DEVELOPMENT OF EMERGENCY MEDICAL SERVICE SUPPORT SYSTEM THROUGH GIS AND TRAUMA REGISTRY RECORD: A CASE STUDY OF KHON KAEN, THAILAND

Abstract: This study intends to develop the Emergency Medical Service Support System (EMSS) by incorporating Emergency Medical Service (EMS) data and trauma registry data recorded by the Khon Kaen Regional Hospital with the aid of GIS. Landmark, street networks and intersection’s name incorporated into the developed digital map of Khon Kaen provide a means to help the dispatcher to identify and confirm the location of any accident sites from the receiving emergency calls. Consequently, from a well-prepared database system, using GIS capabilities can provide the appropriate route, the travel direction and information. Additionally, the accident severity derived from systematic medical data can be spatially monitored in the developed map. Using their spatial proprieties, the black spot locations are automatically identified as well. Finally, to assist those who are not familiar with the GIS software, a customized graphical interface is provided in this developed EMSS for the accessibility of the non-technical users.

Key words: EMS, GIS, database system, trauma registry, black spot locations

1. INTRODUCTION

In Thailand, two persons died every hour on the average due to road accidents, and economic losses were estimated at about 100 billion Baht (about US$2,500 million) per year. In addition, nearly 60,000 injuries victims were also recorded every year. With the effective and efficient Emergency Medical Service System, EMS, the severity of these injuries victims can be reduced. In general, when accidents take place, the EMS plays a major role in the medical service processes especially for the survival rate improvement. To reduce the severity of injuries of crash victims, proper and timely treatment of road casualties are essential. Although EMS has been gradually developed in Khon Kaen since 1994 and the ambulance crews are well trained resulted in proper first aid procedures and proper transfer of crash victims, some operating problems still occur. In Khon Kaen Municipality, there are 4 main agencies involved in emergency services, which are, police, fire brigade, hospital ambulance, and NGOs through some established foundations. Normally at any accident scene, the first agency to reach the accident site is the NGO; they normally arrive the site even well before the police. Although this reflects a good example of public participation in road accident, the
staff of this non-profit foundation have normally been trained only in a short-course on emergency first-aid service. Therefore, the effectiveness of their operations in term of survival rate improvement is still questionable. The hospital ambulance, fully equipped with paramedics, on the other hand, is found to be delayed in reaching to the victims. An interview with the head of ambulance operation who stated that occasionally drivers could not find the accident sites and requested for further guidance. Moreover, in some instances, accident was not found at the reported site. These imply that there are some difficulties in confirmation/verification of accident occurrence and in locating the accident site based on the received information. Needless to say, these cause ineffectiveness of ambulance operations. Thus, there is a need to improve such emergency services in Khon Kaen. This paper, therefore, intends to improve the effectiveness of ambulance operation in Khon Kaen. Specifically, it aims to develop the Emergency Service Support System (EMSS) to improve the effectiveness and efficiency of emergency services in Khon Kaen.

2. STUDY AREA

Khon Kaen is a city located in the heart of northeastern part of Thailand, about 450 kilometers from Bangkok. The province covers an area of 13,404 square-kilometers with a total population of 1,756,995 in 2001. The gender ratio is nearly the same. The Khon Kaen Municipality has a total area of 55 square kilometers, with a population of 129,891 persons. The first Emergency Medical Service System in the provincial level in Thailand was established in this city. The Khon Kaen Regional Hospital (KKH), the biggest public hospital in the city, has set up their “EMS Unit” since 1994. During the period of 1997-2000, this EMS Unit handled 5678 cases involving both traumatic and emergency cases.

For the safety research aspect, Ruengsorn et all. (2001) initiated the GIS road accident database system in this city. The research developed the large-scale digital map and making systematic use of KKH’s Injury Surveillance (IS) data as part of the accident database. Furthermore, this study utilized the IS data to develop the Probability of Survival (PS) model to evaluate survival probability for Thai victims. The severity indices, derived from the PS, can be used to assess the road accident severity, review risk factors, and identify hazardous locations in Khon Kaen Municipality as well.

