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Predictive Mathematical Emergency Information System (EIS) Using GIS, GPS and Digital Photogrammetry (DP)

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Abstract. Predictive Traffic Response Emergency Information System (PTREIS) was developed based on proven mathematical models. Unlike many traditional systems, PTREIS contains an intelligent spatial mechanism and attributes for building a database. On one hand, the spatial mechanism searches for the nearest accessible route to the accident location. On the other hand, the contents of the database can be used for three purposes: (1) building statistical data based on which parameters of PTREIS mathematical models can be improved, (2) defining the most probable dangerous traffic locations and reporting them to planners, engineers, and authorities to make further analysis and to take actions towards correcting the causes of accidents at theses spatial sites, and (3) defining the shortest path to an accident location based on newly introduced advance models, concepts, and mechanisms. The system was tested using a central urban area of Riyadh City, the capital of Saudi Arabia. The model was applied to three primary categories of emergency centers: hospitals, fire stations, and police stations.

Introduction and Literature Review

PTREIS was developed based on Geographic Information Systems (GIS), Global Positioning Systems (GPS), Digital Photogrammetry (DP), and remote sensing images. PTREIS is, in fact, a GIS that was designed as a traffic management system. Although GIS has gained a foothold in science and technology, it may not have yet reached the level of universally accepted terminology and definitions. As a result, GIS today is beset with a variety of definitions, each affected by relevant applications or disciplines. Most practitioners agree, however, that GIS has a powerful ability to perform spatial analysis. In 1988, the National Science Foundation (USA) created the National Center for Geographic Information and Analysis (NCGIA) and adopted the following definition for GIS:

> "A geographic information system is a computerized database management system for capture, storage, review, analysis, and display of spatial (i.e. locationally defined) data" (Huxhold, 1991).

Even though this definition is comprehensive and widely accepted, as with any other technology or science, it requires refinement from time to time to accommodate newly introduced concepts. For example, real-time GIS and intelligent databases evolve with new concepts, more efficient integration, and wider applications in the real world. This basic principle of GIS can be found in (Burrough, 1986).

It is very important to accept the fact that the following three basic themes reflect GIS' qualifications and efficiency:

1. Design concepts and applicability to the real world.
2. Data quality currency and standardization.
3. The faithfulness of the mathematical modeling (the driving force of GIS' engine mechanism) of the problem.

These three factors are decisive in judging the overall quality of any application-oriented GIS, as is the case of the PTREIS.

In this research, the third factor is emphasized more. It is often believed to greatly enhance PTREIS for the reason that large numbers of model parameters are culturally oriented. That is, social traditions and governmental policies have a major impact on traffic modeling and behavior. In return, parameters fully calibrated for USA may not be suitable for Saudi Arabia and vise versa.

Spatial analyses of PTREIS rely heavily on the quality of acquired spatial information. Accordingly, evaluation and assessment of available data for developing application-oriented information systems should be considered. In many publications such as (Carbone *et al.*, 1996), (Ehlers, 1991) and (Fairbairn *et al.*, 1991), the assessment of spatial information is treated in depth. In fact, technology assessment for object-oriented applications is investigated in many publications, as well (Guptil, 1989), (Davis *et al.*, 1993) and (Ehlers *et al.*, 1989).

In this research, remote sensing, GPS and DP are used extensively to acquire spatial data. Spatial information is also derived from remote sensing, photogrammetry, and ground surveying. In raw forms, these sets of information may not be suitable for various PTREIS applications. Therefore, prior processing, such as orthorectification and geo-registration, and interpretation of data sets are required (Al-Garni, 1995). In transportation and related issues, GIS plays a great role (Venderohe *et al.*, 1991). Commercial GIS applications for vehicle routing and dispatching are just now entering the market. These ready made software lack many social/traditional parameters that are necessary for robust prediction of best routes. Shortest path and multi-path routing have been treated at large by many researchers (Rom *et al.*, 1999), (Krishan *et al.*, 1993), (Lee *et al.*, 2000), (Wang *et al.*, 2000) and (Lee *et al.*, 2001). Planning and routing for load balancing are very important in traffic modeling and have been treated in many publications (Pearlman *et al.*, 2000), (Nasipuri *et al.*, 1999), (Park *et al.*, 2001) and (Pham *et al.*, 2002). Most of these activities in routing, dispatching, and load balancing activities contain a certain type of mathematical models, some of which are primitives while others are advance. Algorithms and wireless developments should be inspected and understood for further improvements. Many literatures in this respect may be consulted (Johnson *et al.*, 1996), (Tsirigos *et al.*, 2001), (Perkins *et al.*, 1999) and (Ogier *et al.*, 1992). "Real Dense Stereo for Intelligent Vehicle" is an advanced scientific paper shows an intelligent dimension that can improve transportation systems (Mark *et al.*, 2006). Using GIS concepts, topological relations have been applied for travel time predictions based on vector regression modules (Wu *et al.*, 2004).

