LOWLAND TECHNOLOGY INTERNATIONAL Vol. 12, No. 1, 30-40, June 2010
International Association of Lowland Technology (IALT), ISSN 1344-9656

IMPACT OF URBAN FACTORS ON ROAD ACCIDENT IN BANGKOK, THAILAND

P. Iamtrakul[1] and P. Pimonsathean[2]

ABSTRACT: A decade of road accidents situation in Thailand is a key evidence to call for an in depth understanding for alleviating this complex situation. This study carried out to identify the impact of factors inducing on road accidents in urban area by assessment of the road users' attitude on risk factors. Analytical hierarchy process was applied to determine unsafe component of road environment and the urban factors that significantly contributed to the deterioration of road safety situation. Furthermore, indicators for estimating accident prone area could be also derived in term of mathematical relationships with a visual analysis based on an application of spatial approach. While the specific accident mitigation or safety improvement program can be effortless designed, an inter collaboration among traffic police, health, law, and transport authorities can be gradually initiated in developing a strategy for prevention and sustainable reduction of casualties and deaths on the road.

Keywords: Urban factors, land use, road accident, safety

INTRODUCTION

In the recent year, more than 100,000 road accidents occurred in Thailand that has resulted in death (12,492 cases) and injury (79,029 cases) with economic loss about 1,218,575,047 baht (0.016 of GDP). A decade of this aggravating situation during 1997 through 2007 is a key evidence to call for an in depth understanding for alleviating this complex situation. Due to road accident consequence primarily from human, vehicle, and environmental contributing factors, these several factors bring up the question of the effects of each factor on road safety.

However, environmental factors in term of road component and urban environment are simply to be controlled and manipulated rather than human factors. Thus, this study carried out to identify the impact of each factors inducing on road accidents in urban area by focusing on controllable factors and selecting the inner Bangkok area as a case study.

Base on this approach, the data was collected by means of questionnaire survey to assess the road users' attitude on risk factors in accordance with fatalities, injuries and economic losses. Then, its relationship that is characterized by several classifications of urban factors, e.g., urban density, land use, activities, can be analyzed by using Analytical Hierarchy Process (AHP) and displayed based on an application of Geographical Information System (GIS). This powerful tool for analyzing a structured data with complex decisions can provide the understandable linkage of accident production factors.

By performing the analysis, it was found that not only the unsafe component of road environment, but the urban factors also significantly contribute to the deterioration of road safety situation. Furthermore, indicators for estimating accident prone area can be also derived in term of mathematical relationships with a visual analysis base on an application of spatial approach. With a more precisely geographical approach, the potential for traffic crashes in urban area can be identified in term of risk area and help to alleviate or improve on the practical applications for use by city planners, traffic safety engineers and concerned authorities.

Thus, potential impacts of some planning variables and association of urban characteristics on road safety in urban areas can be simply understood to provide collaborative evidence about the most commonly occurring factors, and to further light on accident causation. While the specific accident mitigation or safety improvement program can be effortless designed, then an intersectorial collaboration between, traffic police, health, law, and transport authorities could be gradually initiated in developing a strategy for prevention and sustainable reduction of casualties and deaths on the road.

[1] IALT member, Faculty of Architecture and Planning, Thammasat University, Pathumthani 12121, THAILAND
[2] Faculty of Architecture and Planning, Thammasat University, Pathumthani 12121, THAILAND
Note: Discussion on this paper is open until December 2010

SITUATION OF ROAD ACCIDENT IN THAILAND

Road traffic accidents are recognized as a growing public health problem in Thailand same as other developing countries as indicated in Table 1 (Bener et al., 2003). As a consequence, traffic problems has become the most urgent issue to be dealt for healthy socio-economic development while steady increasing accident rate as well as injury and fatality rate. Furthermore, the other significant evidence of the road accident was the loss in mortality and morbidity. It was estimated the intangible of accident loss in term of the total loss of accident cost per case for the whole of Thailand. It was found to be between 3,959,387 – 4,658,004 baht, 4,503,479 – 5,404,175 baht, 123,245 – 128,836 baht, 30,289 – 30,461 baht and 40,220 baht for fatal, disability, serious injury, slight injury and property damage only case respectively (The World Bank, 2008).

These issues constitute a great challenge for the country, especially Bangkok, a central city of Thailand which is undergoing rapid socio-economic change and where the population is one of the topmost dense in the world. As well as, the situation may be deteriorated with the urban traffic environment due to the reason that it plays a role as one of the main external effects brought by the agglomeration of population and industries in metropolitan areas. Figure 1 showed the catalyst factors of road accident that comprise of the continued increasing in percentage change of number vehicle registrations and the road construction rate. According to this frustrating situation, the effects are accompanied by decreased efficiency of transportation systems, environmental problems, public health and safety problems, and sometimes by social in equity (Zhang and Gao, 2008).

