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AN INTEGRATION OF HAND-HELD COMPUTERS, GPS DEVICES, AND GIS TO IMPROVE THE EFFICIENCY OF EMS DATA SYSTEM

Wichuda KOWTANAPANICH
Graduate Student
School of Civil Engineering
Asian Institute of Technology
P.O. Box4, Klong Luang,
Pathumthani, 12120,Thailand
Fax: +66-2-524-5509
E-mail: st019858@ait.ac.th

Yordphol TANABORIBOON
Professor
School of Civil Engineering
Asian Institute of Technology
P.O. Box4, Klong Luang,
Pathumthani, 12120, Thailand
Fax: +66-2-524-5509
E-mail: yord@ait.ac.th

Witaya CHADBUNCHACHAI, MD.
Deputy Director
Khon Kaen Regional Hospital
Khon Kaen 40000Thailand
Fax: +66-4-333-7958
E-mail:bancha@health2.moph.go.th

Abstract: This paper presents the development of an advanced tool to facilitate accident data-collection and analysis processes. An integration of three technologies: hand-held computers, GPS and GIS is proposed with objectives to replace cumbersome primitive processes, to make accident data-collection and analysis more standardized, less error-prone and, therefore, more efficient. Under a proposed concept, the hand-held computers would play a major role in recording non-spatial data, while a main function of GPS is a spatial data collector. GIS would be a versatile database management tool for other tasks including data retrieval, data analysis, and information distribution. In order to demonstrate the proposed concept, the EMS data system in Khon Kaen City, Thailand, was selected as a case study. The development is potentially useful as it can offer a means to facilitate EMS data collection as well as explore the new dimension for EMS data analysis.

Key Words: Hand-held computers, GIS, GPS, Traffic Accident, EMS

1. INTRODUCTION

Over the last two decades, Thailand has been experiencing enormous changes in terms of economic development, urbanization, and vehicle ownership. The explosive growth of vehicle ownership and the mix of traffic have, combined with other changed factors, created significant road safety problems. Presently, more than 13,000 people were killed on the road every year. The economic losses were estimated at about US$ 2,380 million per year, which correspond to 2.55 percents of the GDP. Therefore, there is a need for systematic methods to plan, prevent, manage and engineer to problems. However, before any actions are made in dealing with accident situation, the first and most important resource needed is accident data. In Thailand, as same as other ASEAN countries, the absence of accident data is widely acknowledged. While data is limited but needed, it is important to develop the tools to collect the accident data effectively. Besides data acquisition issue, data analysis is another vital issue to be mentioned. Clarification of the current situation in terms of priorities and problem areas would provide the framework of knowledge against which policy decisions should be undertaken and countermeasures devised to the policy maker. To achieve this, efficient tools to analyze accident data are required.

Fortunately, several constantly developed technologies provide great opportunities to develop a working procedure to apply these technologies for the mentioned tasks. This paper, therefore, aims to propose a framework for an integration of three technologies; hand-held computers, the Global Positioning System (GPS), and the Geographic Information System (GIS), to facilitate accident data acquisition and analysis processes. Specific objectives are to replace cumbersome primitive processes, to make accident data-collection and analysis more standardized, less error-prone and, therefore, more efficient. To demonstrate the concept, the case study of the Emergency Medical Service (EMS) System, i.e. a system to arrange for emergency care to both trauma and non-trauma patients before arriving a hospital, was selected.

2. LITERATURE REVIEWS

This section reviews generic descriptions of the three technologies employed in this study: hand-held computers, GPS devices, and GIS system. An attempt is made to explain key functions used and discuss potential applications for each technology in areas of accident data acquisition and analysis.

2.1 Hand-held Computers

Recently, the popularity of hand-held devices, such as Palm-tops and Personal Digital Assistances (PDAs), has been growth significantly. They become a key technology in constructions, shipping, education, and especially in health care (Moore and Najafi, 2004). Because of the nature of work, in the developed countries, the use of hand-held computers to collect the data at the accident scene becomes popular for public safety agencies such as police, fire safety and ambulance services.

