GIS-BASED TRANSPORTATION INFRASTRUCTURE MANAGEMENT SYSTEMS: CASE OF SARIYER

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Abstract

Most authorities do not actively plan the maintenance of their transportation infrastructure. Officials generally react to problems when they appear. Often the approach to transportation infrastructure management is looking away and hoping that the transportation system will keep up with the ever-increasing demand. The pro-active approach of managing assets and planning proper maintenance is not a common practice today; preventive maintenance is often considered an up front expense whose return on investment is hard to quantify. It has been proven repeatedly that in the long run, pro-active maintenance of transportation infrastructure will save money and lives.

This paper explains the first phase of the development of a Geographical Information System (GIS) based Transportation Infrastructure Management System for the district of Sariyer in Istanbul. The major objective of this study is a better utilisation of available resources for the transportation infrastructure of Sariyer; and at the same time, improvement of maintenance of the transportation infrastructure. At the beginning of the study, available maps (geodetic) of the whole district were used and digitised with the roads to serve as a base map for the initial GIS. Then, a road inventory (Annual Average Daily Traffic Volumes, Capacity Usage of Lines, Road Type, Pavement Type, Location of Junction, Type of Junction, Public Transportation Lines, Location of Bus Stops, Location of Parking Lots, Applied and Planned Rehabilitation, Maintenance, and Reconstruction works about Transportation Infrastructure etc.) related with transportation infrastructure was gathered into the data base system of the GIS. By using this, it will be possible to sort, add, and access the data from geo-referenced data base system for managing, assessing and planning of the transportation system. Finally, advantages and disadvantages of GIS-based Transportation Infrastructure Management System for Sariyer are demonstrated.
1. Introduction

The main property of the transport infrastructure in cities is to create safer, comfortable and reliable areas for the transport facilities. To get better performance, they need very complicated systems for the transportation assets. All assets of the transportation infrastructure must be checked, surveyed, monitored and continuously measured for the maintenance and rehabilitation and even for emergency reason. In the city road transportation system, geographic analysis is the key to making better decisions. Monitoring transportation system systems and conditions of roads, finding the best way to deliver goods and services, maintaining transportation networks, understanding these issues from a geographic perspective is crucial to deploying or spending resources wisely. Geographical Information Systems (GIS) has spatial referencing and graphical display features and it would be useful to link relevant road data to assist in information management and safety analysis. Used with other analysis technologies, GIS can help identify factors that contribute to road problems at specific locations and to identify countermeasures. Integration of road information into a GIS is a low-cost, high-benefit way to analyze factors that affect road problems and their associated mitigation measures.

In this study, Sariyer Road Transport Network was transferred into GIS environment in order to provide high quality analysis of transportation assets. It was extremely a complex procedure to transfer all road infrastructure data to demonstrate the graphic database. This paper describes the process of developing a GIS-based Transportation Infrastructure Management System for Sariyer. Arcview software was used to graphically represent the information pertaining to any section on the road network.

2. Geographical Information Systems

GIS’s are computer-based systems for the capture, storage, manipulation, display, and analysis of geographic information. The multiple functionality afforded by GIS distinguishes it from older technologies. The integration of multiple functionality within one rather seamless environment dispenses users from mastering a collection of disparate and specialized technologies. As it turns out, this aspect is often held by organizations as one of the decisive criteria in their decision to adopt GIS technology because of its efficiency benefits.

The functional complexity of GIS is what makes it a system different from any other. Without geo-visualization capability, the GIS are merely a database management engine endowed with some power to extract meaningful relationship between data entities. Without analytical capability, GIS would be reduced to an automated mapping application. Without database management features, GIS would be unable to capture spatial and topological relationships between geo-referenced entities if these relationships were not pre-defined. What sets GIS apart from other database management systems (DBMS) is not the nature of the information handled. Indeed GIS
and DBMS may contain exactly the same information. The difference between the two systems is "under the hood", namely in the way information is referenced. A DBMS references data by some unique index or combination of indexes. By contrast, information is all about a geographic description of the surface of the Earth in a GIS. Each data record is a geographic event in the sense that it is tied to a unique location defined in a given referencing framework (global, national or local datum). With the spatial referencing of objects, topology of the data can be defined, which in turn enables a host of spatial query operations of objects and set of objects as shown in Figure 1. (J.R William, 1989 and Yomralioglu, T., 2000).