Many important factors may contribute to improving road capacity. For instance, Central Traffic Control Systems (CTCS) are one of the basic time cost factors. Their efficiency and sensitivities to emergency incidents should be investigated. They may be used to reduce or increase time cost (Ceder, 1994). It is also claimed that the full capacity of existing roads is not properly used due to the lack of proper information system to support drivers. In-vehicle route guidance systems are expected to increase the capacity of existing roadways and, therefore, reduce time cost of emergency vehicles (Koutspoulos *et al.*, 1991).

Motorist information projects that provide accurate and timely information on freeway construction, accidents, and disabled vehicles are of interest to many organizations (Albert *et al.*, 1989). Given proper road-traffic information, route guidance systems may support transportation emergency decisions (Hobeika, 1989). With greater demand on emergency vehicles, there should be certain mathematical models that will respond to priorities and select nearest available vehicle for deployment (Marianov *et al.*, 1996). For modeling purposes, many parameters are involved in locating proper emergency vehicles to respond to certain locations.

Finally, precise concepts of designing PTREIS are important issues that must be carefully considered in the early stages of system development. Just like most GIS projects, precise and clear designing concepts may lead to better standards for PTREIS design and accuracy (Al-Garni, 1994), (Exler, 1988), (Jordan *et al.*, 1992), (Lanter *et al.*, 1992), (Moellering, 1991), (Thapa *et al.*, 1992), (Antenucci *et al.*, 1991) and (Burtch, 1991).

More comprehensive modeling and variable parameters would be involved in cases where the highest demands on emergency centers occur. In this case, any queued or on-duty vehicle would be in real-time communication with emergency centers (Goldberg *et al.*, 1991).

The main objective of this research, therefore, was to design and implement a Predictive Traffic Response EIS (PTREIS). This included designing a database with expandable, robust, and predictive mathematical modules. Mathematical models were developed based on actual field observations of numerous social and traffic parameters. Three new contributions are introduced by this research: 1) new social/traditional mathematical parameters; 2) statistical intelligent database for defining dangerous traffic locations on short and long terms; and 3) auto-detection of the nearest accessible route to the accident locations. Other properties, such as multi-path selection and shortest path evaluations, are developed in PTREIS as well.

One major difference between traditional routing models and our model (PTREIS) can be recognized by the newly introduced local cultural and social parameters, which are included in the prediction math model of the (PTREIS). Another major difference is found in the automation property of locating the nearest accessible route to the accident locations.

Based on received calls, the system can instantly identify accident locations as well as the nearest suitable emergency centers. The system performs automatic computations and provides alternative routes between the accident locations and the emergency centers or vehicles. The predictive model for these computations is presented in this study along with the introduction of new and important parameters for mathematical prediction of a *best traffic route*.

Basic Theory and System Development Phases

One major difference between traditional routing models and our model (PTREIS) can be recognized by the newly introduced local cultural and social parameters, which are included in the prediction math model of the (PTREIS). Another major difference is found in the automation property of locating the nearest accessible route to the accident locations. That is, the nearest road at the accident locations is not necessary accessible. Other PTREIS properties are similar to normal available routing models. In order to achieve the newly introduced models, concepts and mechanisms of PTREIS, two basic levels of data modules are treated in this system. The first data module comprises the *semantic* level (referred to in this paper as *high-level modeling* or *info-logical modeling)*. This kind of modeling links land-related data and human concepts to form a robust representation of the real world. It normally requires specialists in the relevant disciplines to conceptualize the problem and reduce those concepts to a format suitable for efficient computer programming. This level of modeling is the one that this research attempts to achieve.

The other, *logical* level of data modeling is referred to in this paper as *low-level modeling* or *syntactic modeling*. It deals with computer-oriented issues such as database field structuring, data storage, and other GIS and database mechanisms. This part is treated in this research through developing and processing proper digital maps, remote sensing or digital photogrammetric images.

Info-logical modeling consists mainly of two major sub-modules, namely *geographic environment* and *mathematical representation*. The geographic sub-module is a user-meaningful part of the system. It is an abstract of the real world in a computer environment. On the other hand, the mathematical sub-module serves as a spatial/quantitative information part of the system. It is the dynamic mechanism of the database. This part is represented in this system through the PTREIS predictive mathematical model.