These pocket-sized computers share several features that make them well suit for the mobile professional (Embi, 2001). Being small, lightweight and durable, they are more likely to be carried around than a laptop computer. They turn on and off instantly, making it convenient for access the information they contain whenever it is needed (Embi, 2001). Most systems are controlled with a pen like stylus and have handwriting recognition software for entering text (Embi, 2001). Many also offer the ability to record voice, though voice recognition software is rarely available for some devices. Most hand-held computers have built-in software for managing personal information. Besides, the third-party applications can also be installed from the PC to the hand-held for any specific purposes through the synchronization process. The widely used operating systems are Microsoft Pocket PC (for Window CE) and Palm Operating System (for Palm-tops).

2.3 GPS Devices

Fully named as the NAVigation System using Time And Ranging (NAVSTAR) Global Positioning System, this system was initially developed in 1973 by the U.S. Department of Defense. The basic idea was to use trilateration to determine the location of a GPS receiver antenna using its distance from orbiting satellite vehicles (SVs) at a known time (Papacostas, 2000). GPS technology allows the user to establish, a very high degree of accuracy, their location in three dimensions anywhere on or above the surface of the earth. In 1994 the GPS system was declared to be fully operational. It consists of three major elements-- the space segment, the control segment, and the user segments. The user segment requires GPS receivers and software that use signals transmitted by each satellite to perform navigation, surveying, and other positioning tasks. The most common use of GPS in public safety is to locate mobile assets from a central control station. GPS also be useful in plotting maps of incident locations over time (Graettinger *et al.,* 2001).

The quick and accurate determination of geographic positioning offered by the GPS can enhance the development of GIS applications in various aspects. Successfully integrating GPS data with GIS is the key step in developing an operational data collection and data management system (Sun *et al.,* 1999). Significantly, it can greatly enhance the task of data collection relating to real-world objects served as an input into the GIS system.

2.2 GIS Systems

The geographic information system (GIS) is a system for management, analysis, and display of geographic knowledge, which is represented using a series of information sets such as maps and globes, geographic data sets, processing and work flow models, data models, and metadata (ESRI, 2004). A digital map created by GIS has points, which represent features on the map such as cities; lines that represent features such as roads; and small areas that represent features such as lakes. In order for GIS technology to be utilized, a significant amount of time must be dedicated to populating the GIS databases to provide the information that will be useful to perform analysis upon (Moore and Najafi, 2004).

GIS has a potential to improve efficiency of the accident database and analysis in several significant ways. It is proven to be a powerful tool for accident database, study, analysis as well as program development (Carreker *et al.*, 2002, Ruengsorn *et al.*, 2002, Mendoza *et al.*, 2001). In terms of economic, Hall *et al.* (2000) proved that GIS implementation offers the large benefits for accident analysis as well as application development.

3. AN INTEGRATION CONCEPT

As shown in Figure 1, basic components of an accident data system can be divided into two parts: field-based and office-based components. Recording and reporting accident occurrence at an accident scene are involved in the first part followed by the second part of data storage, data retrieval, data analysis, and information distribution. To facilitate the accident data system, this study proposed an integration of three core technologies, which are hand-held computers, GPS and GIS.

Under this framework, hand-held computers and GPS are used as a tool to collect data at an accident scene involving spatial and non-spatial data. At the scene, hand-held computers would play a major role in dealing with non-spatial data while GPS is mainly functioned as a spatial data collector. Software applications can be developed and programmed into the hand-held computers that not only collect data but also provide information to field users. In addition, other technologies such as imaging, software data extraction, high-speed data entry such as voice recognition system or bar code readers, when possible, could be incorporated as many as appropriate. After the non-spatial and spatial data are gathered, GIS would be a versatile database management tool for other tasks including data retrieval, data analysis, and information distribution.