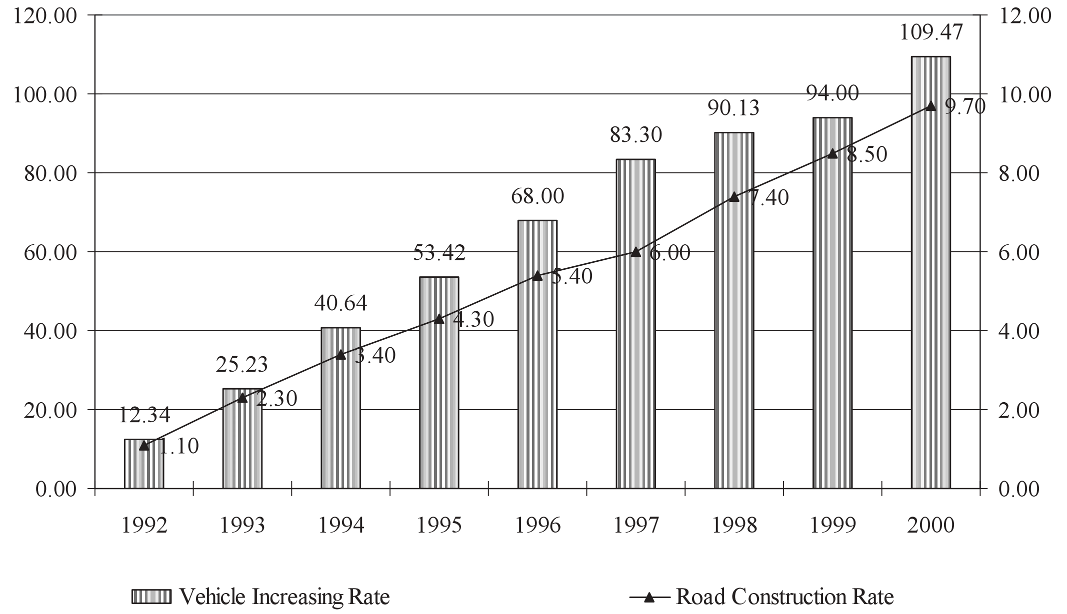
These consequences may result on a large number of traffic accidents that have high serious fatality in the future depend on different policy instruments to cope with these problematic. Recent research has shown that many developing countries have a serious road accident problem and that accident rates are higher than those of western industrial countries (Vorko-Jović and Biloglav, 2006). Nevertheless, road traffic accidents are significant but preventable, cause of death, disability and economic loss in developing countries. However, the dramatic growth of urban population caused a rapid rise in urban vehicle ownership and accidents.

This study aims to review the road safety situation in the study area as a case study of city in developing countries and suggests a strategy to improve it on the means of an integration of analytical tool and geographic information system. The role of different stakeholders is highlighted on the contribution of the improvement of the situation based on a clear understanding of the problem. It necessitates an objective assessment to clarify the spatial features of the traffic problems and the travel behaviors of residents, and to examine their significance from the perspective of planning policies.

Table 1 Accident statistics in Thailand (1998-2007)

Year	Bangkok and Vicinity Area			Other Regions			Whole Country		
	Number of Accident	Dead (Person)	Injury (Person)	Number of Accident	Dead (Person)	Injury (Person)	Number of Accident	Dead (Person)	Injury (Person)
1998	46,800	732	18,920	26,925	11,502	33,618	73,725	12,234	52,538
1999	40,178	1,718	20,681	27,622	10,322	27,089	67,800	12,040	47,770
2000	43,485	1,582	20,362	30,252	10,406	32,749	73,737	11,988	53,111
2001	45,711	1,519	22,854	31,905	10,133	31,106	77,616	11,652	53,960
2002	48,507	1,734	23,488	43,116	11,382	45,825	91,623	13,116	69,313
2003	46,806	1,491	23,597	60,759	12,521	56,095	107,565	14,012	79,692
2004	55,381	865	23,597	69,149	12,901	70,567	124,530	13,766	94,164
2005	52,533	1,048	24,491	69,589	11,823	69,954	122,122	12,871	94,445
2006	53,419	1,483	25,067	57,266	11,208	58,223	110,685	12,691	83,290
2007	47,516	1,302	23,124	54,236	11,190	55,905	101,752	12,492	79,029

Source: Royal Thai Police, 2008



Source: Office of Transport and Traffic Policy and Planning, 2005

Fig. 1 The increasing rate of vehicle registrations and road construction in Thailand

MATERIAL AND METHOD

In order to obtain an in-depth understanding of safety situation, this study proposes a method of survey research for further analysis of all stakeholders on road safety to assess their safety attitude and satisfaction of study area as described in Fig. 2.