3. DATA

Data is one of the major obstacles to safety research in Thailand. Lack of in-depth and reliable accident data are wildly acknowledged throughout the country. Fortunately, one of the richest sources of accident data is provided by the KKH. This hospital collects and maintains accident data through their injury surveillance program. This program aims to set up the injury surveillance database in order to obtain more insight information on the causes of injuries and their trends. Thus, accident data used in this study are mainly obtained from this data source.

To develop the Emergency Medical Service Support System (EMSS), there are two main data sources used in this research. First is a trauma registry data. Both diagnosis and general information of the patient’s that entered the Emergency Room (ER) are recorded and kept in a well-prepared electronic file. However, this study only considered accidents, which occurred within the Khon Kaen Municipality. As a result, a total of 4,963 traffic accident patients with...
a total of 3,354 traffic accident cases were recorded during May 2000 to April 2002. Secondly, the data used in this study are the emergency service data and a total of 1,987 cases was recorded in 2000. These data included all cases that the emergency vehicles have dispatched. For every ambulance trips, hospital staff must record the information in both general details of accident occurrence and diagnosis. These data are currently collected in two separate approaches: paper-based and computer-based system. Other than these two mentioned data sources, this study also relies on the digital map of Khon Kaen, which was obtained from Ruengsorn’s study (Ruengsorn, 2001).

4. OVERVIEW OF THE SYSTEM

As shown in Figure 1, many institutions including the command and control center, the emergency vehicle dispatcher, etc. are involved in emergency service system. During complex scenes they operate as part of a triad of care with police handling security and access, fire officials being responsible for overall safety and rescue and EMS being in charge of patient care and movement.

![Figure 1. Related Organizations Involved in EMSS](image)

The system that supports the emergency medical service proposed in this study is the Emergency Medical Service Support System (EMSS). The system is designed to support different levels of tasks depending on the user types—the policy maker level and the operator level. For the policy maker level, the present operation performance can be brought out through the developed database management system. The system is also designed to allow the policy maker to monitor the accident situation in the Khon Kaen Municipality spatially. The black spot locations can be automatically identified and graphically displayed in the GIS environment. It is high hoping that the acquired information from this part of EMSS will be helpful as resources for implementing proactive policies to improve the emergency medical services in the future.

For the operator level, the system is designed to assist the emergency vehicle to reach the scene at the earliest possible time under the technology available in small-urbanized area. Under this system, when an accident takes place and the emergency call is requested to the control and command center, the information in regard to accident’s location has to be firstly interpreted by the operator. The accident site can then be located on the well-prepared GIS map by the operator himself/herself or by using a supportive tool through the user interface. After the accident site is located and confirmed, by employing the GIS capabilities, the recommended route and their associated travel information are generated. The operator can then dispatch a requested emergency vehicle accordingly.
Details of ambulance dispatching process are illustrated as shown in Figure 2. Ambulance can be dispatched by two approaches: manually dispatched by operator and/or dispatched by aids of the developed computer package.

![Ambulance Dispatching Process Diagram](image)

In the first approach, the operator at the control and command center once receives the emergency call, then interprets and locates the accident scene and if it is necessary, communicates with other institutions. However, if the operator can not or has difficulty in identifying the accident location, then the computer package can be used as an aid tool to assist the operator in locating the accident site through the input of keywords of the nearest landmark provided in the package. The developed computer package, which can reduce the time required to identify an accident's location as well as to reduce fuzziness of a call. Once the accident location can be identified, the computer package is also designed through the application of GIS to recommend the best possible route to and from between the KKH and any accident site. This best route can also be displayed on the digital map together with the associated travel information such as direction, distance, street name, etc.

