A STUDY ON PEDESTRIAN ACCIDENTS AND INVESTIGATION OF PEDESTRIAN'S UNSAFE CONDITIONS IN KHON KAEN MUNICIPALITY, THAILAND

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Abstract: This research examined the pedestrian accidents in Khon Kaen Municipality, Thailand. The data used to analyze the pedestrian accidents were obtained from Khon Kaen Regional Hospital. Initially, to determine the contributing factors of pedestrian accidents, the category analysis of data involving pedestrian accidents were conducted by using the chi-square test. Afterwards, the SPSS program was employed to develop the pedestrian prediction crash models. A step-wise analysis was performed on several selected contributing factors of pedestrian accidents. To identify locations where pedestrian crash problems exist in Khon Kaen Municipality, the ArcView GIS spatial was employed to create the pedestrian crash density map. The pedestrian unsafe conditions were also investigated through the concept of road safety audit at the identified high pedestrian crash locations. Finally, recommendations to improve these unsafe conditions were suggested.

Key Words: Pedestrian Accidents, Pedestrian Prediction Crash Models, Pedestrian Crash Density Map and Pedestrian Unsafe Conditions

1. INTRODUCTION

1.1 Rationale and Background

Walking is a routine action for all human beings. People walk everyday to different destinations for various reasons. Pedestrians consist of all age groups, including both genders with all different kinds of occupation. The pedestrians are known as the most vulnerable of all road users. The children and the elderly people are considered to be at a higher risk regarding pedestrian crashes or accidents. Major results of recent pedestrian accident studies revealed that pedestrians represent a significant number of those involved with pedestrian accidents sustaining serious injuries and often have rate of fatality. The fatality rate for various modes of transport in Britain, expressed as deaths per 100 million hours of exposure, presented that the fatality rate of walk mode is higher than public transport modes or motor car modes (Evans, 1994). Crashes between pedestrians and motor vehicles continue to be a serious problem throughout the world.

Pedestrian crashes continue to be a serious traffic accident problem in Thailand. Not only the number of death and injured pedestrians have continued to increase from year 1998 to 2000 but also the percentages of death and injured pedestrians as related to the total number of traffic death and injured victims, as shown in Table 1.

Khon Kaen, the central province of commerce and politics in the Northeastern part of Thailand, has experienced serious pedestrian crash problems. Half of which involves children and students. Thus, this research intends to use pedestrian traffic accident data obtained from the Trauma Registry and GIS road accident database of the Khon Kaen Hospital (Ruengsorn et al., 2001) as the primary data to investigate the pedestrian accident problem in Khon Kaen Municipality.

Table 1. The Situation of Pedestrian Accidents in Thailand during Year 1998-2000

Year	No. of Injured and Dead Pedestrians	Total No. of Traffic Injured and Dead	Percentages of Injured and Dead Pedestrians
1998	3,673	64,772	5.7 %
1999	3,839	59,810	6.4 %
2000	4,469	65,099	6.9 %

Source: (Royal Thai Police, 2002)

1.2 Purpose of this paper

The purpose of this paper is to alleviate the pedestrian crash problems in Khon Kaen Municipality. Specifically, it aims:

- To analyze pedestrian traffic accidents in Khon Kaen Municipality.
- To develop models that predict the number of pedestrian crashes at intersections or road sections in Khon Kaen Municipality.
- To identify locations where high pedestrian crash problems exist by using computerized Geographic Information Systems (GIS) software.
- To identify unsafe conditions to pedestrians at identified high pedestrian crash locations and also to propose improvements for the safety of pedestrians.

2. METHODOLOGY

2.1 Pedestrian Accident Data Collection

This research acquired data from the Trauma Registry and GIS road accident database.The acquired data was used to investigate and analyze the pedestrian traffic accident that occurred in Khon Kaen Municipality. These data had been collected by the Critical and Trauma Center, a unit of Khon Kaen Regional Hospital (KKH). The data on 159 pedestrian casualties from January 1999 to June 2001, was used for analysis.