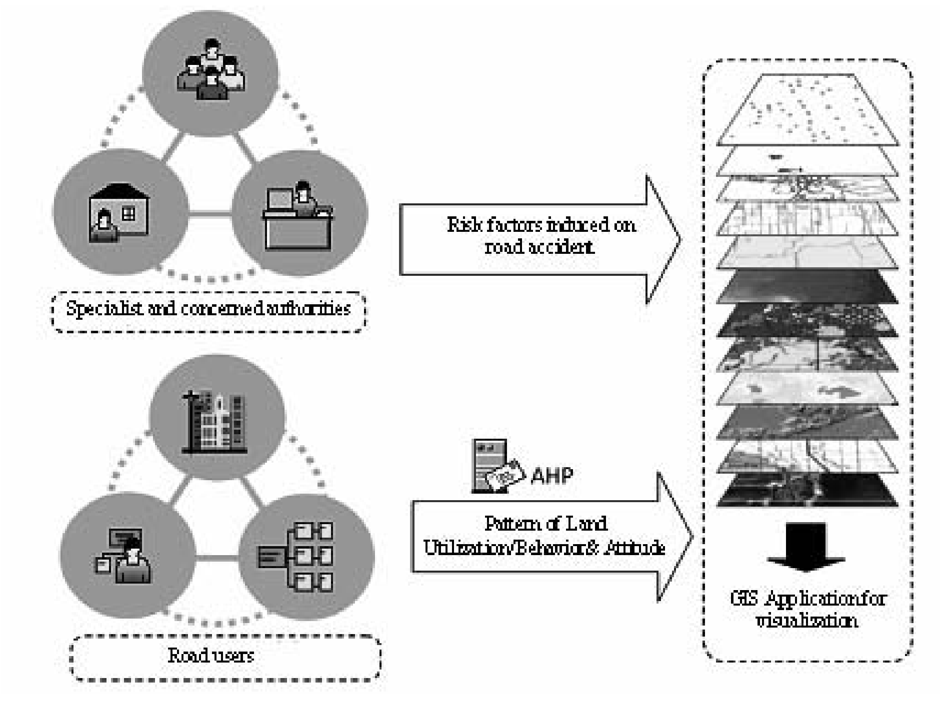


Fig. 2 Stakeholders for data collection and questionnaire survey

This approach also takes into account of some aspects among road users, concerned authorities and experts whose works relevant to road safety and, separately make an analysis in a conventional approach. This is due to the reason that there will be different perceptions while road utilization among both different groups such as the general road users, e.g., road users may exercise particular caution in the vicinity of specified location of land use within their familiarity (schools or hospitals). On the other hand, experts may consider risk factors from other aspects of the vicinity area (Wedagama and Metcalfe, 2006). This study also attempts to introduce built environment factor to be considered as one of the high association with number of casualties, and advise on the most efficient strategy for reducing these casualties. Subsequently, Analytical Hierarchy Process (AHP) was employed on the identification of the weighting among different factors contribute on accident investigation.

This methodology had to be developed and suitable data sources identified for both primary and secondary data was also gathered in this study from various sources, e.g. planning office, police station. For primary data, this study conducted a 300 set of questionnaire survey in the study area (Phranakorn District) during June and July of 2008, where road users were questioned on travel behaviors, satisfaction with the traffic environment, as well as other factors of their living environments. The survey was confined to the built-up area, and Phranakorn district was selected as a case study among other urban districts. The sample size was approximately 4/1,000 of the real population. Secondary Data was obtained from the concerned authorities of district level, official statistical reports and police station on road traffic accidents, injuries and fatalities.

On the basis of survey results, this study applied the AHP to assess the important of each factor induced on road accident and display the result by means of computer based. With GIS environment, the result of study could be analyzed the data through the utilizing its spatial nature geographical information system as depicted in Fig. 3.

