DEVELOPMENT OF GIS BASED TRAFFIC ACCIDENT DATABASE THROUGH TRAUMA MANAGEMENT SYSTEM: THE DEVELOPING COUNTRIES EXPERIENCES, A CASE STUDY OF KHON KAEN, THAILAND

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Abstract: This paper established the GIS road accident database for the selected study area, Khon Kaen Municipality, Thailand. The uniqueness of this database is that it made systematical use of the hospital's trauma data to develop the needed accident database system. This alternative source of traffic accident data with some modifications together with traffic engineering knowledge can be used to analyze traffic accident situations particularly in identifying hazardous locations. Furthermore, the GIS concept was incorporated in the development of this database to alleviate tedious tasks of coding accident location by using existing road locational referencing scheme. Any accident occurrence can be simply located on a large-scale digital map composed of well-prepared road database and well-known landmark information.

Key Words: Traffic Accident, Trauma Management, GIS, Thailand

1 INTRODUCTION

Road accident is one of the major problems for most communities in developing countries which requires serious attention in searching for preventive measures to minimize this problem. To achieve the sustainable community road accident prevention, an accident database must be firstly established. Unfortunately, most developing countries are facing the similar problem that traffic accident data are just merely statistics which will not lead to further analyses and detailed study. Lack of accident database leads to the difficulty in searching for proper measures and is the major hindrance to create effective management of road accidents for communities. This research aims to solve this problem by establishing the GIS road accident database for the selected study area, Khon Kaen Municipality, Thailand. It intends to make systematical use of the hospital's injury surveillance data, which is a part of the National Trauma Management System in developing the needed accident database system. The ultimate aim of this research is to encourage the multi-disciplinary professionals such as engineers and medical personnel to co-develop the road accident database system and to be used as a prototype for community uses.

2 STUDY AREA

Khon Kaen Province as a development center of the northeastern part of Thailand and is considered to be a capital of the Northeast Region of the country. It is located about 450 km from Bangkok. The province has a total area of 10,886 km^2 with the 1999 population of 1,747,700. In 1998, a total of 439,900 vehicles were registered in Khon Kaen of which 73% were motorcycles.

3 DEVELOPMENT OF GIS BASED ACCIDENT DATABASE SYSTEM IN KHON KAEN

Although, this paper developed the traffic accident database system using Khon Kaen as a case study, its ultimate aim is to set up a prototype GIS based database system. The main objective is focused on making use of trauma registry of the Khon Kaen Regional Hospital. Modification of the existing trauma data in particular the traffic accident record form as well as the hospital's injury surveillance report form were recommended to achieve the desired objectives as well as to set up a prototype for other hospitals to follow. In addition, GIS concept was applied to assist in recording accident locations through the developed digital map of Khon Kaen municipal area. Eventually, all information are stored and can be retrieved as well as the visualization of any accident location through the application of GIS. Finally, all analyses can be well presented particularly the identification of hazardous locations in Khon Kaen. These identified hazardous locations in either intersections and/or sections of any streets can also be visualized through GIS concept. Counter measures to solve or minimize these accident problems can then be made and implemented.

The following sub-sections describe the development of this GIS based traffic accident database system.

3.1 Sequence of Activities in Utilizing Hospital Data

It is believe that this research is the first of its kind to utilize the hospital's trauma registry for traffic accident analysis in Thailand. Therefore, it is essential to describe the sequence of activities employed in this paper. For the better understanding of hospital related accident activities, experiences of the Trauma Registry Program conducted by the Khon Kaen Regional Hospital (KKH) are described briefly as follows:

The KKH is a pioneer hospital in Thailand which established its own Trauma Registry Program since 1989 with the intentions to prepare resources for further hospital cares, trauma audit, accident analyses and propose preventive measures, etc. The KKH has also prepared the computerized trauma database for this registry program. It contains general information, diagnosis data, and results of treatments for all accident patients (Sriwiwat, et.al, 1999).

In 1995, the Ministry of Public Health started to establish the national trauma registry program. This program was called "Injury Surveillance or IS" and this program was later revised in 1997. Presently, IS is a part of the National Trauma Management System and the KKH also uses the IS as a part of its trauma registry. To process the IS database, hospital staff would collect each trauma patient's information and record these information in the IS report form. Later, these information were coded and processed by using the IS database program produced and provided by the Medical Institute of Accident and Disaster (MIAD, 1997). In

case of traffic accident patients, prior to the modifications as recommended by this research, the KKH had collected additional data for traffic accidents cases by recording in its own developed "Accident Report" Form. This accident report form contains information on descriptive location of each accident occurrence and factors affecting accidents. The KKH also attempted to link these additional accident information to the IS database by employing certain indices such as Hospital Number (HN) and accident occurrence dates. However, there are shortcomings regarding these practices. First, the complexity of record linkages between traffic accident and IS records did exist since there was not any specific accident ID. Secondly, accident locations recorded in the accident report form can be misleading as some locational references are not widely recognized. To overcome these mentioned problems and to simplify the traffic accident data collection procedure, this paper re-organized and re-designed the sequence of activities in hospital related traffic accident database system as depicted in Figure 1.

Detail procedures consisted of the following steps. Once an accident occurs and accident patients arrive to the Emergency Room (ER). While in the ER, hospital staff have to obtain all necessary information from either patients themselves, or relatives who accompany patients or senders such as ambulance personnel, etc. Then, the hospital staff must assign the specific accident ID for these patients in both Accident Report and IS forms. To assign the accident ID, this paper proposed the revised Accident Report form as shown in Figure 2 for assisting hospital staff to group all patients involved in a same accident case since the accident ID must be specific for each accident case. This would ensure the correct record especially if any accident case that involved more than one patient. Previously, information only indicated the number of patients and number of accidents but cannot identify number of victims involved in one particular case.