2.2 Prediction Pedestrian Crash Model Development

In order to develop appropriate prediction pedestrian crash models, which can predict the number of pedestrians who were victims of road accidents at any intersections or road sections in Khon Kaen Municipality, different functions and formulations of models used in previous studies were tested and run. Due to the limited data available, only the number of crashed pedestrians were established as a dependent variable. Where as, the independent variables, many of the contributing factors, were included to establish the models. The stepwise elimination approach was utilized to build the final models. T-tests, F-tests and R-squared values were also used in the model development and selection.

2.3 Category Analysis

In order to compare the characteristics of the pedestrian traffic accidents, the chi-square test was conducted at 95 % level of confidence. The crashed pedestrians were classified in different groups and specified by different characteristics such as age of the victims, time the accidents occurred, and the type of vehicles involved. The main contributing factors involving pedestrian traffic accidents were also determined.

2.4 High Pedestrian Crash Location Identification

The first step in the process of improving pedestrian safety is the identification of locations or areas where pedestrian crash problems exist. One method of identifying crash locations is the use of computerized Geographic Information Systems (GIS) software (FHWA, 2002). In this research, ArcView GIS spatial analyst was used to identify high pedestrian crash locations and to create a reported pedestrian crash density map with 400 m of Kernel density search radius. Any location that has a high pedestrian crash density was identified as high pedestrian crash location.

2.5 Investigation of the Unsafe Conditions to Pedestrians

The unsafe conditions to pedestrians were investigated not only at daytime but also at nighttime. The specific checklist based on Road Safety Audit (Austroads, 2002), was modified and developed to concentrate on pedestrian safety. This checklist was used as a guideline to audit existing road conditions and pedestrian facilities at identified high pedestrian crash locations. For the investigation of road user's unsafe behavior, the crossing pedestrian and other road user's behavior were recorded by using a video camera. The behavior of pedestrians crossing the road was specified either as legal crossing or illegal crossing. The pedestrians crossing the road legally were those who cross the road by using the facilities provided (pedestrian overpass, crosswalk during traffic red time interval). In contrast, the pedestrians who cross the road illegally were those who ignore using the facilities provided within the 100 m radius crossing lane and also those pedestrians crossing the road at "crosswalk" during traffic "green time" interval.

2.6 Pedestrian Safety Improvement Recommendation

Recommendations based on Engineering, Education and Enforcement were proposed in order to improve existing unsafe conditions to pedestrians.

3. PEDESTRIAN ACCIDENT ANALYSIS

The analysis was based on trauma registry data and GIS road traffic accident data that recorded during January 1999 to June 2001 by the Trauma Center, Khon Kaen regional hospital. However, the data were not available during January 2000 to April 2000 due to Khon Kaen regional hospital had installed the new accident database system. The general characteristics of pedestrian accidents in Khon Kaen Municipality are presented as Table 2. During the study period, there were 163 pedestrian accident cases with 171 pedestrian victims; however, out of these total 163 pedestrians accident cases, only one fatality victim was found in 1999.

Table 2. The Summary of Pedestrian Accident Statistics in Khon Kaen Municipality

Years	Months		No. of Pedestrian Accidents	No. of Fatalities	No. of Injuries	No. of Pedestrian Casualties
	From	To				
1999	January	December	57	1	61	62
2000	May	December	79	0	81	81
2001	January	June	27	0	28	28
	Total		163	1	170	171

Source: (Khon Kaen Regional Hospital, 1999-2001)

3.1 Cause of Pedestrian Accident

This research carried out a category analysis of the data involved regarding pedestrian accidents by using chi-square test to find the main factors that contribute to the disproportionate number of pedestrians involved in traffic accidents. The category analysis of pedestrian accidents by various contributing factors are presented in the following subsections:

3.1.1 Time of Accident Occurrence and Pedestrian Age

A total number of 171 pedestrians involved in accidents were classified and grouped according to the time they met the accidents. The classifications according to time are the following; morning, afternoon and night time. All victims were classified according to age as well.

The highest pedestrian accident group (12 victims) involves teenagers (16-20 years of age) which occured during night time. Another group with a high frequency of pedestrian accidents involved younger children (less than five years old) with 11 victims which occurred in the afternoon. These results were similar to the results obtained by a Columbia University research that was conducted involving 0-19 year old pedestrians living in New York City. The reseach revealed that 0-5 year old children in New York have high crash risk at daytime and teenagers have high crash risk at nighttime (Matichon, 2002). The result found in Khon Kaen Municipality also revealed that nearly 30 percent of victims were less than 5 years old and 16-20 years old. These incidents may be caused by playfulness on the road by the parties involved and the lack of precaution to the younger children (less than 5 years of age) and illegal crossing of the road for teenagers (16-20 years of age).