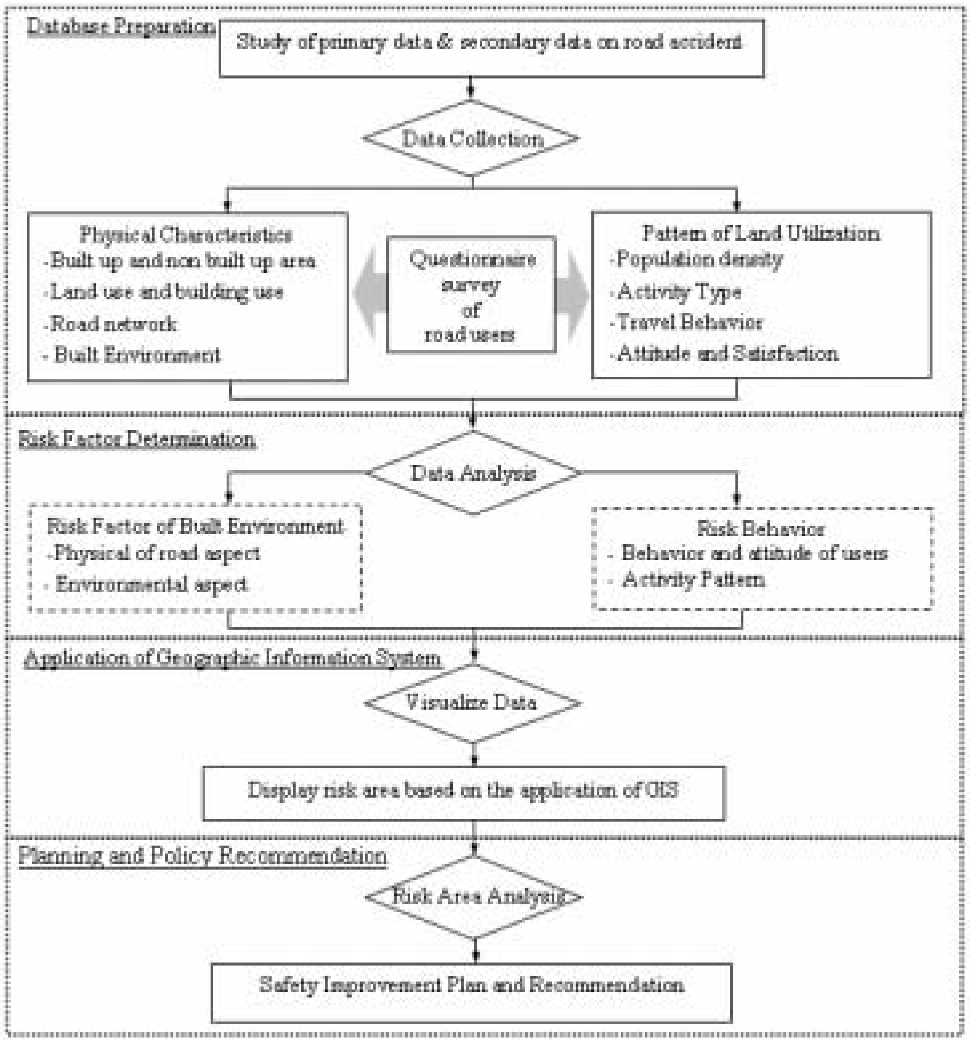


Fig. 3 Methodology of this study

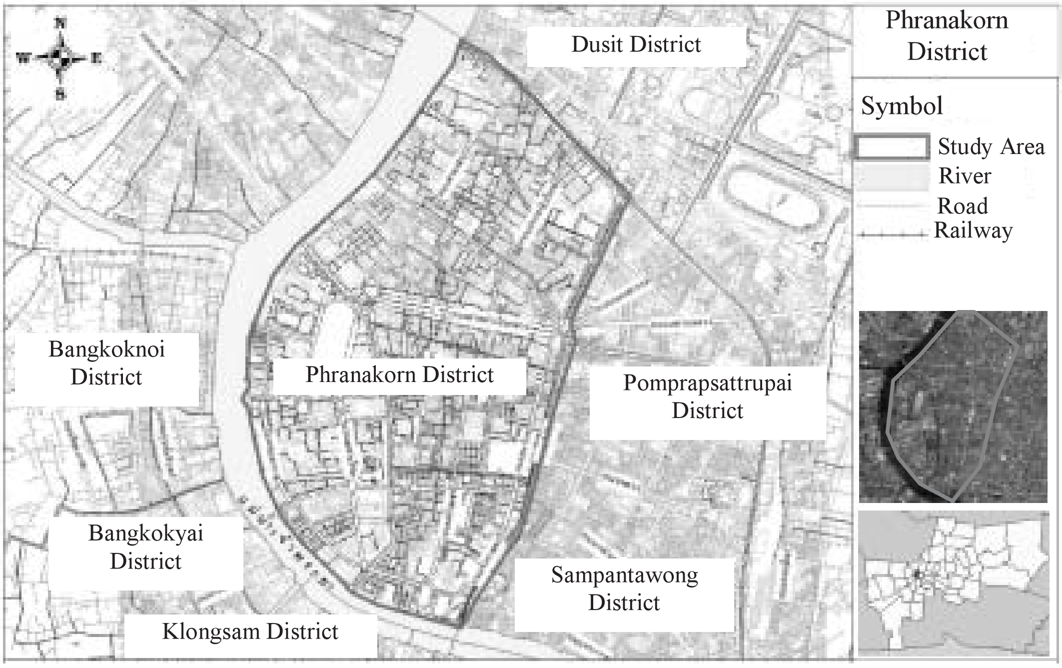


Fig. 4 Study area: Phranakorn district, Bangkok, Thailand

STUDY AREA

To perform data collection in this study, Phranakorn district was selected as a case study among 50 administrative districts in Bangkok area. As this area is one of the low level area which has been influence on its urban structure. Furthermore, there is also an influence on travel patterns of its spatial context with mixed land use settlements. This is an important driving factor on road safety problem. Thus, for providing better understand of its relationship, this paper reports some of the findings of analyzes, conducted to identify underlying factors in various aspects of unsafe condition which influence on road accident. This area represents as the richest of cultural area in Bangkok with 5.536 km^2 or 3,460 rai and the allocation of study area with its vicinity. The characteristics of road network in the study area are also described in Fig. 4.

The built-up area is located mostly within the study area and it was found that single house is the most popular form of housing (about 61 percent). A strict height limit control has been imposed to this area (the inner city), and many blocks were designated as historical preservation areas within 1-2 storey.

In addition, some are occupied by low-income families who have lived there for a long time approximately 2 percent. Furthermore, several project of urban redevelopment has been conducted to improve the living environment of the inner city since this area is the situated of the most original residents and street which could reflect the historical of Bangkok city. When consider about land-use classification in this study, the detail of different type of activity consists of (Fig. 5):

- Residential, such as houses and flats, and roads or paths within such areas.
- Commercial, such as shops, garages, public houses, restaurants and post offices, banks, building societies and other service industries.
- Industry, such as factories, refineries, shipbuilding yards, mills and other industrial sites.
- Storage and warehousing, such as depots, scrap and timber yards and warehousing.
- Government Institutional, such as local and central government offices, and police stations, prisons, fire stations.
- Educational Institutional, such as educational and school.
- Religious buildings, such as cemeteries and crematoria, community and religious buildings.
- Vacant land previously developed, includes cleared sites used as temporary car parks or playgrounds, and buildings associated with outdoor recreation.
- River and canal, such as, power stations, water works, gas works, refuse disposal places (except those in landfill waste disposal (Y)), TV masts and electricity substations, or water works.
- Highways and road transport, such as through routes and distributor roads in housing estates, bus stations and public car parks.
- Railway