3.2 The Proposed Report Forms

The proposed revised accident report form as shown in Figure 2 was developed by considering the ability of hospital staff to gather accident information. Certain important information for accident analysis such as causes of accident and property damages are not included in this report due to the fact that these information require site investigation. In addition, other implicit data such as alcohol consumption, etc. are not included as these can be obtained and retrieved from the IS form.

Regarding the IS Report Form, as the IS database should be consistent since it was adopted as the national trauma database, thus the main data structure would remain the same. Only the addition of data fields was recommended in this paper. This added Accident ID field can be used as an index for retrieving the severity of accident victims. The modified IS report form is depicted in Figure 3.

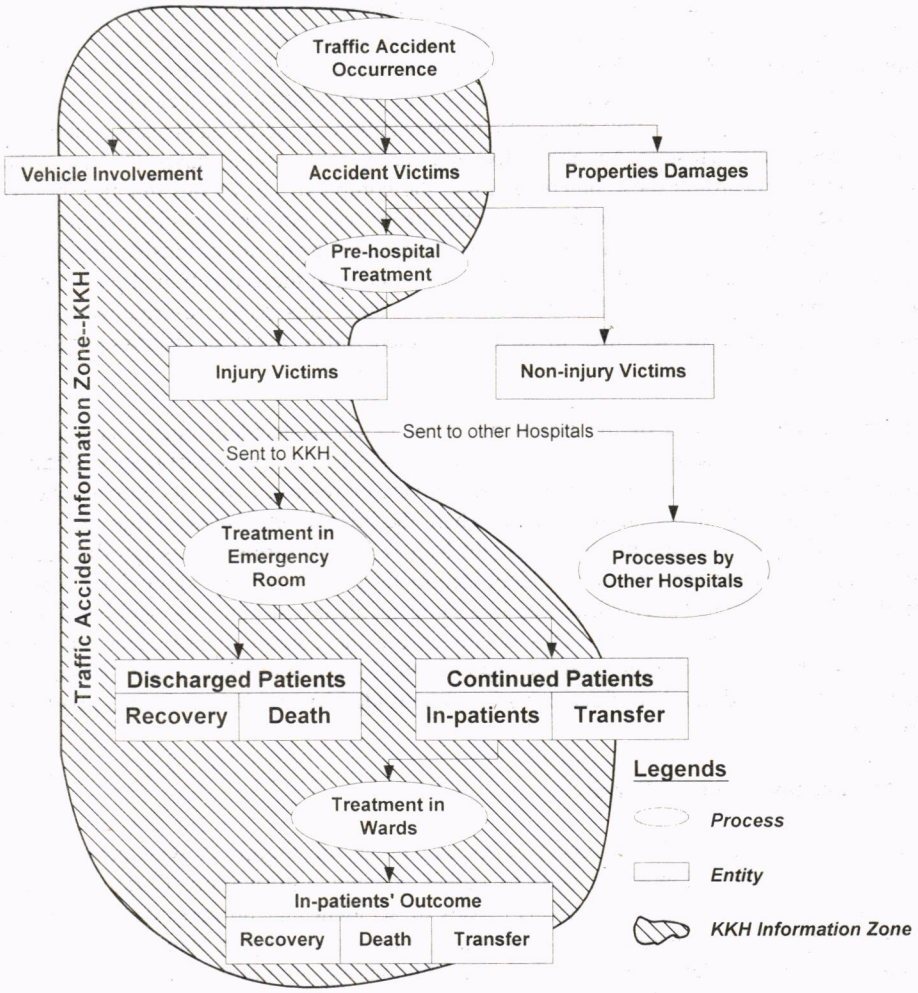
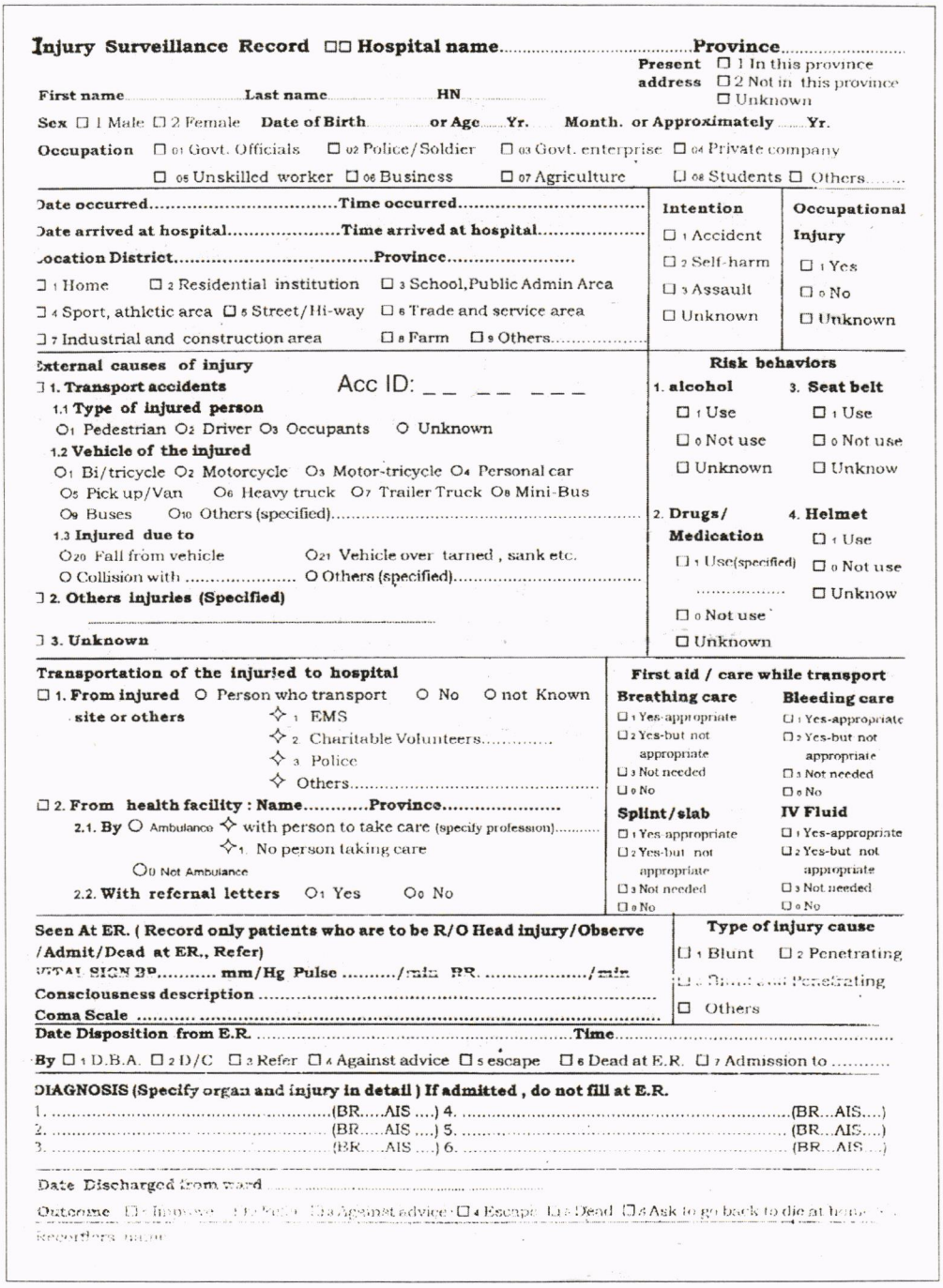