3.1.2 Vehicle Type and Pedestrian Age

To study the types of vehicles and the ages of pedestrian victims involved in traffic accidents, a total of 156 crashed pedestrians was used for analysis.

Results of the chi-square tests indicated that these differences in pedestrian accident frequency by vehicle types and pedestrian ages were statistically significant at 95 percent significance level. The highest frequency of pedestrian accidents with 29 victims involves children pedestrians (1-10 years of age) which were crashed by motorcycles. Moreover, the result also indicated that more than 60 percent of pedestrian victims were crashed by motorcycles. According to the facts and previous research analysis of the traffic accidents in Khon Kaen Municipality which occurred from November 1995 to October 1996, indicated

that most of the vehicles causing accidents were motorcycles with 1,305 accident cases (82%) (Ruengsorn, 1997). Consequently, it can be said that motorcycles play a major role in contributing accidents in Khon Kaen.

3.2 Prediction Pedestrian Crash Model Development

3.2.1 Linear Multiple Regression Model Development

Different functions of both dependent and independent models were tested. The statistical significance and relative high coefficient determination models were only reported. The linear multiple regression produced a desirable result. This research applied such approach since it was seen as an advantage which include a relatively effective multiple combination of dependent and independent variable and is relatively more comprehensive. The linear multiple regression was conducted through the SPSS program. The selected independent variables were eliminated by a series of Stepwise, Forward and Backward to build final models. The developed models of linear multiple regression are summarized in Table 3.

Table 3. The Summary of Pedestrian Crash Prediction Linear Models

Elimination Variables Methods	Pedestrian Crash Prediction Models	R^2	Results of F test
Stepwise	$Y = 1.626\ X_1 + 0.184\ X_3 + 0.25\ X_5 + 0.627$	0.383	Significant
Forward	$Y = 1.626\ X_1 + 0.184\ X_3 + 0.25\ X_5 + 0.627$	0.383	Significant
Backward	$Y = 1.461\ X_2 + 0.210\ X_3 + 0.283\ X_4 + 0.543$	0.382	Significant

Where
Y = Number of Pedestrian Casualties per Intersection/Section
X_1 = Number of Hospitals Located in the Radius of 100 m
X_2 = Number of Hospitals Located in the Radius of 150 m
X_3 = Number of Lanes
X_4 = Number of Schools Located in the Radius of 100 m
X_5 = Number of Schools Located in the Radius of 150 m

As shown in Table 3, the result revealed that the Stepwise and Forward methods yielded the same model that the total number of pedestrian casualties in a particular intersection/section are positively influenced by the number of hospitals located within the radius of 100 m, number of lanes and the number of schools located within the radius of 150 m. This model demonstrates that more than 38 percent of the total variance in the count of total crashed pedestrians, by intersection/section, can be explained by the combination of variables included in the model. All of these are significant at the 0.05 level. The summary of coefficients and correlation of variables are presented in Table 4. According to standardized coefficients and partial correlations in Table 4, the number of crashed pedestrians are positively influenced by the number of hospitals located in the radius of 100 m, the number of lanes and the number of schools located within the radius of 150 m, in significant order.

However, for backward method, it yielded a different model. The total number of pedestrian casualties in a specific intersection/section is positively influenced by the number of hospitals located within the radius of 150 m, number of lanes and number of schools located within the radius of 100 m. The combination of the variables in this model also explains by the total variance of the total crashed pedestrians are same as the previous model. Results in Table 4

interprets that the number of hospitals located within the radius of 150 m, the number of lanes and the number of schools located in the radius of 100 m are directly related to the number of crashed pedestrians, in significant order.

In conclusion based from the results of the two models, the number of crashed pedestrians has positive significant order and is influenced by the number of neighboring hospitals, the number of lanes and the number of neighboring schools. The findings indicated that any roadway which has hospitals and schools within their vicinity have a high potential to involve pedestrians into accidents. Moreover, roadways having a more number of lanes, which enable vehicles to travel with high speeds, would also increase the risk of pedestrian crashes.