GIS design and relevant areas of applications influence system definition. The system presented in this paper is an *application-oriented system*. Moreover, its development is an incremental process passing through several major phases as follows:

1. Defining the problem and developing proper concepts and theories for it.
2. Designing a system that best fits the problem being considered by applying proper plans and workable solutions.
3. Developing the system by acquiring proper PTREIS components that meet user applications and accommodate future expansions and modifications of the system.
4. Developing and implementing a mathematical model based on global parameters.
5. Operating and testing the system.

These five major phases are explained in the next few sub-sections as they pertain to this study.

Problem Identification

GIS-based projects require clear definition and understanding of the problem that should be treated and solved. Due to the fact that PTREIS is generally an application-oriented system, the problem and its proper solutions must be clearly defined. In this paper, the definition of the problem includes five major factors that may influence other designing stages of the PTREIS:

(a) *Problem Statement and Extent*: Problem statement should be precisely reported. The problem and other anticipated future problems that may be introduced in the relevant application should be described in clear terms. Defining traffic dangerous locations, developing advanced multi-path routing predictive model, and automatically locating the nearest accessible route to the accident locations are three basic problems treated in this research.

(b) *Problem Size and Effects:* The size of the problem and its relation to other indirectly-related disciplines in the relevant organization should be investigated. The designed system in this paper is a pilot project conducted on the partial area of the capital city of Saudi Arabia (Riyadh City). The system, however, is scalable and can be expanded to accommodate the whole city.

(c) *Actual Manual Treatment of the Problem*: The classic methods that are currently used to deal with the problem and the evaluation of its performance should be comprehended. Currently, manual reports of accidents are described by participants. No precise geographic coordinates are reported. Many misleading descriptions are found in the reports. Also, no accumulative digital reports are obtained to track the causes of accidents.

(d) *Human-technology Integration*: Classification of users and their level of education that may determine the type of technology and its level of complexity should be understood. In most cases we found that personnel interact with accidents and routing is of low level education and qualifications. This means that a user-friendly system through proper customization must be developed. Advanced complicated system applications may lead to resisting system use and end up with system rejection.

(e) *Budget Availability and Allocation*: The organization's financial resources available to support the development of problem solutions should be estimated and should be available. Since our research is a pilot project, its cost is minimal. However, the pilot project may be used as a good approximate model to estimation cost of larger projects.

All five factors include variable parameters that may vary according to the general nature of a project. Their labels or headings (database fields), however, suggest fixed concepts that should be considered in every project regardless of the variable parameters (database records) or factor characteristics.

System Design

According to problem definition and user applications and needs, the system was designed to fulfill three requirements:

(a) Accommodate a database that may contain two types of functional data and queries:
   i. Reference information regarding accident-related organizations such as fire departments, police stations, hospitals, emergency centers, ...etc.
   ii. Accident locations. This part of the database documents accident locations and all related information, such as accident time, accident date, injury type, road information accident date, driver information, ...etc.

These two parts of the database act as rescue data and problem diagnostic data.

(b) User-friendly system with minimum, but adequate, function to perform rescue orders and to document, manage and analyze accident information.

(c) Observation-facility interfaces (GPS, GIS, DP) to document spatial information (graphical data) and describe its attribute.

System Development

The development phase is described as an execution task that is affected by the previous two phases (problem identification and system design). In developing the PTREIS, four important sub-tasks of the system development were performed:

(a) Acquiring information about PTREIS components and evaluating the following items:
   i. Their prices and their suitability to the available financial resources.
   ii. Their suitability to the designed system and flexibility for future expansion to solve the problem.
   iii. Level of complexity of the technology as compared to the level of knowledge of the users.

(b) Formulating the problem into certain forms that will be suitable for coding or programming the problem in proper computer environment.

(c) Presenting the data and proper models that will manipulate and analyze that data. In this sub-task, programmers, experts in traffic problems and professionals in solving the problem in the traditional way are participating. The data presentation includes:
   - Data base structuring and computer programming.
   - Mathematical modeling.
   - Interfacing and output presentation in proper forms according to user anticipation.

(d) Operating and testing the system.

Most of these implementations are too detailed to be presented here. In fact, many interfacing programs such as Map Objects, Map X, Avenue, and Visual Basic were used in developing and operating PTREIS theories and functions.

