# A GIS web-based traffic accident information system

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## Abstract

Humanity has faced an enormous technological evolution over the last 15 years in the area of Networks and Communications, in parallel with the continuous progress occurring in the computer hardware and software technologies. Communications and Informatics are undoubtedly considered as the fundamental sections for developing systems and managing their critical component, the data, in order to obtain information and consequently knowledge. As far as spatial data is concerned, the applied aspect of the relevant sciences and the involved technologies lay in the greater area of Geographic Information Systems (GIS). GIS-based software implementations comply with the principles governing contemporary software developments and they often need to be integrated with existing systems of human activities. As a result, specialised server applications termed Internet Map Servers (IMS), satisfy client requests for different purposes including spatial based information retrieval. In addition, existing Database Management Systems (DBMS), handle spatial information and through special software connectors serve requests sourcing from GIS-based applications. Systems dealing with traffic accidents and road safety, may be generally termed as Traffic Accident Information Systems (TAIS), and serve the objectives of the present paper. Accidents are handled as point events and are positioned over the transportation network through appropriate Linear Referencing Systems (LRS). Although, numerous systems have been developed, the system proposed by the present study exploits the benefits of modern, state-of-the-art software modules, regarding spatial information related services.
*Keywords: traffic accident information systems, web-based information systems, GIS, linear referencing systems, internet map services.*


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# 1 Introduction

Improving road safety requires, among other measures, the existence of a properly designed Traffic Accident Information System (TAIS) that can retain accident, traffic and road geometry related data for accident analysis purposes. A TAIS should be able to spatially and temporally represent and analyse accidents and their consequences. In addition, it should provide capabilities for relating accident data to other structural and functional data such as the geometric characteristics of the road sections or intersections and the volume and composition of traffic at these locations. Road safety indicators and predictors, necessary to estimate, predict and/or assess the safety level of an area, roadway section or specific spot, can be properly calculated only if a suitable and reliable TAIS is in place.

Geographic Information Systems (GIS), could, by default, be considered as the critical part of a TAIS. First of all, it is the spatial dimension of traffic accidents along with the geospatial identity of the underlying transportation system to which they occur that necessitates GIS involvement. Furthermore, GIS provides significant tools for maintaining, analyzing, locating, and publishing traffic accident-related spatial information.

Recent developments in GIS software packages include the adoption of geographic database as the main data structure maintaining spatial information, replacing the traditional georelational data structure (Zeiler [1]). From the developer's point of view, the benefits of accessing a Database Management System (DBMS) to process spatial information, instead of developing code to handle binary spatial data formats are enormous. In addition, the ease by which a DBMS cooperates with a world wide web (WWW) server combined with the high capabilities offered by contemporary Internet Map Services (IMS) provide further development challenges.

In this respect, this study paper aims to propose a GIS web-based TAIS application, by exploiting the benefits provided by the above-mentioned technologies (section 4). Building point and/or line events related to traffic accidents through Linear Referencing Systems (LRS) provide valuable assistance towards this effort. Specific GIS development packages (ESRI ArcIMS, ArcSDE) were employed to demonstrate this initiative. Prior to this, a review of existing local and international TAIS is presented (section 2) and the related GIS-based technologies involved are identified (section 3).

# 2 Review of existing traffic accident information systems

TAIS have been developed lately at several occasions, mainly in the US and Canada. This part of the paper provides a short overview of some of these systems.

A web-based application concerning traffic accidents (live accident data) exists in the city of Tulsa (Official web site of the City of Tulsa [2]), which is located in the north-eastern quadrant of Oklahoma. The application includes a map with the overall view of the city, its arterial streets and current car crashes.

There is the option to zoom in on a crash number. The information provided by the system includes the exact data, time and location for every accident. The web page utilises data from the city of Tulsa (911 Emergency Centre) and is updated approximately once a minute from information entered by call-takers into Tulsa's Computer Aided Dispatch System (CADS).