Table 4. The Summary of Coefficients and Correlation of Developed Models

Model No.	Variables	Unstandardized Coefficients	Standardized Coefficients	Significant t	Partial Correlation
1 (Stepwise)	Constant	0.627	-	0.016	-
	x_1	1.626	0.391	0.000	0.411
	x_3	0.184	0.260	0.004	0.295
	x_5	0.250	0.174	0.047	0.205
2 (Forward)	Constant	0.627	-	0.016	-
	x_1	1.626	0.391	0.000	0.411
	x_3	0.184	0.260	0.004	0.295
	x_5	0.250	0.174	0.047	0.205
3 (Backward)	Constant	0.543	-	0.035	-
	x_2	1.461	0.400	0.000	0.433
	x_3	0.210	0.298	0.001	0.340
	x_4	0.283	0.171	0.042	0.210

Where
Y = Number of Pedestrian Casualties per Intersection/Section
X_1 = Number of Hospitals Located in the Radius of 100 m
X_2 = Number of Hospitals Located in the Radius of 150 m
X_3 = Number of Lanes
X_4 = Number of Schools Located in the Radius of 100 m
X_5 = Number of Schools Located in the Radius of 150 m

3.2.2 Non Linear Multiple Regression Model Development

Other than the proposed linear model that predict number of pedestrian casualties, this study also attempted to derive their non-linear relationship by selecting the contributing factors which were not eliminated from the previous determination. The developed non-linear models are presented in Table 5.

Table 5. The Summary of Pedestrian Crash Prediction Non-Linear Models

No.	Pedestrian Crash Prediction Models	R^2
1	$Y = 1.068e^{(0.563 X_2 + 0.086 X_3)}$	0.353
2	$Y = 0.822e^{(0.396 X_1 + 0.098 X_3 + 0.209 X_4)}$	0.473
3	$Y = 0.777e^{(0.342 X_2 + 0.108 X_3 + 0.223 X_4)}$	0.463
4	$Y = 1.224 X_1^2 + 0.197 X_3 + 0.795$	0.416
5	$Y = 0.867 X_2^2 + 0.229 X_3 + 0.696$	0.355

Where
Y = Number of Pedestrian Casualties per Intersection/Section
X_1 = Number of Hospitals Located in the Radius of 100 m
X_2 = Number of Hospitals Located in the Radius of 150 m
X_3 = Number of Lanes
X_4 = Number of Schools Located in the Radius of 150 m

Focusing on the models in Table 5, the most desirable model is the combination of the number of hospitals located within the radius of 100 m, number of lanes and number of schools located within the radius of 150 m in exponential function, which yielded that nearly 50 percent of the total variance of the total pedestrian casualties, by intersection/section, can be explained by the combination of variables in this derived model. However, other non-linear models can also be employed to predict the number of pedestrian casualties depending on the various requests of individual users.

Thus, it can be concluded that not only the linear models can be used to predict pedestrian casualties depending on individual needs but also the non-linear models.

3.3 High Pedestrian Crash Location Identification

To identify high pedestrian crash locations in Khon Kaen Municipality, this research employed the GIS crash mapping techniques. A total of 154 pedestrian crash locations in Khon Kaen Municipality were plotted. The ArcView GIS spatial analyst was used to create a reported pedestrian crash density map with 400 m of Kernel density search radius as displayed in Figure 1. Locations that have a high pedestrian crash density were assigned as the high pedestrian crash location.

As a created map, there are three locations which indicate a relatively high pedestrian crash density. The names, general characteristics and landscape photos of these high pedestrian crash locations are presented in Table 6. It seems that these high pedestrian crash locations have many characteristics corresponding to the developed pedestrian prediction crash model's variables, which relate to the number of pedestrian casualties.

4. INVESTIGATION OF PEDESTRIAN UNSAFE CONDITIONS

According to previous studies, people can notice that the traffic accidents are caused by three contributing factors; human factors, road environment factors and vehicle factors. However, more than ninety percent of the total traffic accidents occurred were caused by human factors and road environment factors (Osborne, 2001). Therefore, this research considered unsafe

pedestrian conditions not only its physical characteristics but also the behaviors of road users. Furthermore, this research also proposed some recommendations based on engineering, enforcement and education to improve identified unsafe conditions for pedestrians. The identified unsafe conditions and proposed recommendations to improve safety for pedestrians at identified locations are presented in Table 7.