Predictive Mathematical Modeling (PMM)

The main strength of PTREIS models compared to other models comes from its ability to include all local/traditional factors that may reflect traffic behaviors precisely. In Saudi Arabia, Social/Traditional/Economic Factors and Occasions (STEFO) play great roles in shaping traffic characteristics. Accordingly, International Standards of Multi-path evaluation and STEFO are both accommodated in PTREIS.

The main concepts of developing predictive mathematical models of PTREIS for best route selections and dangerous location analysis were based on three major factors. These are:

(a) Global parameters that can be divided into three sub-attributes:
  - fixed attributes (road names, emergency centers, codes, etc.).
  - variable attributes (traffic signals, rush hours, road suitability, etc.).
  - unknown attributes (weather conditions, vehicle condition, psychological conditions, new legal enforcement policies, social occasions, traditional behaviors, etc.).

(b) Robust and representative samples for developing statistical models for prediction purposes. This model becomes more precise with time. It uses the database observations and improves predictability by learning mechanism.

(c) Heuristic information that can be obtained from experienced people and sources such as questionnaires.

These three factors are theorized and itemized as precise elements that can be formulated in mathematical equations.

Based on the collected information (observations), a predictive mathematical model that can automatically estimate the cost of travel to an accident location from an emergency center was developed. The mathematical module is expressed as follows:

$$\gamma_i = [(\gamma_{norm} + \gamma_{ubnorm} + \xi_i)\, w_i]_{g_i k_i} \qquad (1)$$

$$\gamma_{norm} = \left[\frac{D_i}{S_i\beta_i} + \tau_i\,\alpha_i\,N_i\right]\omega_i \qquad (2)$$

$$\gamma_{ubnorm} = \left[\frac{D_i}{S_i\beta_i} + \tau_i\,\alpha_i\,N_i\right]\omega_i \qquad (3)$$

$$\omega_i = \Psi_i\,\phi_i \qquad (4)$$

$$\gamma_t = (\gamma_{norm} + \phi_{ubnorm}) \qquad (5)$$

where:

i denotes the alternative route to be evaluated; γ_t is the total cost in minutes; γ_{norm} represents time delay in normal traffic behavior; γ_{abnorm} denotes time delay in abnormal traffic behavior; *D* is the distance in meter; *S* is speed in meter per minute, β rush hour factor for speed; α represents rush hour factor for signals; N is the number of signals; ω is an evaluation indicator factor; ϕ is road suitability factor; ξ represents expandable parameters (unknown and can be introduced to the system as soon as they are realized). Expandable parameters appear in abnormal part of the PTREIS; τ is delay time in minutes due to traffic signals; and ψ is an accident factor that may block the road. The other symbols w_i, g_i and k_i are setting agent factors for PTREIS.

The elements D, S and N of the equations are fixed and automatically acquired and evaluated by the system. τ, α and β are to be estimated from the statistics of available traffic information. In this particular experiment, these were estimated and found to be 2, 1 and 1, respectively, in all times other than the rush hour times. During rush hour times, τ, α and β were 2, 0.5 and 1.5, respectively. The last two factors (ψ, ϕ) are treated as binary values for the evaluated roads. That is, in case of an accident blocking the road or any other matter that causes the road to be unsuitable for dispatching, these factors are given a value of zero. If there are no accidents, and if roads are suitable for dispatching, each of these two factors is given a value equal to one. That is, if $\omega_i = 0$, then the road is excluded and considered unusable, and γ_i, for that particular road, is not evaluated. Accordingly, ω_i is evaluated prior to evaluating γ_i. ω_i is always an immediate piece of information that an operator must know as soon as he receives calls regarding accidents.

The agent g_i is not a calculation factor, rather it is an agent that a user must go through to initiate proper PTREIS's modes for calculations. In this system, g_i agent is the second element after ω_i to be assigned for PTREIS before any calculations can be conducted. Similarly, k_i is an agent designed to set-up the time modes of PTREIS such as normal times, rush hours, or abnormal times. It also sets up the occasion modes of PTREIS such as V.I.P. visit times, soccer game times, Friday prayer time, etc.

In fact, g_i has two options in full activation mode. One is the manual or interactive option mode where a user may consider some roads in normal modes γ_{norm}, while others are in abnormal modes γ_{abnorm}. The other option is an automatic one where all roads are considered in one mode, either in normal mode γ_{norm} or in abnormal mode γ_{abnorm}. This option can be activated by spatial circle or rectangle queries of PTREIS. In case of single mode, PTREIS deactivate either γ_{norm} or γ_{abnorm}. However, in case of mixed mode both, γ_{abnorm} and γ_{norm} are activated by the system. These modes depend on user set-up for the system based on actual accident or dispatching requirements. Two more computational mathematical formulas were developed by this study for system evaluation purposes. The mathematical formulae are discussed in the upcoming sections.

