-effective nature and the large impact that heavy trucks have on many aspects of the transportation system.


This article discusses the need for data sharing and interoperability in GIS transportation data sets. It looks at associated issues with regards to accuracy, level of generalization, currency, completeness, differences in structure, and metadata. Techniques are developed for gathering GIS transportation data, transforming the spatial data structure of the data sets as appropriate, and merging the sets. It then formulates a conceptual framework for guiding the implementation of these techniques. Spatial and attribute data are handled separately, with the framework revolving around the spatial data. Sample technique derivation procedures are illustrated. Integrated multijurisdictional GIS transportation analysis platforms are then created for the greater Winnipeg area and a prairie region by means of derived techniques. This paper does provide useful strategies for GIS data integration, though it is at least partially out-of-date, as with its assertion that few data sets come with standard FGDC metadata.


This article seeks to use light detection and ranging (LiDAR) data visualized three-dimensionally in a geographic information system to locate sections of road that have potentially dangerous obstructions to stopping and passing sight distances. The literature review conducted by the authors indicated that GIS data visualization is being successfully used for transportation safety, public information relaying, and land use and transportation integration applications. LiDAR and orthophoto data was collected from two-lane rural highways in Iowa. Data analysis consisted of entering data into ArcView and creating 3-D models, identifying potential sight distance problem areas visually, verifying that the identified obstructions prevented safe sight distances, and validating these results in the field. The authors conclude that data visualization with LiDAR
provides for reliable and efficient safety assessment of rural two-lane roads. It should be noted, however, that gathering LiDAR data for this sole purpose is not justified by cost. The article also cautions that more research should be conducted before recommending data visualization in lieu of traditional techniques, and that building overhangs and tree canopies can be problematic. It does seem that in many areas where LiDAR data is available, this technique should be the clear choice for assessing the safety of sight distances.


The goal of this work was to create an advanced traveler information system (ATIS) for Hyderabad using ArcView. ATIS is explained as a system that uses a variety of technologies in order to provide pre-trip and en-route information to help motorists make good departure, route choice, and mode choice decisions. GIS-based ATIS, with its ability to efficiently store large amounts of information and to graphically display this information, is recognized as an excellent tool for trip planning, route selection, mode choice, flow prediction, and traffic monitoring and analysis. The study’s GIS-based ATIS was created by first collecting and digitizing maps with roads, important destinations, and major geographic features. Databases were also created with attributes for these features and with transit itineraries. ArcView GIS-based software then pulls this information together in a friendly GIS platform that can be used for route selection, finding facilities, getting transit details, and trip planning. Furthermore, this platform can or will be able to be used from bus stops, train stations, airports, information centers, and personal computers, with an online application. Further intelligent transportation system use in the city could allow for this platform to base its output on real-time information. This proposed system seems to be a very cost-efficient way to allow motorists and tourists to make educated trip planning decisions in cities with large amounts of congestion and/or tourist appeal.

Meaker, J., and M. W. Horner. 2004. Use of automatic position reporting system data for enhancing transportation planning operations. Transportation Research Record: Journal of the Transportation Research Board 1870: 27-34

This article is interested in speed and travel time data collection alternatives to expensive and highly limited point sensors. The article thus takes interest in gathering this data with probe vehicles equipped with a Global Positioning System (GPS). It recognizes an available source for this data in a network of automatic position reporting system stations that have been established by amateur radio operators. Though intended for supplying the needs of mobile radio stations, these probe vehicles provide position, speed, and direction information that can then be found on the internet. This data is georeferenced, of high quality, and widely available where volunteers are plenty, namely in urban areas. This approach to data gathering has the potential to provide real-time traffic performance and allows for highly accurate and thorough traffic analysis, since it is conveniently maintained and managed as a point layer in GIS. This article espouses the benefit of the automatic position reporting system as a means for using GPS-enabled vehicles for a regional travel assessment system. The extremely positive findings of this study make it surprising that transportation agencies have not taken advantage of this system data.


In response to U.S. and Canadian goals of drastically reducing truck-related fatalities and injuries despite expectations of increased truck traffic, this article looks at how transportation geographic information systems (GeIS-T) may be used in heavy truck safety analysis. Statistics
are used to show that in the Canadian prairie provinces studies, heavy truck collisions are responsible for a large share of fatalities and injuries suffered on the road. GIS is recognized as important since it can support safety analysis as it relates to road design, traffic engineering, and highway maintenance. These categories have typically been neglected in favor of ensuring the soundness of the truck itself, limiting driving times, and monitoring and rating truck safety history. GIS-T spatial analysis of collisions allows for identification of dangerous highway sections and types of sections. The main benefit of using GIS-T, as stated by the article, is that it allows for integration of collision, location, and traffic databases for safety analysis purposes. These applications are unfortunately limited by the quality of collision data as reported by police and entered by a management center. Despite this, the article makes a convincing case for the need to improve heavy truck safety and the benefits that may be derived from using GIS-T for heavy truck safety spatial analysis.


This article is concerned with the impact of India’s huge urban population growth and the inability of the transportation infrastructure to cope with this surge. As such, it recognizes the need for optimal use of public transportation through integrated transit planning. The study proposes a GIS-based model for establishing an optimal rail corridor to facilitate this need, as part of the larger goal of creating an efficient demand-sensitive multimodal mass transit system. This model identifies transit demand and uses an heuristic algorithm in TransCAD GIS software to identify an optimal rail corridor. This corridor can then be conveniently displayed graphically with GIS. Thane City, in the greater Mumbai area, is used as the case study in the successful application of the model, which leads to recommendation of light rail for an identified transit corridor. The study claims that this model, proven by the case study, may be applied for a typical Indian city. Though this study does not take into account changes in land use and traffic patterns instigated by the identified optimum corridor, it does provide a useful tool in combating the negative effects of urban area expansion on traffic.