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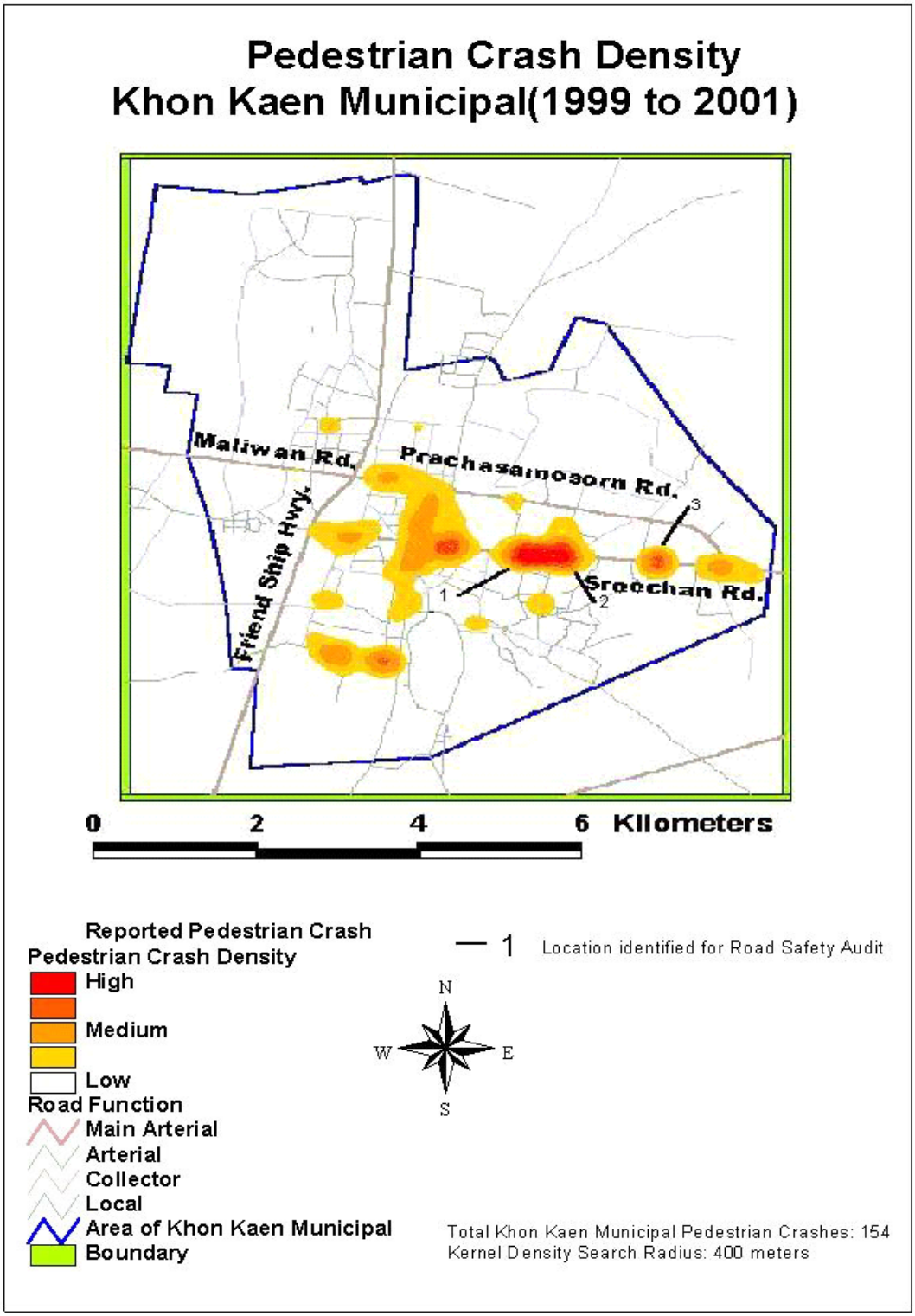