The system interface is capable of accommodating two types of information to define accident locations. The first type is automatic or semi-automatic input of caller ID coordinates in case of land-based telephones, mobiles having GPS capabilities, cars equipped with GPS. The second type is manual descriptive information such as area name, road name, land mark name, or any other descriptive information.

Intelligent Database

The PTREIS was designed with simple interface to have the operators input many sets of information (in real time) at accident locations. Information includes accident GPS locations, accident type, road name and type, time of accident, types of cars, names and ages of drivers, types of injury, type of impacts on environment, weather, digital pictures, and many other observations. With time, this kind of very huge database can be used to study causes and impacts of accidents (socially and economically). Based on database diagnoses, the reasons of accidents such as engineering, or human, or environmental or other reasons may be singled out to authority for possible correction of the problem.

System Implementation Using PMM

Phases discussed previously were implemented at King Saud University using personal computers and data acquisition systems such as digitizers, image processing, CAD systems and GIS software. In order to execute and implement the described concepts of PTREIS, three sub-sections are presented here:

(a) System configuration.
(b) The study area and acquiring spatial information for pilot project development.
(c) Results of the study and evaluation of the system.

System Configuration

Figure 1 represents the general conceptual modules of PTREIS. Like most GIS systems, four major modules form the PTREIS' core: the *input module*, *global data base and information module*, *data processing module*, and *output module*.

The *input module* is the tool through which

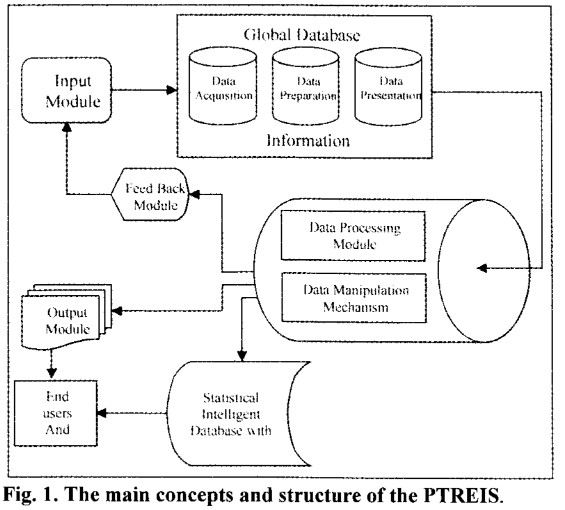

Fig. 1. The main concepts and structure of the PTREIS.

collected data and observations can be entered into the PTREIS. The *global database and information module* consists of three sub-modules namely, data acquisition, data preparation, and data presentation. All are basically important in the development and modification stages of the system. The *data processing module* is the system's manipulation and management mechanism. This module can be also referred to as the *intelligent operational mechanism* of the PTREIS. The *output module* is an important module to users as well as to system designers for providing valuable feedback information.

Study Area and Spatial Information

In order to evaluate and further develop workable modules for PTREIS, a central urban study area in

Riyadh City, Saudi Arabia was selected. This area provided every kind of emergency, emergency centers and vehicles, traffic problems, and other information that PTREIS was designed for. The area is about 40 km^2 with major classes of transportation network, heavy population and several emergency centers.

Five basic phases for acquiring spatial data to develop a recent Traffic Base Map (TBM) were performed as follows:

Phase	Data Acquisition Activity
1	Remote sensing was used to conduct the primary investigation for the study area. A 60 x 60 km digital SPOT coverage for the whole city was investigated. Based on many parameters such as road density, vehicle density, population density, and emergency center density, an area for further investigation was selected.
2	Field trips to confirm the findings of the primary investigation of the study area were conducted. That is, confirming the existence of emergency centers, seeking their cooperation, and checking some traffic parameters were performed.
3	Recent large scale (1:5000) aerial photographs as well as available maps for the study area were acquired from proper sources. All maps were prepared in their digital forms and aerial photographs were scanned at high resolutions (1000dpi). Proper locations for ground controls were identified on the aerial photographs in proper distribution.
4	Differential GPS was used to accurately acquire the pre-defined photo-ground-controls. Based on ground controls, digital aerial photographs were processed (interior orientation, exterior orientation, photo-rectification, stereo-pair development, stereo-correlation for DEM, and producing mosaics of orthophotos that cover the study area).
5	Using digital photogrammetric capabilities to update maps, recent digital base maps for the study area were produced. Basic traffic information was attached to these maps. The prepared maps form the basic TBM for the PTREIS where a proper database was developed for the system. Recent Quick Bird Image were used in some tested areas (see Fig. 2).