Figure 1 Sequence of Activities in the Hospital Related Traffic Accident Data System

No..... Accident ID #3 ___ ___ ___ ___ Date ...../...../..... Time ...... : ..... Recorder		
Location	Environment	Patient/HN
Name	Climate	1.
Landmark	(1) Fine (2) Foggy (3) Dust (4) Rainy (5) Unknown	2.
.....	Light	3.
Location Type	(1) Day light (2) Dark/Non (3) Dark/Proper street light	4.
(1) Road (2) Intersection (3) Ent/Exit	(4) Dark/improper street light (5) Unknown	5.
(4) Opening island (5) Bridge	Pavement	6.
(6) Railway crossing (7) Footpath	(1) Dry (2) Wet (3) Dirty (4) Crack (5) Hole (6) Unknown	7.
(8) Pedestrian crossing (9) Parking	Work zone	
	(1) No (2) Yes/careless driving (3) Yes/no warning sign (4) Unknown	

Figure 2 Revised Traffic Accident Report Form



Injury Surveillance Record ☐☐ **Hospital name**.....**Province**.....

Present address ☐ 1 In this province ☐ 2 Not in this province ☐ Unknown

First name.....**Last name**.....**HN**.....

Sex ☐ 1 Male ☐ 2 Female **Date of Birth**.....**or Age**.....**Yr.** **Month. or Approximately**.....**Yr.**

Occupation ☐ 01 Govt. Officials ☐ 02 Police/Soldier ☐ 03 Govt. enterprise ☐ 04 Private company ☐ 05 Unskilled worker ☐ 06 Business ☐ 07 Agriculture ☐ 08 Students ☐ Others.....

Date occurred.....**Time occurred**.....

Date arrived at hospital.....**Time arrived at hospital**.....

Location District.....**Province**.....

☐ 1 Home ☐ 2 Residential institution ☐ 3 School,Public Admin Area

☐ 4 Sport, athletic area ☐ 5 Street/Hi-way ☐ 6 Trade and service area

☐ 7 Industrial and construction area ☐ 8 Farm ☐ 9 Others.....

Intention
☐ 1 Accident
☐ 2 Self-harm
☐ 3 Assault
☐ Unknown

Occupational Injury
☐ 1 Yes
☐ 0 No
☐ Unknown

External causes of injury

☐ **1. Transport accidents** Acc ID: _ _ _ _ _ _ _

1.1 Type of injured person

O1 Pedestrian O2 Driver O3 Occupants O Unknown

1.2 Vehicle of the injured

O1 Bi/tricycle O2 Motorcycle O3 Motor-tricycle O4 Personal car
O5 Pick up/Van O6 Heavy truck O7 Trailer Truck O8 Mini-Bus
O9 Buses O10 Others (specified).....

1.3 Injured due to

O20 Fall from vehicle O21 Vehicle over turned , sank etc.
O Collision with ..... O Others (specified).....

☐ **2. Others injuries (Specified)**

.....

☐ **3. Unknown**

Risk behaviors

1. alcohol
☐ 1 Use
☐ 0 Not use
☐ Unknown

2. Drugs/ Medication
☐ 1 Use(specified) .....
☐ 0 Not use
☐ Unknown

3. Seat belt
☐ 1 Use
☐ 0 Not use
☐ Unknow

4. Helmet
☐ 1 Use
☐ 0 Not use
☐ Unknow

Transportation of the injuried to hospital

☐ **1. From injured site or others** O Person who transport O No O not Known
- ✧ 1 EMS
- ✧ 2 Charitable Volunteers.....
- ✧ 3 Police
- ✧ Others.....

☐ **2. From health facility : Name**.....**Province**.....