![GIS-base for Municipalities](image)

**Figure 1. GIS-base for Municipalities.**

Components of GIS: GIS consists of some important components to carry out its fundamental functions properly. These components are as follows:

a) Hardware: The computer and the secondary devices attached to it, which enable GIS to operate, are called as hardware.

b) Software: Software is sum of algorithms written in high level programming languages in order to storage, analyze, and display geographical data.

c) Data: Data is the most important component of GIS. The complexity of data sources and huge amount of data having different structures require much more time and high costs.

d) People: GIS technology has a wide application with human creativity. People manage the required systems to solve real world problems, and prepare long and short term plans.
e) Methods: GIS works properly only when plans and work principles are prepared precisely. These plans and principles are generally in the form of models and applications specific to each organization.

3. GIS Applications in Transportation

The integration of multiple functionality within one environment has caused organizations to adopt GIS technology for their specific applications. Because of its efficiency, GIS has been also used widely in the field of transportation since the late 1980s. In this context, it is necessary to mention three classes of GIS models (Thill, J.C., 2000).

- Field models used to represent the continuous variation of a phenomenon over space. Terrain elevation exploits these models.
- Discrete models used to describe discrete entities (points, lines or polygons) that populate space. Highway rest areas, toll barriers, urbanised areas usually use these models.
- Network models used to depict topologically connected linear entities (such as highways, railroads, or airlines) that are fixed in the continuous reference surface.

Although all of these models may be useful in the field of transportation, the network models play the most dominant role in this application area since infrastructure networks are extremely important elements for providing the movement of passenger and freight. As it is known, most of the transportation applications only necessitate a network model to represent relevant data. Some of the examples in this context are given below:

- Pavement and other facility management systems;
- Real-time and off-line routing procedures as well as traffic assignment in the four-step urban transportation planning process;
- Web-based traffic information systems and trip planning engines;
- In-vehicle navigation systems;
- Real-time congestion management and accident detection.

In transportation systems, geographic analysis is also the key used to make better decisions. Understanding the issues such as monitoring transportation systems, finding the best way to deliver goods and services, checking fleet vehicles, or maintaining transportation infrastructure from a geographical perspective is crucial to deploy or spend resources wisely. Hence road transportation finds great utility in using GIS to manage the information related to public bus operations, maintenance, asset management, and decision support systems. The list given below identifies the major areas in which GIS have been successfully deployed in transportation systems (Figure 1, ESRI webpage).

- Real estate management,
- Facility management,
- Asset management,
- Commodity flow analysis,
- Emergency response management,
- Environmental and construction management,
- Inter-modal management,
- Passenger information, capacity planning,
- Marketing,
- Supply chain management,
- Site selection,
- Risk management.

4. Creation of Road Network

In Istanbul, the public transport service is owned by the Metropolitan Municipality and private transport companies. In Sariyer Municipality, there is a section for planning and coordinating the city infrastructure.

Sariyer transportation network was transferred into a GIS environment in order to create an effective decision support system (DSS) for city transportation infrastructure. This procedure required large amount of data to be processed. These data contained general, layout and operating, maintenance, and map data of the transportation network. Mainly, road network is transferred into the transportation network because of non-existence of the other transportation modes. Only harbours are added to the transportation system.

In this study, first of all, digital maps were used to create the road network map. Then, the vector map of the road network was obtained by linking the lines of roads. As a result, the Sariyer Transportation Network having a scale of 1/5000 and coordinates in accordance with ED 50 (European Datum) and UTM 36 (Universal Transverse Mercatory) was created on a digitalised environment. Roads and junctions were defined as polylines and points on this map, respectively.