Although there are many tables containing real world observations conducted by this study, only Table 1 is presented here as samples. Relevant information collected includes district name (or code), road numbers, names of emergency centers, traffic signals, spot speed, distance, and travel time. Other information such as rush hour delays was collected from appropriate authorities in the area.

Result and Analysis of Cost Optimization Models

In order to operate and test the developed system, real or simulated data must be used. In this study, the data being utilized was divided into two sets:

(a) Real data, which included all digitized base, maps of an urban area in Saudi Arabia, real locations of dispatching (emergency) centers, actual traffic data, and other heuristic data about population and roads.

(b) Simulated data which included two basic types:
   i. Random simulation of accident locations, and
   ii. Random simulation of roads that was unused due to maintenance or construction or roads subjected to abnormal conditions.

Table 1. Sample of collected information to serve fire station A (FA)

District ID	Road Segment Code	Distance (m)	Spot Speed km/hr.	Traffic Signals	Cost in Minutes
1	1	1427	70	4	9
1	2	2138	70	2	6
2	3	2138	70	2	6
2	4	3000	70	2	7
3	5	4704	70	3	10
3	6	4704	70	4	12
5	0	0	70	0	0
5	7	1125	70	1	3
6	8	2633	70	3	8
7	9	315	70	1	2
8	10	315	70	0	0
9	12	1125	70	1	3
10	13	2633	70	3	8
••	••	••	••	••	••
••	••	••	••	••	••
••	••	••	••	••	••
18	26	3173	70	3	9
19	28	4193	70	4	11
20	29	4643	70	6	16

Many tests were conducted to evaluate the system's performance during an emergency (such as a simulated accident at the center of a district). Calls were received by the closest fire stations, hospitals, and police stations. Each of these stations was assumed to have the PTREIS and would use the system to display the best route, and how to reach the accident scene at the least cost.

Figure 3 represents a sample of the simulated cases. It represents normal cases within non-rush hours and where all roads are suitable for dispatching. The attached browsers (tables) show the automatic computation of the PTREIS based on which best routes were highlighted.

Fig. 2. Customization and interfaces of PTREIS and its functions along with sample of used Quick Bird Image in the system

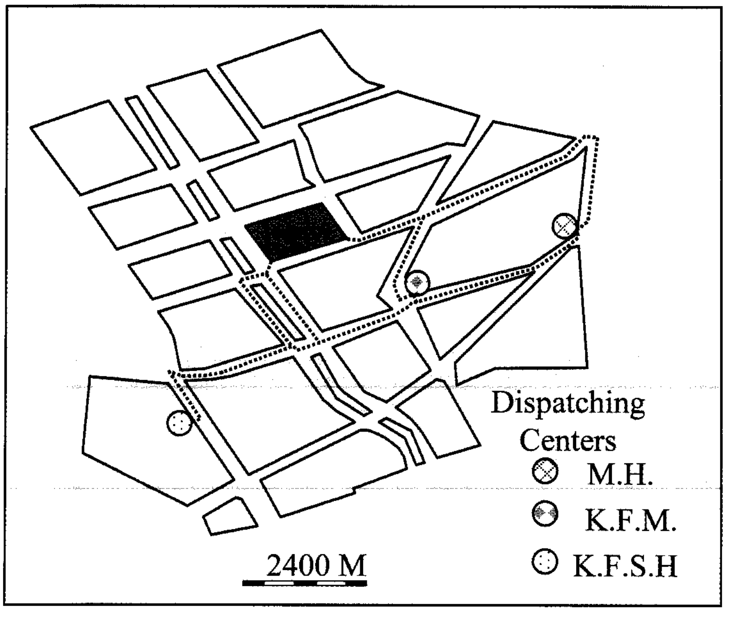

Fig. 3. Layer containing 3 hospitals and best routes to district 09.