2.1. By O Ambulance ✧ with person to take care (specify profession).....
✧1 No person taking care
O0 Not Ambulance

2.2. With refernal letters O1 Yes O0 No

First aid / care while transport

Breathing care
☐ 1 Yes-appropriate
☐ 2 Yes-but not appropriate
☐ 3 Not needed
☐ 0 No

Bleeding care
☐ 1 Yes-appropriate
☐ 2 Yes-but not appropriate
☐ 3 Not needed
☐ 0 No

Splint/slab
☐ 1 Yes-appropriate
☐ 2 Yes-but not appropriate
☐ 3 Not needed
☐ 0 No

IV Fluid
☐ 1 Yes-appropriate
☐ 2 Yes-but not appropriate
☐ 3 Not needed
☐ 0 No

Seen At ER. (Record only patients who are to be R/O Head injury/Observe /Admit/Dead at ER., Refer)

VITAL SIGN BP..... **mm/Hg Pulse** ...../min **RR**...../min

Consciousness description .....

Coma Scale .....

Type of injury cause
☐ 1 Blunt ☐ 2 Penetrating
☐ 3 Blunt and Penetrating
☐ Others

Date Disposition from E.R. .....**Time**.....

By ☐ 1 D.B.A. ☐ 2 D/C ☐ 3 Refer ☐ 4 Against advice ☐ 5 escape ☐ 6 Dead at E.R. ☐ 7 Admission to .....

DIAGNOSIS (Specify organ and injury in detail) If admitted , do not fill at E.R.

1. .....(BR.....AIS ....) 4. .....(BR...AIS....)
2. .....(BR.....AIS ....) 5. .....(BR...AIS....)
3. .....(BR.....AIS ....) 6. .....(BR...AIS....)

Date Discharged from ward .....

Outcome ☐ 1 Improve ☐ 2 Refer ☐ 3 Against advice ☐ 4 Escape ☐ 5 Dead ☐ 6 Ask to go back to die at home

Recorders name

Figure 3 Modified Injury Surveillance Report Form

3.3 Base Map

To assist in locating and recording the accident locations, the large-scale digital map (1:10,000) was set up to achieve the following desired objectives:

- Facilitate the data recording process. Generally speaking, those hospital staff who are assigned to record the accident information are not familiar with road locational referencing scheme. Design of GIS application must provide visualization mode to locate each accident location easily.
- Facilitate IS data retrieving process for further accident analysis.
- Facilitate an attractive presentation of accident results such as hazardous locations, etc. in order to create awareness of traffic safety to local community.

With these desired objectives, the base map consisted of ROAD theme and other reference themes such as BUILDING, RECREATION AREAS, EDUCATIONAL PLACES, RELIGIOUS PLACES, COMMUNITY AREAS, INFRASTRUCTURE FACILITIES, WIDELY KNOWN TOPOGRAPHY, etc. At present, the developed base map as shown in Figure 4 was printed on A0 paper size (scale 1:10,000) and posted on the wall in the Emergency Room of the KKH to facilitate the accident data recording system.

3.4 Locational Referencing Scheme

There are various methods of road locational referencing schemes but the most popular schemes are road name, mile post, control section, and nodes-links referencing systems (Faghri and Raman, 1995). Each method has its inherent advantages and disadvantages. The evident disadvantage of those existing road locational schemes is the difficulty in coding with too many digits of location ID. Thus, this research has developed an instant location recognition technique on GIS for any users to locate the accident locations easily. This is called "Link Recognition Technique (LRT)".

3.4.1 Link Recognition Technique

The Link Recognition Technique or LRT represents roads a line features as shown in Figure 5. Each line represents geography of a uniform road-section, which can be classified as section, intersection, roundabout, railroad crossing, etc., depending on its data attributes. The LRT has more advantages to obtain geometric and attributes properties of any road whether it is classified as a section or as an intersection, which could not be retrieved on nodes-links method. The LRT enables users to input data visually, e.g. locating accident location by mouse or digitizer as employed in this developed database system.