Figure 1. Pedestrian Crash Density Map of Khon Kaen Municipality

Table 6. High Pedestrian Crash Locations

General Characteristics	Landscape Photos
Location 1: Sreechan Road Section (From Anamai Road to Chataphadung Road)	
• Eight-lane divided road • Section length 699.7 m • Daily average traffic 17,444 vpd • Island median with fencing • Sidewalks with street lights along both roadsides • Pedestrian overpass at the mid-section • Provincial hospital, polytechnic school and commercial areas along both roadsides • This location experienced 10 crashed pedestrians during year 1999-2001	
Location 2: Sreechan Road and Chataphadung Road Intersection	
• Signalized intersection of eight-lane divided road and four-lane undivided road • Daily average traffic 11,000 vpd • Sidewalks with street lights along the both roadsides • Crosswalks at all four approaches • Primary school, college and two large hospitals located nearby this intersection • Three pedestrian crashes during the study period • Identified as hazardous intersection (Ruengsorn, 2001)	
Location 3: Sreechan road Section (From Department of Highway's Khon Kaen Branch Office to Khlongchonlaprathan)	
• Eight-lane divided road • Section length 595.9 m • Daily average traffic 17,500 vpd • Island median with sling fence • Street lights on sidewalks along both roadsides • Pedestrian overpass in front of the kindergarten and the educational institute. • Commercial areas along both roadsides. • One pedestrian fatality at night and five pedestrian injuries during study period • Identified as hazardous road section (Ruengsorn, 2001)	

Table 7. Pedestrian Unsafe Conditions and Safety Recommendations

Unsafe Conditions and Safety Recommendations	Pedestrian Unsafe Condition Photos
Location 1: Sreechan Road Section (From Anamai Road to Chataphadung Road)	
Unsafe Condition on Sidewalk • Vendors along both sidewalks place some goods on the sidewalks. Pedestrians must escape by walking along the road. **Recommendation for Improvement** • Responsible authority should enforce street vendors and neighbor stores not to sell or place some goods on the sidewalks.	
Unsafe Condition at Fence • Due to some parts of broken fence on the median island, there were gaps that pedestrians used to cross illegally on the road. These behaviors increased the risk of pedestrian accidents. **Recommendation for Improvement** • Responsible authority should repair broken parts of the fence and campaign pedestrians using pedestrian overpass to cross the road.	
Unsafe Condition at Pedestrian Overpass • Elderly people seldom use this overpass due to its high slope and steep stairs. **Recommendation for Improvement** • Since this overpass is located in front of the hospital, it is best that this overpass should be modified to serve more safety and convenience for pedestrians.	
Unsafe Pedestrians Behavior • More than a half of crossing pedestrians do not use pedestrian overpass. Most of illegal crossing pedestrians are students and hospital staffs. **Recommendation for Improvement** • The school and hospital should educate people about traffic safety and campaign using overpass. For maximum effectiveness, approach footpaths should lead the pedestrian into overpasses, for safety so pedestrians actually have to go out of their way to avoid using it (Ogden, 1996).	

Table 7. (Continued) Pedestrian Unsafe Conditions and Safety Recommendations

Unsafe Conditions and Safety Recommendations	Pedestrian Unsafe Condition Photos
Location 2: Sreechan Road and Chataphadung Road Intersection	
Unsafe Condition on Sidewalk • Parked cars along the sidewalk makes it inconvenient for pedestrians so that they walk along the road. **Recommendation for Improvement** • Responsible authorities must not allow cars parked along the sidewalks.	
Unsafe Condition at Corner • Vegetation at a corner of intersection caused the poor visibility of traffic from the crosswalk and the poor visibility of pedestrians waiting. **Recommendation for Improvement** • The vegetation near intersection concealing visibility of traffic from crosswalk point and visibility of pedestrians from approaching traffic should be removed.	
Unsafe Pedestrians Behavior • Nearly forty percent of pedestrians crossed the roadway illegally at this intersection. More than a half of them are primary school students studying at the neighboring school. The pedestrian crossing behavior at this intersection is presented in Table A-1 of Appendix. **Recommendation for Improvement** • The school should educate traffic rules to students and provide well-trained guards to assist young students crossing the road safely.	
Behavior of Drivers Unsafe to Pedestrians • Some drivers stop their vehicles illegally along the crosswalk thus, interfering pedestrians to use the crosswalk. **Recommendation for Improvement** • The pedestrian crossing signs should be posted to warn drivers and identify the crosswalk. The law enforcement should strictly imply to the motorists who park their vehicles at an illegal place.	