For the transportation infrastructure information, all information about the road inventory, junctions, harbours and etc. were categorised according to available data obtained from different sources and making visual inspections. Sariyer road network was divided into sections. All road information was linked with the sections. A spatial database was created by transferring the Road network into a GIS environment. The location of Sariyer is shown in Figure 1. The map that includes the road network, road sections, junctions, harbours, and important places for the public is given in Figure 2.
From this map, the names of roads, junctions and transport infrastructure assets and their pictures can be seen. As a result, information such as the lengths of streets, arterials, type of the junctions could be accessed easily on this GIS environment.
The software named Arcview was used in this study for geographical information analysis. As it is known, it is a GIS software written in high-level programming languages by ESRI in order to perform geographical analyses. Arcview Professional sets the standard for desktop mapping, visualization, and geographic analysis. Its direct remote database read/write capability allows users to access their corporate data through ODBC connections, and keep them current. Arcview users throughout the organization can connect to a central Spatial Ware database to manage and share information among different departments. Thus, everyone can have access to the vital spatial information used in decision making.

5. Evaluation of Data by GIS

After the date necessary for the road inventory, it is necessary to determine constrains and limitations of roads. As we know, the date entered is mainly about the transportation assets and the monitored information from the on-line traffic accounts. These data cover road inventory information such as annual average daily traffic (AADT) volumes, road type, pavement type, location of junction, type of junction, public transportation lines, location of bus stops, location of parking lots, applied and planned rehabilitation, maintenance, and reconstruction works about transportation infrastructure etc. Thus, for the future works of Sariyer Municipality, it is possible to know on which road there will be traffic congestion or capacity constraint; on which road there is construction, maintenance or rehabilitation process going on. It will be possible to answer the following question: If there is an incident on a road section, how can the problem be solved?

Figure 3 shows a sample junction, its present condition, type, and capacity.
6. Conclusion

GIS based Transportation Infrastructure Management systems can greatly improve the efficiency of operations, while at the same time; can make significant contributions to planning processes and decision making processes. GIS-based Transportation Infrastructure Management would be helpful to decision makers, planners or designers. In this study, it is concluded that a carefully designed GIS system can efficiently help transportation professionals with solving traffic and transportation infrastructure problems.

The benefits of Transportation Infrastructure Management Systems (TIMS) are given below:

From the general factors;

- Realization of the magnitude of the investment that the agency has better chances of making correct decisions on spending funds,
- Improved intra-agency coordination,
- Improved use of technology,
- Improved communication.

From the elected representatives;

- Being able to defend/justify programs of maintenance and rehabilitation,
- Having assurance that programs represent best expenditure of public funds,
- Reduction of pressure (from constituents) to make arbitrary program modifications,
- Getting objective answers to the implications of lower levels of funding and lower standards.

From the Senior Managers;

- Comprehensive, comparative assessment of
  - Current status of the network,
  - Expected future status objectively based answers to,
  - What level of funding is required to keep the current status,
  - The implications of greater or lesser budgets,
  - The implications of deferred work,
  - The implications of lower standards,

- Being able to objectively justify capital spending and maintenance programs to the elected council, or legislature
Having the assurance that the recommended program represents the best use of available sources

Being able to define the "management fee" as a percent of the spending on capital and maintenance work.

While Transportation Infrastructure Management Systems (TIMS) have been around in one form or another for over two decades, there is still major scepticism at middle- and upper-management levels in public agencies. The following list summarizes some sources of this scepticism:

- Insufficient planning and resources allocated for TIMS development, maintenance, and upgrading of the process,
- Use of the TIMS is delegated to people who do not truly understand the process,
- Lack of incentives to properly implement and document TIMS,
- Overemphasis on use of computers as a "black box",
- Improper calibration, validation, and verification of some TIMS models,
- Lack of communication among developers, users, and beneficiaries of TIMS,
- TIMS must be recognized as "means" not "ends",
- Lack of an interdisciplinary team in the development process - for example, lack of a statistician in many agencies,
- Strengths, weaknesses, and limiting assumptions of TIMS often unrecognized by decision-makers,
- Insufficient data available to properly use the methods in early phases,
- Inadequate understanding of the true "costs" and "benefits" of TIMS,
- Lack of money for buying the monitoring equipment.
References