To: District 09 From: Police Stations

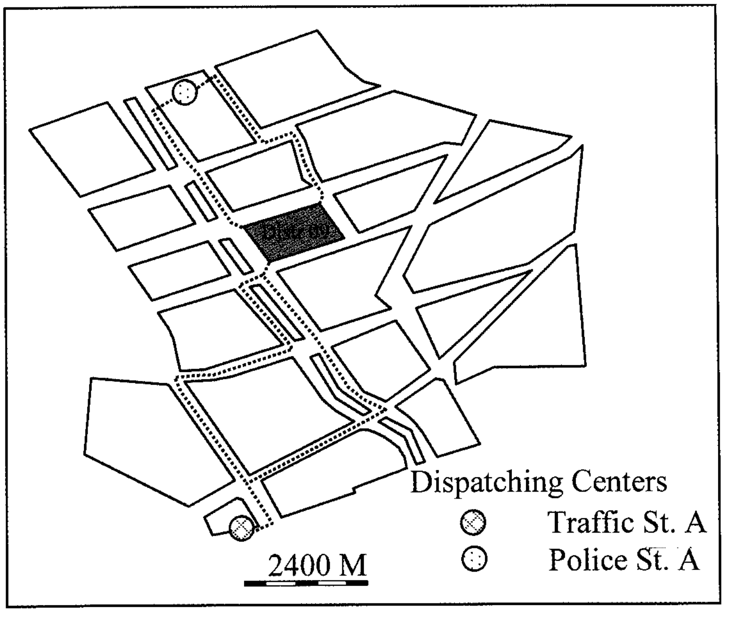

Fig. 4. Layer containing 2 police stations and best routes to district 09.

Stations (Names)	Roads (ID)	Distance (Meters)	Speed (km/hr)	Signals (Number)	Cost (Minutes)
TA	17	5075	70	6	16
TA	18	5208	80	3	10
PA	12	1351	70	3	7
PA	13	0833	70	2	5

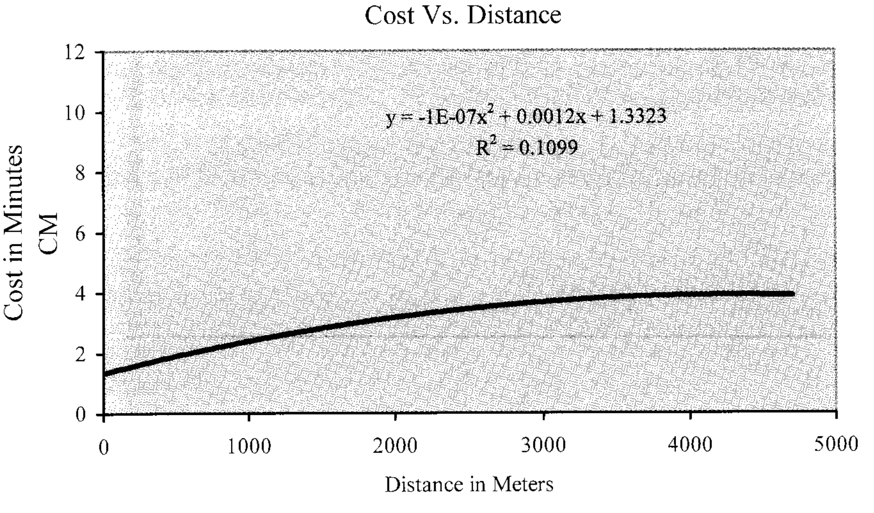

Fig. 5. Modeling the relationship between distance and cost.

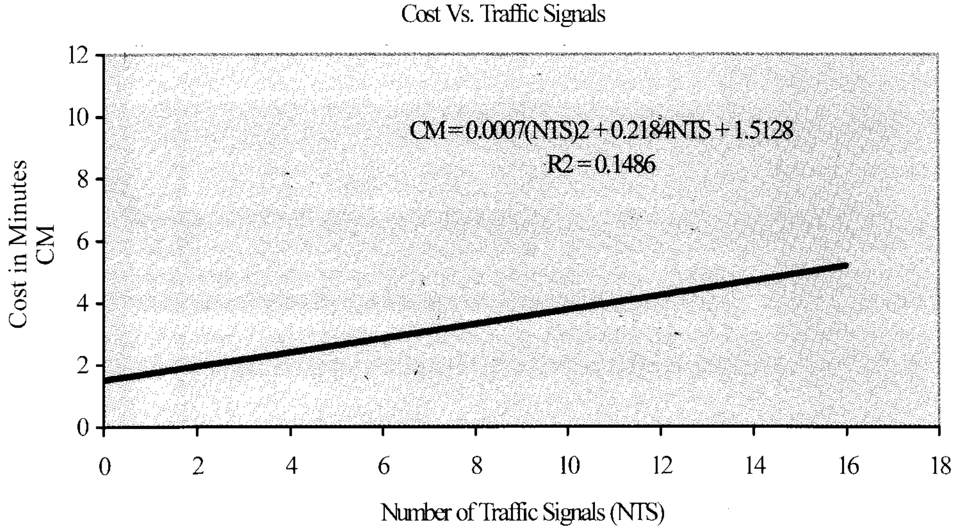

Fig. 6. Modeling the relationship between traffic signals and cost.