5. DATABASE DEVELOPMENT

Information used for spatial database development contributed from two main sources of data. In the first data source, data are in the form of the electronic files in the spatial data format of GIS known as ArcView shapefile. These data are installed in a digital map of the municipal area of Khon Kaen. This map includes the road networks and other existing geographic data of interests such as land boundaries, hydrology, natural boundary etc. Several modifications were made on the existing map in order to enhance the visualization capability as well as to reduce the fuzziness in locating the accident site. For example, the theme that represented road edge, road and median widening as well as U-turn location is revised so that the real
geometric characteristic conditions of the road can be reflected on the map. The second source of data is the EMS’s data. The data used are mainly based on the recorded accident locations. From this information, the following two main databases were created and modified--Reference for Accident Site Identification and Road Network Model.

5.1 Reference for Accident Site Identification

For the identification of an accident site, there are several techniques used previously such as located by the address, the landmark, the telephone numbers, etc. However, the method employed in this study is to refer to the nearest landmark of the accident location. This identification system takes an advantage on the ease of use and the availability of existing accident data. Under this system, the accident scene is identified by referring to the nearest landmark and then located into the digital map. Considering the actual accident’s locations as recorded by the KKH and also other major landmarks in Khon Kaen Municipality, the total 395 selected landmarks were coded and used as accident sites identification. These landmarks are classified into 22 categories based on their land use functions, as shown in Table1. The primary attributes associated with landmarks are their locations, names and nicknames. The nicknames, locally known and called by Khon Kaen communities, are the key attribute that provides the accessibility in the landmark query.

<table>
<thead>
<tr>
<th>Categories</th>
<th>No. of Landmark</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public health</td>
<td>12</td>
<td>Public and Private Hospitals, Mental Hospital, Pediatric Hospital health center and Animal Hospital</td>
</tr>
<tr>
<td>Agriculture</td>
<td>2</td>
<td>Agriculture Office</td>
</tr>
<tr>
<td>Warehouse</td>
<td>1</td>
<td>Portland Cement Warehouse</td>
</tr>
<tr>
<td>Market</td>
<td>7</td>
<td>Agriculture Product Market, Fruit &amp; Vegetable Market and Grocery Market</td>
</tr>
<tr>
<td>Military and constabulary</td>
<td>9</td>
<td>Highway Police Office, Provincial Constabulary Office, Border Police Office, Radio Transmitting Station</td>
</tr>
<tr>
<td>Intersection</td>
<td>92</td>
<td>Crossroad, Roundabout</td>
</tr>
<tr>
<td>Residential area</td>
<td>6</td>
<td>Apartment, Condominium and Nursing home</td>
</tr>
<tr>
<td>Entertainment</td>
<td>3</td>
<td>Movie Theater</td>
</tr>
<tr>
<td>Commercial area</td>
<td>3</td>
<td>Corporation, Insurance Company</td>
</tr>
<tr>
<td>Factory</td>
<td>5</td>
<td>Labor Training Factory and Fishnet Factory</td>
</tr>
<tr>
<td>Hotel</td>
<td>30</td>
<td>Hotel, Motel and Inn</td>
</tr>
<tr>
<td>University and College</td>
<td>8</td>
<td>Institute Of Technology, Police College, Regional College, Nursing College and Chancellor Office and University</td>
</tr>
<tr>
<td>Religious</td>
<td>43</td>
<td>Shrine, Protestant Church, Catholic Church and Buddhism Temple</td>
</tr>
<tr>
<td>School</td>
<td>60</td>
<td>Tutoring School, Public High school, Informal School, Municipal School and Kindergarten</td>
</tr>
<tr>
<td>Gas Station</td>
<td>24</td>
<td>Private Gas Station</td>
</tr>
<tr>
<td>Financial institution</td>
<td>30</td>
<td>National Bank, Bank Of Agriculture, Private Bank, Public Bank and Enterprise Bank</td>
</tr>
<tr>
<td>A Public Utility</td>
<td>19</td>
<td>Post Office, Bus Station, Water Supply Office, Train Station and Stadium</td>
</tr>
<tr>
<td>Private sector</td>
<td>1</td>
<td>Religion Association</td>
</tr>
<tr>
<td>Public sector</td>
<td>16</td>
<td>Court, Laos's Consulate</td>
</tr>
<tr>
<td>Village</td>
<td>15</td>
<td>Village</td>
</tr>
<tr>
<td>Shopping center</td>
<td>6</td>
<td>Wholesale Department Store, Mall and Department Store</td>
</tr>
<tr>
<td>Others</td>
<td>3</td>
<td>Other landmark not mentioned in all above categories including National Museum, Cavalry Bureau, Military Camp and Park</td>
</tr>
<tr>
<td>Total</td>
<td>395</td>
<td>Locations</td>
</tr>
</tbody>
</table>
5.2 Road Network Model