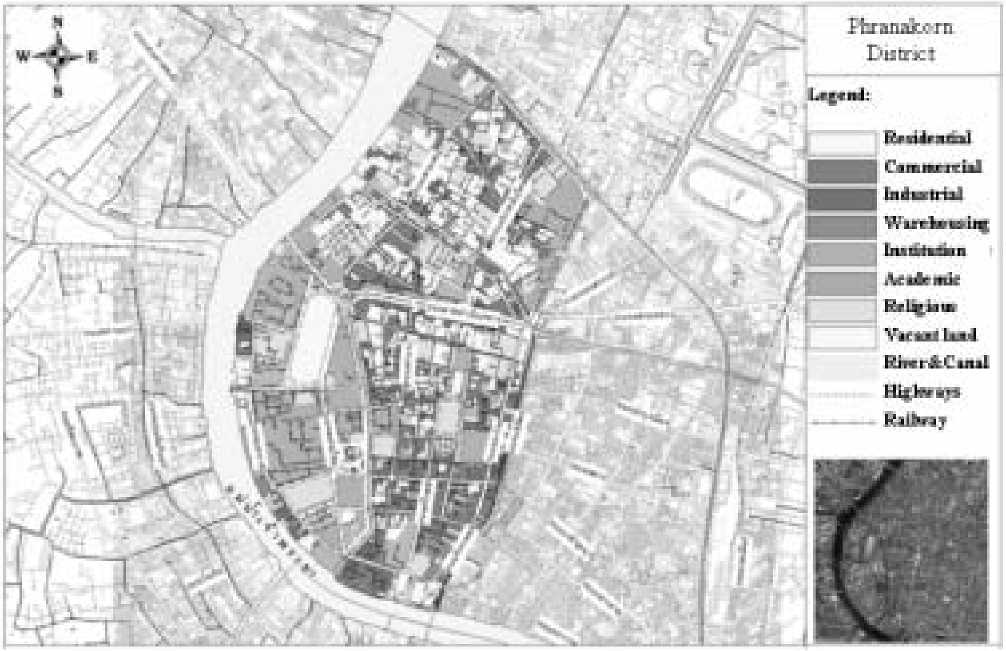


Fig. 5 Land use classification in study area

DATA ANALYSIS

Road Users' Behavior and Attitude

A sample of 300 set of questionnaires were used to assess road users' behavior and attitudes. The component of factors adopted in the study can be explained in term of behavior and attitudes on their travel characteristics. Mode usages, frequency of visit and accident experience were considered in this study as preliminary information of road users' opinion in. To identify differentiations of the satisfaction level across the whole range of road users, the classification of travel behavior and attitude of road users can be demonstrated as follows:

- Mode usage: This group consisted mainly of car users, about 41 percent, follow by public transportation, bus (31 percent) and sky train (BTS) (19 percent), respectively (Fig. 6). The least group is Para transit users that are taxi (8 percent) and tuk tuk (1 percent), correspondingly.
- Frequency of visit: Their frequency of visit is, though varying widely, and they mainly traveled on weekday (25 percent) that could be a group of workers. Follow by, 2-3 days/weeks (22 percent) that could be persons who have shopping or business trip in the study area (Fig. 7).

Most had a rather low frequency of visit about 2 times per month that could be counted for the group of road users who appointment to the institutional in the study area.

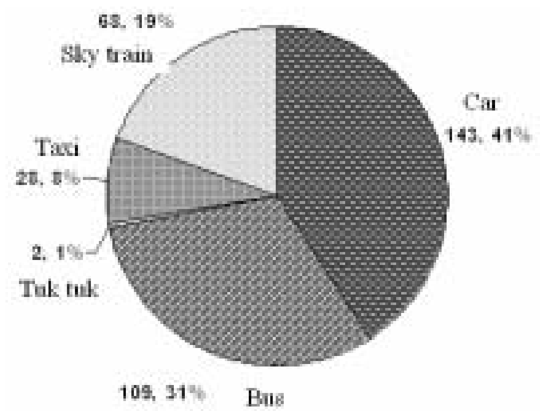


Fig. 6 Mode Usage

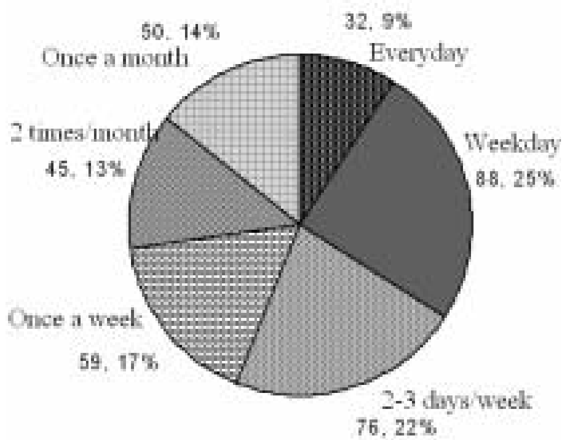


Fig. 7 Frequency of visit

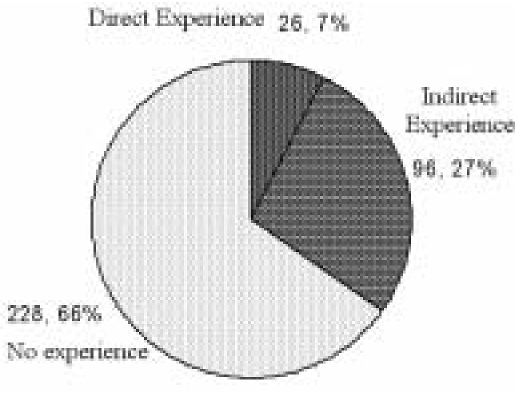


Fig. 8 Accident experience

▪ Accident experience: These were mainly 66 percent of sampling have no experience of road accident as seen in Fig.8. While about 7 percent have direct experience on accident and 27 percent might have safety awareness due to indirect experience on accident.

AHP Analysis

As well as 150 participants of experts and concerned authorities was gathering for AHP analysis. Their areas of responsible were related to traffic and transportation policy, department of highway, traffic police, urban and transportation planners and lecturers. This is to determine the significant of different contributing factors on road accident. The AHP is a Multi-Criteria Decision Making (MCDM) tool at the core of which lies a method for converting subjective assessments of relative importance to a set of overall scores or weights.