Figure 4 shows a sample of abnormal simulation cases. These include unsuitable road(s), an accident on a road, or rush hour or similar occasional factors such as V.I.P visitor, soccer games, ..etc. In the browsers, these cases are shown in columns as data input to the mathematical model. Then, automatic computations of cost considering abnormal situations were performed by the system.

To evaluate system performance, the results obtained by PTREIS were compared with current statistics in emergency centers based on empirical studies. Empirical formulas of the Ar-Riyadh Development Authority (ADA) center show that signal delays constitute 35 % to 50 % of the total cost of a route in Riyadh City. In PTREIS system the following formulas are used to compute total cost of signals on routes as follows:

$$Psd_i = \left[\frac{N_i \tau_i}{\gamma_i}\right] 100 \qquad (6)$$

$$Apsd_i = \frac{\sum N_i \tau_i}{n} \qquad (7)$$

where *Psd* is the "percentage signal delay," *Apsd* is the "average percentage signal delay," and n is the "number of road." *Apsd* was estimated and found to be 47%, which is within the range of the previously stated empirical studies. Figures 5 and 6 represent the analysis the system may provide (e.g. showing the relationship between the cost in minutes and the distance and traffic signals as factors affecting the cost). Similar models may be established in the future for dangerous locations analyses.

Conclusions

In conclusion, this study is believed to provide a simple and possibly effective system to serve real operational tasks in emergency centers where quick decisions must be made. It seems to be promising since observations may lead to accurate estimation through very robust mathematical models. That is, Figs. 5 and 6 can be improved with citywide observations leading to the best least-squares fit model from which better-cost estimation may be computed. Similar models, which include all factors contributing to the total cost, can be developed as well. The current PTREIS is accurate and comparable or better than the manual methods currently in use in Riyadh City. The same concept can be applied to many other urban areas throughout the world. Only statistics and road conditions (observations) will vary. Finally, the causes of accidents can be figured out, hence corrected by authority. Recent technologies provide what is known today as "Location Based Service Systems" (LBS). Such systems may be integrated, in another research, with PTREIS to provide comprehensive and diagnostic system. This may contribute to produce better decision-making and proper traffic planning system.

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نظام معلومات تــنبؤي للطوارئ باستخدام نظم المعلومات الجغرافية (GIS) ونظم تحديد المواقع العالمية (GPS)، والمسح الجوي الرقمي (DP)

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(قدِّم للنشر في ٢٠٠٦/٠١/٣٠م؛ وقبل للنشر في ٢٠٠٧/٠٢/٠٥م)

ملخص البحث. أنشئ النظام التنبؤي للاستجابة للطوارئ المرورية (PETRIS) اعتمادًا على نظم رياضية موثوقة. خلافًا للنظم التقليدية، يحتوي PETRIS على آلية ذكاء مكانية ووصفية لبناء قواعد المعلومات. فمن ناحية، تقوم الآلية المكانية بالبحث عن أقرب طريق سالك للوصول إلى موقع الحادث. ومن ناحيةٍ أخرى، يمكن استخدام محتويات قاعدة النظام لثلاثة أغراض: (١) بناء قاعدة معلومات إحصائية لها القدرة على تحسين عناصر نموذج PETRIS الرياضي مع مرور الوقت؛ (٢) تحديد أخطر المواقع المرورية وتقديمها للمخططين، والمهندسين، وأصحاب القرار لعمل التحليلات المناسبة لها ومن ثم اتخاذ الإجراءات اللازمة حيال معالجة أسباب الحوادث في هذه المواقع؛ (٣) تحديد أقصر المسارات المؤدية إلى موقع الحادث بناءً على النماذج الرياضية، والمفاهيم، والآليات الجديدة المتقدمة التي زود بها النظام. وقد تم اختبار النظام من خلال تطبيقه على منطقة مركزية في مدينة الرياض، عاصمة المملكة العربية السعودية. طُبِّق النظام على ثلاثة أصناف من مراكز الطوارئ: المستشفيات، والدفاع المدني، والمرور.

الكلمات المفتاحية: نظم المعلومات الجغرافية (GIS)؛ نظم تحديد المواقع العالمية (GPS)؛ الحركة المرورية؛ طوارئ، إسعاف؛ نموذج رياضي؛ أقصر المسارات.