In this study, ArcView line shapefile was employed to represent the road network, including cartographic representation, classification, road and intersection names. The existing location referencing scheme, Link Recognition Technique (LRT), was preserved to provide the simplified input mode to record accident location. Under this technique, each line in road network can be classified into section and intersection depending on its data attribute. The section of road with uniform carriageway type will be classified as road section and the road sections that form the intersection will be classified as an intersection. In addition, the software package used as a routing tool was developed in a GIS environment. ArcView, GIS software, was utilized for the path analysis as well as the result presentation.

The modifications of line themes made in this study are shown in the following subsections.

5.2.1 Preparing Road Network

The existing road network theme is initially designed to use as a base map for recording and presenting of accident data. In order to perform the routing analysis on this theme, many modifications on line feature had to be made. For each line representing the road network, they have to meet and align perfectly. It is important for all lines joining together at an intersection to share the same endpoint, and to avoid the overshoots or undershoots, every lines that form the intersection had to join their end nodes. It is essential to check the connectivity for each line, so that the accessibility can be provided for every line that represented the road network. Since, the network modification made in ArcView environment encountered several error problems and it is time consuming, therefore, ArcInfo, the larger and non-desktop GIS software, is adopted for the network modification.

5.2.2 Setting Travel Cost and One-way Streets

Working with routing problems require a numeric value, which represents the cost of traversing each line feature. The travel cost employed in this study is line length representing the distance to travel along the road. In addition, one-way streets are also incorporated in the developed database to reflect the actual conditions of traffic movements in Khon Kaen. All one-way streets are set by adding a string field called ONEWAY to the line theme feature table and then restricted travel to certain directions are coded on to their attributes.

5.2.3 Working with Divided Road

Under ArcView environment, it is impossible to model the physical barrier between two-traffic streams in one line feature. However, this study, attempted to model the divided road by editing two-parallel line features representing two traffic streams. Each line is coded to be one-way street following traffic direction. In addition, using the small line feature connected between the two parallel lines provides the U-turn along the road.

In this step, the road network is ready for the routing problems. When accident site is located onto the map, its co-ordinate then will be used as an input for the routing calculation.
route from the hospital to the accident site and on the contrary way can be calculated and displayed using the basic function of Network Analysis, extension module of ArcView. This function compute the best path that visits for a list of points and returns the path’s total cost or zero if the path could not be found.

In order to verify the database and the proposed route, the validation test was performed. It aimed to compare the proposed route generated from the program with the route selected by the ambulance driver. A total number of 280 traffic accident ambulance trips records obtained from the KKH are used for the validation. The verification is acceptable if the travel distance from the proposed route is equal or less than travel distance selected by the driver. In overall, the comparison results showed that the proposed routes provide the shorter route distances as compared with the actual practice of the KKH’s ambulance vehicles.

6. EMS MONITORING AND SEVERITY MAPPING

To allow the policy maker to monitor and understand the accident situation in the Khon Kaen Municipality, EMSS is designed to automatically provide the accident statistic and to identify the black spot locations. Data management concept is applied to the existing EMS data to provide the capability to retrieve, update, input and analyze data.