The AHP is a top-down decision model and, therefore, the criteria and alternatives are assumed independent (see Table 2). The modeling process can be divided into four steps for the ease of understanding which are described as follows (Saaty 1980, 1990).

▪ Step I**:** Pairwise comparisons of the elements in each level are conducted with respect to their relative importance towards their control criterion based on the principle of AHP. Saaty (1980) suggested a scale of 1–9 when comparing two components.

▪ Step II: The score of a_{ij} in the pairwise comparison matrix represents the relative importance of the component on row (i) over the component on column (j), i.e., $a_{ij}=w_i\ /w_j$. The score of 1 represents equal importance of two components and 9 represents extreme importance of the component i over the component j. The reciprocal value of the expression ($1\ /a_{ij}$) is used when the component j is more important than the component i.

▪ Step III**:** After all pairwise comparison is completed the priority weight vector (w) is computed, the consistency index (CI) of the derived weights could then be calculated. In general, if CI is less than 0.10, satisfaction of judgments may be derived (Saaty, 1980). With respect to any criteria, pair wise comparisons are performed in two levels, the element level comparison and the cluster level comparison (as shown in Table 3).

This study applied the steps as previously described to formulate the weight of several factors induced on road safety of which sums to one. Base on the weight determination in Table 3, the calculation of satisfaction score with the derived weight could be displayed for comparison in different factors. The whole procedure of AHP integration of experts' opinion is based on calculating the geometric mean.

Finally, the final result could then be combined with the satisfaction score based on road users perceived of the quality of site. Then, the spatial distribution can be presented based on quantitative analysis which has gained widespread recognition. The enormous potential of Geographic Information System (GIS) in storing, processing and manipulating digital data has revolutionized the technology of hazard mapping. This tool provides graphical data access, enabling the user to view and select desired locations on the network, eliminating the need for node tables and paper maps.

Table 2 Pair wise comparisons (Saaty, 1980)

Comparative importance	Definition	Explanation
1	Equally important	Two decision elements (e.g., indicators) equally influence the parent decision element.
3	Moderately more important	One decision element is moderately more influential than the other.
5	Strongly more important	One decision element has stronger influence than the other.
7	Very strongly more important	One decision element has significantly more influence over the other.
9	Extremely more important	The difference between influences of the two decision elements is extremely significant.
Reciprocals	If v is the judgment value when i is compared to j, then $1/v$ is the judgment value when j is compared to i.	

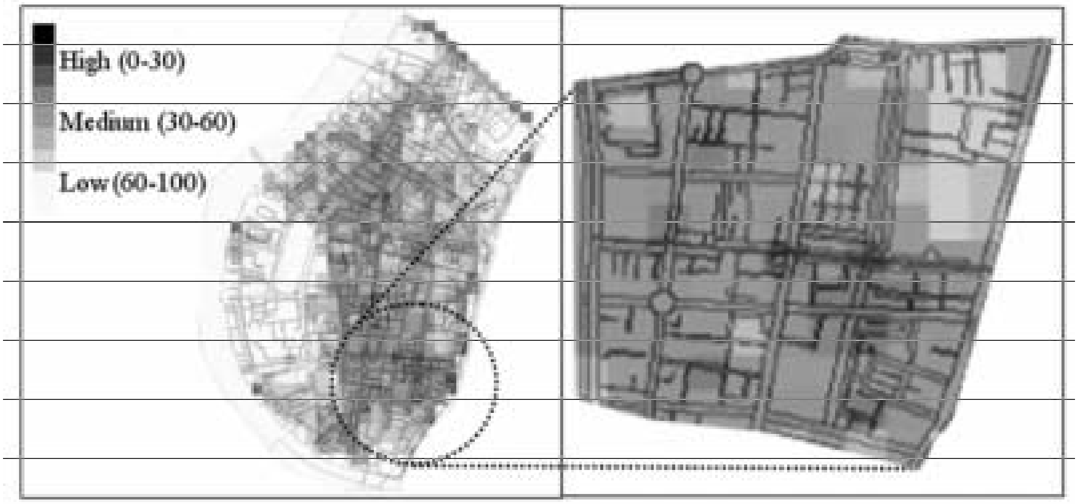
Table 3 Risk factors contributing to road accident

Level 1	Weight	Level 2	Weight	Satisfaction Score
Urban factors and its components	w_1=0.2705	Commercial Type	w_{11}=0.3271	0.3271
		Institutional Type	w_{12}=0.0990	0.0990
		Residential Type	w_{13}=0.1320	0.1320
		Set back	w_{14}=0.1550	0.1550
		Intensity	w_{15}=0.2394	0.2394
		Built environment and landscape	w_{16}=0.0874	0.0874
Road factors and its components	w_2=0.3032	Road hierarchy	w_{21}=0.0929	0.0929
		Traffic volume	w_{22}=0. 2304	0.2304
		Number of lanes	w_{23}=0. 0886	0.0886
		Street furniture	w_{24}=0.0923	0.0923
		Pavement surface	w_{25}=0.0876	0.0876
		Route characteristics	w_{26}=0.0887	0.0887
		Direction	w_{27}=0.1188	0.1188
		Conflict	w_{28}=0.2008	0.2008
External factors	w_3=0.4263	Possibility of accident	w_{31}=0.356	0.3560
		Risk environment	w_{32}=0.6440	0.6440

Query results can be displayed in both map and tabular form, thereby creating more easily interpreted query results and promoting the analysis of accident patterns and causal relationships (Souleyrette, et al., 1998). The application of GIS in this study is for direct comparison based on the indication of risk area in the relationship among contributory factors. Base on this process, GIS provides an approach for visualize through the integration of the application of Potential Surface Analysis (PSA). PSA technique has been used for spatial analysis which include overlaying and weighting-rating model for the suitable area of traffic safety zone.