Figure 4 Study Area Map—KhonKaen Municipality

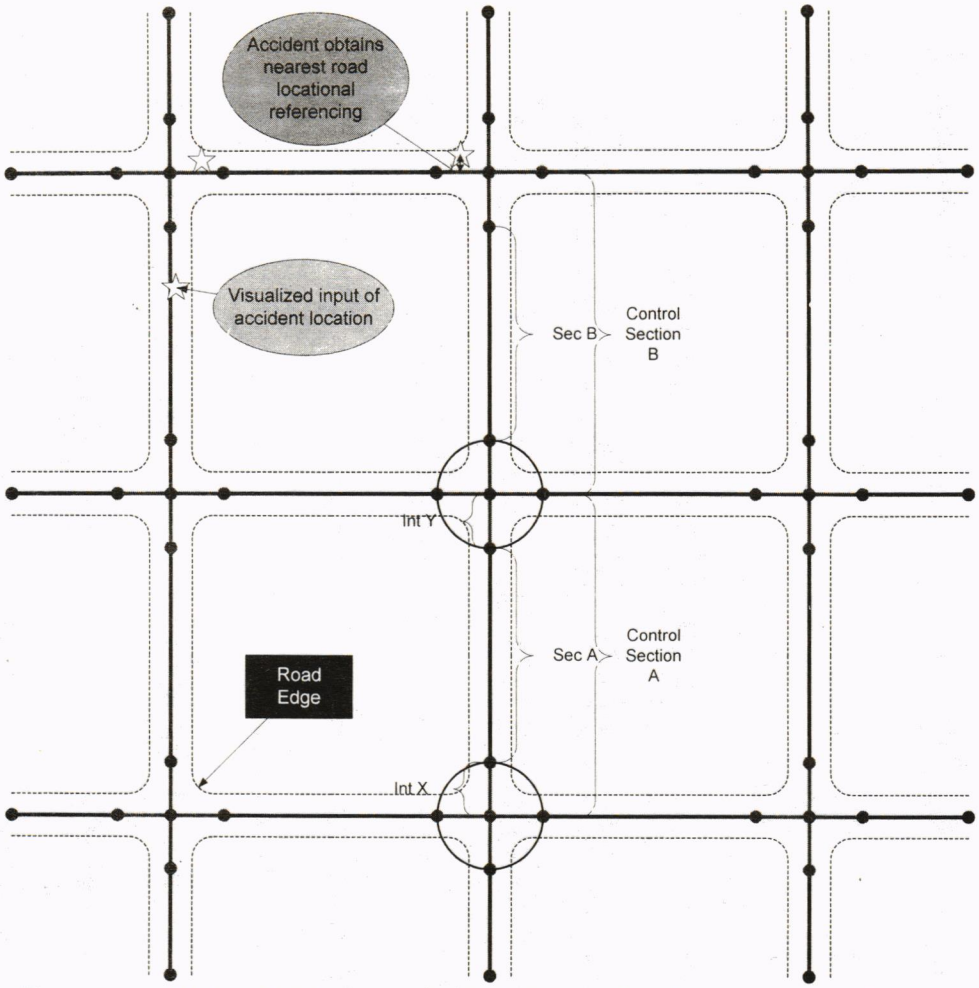


Figure 5 Model of Link Recognition Technique for Accident Locational Referencing

4 SEVERITY MEASUREMENT BASED ON INTENSIVE MEDICAL DATA

The significance of measuring accident severity is sensitive for road accident studies. Reliable severity levels of accident victims should be rated by medical professionals. This paper employed a medical mortality rate for trauma victims to measure accident severity. The medical mortality rate used in this paper is the probability of survival (PS) from TRISS Methodology.

4.1 Probability of Survival

The widely used technique—TRISS Methodology (Champion et.al., 1991) is used to evaluate probability of survival (PS) for patients involved with single or multiple body-region injuries by a logistic model as shown in Equations 1 and 2.

$$PS_j = \frac{1}{1+e^{-Z_j}} \quad (1)$$

$$Z_j = b_0 + b_1(RTS_j) + b_2(ISS_j) + b_2(AGE_j) \quad (2)$$

where,

PS_j = Probability of Survival of patient j^{th}
RTS_j = Revised Trauma Score of patient j^{th}
ISS_j = Injury Severity Score of patient j^{th}
AGE_j = 0 if patient age < 55, AGE_j = 1 otherwise
b_i = TRISS weights, i = 0, 1, 2, 3

The TRISS weights as shown in Table 1 was derived by applied Walker-Duncan regression algorithm (Walker Duncan, 1967)

Table 1 TRISS Probability of Survival Weights

Injury Type	b_0	b_1(RTS)	b_2(ISS)	b_3(Age)
Blunt	-1.2470	0.9544	-0.0768	-1.9052
Penetrating	-0.6029	1.1430	-0.1516	-2.6676

Source: Champion et al. (1989)

The Revised Trauma Score (RTS) is a physiological scoring system. It was calculated from the set of data which consisted of the Glasgow Coma Scale (GCS), Systolic Blood Pressure (SBP), and Respiratory Rate (RR). The RTS's values ranges from 0 to 7.8408. Higher values indicate better prognosis.

The Glasgow Coma Scale (GCS) is a widely used index to evaluate the degree of coma for patients with craniocerebral injuries. It can be used to evaluate brain function, brain damage, and patient progress. Measurement of CGS is summation of scores of three behavioral responses: eye opening, verbal response, and motor response. The CGS is ranged from 3 to 15. Higher scores indicate increased consciousness.

The Injury Severity Score (ISS) is a rating method for multiple organ injuries. ISS is based on the Abbreviate Injury Scale (AIS) scores but considers only the three highest body regions among the six injuries body regions of—head and neck, face, thorax, abdomen and pelvic contents, extremities, and external by summing the squares of these 3 highest AIS scores. AIS has 6 scores ranging from AIS-1 to AIS-6, the highest level (AIS-6) indicated the most serious injury. While the ISS values range from 1 to 75 but if the patient has an AIS-6 injury, the ISS value is set to 75 automatically (Mcdermott, 1992).

4.2 Accident Severity Rate

Accident severity rate (ASR) is an exposure measurement, which is an average of accident victims' losses per exposure unit. The ASR is defined as follows:

$$ASR_i = \frac{\sum_{j=1}^{k_i}(1-PS_{ij})}{V_i} \quad (3)$$

where,

ASR_i = Accident Severity Rate for k victims at location i
PS_{ij} = Probability of Survival of patient j^{th} involved accidents at location i
V_i = Exposure base of location i

5 IDENTIFICATION OF HAZARDOUS LOCATIONS

Identification of hazardous locations is one of the application modules contained in the developed traffic accident database system. Hazardous locations are classified into two categories: intersection and road-section. However, this paper presented only the hazardous roads in Khon Kaen. The Rate Quality Control Method, RQCM (Zegeer, 1982) was used to calculate the critical value of Accident Severity Rate. The critical value of ASR is defined as follows:

$$ASR_{ic} = \lambda_0 + k\sqrt{\frac{\lambda_0}{V_i} + \frac{1}{2V_i}} \quad (4)$$

where,

ASR_{ic} = Critical value of Accident Severity Rate for location i
λ_0 = Average Accident Severity Rates of all locations
k = Value of statistical distribution for one-tail test with a certain significant level
V_i = Exposure base for location i

A location can be evaluated either normal or hazardous by comparing observed and critical value of Accident Severity Rates. A location with an observed ASR greater than or equal to a critical value of ASR is classified as a hazardous location. Conversely, a location with an observed ASR less than a critical value of ASR is classified as a normal section. In this paper, the observed ASR values were calculated by using the previous defined ASR equation, Equation 3. On the other hand, V_i values were travel volumes in veh-km.