To achieve this desired objective, the database and the user interfaces are developed in MS Access environment. Visual Basic in Application (VBA) is used to automate task while SQL language is employed to design the database. As shown in Figure 3, the main menu of the developed program consists of four main buttons. The first button allows user to view the information of an individual EMS operation case. Both general details of accident occurrence and diagnosis of the selected case can be displayed individually as shown in Figure 4. The second and the third buttons present the statistics of EMS operation performances. In addition, the chart diagrams can also be presented to assist policy maker for better understanding of the existing EMS service.

![Figure 3. Main Menu of the Developed Program](image)

While the first three mentioned buttons provide information which are based on the EMS recorded data, the forth button, on the other hand, employs the Trauma Registry Records to
locate the accident occurrences along the road network in the ArcView environment. As mentioned earlier, the KKH personnel can digitize the accident location as a point on the digital map. Therefore, information associated with each accident occurrence can be linked to this particular location. Considering the advantage of their spatial relationships, which not only provide capabilities for viewing and querying these data, but can also create an integrated custom application. Series of command can be customized by the Avenue, the programming language that is attached with ArcView software. Therefore, the black spot locations both in terms of frequency and severity of accident occurrences can be automatically identified via the developed program. Under this program, the accident severity is estimated from the severity of patients involved in road accidents. Severity of each patient is estimated through the logistic regression model known as the Probability of Survival (PS) model developed by Ruengsorn (2002).

Figure 4. Emergency Service Information

Regarding to accident occurred on the network, they could be classified into two categories: intersections and road sections (Ruengsorn, 2002). As shown in Figure 5, the users are allowed to select the location for analysis as along the road sections or intersections.

Figure 5. Black Spot Locations Module
The program also provides two options for the analyses—accident frequency and severity—in any selected period of time. By clicking on the “Done” button, the program would create the new accident map theme and added to a “view”. The top ten locations are ranked and displayed in the coded colors to reflect their accident statistic values as shown in Figure 6. In addition, the program also provides the capability for making the report of the analysis results.

![Figure 6. Black Spot Locations in the Year 2001](image)

7. **SUPPORTIVE TOOLS DEVELOPMENT**

As afore-mentioned that the system will also be designed to assist the operator and the emergency vehicle drivers in urgent situations. In this part of the system, the basic function of GIS, ArcView software is utilized. The command is also customized by Avenue—the object programming language.

7.1 **Working Scene**

The working scene included three major types of control: main menu, buttons and tool as shown in Figure 7. At the top of the working scene, the main menu bar shows the available menus including File and Help. In the middle row of controls, there are eight buttons, which have icon faces and recognize the click event. Underneath the buttons bar is the tool bar. This tool bar contained a tool that provides means of interacting with the map display. After clicking on this tool over the map, each click is triggered by the apply script attached with this tool to activate. The apply script includes request which is recognized by the mouse clicks and then activate the location information to find features or locate new elements on the map. In addition, this tool remains displayed until user click on another tool.

![Figure 7. Controls Available in the Working Scene](image)
7.2 Accident Site Identification

By clicking on the path analysis button ( ), the path analysis dialog box as shown in Figure 8 is displayed. In the path analysis dialog box, there are several controls such as; radio buttons, tools, text line, list box, check box and buttons. The functions of each control are explained on the following subsections:

7.2.1 Radio Button

This control is used to present a set of mutually exclusive options. By selecting one radio button, another is automatically unselected. There are two radio buttons allow user to select whether the accident site is located by user himself/herself or by using the landmark query-supporting tool. The radio button is always appeared at the landmark query mode for the first access to dialog box.

7.2.2 Tool

The add location tool ( ) is activated after the radio button for locating accident site was selected. This tool is used to specify a location of the accident site. After user clicked this tool, a cursor is changed to a flag shape ( ). When the user click on the map, if the specified location is within an acceptable distance (1/100th the horizontal extent of the view or line theme, whichever is less) of a line feature, it is added and recognized as an accident site. On the other hand, if it is not within this acceptable distance, then error message will appear. Under this circumstance, the specified user point is not added, user has to specify the new point that near or lie on the road network.
7.2.3 Text line

The text line is activated after the radio button for the landmark query mode was selected. This text line is used to input the landmark name, nickname or land use. This input text is a key element used in landmark query. Every change is made on the text contained in text line; the new set of matching landmark is created and shown in the list box. The set of matching landmark is narrowed down when more texts are input into the text line. As shown in Figure 9, the items in the list box are changed due to the changes made in text line.