Another web-based traffic accident record system exists in DuPage County, Wheaton, Illinois [3]. Anyone wishes to logon to the system must have a user id and password (these can be obtained by calling at Dupage County DOT). The user can either enter data or query the database for information. All data entry is based on the Illinois Traffic Crash Reports (ITCR), which is a double-sided form. Field entry includes time, jurisdiction, number of motor vehicles involved and accident location. There are three standard, printable reports: all intersection accidents report (all accidents related to intersections that have been entered), top accident intersection report (this report summarizes the top ten locations in the jurisdiction of the user by total number of accidents) and finally, all mid-block accident report which gives the list of all mid-block accidents sorted by primary streets.

A traffic accident information system also exists in the Charlotte-Mecklenburg Police Department [4]. The information is updated every three minutes and it includes the event number, time, Traffic Police division, address and event. A "Questions-Comments" form can be used if the user has questions or experience problems while using the application. The Connecticut Department of Transportation, Bureau of Policy and Planning [5] provides, through the use of the Traffic Accident Viewing System (TAVS), accident data (preliminary 2004 accident data is available for use with the system).

A computer-based Traffic Accident Information System (TAIS) is in use in Saskatchewan, Canada [6]. This system exploits information from traffic collisions occurring on Saskatchewan road and highways (SGI's database on motor vehicle crashes). TAIS is made available online in order to facilitate timely access to the accident data. National Highway Traffic Safety Administration decided in 1996 to make Fatality Analysis Reporting System (FARS) data easier to obtain by using Internet technology. This FARS web-based encyclopaedia [7] "offers a more intuitive and powerful approach for retrieving fatal crash information". An interactive system that enables users to navigate a Geographical Information System to browse detailed information about accidents that occurred in their neighbourhood in the area of Glasgow was recently developed (Zheng and Johnson [8]). According to the same source "members of the public have argued that they might review their regular routes if they had access to local accident data".

Elsewhere, a prototype GIS and Road Accident View System (GIS-RAVS) was developed for the purpose of reducing the number of accidents in the area of the University Putra, in Malaysia (Liang *et al.* [9]). The system was developed using Microsoft Visual Basic 6.0 in Windows XP platform.

A GIS (Arc/Info) based Management System for Traffic Accidents (TAMS) taking place in the Greek Highway network was designed in 1997 (Papaioannou *et al.* [10]). The design of TAMS was based on the Road Accident

Report Sheet that is being used by the police to report all road accidents. The National Technical University of Athens (NTUA) and the Dept of Civil Engineering of the Aristotle University of Thessaloniki maintain both a database with all road accidents in Greece. An information system has been designed in NTUA in order to allow for the correlation of the accident's database with other databases maintaining traffic volumes, road network data, vehicle data etc. (Frantzeskakis and Golias [11]). The database of the University of Thessaloniki was used for the application presented in this paper.

# 3 GIS-based technologies applicable to a TAIS

## 3.1 GIS and TAIS

GIS may be considered as the critical component of a TAIS, as most of data maintenance and analysis concerning traffic accidents is strongly related with GIS based technologies:

- Traffic accidents are events occurring along a transportation network, which is represented through a geospatial data identification standard, like FGDC [12].
- Traffic accidents must be precisely referenced across routes. This georeference provides their strong spatial nature.
- Various relationships between traffic accidents and other geographic-spatial entities, beyond those concerning transportation, may exist (e.g. weather related entities).
- As route events, traffic accidents may be linearly referenced across a transportation route through the process of dynamic segmentation (Keechoo and Wonjae [13]).
- The data collection sub-system of a TAIS may exploit GIS-based devices (e.g. GPS devices).
- Traffic accident analysis may include complicated spatial and/or attributed queries, executable through a geographic database.

The system proposed in the present study is based on the linear reference of point events, a core GIS process described in the following section.

## 3.2 Linear Referencing

Linear Referencing Systems (LRS) for transportation facilities may be developed in an attempt to maintain information on transportation infrastructure. A LRS typically consists of the following components (Nyerges [14]):

- a transportation network
- a location referencing method (LRM), and
- a datum

In the case of traffic accidents the kilometric position of an accident provides the required datum. The road, where the accident occurs, along with related factors such as, its segments, the starting and ending positions of each segment and the line length values, specify the location referencing method to be used. Such a method determines an unknown location within the transportation network using a defined path and an offset distance along that path from some known location (Miller and Shaw [15]), as illustrated in figure 1.