To demonstrate the real world application of this developed traffic database system, this paper obtained the 8 months accident data during May 2000 to December 2000 from the KKH's trauma database. During this 8-months period, there were 1,283 accident cases which involved 1,634 victims of which 17 persons were deaths. Simultaneously, during this same 8-months period, travel volumes were also observed in the municipal of Khon Kaen. Data were obtained from the Department of Highways and the Expressway and Rapid Transit Authority of Thailand. In addition, this paper also employed several manual volume counts at certain locations to verify the obtained volumes from these two organizations.

For analysis of road sections, this paper divided the entire road networks in Khon Kaen Municipal Area into 257 road sections. The sections are divided based mainly on their links between intersections. As for the 8-months obtained data, it was found that traffic accidents occurred along only 147 road-sections. Further analyses also revealed that out of these 147 road sections, 12 sections are classified as hazardous road sections. Locations of these 12 sections are displayed as shown in
Figure 6 and the sample calculations are presented as shown in Table 2. In addition, detail descriptions of these sections as well as their characteristics together with their pictures which have been stored in the developed database can be viewed as presented in Table 3.

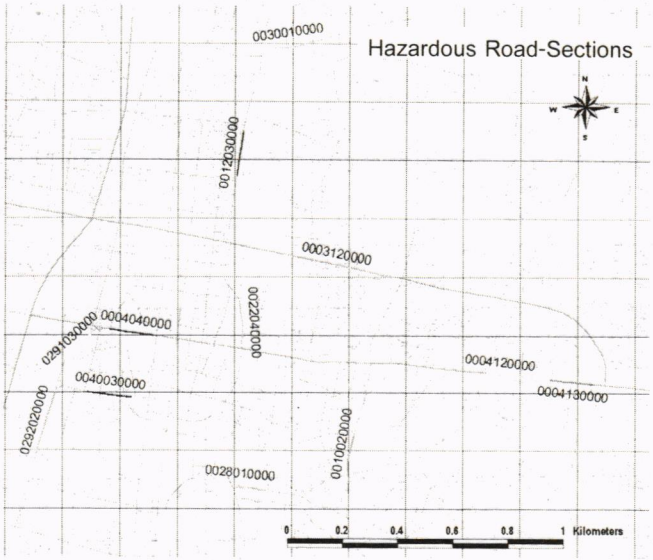


Figure 6 Locations of Hazardous Road-Sections

CONCLUSIONS

This paper presents the development of the GIS based traffic accident database system in Khon Kaen, Thailand. This database is unique in the sense that it was based on the well-developed trauma data of al local hospital. This alternative source of traffic accident data with some modifications together with traffic engineering knowledges can be used to analyze traffic accident situations particularly in identifying hazardous locations. Furthermore, the GIS concept was incorporated in the development of this database to alleviate tedious tasks of coding accident location by using existing road locational referencing scheme. Any accident occurrence can be simply located on a large-scale digital map composed of well-prepared road database and well-known landmark information.