The risk area can be identified base on the AHP weighted calculation with the following step of analysis:

- Create grid cell in study area with the size of (50m.x50m.) 2,500 m^2 about 2,214 cells to calculate the score for an identification of risk area in Phranakorn district base on the determined factors (Fig. 9a).
- After derive the risk prone area, the smaller size of grid cell (5m.x5m.) was applied to perform in-depth investigation of risk factors in the study area (Fig. 9b).
- Finally, there are 221,440 cells were subdivided for allow to overlay of the weighted (normalize score) layers. The summation of potential score (s) of all cells can be calculated to determine the risk area by adopting the following formula.



a. Cell size of 50m.x50m. b. Cell size of 5m.x5m.

Fig. 9 Risk area identification

Table 4 Scenario analysis for safety improvement program

Level 1	Level 2	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Urban factors and its components	Commercial Type	Control	Control	Control	Control
	Institutional Type	Control	Control	Control	Control
	Residential Type	Control	Control	-	-
	Set back	Control	Control	Control	Control
	Intensity	Control	Control	Control	Control
	Built environment and landscape	Control	Control	-	-
Road factors and its components	Road hierarchy	Control	Control	Control	Control
	Traffic volume	Control	Control	Control	Control
	Number of lanes	Control	Control	Control	Control
	Street furniture	Control	-	Control	-
	Pavement surface	Control	-	Control	-
	Route characteristics	Control	Control	Control	Control
	Direction	Control	Control	Control	Control
	Conflict	Control	Control	Control	Control
External factors	Possibility of accident	-	-	-	-
	Risk environment	Control	-	-	-

$$S = w_1x_1 + w_2x_2 + w_3x_3 + \ldots + w_nx_n \quad (1)$$

Where

S = Risk score of all cells

w_n = Weight of factor n

x_n = Criteria Score (Satisfaction score) of factor n

Base on the smaller size of grid cell (5m.x5m.), the scenario analysis for safety policy could be modeled as seen in Table 4. The spatial pattern of policy variation allows for counter check with the effectiveness of safety improvement as illustrated in Fig.10.

According to these circumstances, the evaluation of different policy on each factor (urban, road and external factors) can be given an idea about its variation. Through this spatial differentiation analysis of risk factor contribute on road safety, the problem of existing urban environment in term of both land use and traffic could be identified and analyzed across space and social groups of road users. This is an advantageous approach because the road users' satisfaction is a comprehensive index reflecting the qualities of physical space and transportation service as well as the impact of personal attributes and preferences (Zhang and Gao, 2008).

Moreover, the analysis provides an alternative way to examine land-use planning and housing policy from a broader perspective. Figure 11 and Fig. 12 provide an evidence of implications which are valuable not only for transportation policy, but also for other related policies for safety improvement in the specific area. Base on the scenario analysis, it was found that the most dangerous area in the study area are at Bamrungmueng road, Banmor road and Pahurad road as depicted in Fig. 11 and Fig. 12.

This is due to the high density create a high traffic congestion in that area. Together with a several lanes with complex road network also induce the possibility of accident in that area. Vulnerability in traffic is not an isolated phenomenon but associated with vulnerability in housing and other influencing factors, i.e., landuse. Furthermore, the composition of mixed used and commercial also attract commuter to visit commonly. This can be noticed by the land use classification of risk areas found in this study. Thus the spatial analysis in Fig 4 could provide fruitful benefit for the concerned authorities to understand the impact of urban land use on the vulnerability of transportation networks.