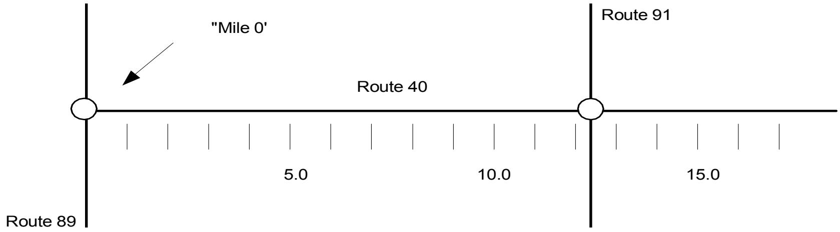


Figure 1: Linear referencing methods - road name and milepoint (Miller and Shaw [15]).

The above provide the basis for maintaining accidents within the network using route events, as a result of the dynamic segmentation process. Dynamic segmentation calculates the shapes of point or line route events during run time. Route events are stored in route event tables and in case they represent traffic accidents they contain accident road name and location and may also contain other attributes such as date, type of accidents, number of vehicles involved, fatalities, and road and weather conditions etc. (ESRI, Inc. [16]). As non spatial data, all the above may simply exist into a standard Database Management System.

# 4 Application

## 4.1 System architecture

In order to manage the Greek traffic accident data collection system, through a real time web-based TAIS, the system architecture, illustrated in figure 2 is proposed. It should be stressed that the schematic, the terminology and components analysis following is mainly based on proven commercial products.

### 4.1.1 Internet Map Sever

The Internet Map Server receives client requests for cartographic information and returns the final map images. Its principal components are:

- Spatial Server: performs the core GIS services (spatial processing, data retrieval and extraction etc.) and it actually, executes client's request by producing the final map image, to be published by the Web Server.

- Application Server: distributes requests to Spatial Server acting as an intermediate for these requests and it also performs other critical information management tasks.

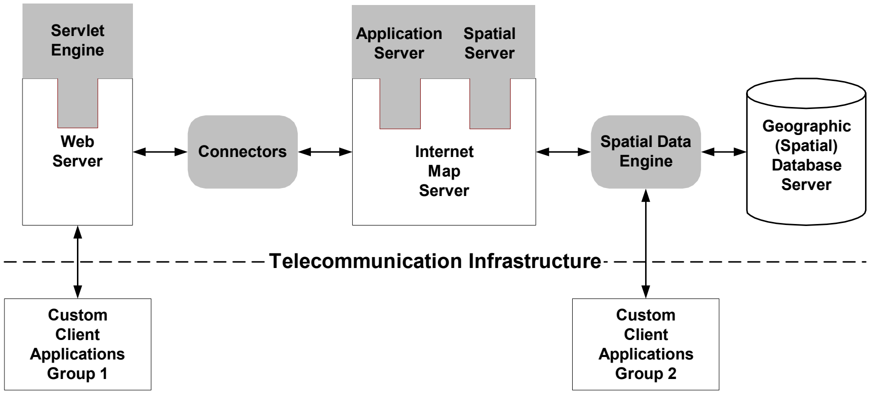


Figure 2: TAIS indicative architecture.

### 4.1.2 Web Server

The Web Server receives web client requests for data, locates the requested data and sends it back to the client application.

### 4.1.3 Servlet Engine

Some client requests require special programs (Servlets) to be executed on the server's side. A Servlet Engine provides support for Servlets running within the Web Server environment, through a Servlet Application Programming Interface (API).

### 4.1.4 Connectors

Connectors provide a communication link between the Web Server and the Internet Map Server, which is achieved through the Servlet Engine. Connectors may also include special Java components for developing client and server applications, custom Servlets and JavaServer Pages (JSP) applications.

### 4.1.5 Spatial Data Engine

The Spatial Data Engine provides communication between a spatial DBMS and any other GIS-related data request activity. It supports, beyond others, concurrent multi-user editing, many concurrent network user serving and unlimited spatial data.

### 4.1.6 Spatial Database Server

A spatial Database Server is a DBMS, maintaining spatial data. Recent developments include special GIS data models for a wide range of human activities to be transformed in relational spatial databases during physical design.