Table 2 Sample Calculations of Hazardous Road Sections

IDSection	Name	From	To	L (km)	ADT (vpd)	N	F	I	A	B	C	D	Result
0001020000	Highway No. 2	Macro	LhaoNaDee	0.993	49,045	5	0	6	0.0134	1.19	11.28	760.53	N
0001030000	Highway No. 2	LhaoNaDee	BanKok	0.370	57,653	1	0	1	0.0021	0.52	4.07	781.81	N
0001040000	Highway No. 2	BanKok	Sreechan	0.909	67,384	24	0	29	0.0813	1.49	54.57	756.06	N
0003070000	PrachaSamosorn Rd.	Thepharak	NhaMueng	0.362	19,875	14	0	18	0.0490	0.18	279.69	827.85	N
0003080000	PrachaSamosorn Rd.	NhaMueng	KlangMueng	0.124	18,854	7	0	7	0.0155	0.06	272.58	913.57	N
0003090000	PrachaSamosorn Rd.	KlangMueng	LhangMueng	0.141	18,636	2	0	2	0.0048	0.06	74.47	901.88	N
0003100000	PrachaSamosorn Rd.	LhangMueng	KasikornTungSang	0.047	18,636	1	0	1	0.0021	0.02	98.34	1044.22	N
0003110000	PrachaSamosorn Rd.	KasikornTungSang	KhlongRongMueng	0.403	16,178	5	0	5	0.0131	0.16	82.54	833.56	N
0003120000	PrachaSamosorn Rd.	KhlongRongMueng	ChataPhadung	1.031	16,178	32	1	41	1.3255	0.41	3265.75	790.07	H
0004010000	SreeChan Rd.	Experimental Paddy Field	Mittaphap	0.281	7,793	4	0	4	0.0119	0.05	222.84	920.10	N
0004030000	SreeChan Rd.	Rail Track	Thepharak	0.102	19,346	5	0	6	0.0134	0.05	279.83	931.58	N
0004040000	SreeChan Rd.	Thepharak	NhaMueng	0.372	17,645	13	1	17	1.1392	0.16	7123.18	833.04	H
0004060000	SreeChan Rd.	KlangMueng	LhangMueng	0.152	14,876	4	0	4	0.0090	0.06	163.29	916.82	N
0004070000	SreeChan Rd.	LhangMueng	RopMueng	0.280	14,695	27	0	33	0.0752	0.10	751.35	864.06	N
0004080000	SreeChan Rd.	RopMueng	KhlongRongMueng	0.121	20,795	9	0	11	0.0239	0.06	389.96	905.93	N
0004090000	SreeChan Rd.	KhlongRongMueng	Anamai	0.146	20,795	11	0	16	0.0358	0.07	484.73	888.82	N
0004100000	SreeChan Rd.	Anamai	ChataPhadung	0.700	17,444	52	0	66	0.1601	0.30	539.11	802.23	N
0004110000	SreeChan Rd.	ChataPhadung	Khon Kaen DOH	0.962	17,444	31	1	40	0.1918	0.41	469.83	789.87	N
0004120000	SreeChan Rd.	Khon Kaen DOH	KhlongChonlaprathan	0.566	17,444	44	2	54	1.2633	0.24	5259.48	811.69	H
0004130000	SreeChan Rd.	KhlongChonlaprathan	PrachaSamosorn	0.374	17,444	23	3	28	2.3539	0.16	14838.03	833.51	H
0010020000	ChataPhadung Rd.	Chaiyapruk	Kanlaya	0.311	5,277	17	0	19	0.0425	0.04	1063.69	952.95	H
0012030000	KasikornTungSang Rd.	SoonRatchakarn	LhangSoonRatchakarn	0.388	21,410	6	0	10	0.2368	0.20	1171.84	820.22	H
0022040000	Robmueng Rd.	Sreechan	Ammart	0.363	6,375	4	0	6	0.2320	0.06	4115.31	914.30	H
0028010000	Phothisarn Rd.	Ropbung	Anamai	0.246	4,562	10	0	14	0.0344	0.03	1262.90	1005.20	H
0030010000	RatKhanung Rd.	KasikornTungsang	SreePhatcharin Ent.	0.419	2,156	7	0	8	0.0511	0.02	2324.69	1039.81	H
0040030000	Runrom Rd.	PrachaSamran	Runrom	0.377	5,455	16	0	20	0.8097	0.05	16163.95	926.71	H
0291030000	DarunSamran Rd.	SanLhakmueng	Rotfai	0.278	4,987	8	0	10	0.0379	0.03	1122.08	974.62	H
0292020000	Rotfai Rd.	Railway Station	NhongWat	0.566	5,896	4	1	6	0.8974	0.08	11043.90	880.53	H
.....	.....	.....	.....	.....	.....	...	.....	.....	.....	.....	.....	.....	.....
Total/Av.				54.228		790	10	971	10.8966	21.08	719.57		

Remark: N = No. of accidents F = No. of fatalities I = No. of injuries
A = Summation of 1-PS (fatality equivalence) B = Vehicle exposure unit (10^7 vehicle-kilometer)
C = Accident Severity Rate (10^3 fatality equivalence per 10^7 vehicle-kilometer)
D = Critical value of Accident Severity Rate (10^3 fatality equivalence per 10^7 vehicle-kilometer)

Table 3 Hazardous Road Sections

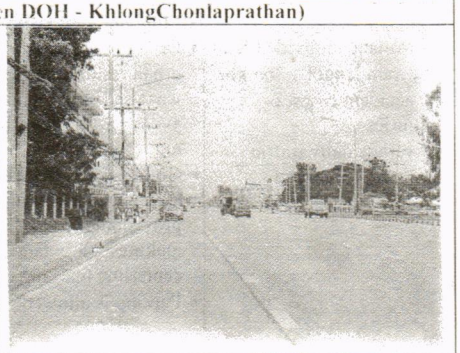
Section Characteristics	Descriptions of Roads Sections	Photo
ID: 0003120000 (PrachaSamosorn Rd.: KhlongRongMueng – ChataPhadung)		
• Four-lane undivided highway • Section length 1.031 kms • 32 accident cases, 41 injuries, 1 fatality • Average daily traffic volume 16,178 vpd	• By-passed highway. • Lane width of this road section is narrower than other sections due to ROW limitation. • Outer lanes are difficult to travel and may cause accidents since manholes' steel screens exist on pavement surface. • Parking is not allowed. • Many skewed connecting road.	
ID: 0004040000 (SreeChan Rd.:Thepharak – NhaMueng)		
• Four-lane undivided road • Section length 0.372 km • 13 accident cases, 17 injuries, 1 fatality • Average daily traffic volume 17,645 vpd	• This road-section is an urban arterial. • Outer lanes are difficult to travel and may cause accidents especially motorcycles since manholes' steel screens exist on pavement surface. • Only centerline marking • On-street parking is partially allowed.	
ID: 0004120000 (SreeChan Rd.: Khon Kaen DOH - KhlongChonlaprathan)		
• Eight-lane divided highway • Section length 0.566 km • 44 accident cases, 54 injuries, 2 fatalities • Average daily traffic volume 17,444 vpd •	• This road-section is a national highway. • Mixed traffics with fast travel speed • One side of section is community area and another side is an academic institution. • Many connecting roads on both sides • Many U-turns exist along the route. • On-street parking is allowed.	
ID: 0004130000 (SreeChan Rd.: KhlongChonlaprathan - PrachaSamosorn)		
• Eight-lane divided highway • Section length 0.374 km • 23 accident cases, 28 injuries, 3 fatalities • Average daily traffic volume 17,444 vpd	• This road-section is a national highway passed through communities. • Mixed traffics with fast travel speed • Many connecting roads on both sides • Many U-turns exist along the route. • On-street parking is allowed.	