![Figure 9. Changing of the List Box Items](image)

7.2.4 List Box

The list box is employed to present list of matching landmark items from the input text. When user clicked on each name in the list box, a selected name is drawn differently. After that, the landmark associated with such selected name was activated which can be zoomed in and highlighted on the map as shown in Figure 10.

![Figure 10. Procedure of Landmark Query](image)
This procedure allows user to access the location of the landmark in the map more quickly. In addition, by double clicking on the landmark name, the recommended route is then calculated and displayed.

### 7.2.5 Check box

A check box is a control, which displayed a Boolean value, a value that represents the concepts of true and false. In the path analysis dialog, the check box is used to provide a true/false or yes/no option on whether the ambulance vehicle can ran through the one way street or not. If the check box is checked, then the program would select the shortest route regardless of one-way street or two-way street. On the contrary, the developed program selected the alternative shortest possible routes to avoid the one-way street if the check box is unselected. The check box is always unselected for the first access to the dialog box.

### 7.2.6 Button

There are three main buttons in the path analysis dialog box: find paths button ( ), get direction button ( ) and cancel button. By clicking on the find paths button, the proposed path is displayed on the map. The proposed routes are displayed on the map by two different color lines. The red line represented travel direction from the hospital to the accident site and the blue line represented the returning direction back to the hospital. In addition, clicking on the get direction buttons can provide the travel information as well as the associated street names and distances along the selected route. By clicking on these buttons, the WordPad window contained the travel direction information would show up. These allow user to make any modification on the direction documentations such as edit, delete and print, etc.

### 7.3 Editing and updating database

The developed program also considered the possibility of road maintenance and temporarily closure of any street or sections of street. Therefore, the program is designed to permit user to be able to update all these activities on the developed map. As such the selection of the shortest ambulance route is not bias and according to the existing actual condition in Khon Kaen. In updating process, by clicking on the road status button ( ) existed in the working scene, the road status dialog box showed up and the working scene is automatically changed to view 2 as shown in Figure 11. In the dialog box, it consisted of text line buttons and the instruction for updating road network status. The user can update the road status by followed the instructions provided in the dialog box.

The road can be temporarily closed or re-opened by the user. The dialog box assists the user to find the location of the road on the map. By typing road name in the text line and presses enter, the road that associated with the input name could be zoom in. The road sections that need to be modified can be selected by using tools ( ) and ( ) contained in a tool bar. After the closing street button ( ) or the re-opening street button ( ) was pressed, the road status presenting in the map is then changed their status depend on which operation is performed. In addition, the user can return to the main work scene by clicking on the “cancel” button.
8. CONCLUSIONS

This study presented the development of the Emergency Medical Service Support System (EMSS) in Khon Kaen, Thailand. This system was aimed to increase the efficiency of emergency services in Khon Kaen municipality. The accident data recorded by Khon Kaen Regional Hospital were used for the EMSS database development. The EMSS is created by integrating series of data, which are cartographic representation, accident data, landmarks, street networks, and intersections name into the GIS software named ArcView. The system is designed to support different levels of tasks depending on the user types—the policy maker level and the operator level. For the policy maker level, the present operation performance can be brought out and monitored through the developed database management system. In addition, this part is designed to allow policy maker to monitor the accident situation through the identification of black spot locations both in term of severity and frequency in the Khon Kaen Municipality. For the operator level, the supportive tool that has the capability to locate accident sites, calculate the route and display the travel directions including travel information is developed. It also provides the accessibility for updating road network status such as temporary closure of street due to maintenance, etc. and re-opening. This software used GIS capabilities to achieve the optimum results, but does not require its users to be familiar with GIS software. Instead, it provides a customized graphical interface. This system has proved to be effective and easy to use.
REFERENCES