#### 4.1.7 Custom client applications

Such applications may be programmed in a variety of programming languages (scripting, visual etc.), and may be installed in a variety of devices (PC, PDA etc.). Communication with the geographic database server may be achieved via the appropriate protocols (TCP/IP, GPRS/3G). Client applications are divided into two main categories depending on whether they are used for importing or extracting traffic accident related data:

- Group 1: Applications used for navigating inside the traffic accident related cartographic information. They are also used for extracting data through simple or complicated queries.
- Group 2: Applications used for storing data into the geographic traffic accident database, through SDE. Accidents are imported as point events referenced by the exact position of their occurrence, through LRS.

### 4.2 System development

A pilot implementation of the proposed architecture made use of the software products presented in table 1. ESRI's Internet Map Server (ArcIMS 9.0) cooperates with specific combinations of Web Server and Servlet Engine versions of the Apache products as reported in ESRI Support Center [17]. On the other hand MS SQL Server responded perfectly during geographic data base creation through SDE [18]. Finally, pilot java applications accessed the DBMS, through JDBC connectivity, without certain troubles to be reported [19].

Table 1: Adopted software products.

| System Component | Software Product |
|---|---|
| Operating System | Windows XP |
| Web Server | Apache HTTP Server 2.0.48 |
| Servlet Engine | Apache Tomcat 4.1.29 |
| Internet Map Server | ArcIMS 9.0 |
| Spatial Data Engine | ArcSDE 9.0 |
| Connectors | ArcIMS Servlet Connector, Java Connector |
| Spatial Database Server | MS SQL Server 2000 |
| Custom Applications | Java Developer Kit 1.5.0 |

### 4.3 Output capabilities of a TAIS

The output capabilities of a TAIS may include spatial related information and special cartographic presentations (views) useful to the application end-users. Table 2 provides an indicative list of the views extracted by various combinations of accident related and other geospatial data.

The number of possible output cartographic views is in theory endless and depends on the precision and reliability of both accident and spatial data. Figure 3 represents an instance of the first class views depicted in the above table.

Table 2: Indicative list of a TAIS cartographic view.

| View | Description |
|---|---|
| 1 | Accident dispersion along a road section, classified in severity classes. |
| 2 | Black spots based on given criteria, simple or complex. |
| 3 | Accident consequences (fatalities, injuries) per black spot, intersection, specific location etc. |
| 4 | Accidents classified according to various criteria, such as accident type, vehicle type(s), time of accident, pavement conditions, weather conditions, lighting conditions etc. |
| 5 | Accidents and relevant statistics in a comparative form according to various criteria such as different years, months, days, periods, etc. |
| 5 | Accident related data combined to traffic volume and composition data. |
| 6 | Accident data combined with other spatial data such as population density, land use data, pedestrian activities, etc. |
| 7 | Driver related data (e.g. age, driving under the effect of alcohol or drugs etc.) alone or combined with other spatial data such land use, recreation activities, etc. |


Figure 3: A screen shot of the 1st indicative view, presented in Table 2.

## 5 Conclusions and further developments

The present study proposed the design and pilot implementation of an integrated TAIS. A set of sub-systems (web server, internet map server and spatial database server) may cooperate in order to serve custom applications, either for data storage and maintenance, or for data retreival and extraction purposes.

The geographic database data model adopted, provides the framework for establishing a LRS through which traffic accidents are referenced over the transportation network as route events. In such way, the traffic accident position reported during its occurrence, along with other attributed information, obtain spatial dimension. The existing application programming environments may assist the development of useful and effective tools for processing accident related information and producing complicated combinations with other geospatial data.

The proposed design of a TAIS for Greece enables the exploitation of existing data from a number of potential users and at the same time provides ground for modernisation of the accident data maintaining structure in Greece. Concerning the initial data creation, this is directly dependent on the legal and institutional framework of the country, and it is the responsibility of certain authorities. For Greece, this application type would be meaningful only for Traffic Police departments that undertake, on a distributed basis, to enter the accident related data. In addition other authorities responsible for traffic and road geometry data might become application users to update and/or refine the data they handle. Therefore, an analytical needs assessment for all the involved in a TAIS authorities, is required, prior to further developments. The results of such a study will be reflected to specific roles and responsibilities regarding the final system utilization. Further developments should be expected, especially in the light of new technological advances.

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