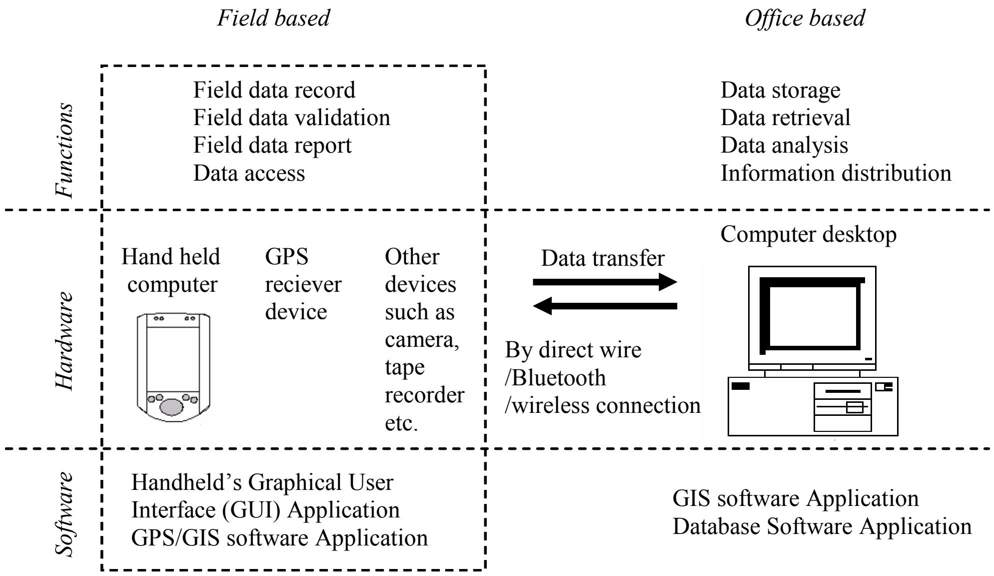


Figure1. The Proposed Accident Data System

Benefits of implementing the proposed framework should be measured by several key parameters such as an overall time reduction, user acceptance, quality of collected data, productivity, and profitability for both component levels and the entire system. The proposed concept can be applied for all accident-related agencies such as police authorities, insurance companies, road-related agencies, and public health agencies, where the collection, retention, analysis, or use of accident data are required.

4. CASE STUDY

In this section, the proposed integrated system is presented for a real world application of Emergency Medical Service (EMS) data system. A case study is performed for the EMS units located in the Khon Kaen Regional Hospital (KKH), Khon Kaen City, Thailand. An attempt is made to illustrate how the proposed concept can be used to improve the efficiency and effectiveness of the existing data system.

4.1 Background Information

Khon Kaen is a city located in the heart of the North-eastern Thailand, about 450 kilometers from Bangkok. The first EMS system in the provincial level was established in this province. The KKH, the biggest public hospital in the province, has set up their "EMS Unit" since 1994. In 2003, this unit handled 2666 cases involving both traffic accidents and other emergencies; about 60% of cases were traffic accidents. Figure 2 shows the number of emergency cases handled by this unit from 1996 through 2003.

For every ambulance trips, a paper-based report form is used to record general information of an operation as well as clinical information for every patients involved. Most of the recorded information are later keyed into the computerized database except descriptive information such as incident location, comments, etc., which were remained in handwritten form. As most of the data are well prepared in a digital format, non-spatial data analysis can be performed using any database software applications. Presently, based on this database, EMS operation performances are evaluated and reported on a yearly basis.