Table 7. (Continued) Pedestrian Unsafe Conditions and Safety Recommendations

Unsafe Conditions and Safety Recommendations	Pedestrian Unsafe Condition Photos
Location 3: Sreechan road Section (From Department of Highway's Khon Kaen Branch Office to Khlongchonlaprathan)	
Unsafe Condition on Sidewalk • Some restaurants place dining tables along sidewalk that force pedestrians to walk along the road. **Recommendation for Improvement** • Responsible authority should not allow stores placing any obstacles on the sidewalks.	
Unsafe Condition at Crosswalk • Provision of footway on crossing island was provided but other treatments (e.g., crossing marking, traffic sign, etc.) were not available. Therefore, this would increase risk of pedestrian accident because approaching motorists are not able to recognize the pedestrian. **Recommendation for Improvement** • Crosswalk marking with pedestrian crossing sign should be provided at the crossing location.	
Unsafe Condition at Nighttime • Nighttime food stores located along the sidewalk caused pedestrians to walk along the road. **Recommendation for Improvement** • Nighttime food stores and also dining tables should not be allowed to settle along the sidewalk. Responsible authority should provide proper place for food stores.	
Unsafe Pedestrians Behavior • Eighty five percent of crossing pedestrians crossed the road illegally. More than half of them are students crossing at nighttime. The pedestrian crossing behavior at this section is presented in Table A-2 of Appendix. **Recommendation for Improvement** • The education of traffic rules and campaign of using pedestrian facilities should be provided to schools. Moreover, law enforcement should be applied to illegal pedestrians not only at daytime but also at nighttime.	

5. CONCLUSION

The key findings derived from this paper are summarized as follows:

- Basing upon the investigation of times of accident occurrence and age of the victims, the result concluded that the highest pedestrian accidents had occurred at night involving teenagers with 16-20 years of age.

- Thirty percent of pedestrian victims were less than 5 years old and 16-20 years old pedestrians.

- Traffic accidents involving children (1-10 years old) crashed by motorcycles have the highest frequency.

- As a result of linear model development using different elimination variable methods, two linear models had been developed based on the relationship between the number of pedestrian casualties per intersection/section and the number of hospitals located within the radius of 100 m or 150 m, the number of lanes, and the number of schools located within the radius of 100 m or 150 m.

- The result of the non-linear model development as the most desirable model was the exponential function, which presented that the number of pedestrian casualties per intersection/section are related to the number of hospitals located within the radius of 100 m, the number of lanes, and the number of schools located within the radius of 150 m. In conclusion, three developed linear and non-linear models can be used to predict pedestrian casualties depending on the individuals' needs.

- Based on the developed density map, the three relatively high pedestrian crash density locations are as follows:
  - Location 1. Sreechan Road Section (From Anamai Road to Chataphadung Road)
  - Location 2. Sreechan Road and Chataphadung Road Intersection
  - Location 3. Sreechan Road Section (From Department of Highway's Khon Kaen Branch Office To Khlongchonlaprathan)

- All these four locations were investigated and recommendations were suggested to alleviate the unsafe conditions of these locations.

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APPENDIX

Table A-1 Pedestrian Crossing Behavior at Sreechan Road and Chataphadung Road Intersection

Crosswalk Locations	No. of Illegal Crossings	No. of legal Crossings	Percentage of Illegal Crossings
North	19	117	14.0%
South	110	105	51.2%
East	135	117	53.6%
West	14	106	11.7%
Total	278	445	38.5%

Table A-2 Pedestrian Crossing Behavior at Sreechan Road Section (From Khon Kaen DOH to Khlongchonlaprathan)

Survey Time	No. of Illegal Crossings	No. of Pedestrians Using Overpass	Percentage of Illegal Crossings
Daytime	272	63	81.2%
Nighttime	159	11	93.5%
Total	431	74	85.3%