Table 3 (Continued) Hazardous Road Sections

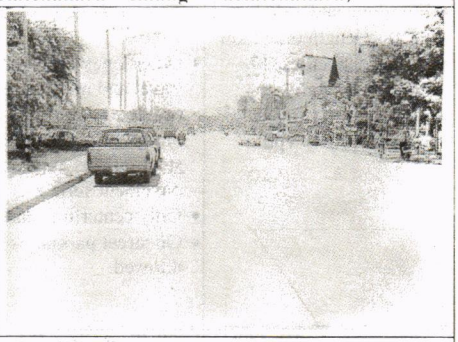
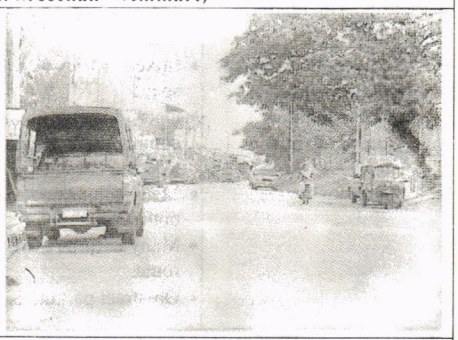
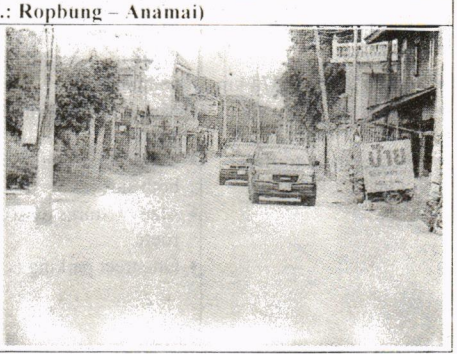
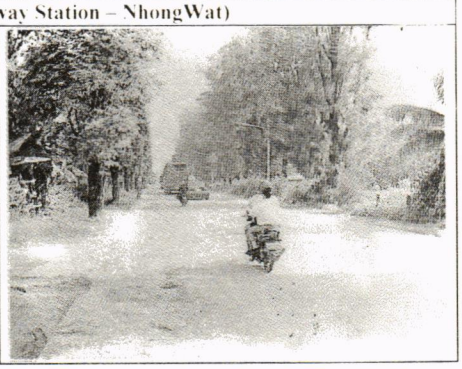
Section Characteristics	Descriptions of Roads Sections	Photo
ID: 0010020000 (ChataPhadung Rd.: Chaiyapruk – Kanlaya)		
• Four-lane undivided road • Section length 0.311 km • 17 accident cases, 19 injuries • Average daily traffic volume 5,277 vpd	• This road-section is an urban road connecting between commercial area and residential area. • Good pavement surface as well as roadway width leads high-speed travelling • No proper signs and markings only centerline marking exists. • Narrow footpath. • Manholes' steel screens exist on pavement surface.	
ID: 0012030000 (KasikornTungSang Rd.: SoonRatchakarn – LhangSoonRatchakarn)		
• Four-lane undivided road • Section length 0.388 km • 6 accident cases, 10 injuries • Average daily traffic volume 21,410 vpd	• Urban road connecting between urban area and suburban area. • Good pavement surface leads high-speed travelling • No proper signs and makings only centerline marking exists. • Parking is allowed.	
ID: 0022040000 (Robmueng Rd.: Sreechan – Ammart)		
• Two-lane undivided road • Section length 0.363 km • 4 accident cases, 6 injuries • Average daily traffic volume 6,375 vpd	• Urban road passed through urban residential area but it was used as shortcut route to avoid traffic congestion on main roads. • Good pavement surface leads high-speed travelling but no provision of proper signs and makings. Only faded centerline marking exists. • Parking is allowed.	
ID: 0028010000 (Phothisarn Rd.: Ropbung – Anamai)		
• Two-lane undivided road • Section length 0.246 km • 10 accident cases, 14 injuries • Average daily traffic volume 4,562 vpd	• Sub-urban local road but it is used as shortcut route to avoid traffic congestion on main roads. • Good pavement surface leads high-speed travelling but no provision of proper signs and makings. • No street light • Parking is allowed.	

Table 3 (Continued) Hazardous Road Sections

Section Characteristics	Descriptions of Road Sections	Photo
ID: 0030010000 (RatKhanung Rd.: KasikornTungsang - SreePhatcharin Ent.)		
• Four-lane undivided road • Section length 0.419 km • 7 accident cases, 8 injuries • Average daily traffic volume 2,156 vpd	• Sub-urban road. • Good pavement surface leads high-speed travelling but no provision of proper signs and makings. • No street light • Parking is allowed.	
ID: 0040030000 (Runrom Rd.: PrachaSamran – Runrom)		
• Four-lane undivided road • Section length 0.377 km • 16 accident cases, 20 injuries • Average daily traffic volume 5,455 vpd	• This road-section is an urban road connecting to the rail station. • Good pavement surface as well as roadway width leads high-speed travelling but no signs and markings only centerline marking available. • Drivers usually use this road for making U-turn.	
ID: 0291030000 (DarunSamran Rd.: SanLhakmueng – Rotfai)		
• Two-lane undivided road • Section length 0.278 km • 8 accident cases, 10 injuries • Average daily traffic volume 4,987 vpd	• This road-section is a local urban road. • Poor shoulder • No Signs and markings • No street light	
ID: 0292020000 (Rotfai Rd.: Railway Station – NhongWat)		
• Two-lane undivided road • Section length 0.566 km • 4 accident cases, 6 injuries, 1 fatality • Average daily traffic volume 5,896 vpd	• This road-section is a local road paralleled a rail track. • Poor shoulder and roadside safety features. • No lane marking	

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