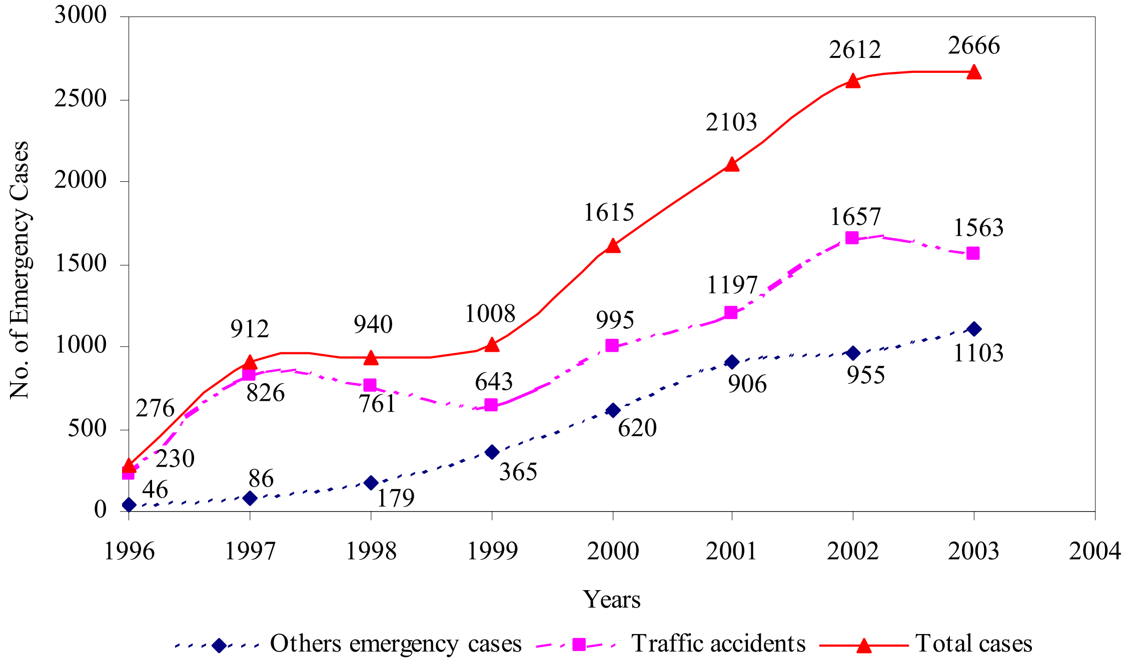


Figure 2. Emergency Cases Handled by the KKH during the Year 1996 to 2003

Although an existing data system is well established, there are still some areas of improvement that can be made to improve its efficiency. As there are large numbers of cases each year, one obvious task is to reduce the time to input data into the computerized database. In addition, as accident occurrences are spatially distributed in nature, relying only on information derived from existing non-spatial analyses may be insufficient to provide valuable insight and some important information may not be revealed. Therefore, the integration of technologies as proposed earlier might help to improve the efficiency of the existing data system.

4.2 Digital Report using Hand-held Computers and GPS Devices

To facilitate the field data collection, the digital version of EMS report form was proposed and developed. Software is designed to provide a friendly user interface with a capability for recording and validating accident data in order to minimize error and maximize efficiency of data input. Besides, GPS device is used to identify and report an exact latitude and longitude of incident occurrence locations.

4.2.1 Hardware and Software

Two-portable hardwares were utilized in this study including a hand-held computer, hp iPAQ Pocket PC h2210 series, which functioned as the non-spatial data collection device and GPS receiver, GARMIN GPS Map 76, providing positioning information. Software is developed on a PC computer and then installed onto a hand-held device. Applications are developed and tested on an emulation environment. This environment provides a virtual computer running Pocket PC software compiled for the desktop PC. Software development was performed using the Visual Basic language. Programming focuses on objects, such as figures on the screen, and events, such as touching or writing on the screen. It is designed to look for the event made by users and then makes appropriate responses (Ralph and Ellis, 1993). Data transfer between the hand-held computers and the PC computer is made by direct connection using USB cradle, Blue tooth, and wireless land connection.

4.2.2 Graphical User Interface (GUI) Design

For the demonstration, it was initially decided that only recording form to capture general information of accident occurrence would be converted to a digital format. The contents of this report form include the following categories:

- *General information*- Operation case ID, date, and source of call
- *Location of incident*- travel distance, zone, and dispatch location
- *Timing data*- call made, departure from hospital, arrival to site, departure from site, and arrival to hospital
- *Operator data*- operator ID, driver ID, and emergency medical technician (EMT) ID.
- *Scene Information*- number of patients found, and type of incident

To input the data, a form is used as an input interface. Data are entered on the form by touching a stylus on a screen or writing on provided spaces. The developed software provides several input mechanisms to help user to input data easily. These input mechanisms are buttons, check boxes, text boxes, combo boxes, and graphics. When a program is activated, the initial screen as shown in Figure 3 appears. Menu selections include new case, view/edit, and quit. Menu selections are made by touching the stylus to an appropriate on-screen button.

Figure 3. A Main Menu

Figure 4A illustrates the working screen when the ‘new case’ button is selected. As shown in the figure, the original report form was converted to a digital format requiring two screens to input the data. Data are entered on the forms by touching the stylus to the check box, touching the stylus to the selected items in the combo box, and writing on the screen. Although it is not possible to show all working screens in this paper, Figure 4 shows the general layouts as a representative of the complete application.