Fig. 10 Scenario analysis for safety improvement program

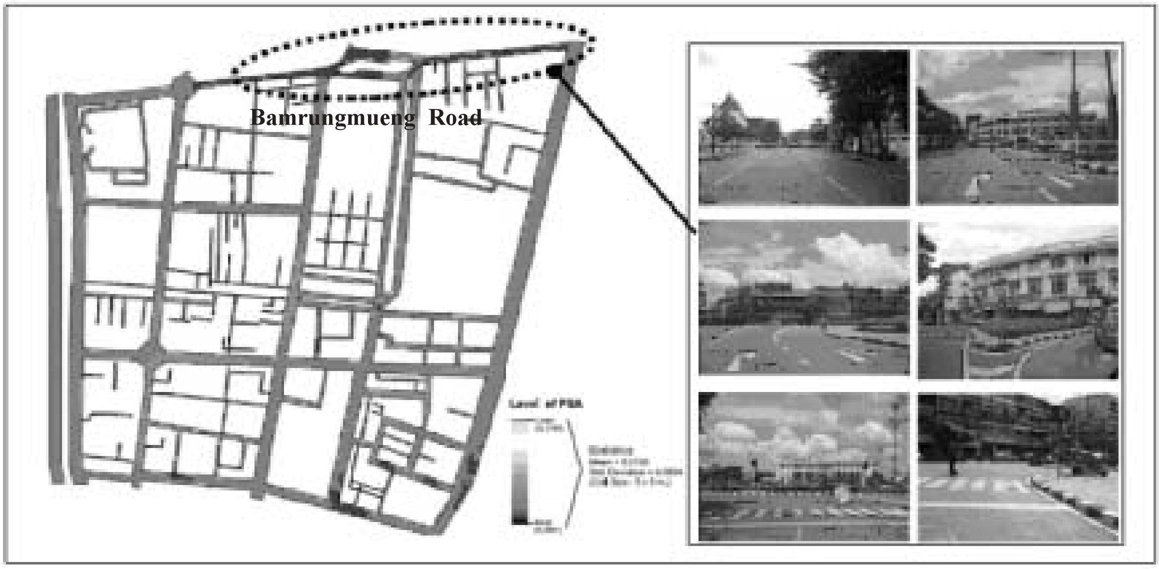


Fig. 11 Risk area: Bamrungmueng road

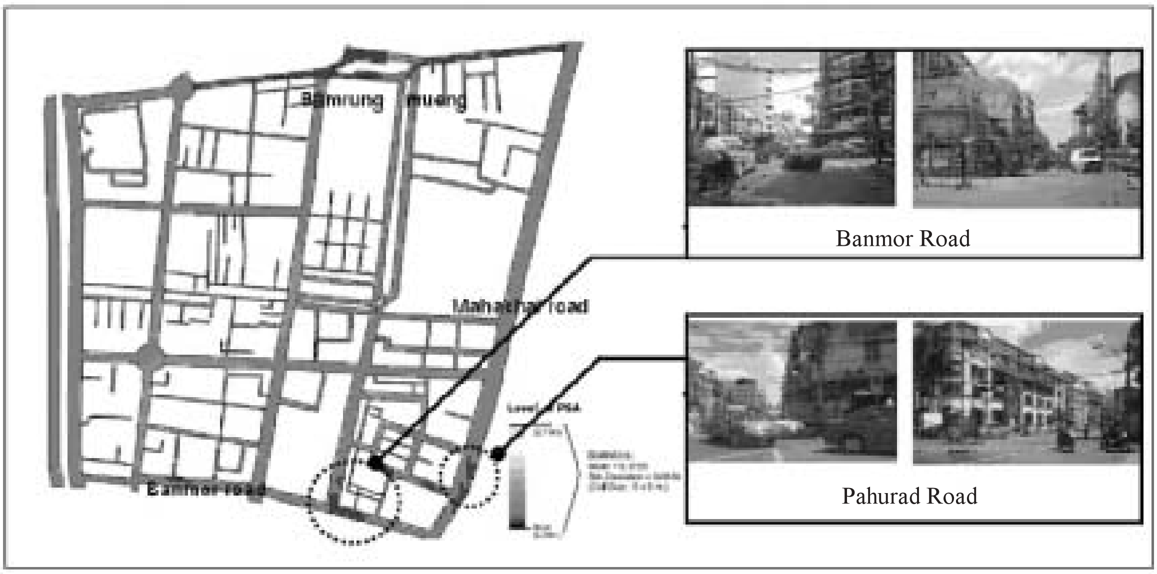


Fig. 12 Risk area: Banmor road and Pahurad road

CONCLUSIONS AND RECOMMENDATIONS

Through a spatial differentiation analysis of road safety factors inducing on unsafe condition of road usage, its relationship can be analyzed by using Analytical Hierarchy Process (AHP) and displayed based on an application of Geographical Information System (GIS). The several classifications of urban factors, e.g., urban density, land use, activities could be analyzing on the application of structured data with complex decisions which can provide the understandable linkage of accident production factors. This is an advantageous approach which could highlight not only the unsafe component of road environment, but the urban factors also significantly contribute to the deterioration of road safety situation.

Furthermore, the analysis provides a way to examine accident prone area in term of mathematical relationships with a visual analysis base on an application of spatial approach. With a more precisely geographical approach, the implications are valuable not only for transportation policy, but also for other related policies which can be identified and help to alleviate or improvement on the practical applications for use by city planners, traffic safety engineers and concerned authorities.

ACKNOWLEDGEMENTS

The authors wish to express their special appreciation to the Thailand Research Fund (TRF) for providing grant support for this research study. The authors also would like to express their profound gratitude to the Police Stations within Phra Nakorn District,Bangkok for providing accident data. Lastly, the authors would like to acknowledge the students of the Faculty of Architecture and Planning, Thammasat University, Rangsit Campus, Thailand for conducting the questionnaire survey.

REFERENCES

Bener, A., Abu-Zidan, F., M., Bensiali, A., Al-Mulla, A., A. and Jadaan, K., S. (2003) Strategy to improve road safety in developing countries, Saudi Med J, Vol. 24, 6, 603-608.

Saaty, T.L. (1980), The Analytic Hierarchy Process, McGraw-Hill, New York, NY.

Saaty, T.L. (1990), Multicriteria Decision Making: The Analytic Hierarchy Process, RWS Publications, Pittsburgh, PA.

Souleyrette, R., Strauss, T., Estochen, B. and Pawlovich, M. (1998) GIS-based accident location and analysis system (GIS-ALAS), Center for Transportation Research and Education, Iowa State University, Office of Transportation Safety, The United States.

The World Bank (2008) The study of traffic accident cost in Thailand, Department of Highways, September, 2007

Vorko-Jović, A., Kern, and Biloglav, Z. (2006) Risk factors in urban road traffic accidents, Journal of Safety Research, 37, 93-98.

Wedagama, D., P., Bird, R.N. and Metcalfe, A., V. (2006) The influence of urban land-use on non-motorised transport casualties, Accident Analysis and Prevention, 38, 1049-1057.

Zhang, W., and Gao, X. (2008) Spatial differentiations of traffic satisfaction and its policy implications in Beijing, Habitat International, Vol.32, Issue 4, 437-451.