(A) (B)

Figure 4. Working Screens

4.3 GIS and Data Applications

Spatial and non-spatial data collected at a field are transferred into GIS at the office. GIS mapping applications will use location reference from GPS device to plot accidents into a map. Facts about accidents occurrence recorded by hand-held computers can be joined to their locations. By clicking on the digital map, circumstances of an accident, number of injured persons, and other related information can be shown automatically. As all data are prepared in a desired format, further spatial analyses of these data are possible.

However, as the proposed system is yet to be implemented, database application is demonstrated based on an existing EMS database. In this database, dispatch locations are remained in a descriptive format, on a paper file. As co-ordinates of dispatch locations do not existed, their locations must be manually located into the GIS map based on the recorded descriptive information such as the nearest landmark, kilometer pole number, and intersection name. The total of 995 traffic accident cases recorded in 2000 were used to demonstrate the system applications. Data screening process was performed to exclude the following cases: (1) occurred outside the study area, (2) no patient found at the accident site, and (3) have inadequate information to locate an accident location. Eventually, the total of 280 traffic accident cases were plotted into the GIS map and linked with other non-spatial data. From this step, although there are various applications can be done on this database, only two-selected applications are performed and illustrated in the following sub-sections.

4.3.1 Accident Density

Planning for proper proactive policies needs knowledge about EMS dispatch positions as well as the locations where emergency cases are often occurred. To achieve this, distribution and density of dispatch positions must be clarified first. Using GIS software abilities, not only spatial distribution of the dispatch locations (as shown by the cross marks in Figure 5) can be revealed, their spatial clusters can also be identified through 'the Kernel Density Estimation technique' (Schneider *et al.,* 2004).

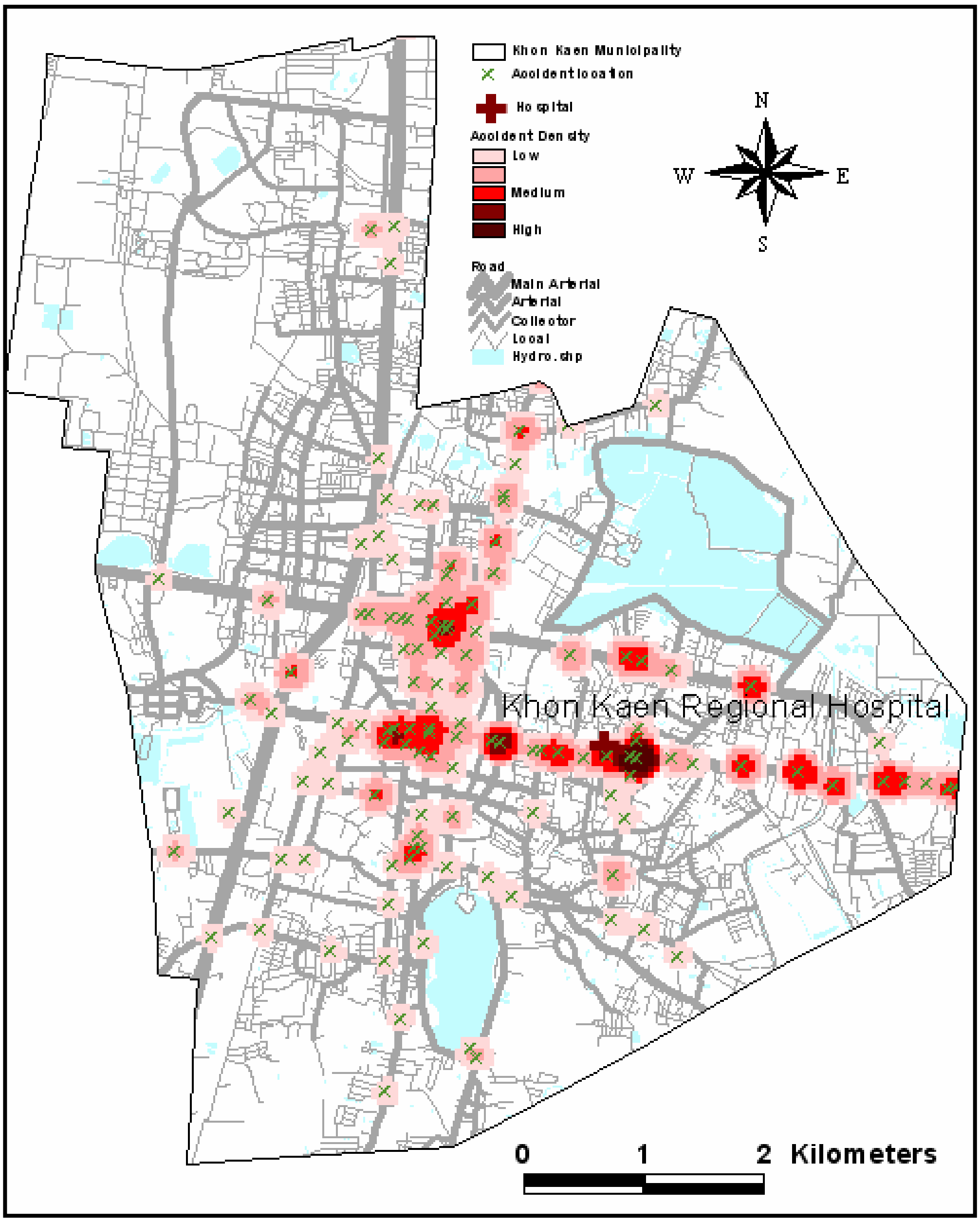


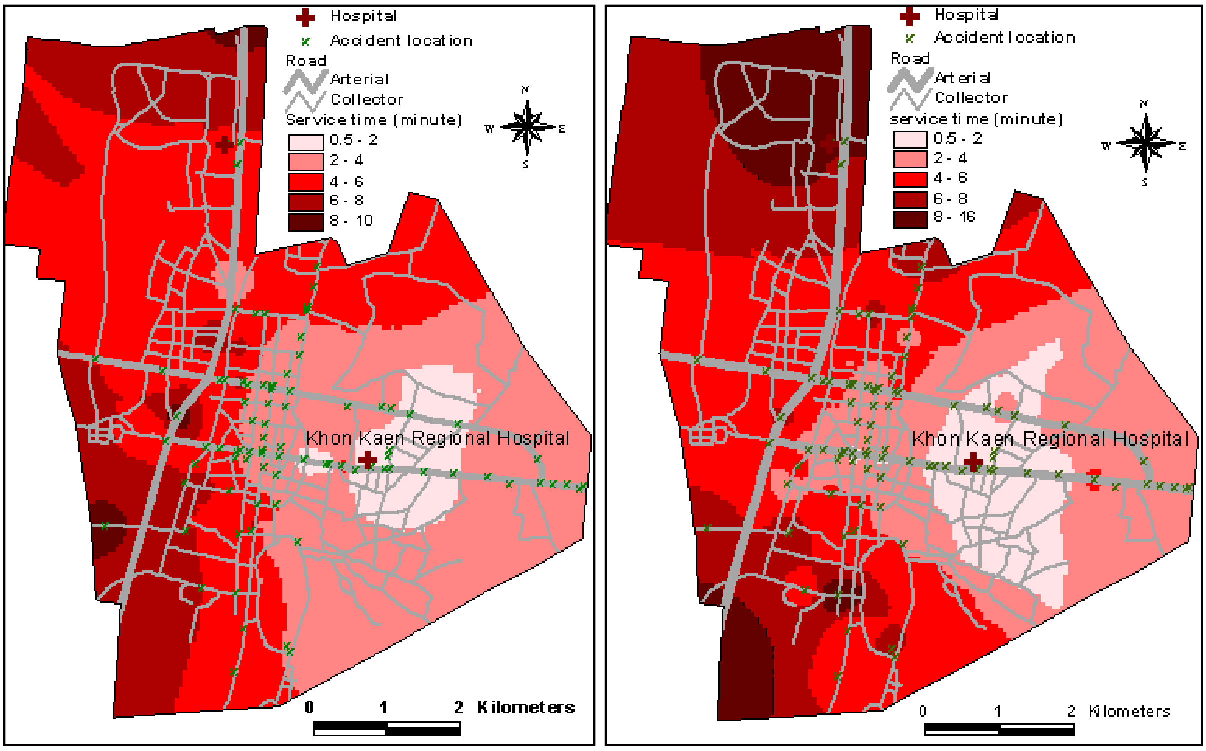
Figure 5. A Kernel Density Map of EMS Dispatch Locations

The dark areas of the kernel density map, as shown in Figure 5, present the high density of dispatch locations. This map can be compared with the actual accident occurrence locations recorded by other units such as the trauma registry or the police. This will allows the policy maker to plan for strategies to improve the service coverage in the future.

4.3.2 EMS Service Time Map

It is widely known that to reduce the severity of injuries of crash victims, timely treatment of road casualties is essential. Although the time that EMS spent to reach the sites depend on various factors such as travel distance, and traffic condition etc., however, it is quite important to have knowledge and understanding about the locations where the existing service cannot reach in a timely manner. If necessary, ambulance sub-stations may be required to provide the service for those areas.

Since all data are well prepared in the desired format, the surfaces represent time spent to reach the accident site can be calculated through the 'Interpolate Grid function' attached with GIS software. Surfaces are created from the time data of each dispatch location. Figure 6A and 6B show the time spent to reach the accident site when accidents occurred during the daytime and nighttime, respectively.



(A) Day Time (B) Night Time

Figure 6. EMS Service Time Maps

5. DISCUSSIONS AND FUTURE DIRECTIONS

As illustrated in the previous sections, for the fieldwork, the developed graphical user interface would ease data collection process. The developed digital report form would minimize error made during data input process and enable users to input more accurate data into their database system. This will reduce time spent transferring paper-based data into the digital format and therefore, result in the overall time reduction in data recording. However, implementation of the developed tool under the real scenarios in the near future would allow the software testing, measuring its practicability, profitability, and level of user acceptance. User comments and feedbacks will be very useful information for the software enhancement process. For the office works, the two demonstrated database applications obviously indicate that the ability to utilize meaningful spatial data is beneficial to provide the resources information for the policy makers. It is high hoping that the acquired information from this part will be helpful for implementing proactive policies to improve the emergency medical services in the future.

In summary, the integration of the three technologies has potential capabilities to eliminate the cumbersome primitive processes and replace time-consuming manual task in EMS data collection as well as explore the new dimension for EMS data analysis. This development is a significant progress for the improvement of the existing EMS data system in Thailand. Nonetheless, the concept can also be applied to other types of activities where the collection, retention, analysis, or uses of accident data are required. To achieve this, modifications and adjustments may be required at a component level. Furthermore, with the advancement and availability of technologies, potential improvement should be focused on the single unit that combined several features to provide the more practicable and convenience to the end users; therefore, increase the practicability of the developed system. Nonetheless, as the current commercial GPS units can optionally integrated the GIS software into one package with necessary hardware and software, GPS can be further utilized for other applications such as routing guidance, travel time and travel speed collection as well.

6. CONCLUSIONS

This research presents an initial framework of supportive tools for accident data collection and analysis process. Three core technologies including hand-held computers, GPS, and GIS, are integrated to provide such tools with objectives of improving acquisition, recording, field verification, transmission, storage and analysis of accident data. In order to demonstrate the proposed concept, the EMS data system in Khon Kaen City, Thailand, was selected as a case study. Under the proposed concept, hand-held computers would play its major role in dealing with non-spatial data while a main function of GPS is a spatial data collector. A computer package with a friendly user interface is developed and programmed into hand-held computers. The program has capabilities for data recording and data validating in order to minimize error and maximize efficiency of data input. After non-spatial and spatial data are gathered, GIS would be a versatile database management tool for other tasks including data retrieval, data analysis, and information distribution. This development is a significant progress for the improvement of the existing EMS data system in Thailand as it can offer capabilities to facilitate data collection process as well as explore the new dimension for data analysis. Nonetheless, the concept can also be applied to other types of activities where the collection, retention, analysis, or uses of accident data are required.

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