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THE STUDY OF URBANIZATION PATTERNS AND THEIR IMPACTS ON ROAD SAFETY

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ABSTRACT: Recently, Bangkok and its vicinities have been growing and become megacity. One of the main affects of land use and transportation interaction is the enormous societal loss in term of road traffic casualties. It requires a tool for safety vision as a proactive and integral approach to coordinate transportation and land use planning decision. This study explores the impacts of urbanization pattern on road safety base on three main driving factors which are physical conditions, economic opportunities and demographic growth together with plans and policies. The results could be compared with the different deterioration of safety level base on an application of severity approach and demonstrated by spatial techniques of aerial photo and geographical information system. With this tool, it is enable for more coordination among different stakeholders for improving road safety situation on an influence of the negative effects of sprawling development while promote sustainable transportation.

Keywords: Urbanization, land-use, urban planning, road safety

INTRODUCTION

The urban growth was recognized as physical and functional changes due to the transition of rural landscape to urban forms which has been addressed by several researchers (Thapa and Murayama, 2010). It occurs when there is a migration of the population distribution changes in relocation to urban areas. These changes also influence to the urban density which would be increasing of its growth rate in several dimensions (Millot, 2004). Especially, when the consideration is taken for the developing countries, the rapid growth of urban area involves in the use of private car, energy consumption, the deterioration of urban environment, particularly the number of injuries and deaths of people on road. Thailand as a rapid development country, transportation sector by motor vehicle plays a significant role as the main functions in normally, that crucial to the economy and urban development. This may be represented as one of the driving factors to the mounting of number of road accidents which can be clearly seen by the aggravating number of casualties. The Office of Transport and Traffic Policy and Planning (2009) reported that each year the number of deaths from road accidents is about 13,000 cases per year, or approximately 22.21 per one hundred thousand populations. When considering the number of injury, disability and loss incurred by families are more than 900,000 cases per year. In the view of economic losses, the road accidents cost is estimated in financial term of damage accumulative more than 7.2 billion US. dollars per year or approximately 2.8 % of the country's GDP (DOH, 2007). With the rapid rate of economy growing, the influence of the socioeconomic pressure also plays an important force on driving of urban growth and in the same time it has been degrading the safety condition of road users. It influences on the reducing of employment rate together with the number of economic activities in urban area which also generates the impact on the travel behavior by reducing number of trip rate (World Bank, 2008; Zhao, 2009). This trend is concurrent indicated by the Royal Thai Police (2008) that the number road crashes increased dramatically after that, from 73,725 cases in 1998 to 124,530 cases in 2004 when in peaked. Afterward, it decreased continually to 101,752 cases in 2007. For the economic losses due to road accidents in 1998, about 12,234 persons were killed, and then it increased continually to 12,492 persons which were killed in 2007. At the same period, the number of the injured person increased from 52,538 in 1998 to 79,029 in 2007.

Although, the trend of accident statistics has been decreasing to some extent, it is also necessary to sustain the situation of road safety. Recent researches have shown several efforts by several organizations focusing on the reduction in the number and severity of road crashes (Bener et al., 2003). However, most of the researches rely on the detail of data for analysis of problems at specific locations in order to design remedial measure. Some of inadequate data of traffic injuries

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which are primarily based upon hospital logs or police records may not allow the road safety problems to be able to manage effectively. Furthermore, it is common problem among developing world about the under-reporting data with lack of coordination among the various disciplines, institutions and organizations. Thus, for proactive measurement the policy and planning might be required to be reviewed to launch the effective plan which is corresponding to the current phenomenon of the problem. Correspondingly, it was found that there are few researches which have been conducted to investigate the affect of the road safety situation due to the rapid growth development (Millot, 2004). The question from the view point of road safety on the rapid pace of urbanization brings about an idea to pay more attention to the other view of the influencing factors on this situation. Nevertheless, Iamtrakul and Pimonsathean, (2010) found that the problem is predominantly urban, concentrated in the large city with particularly sharp increases in deaths and serious injuries experienced in big cities, especially in Bangkok and its vicinity. This might be due to the comprise of inappropriate mixes of road user traffic, particularly in urban areas; high motor vehicle speeds, a poor road environment and poor vehicle crash protection (World Bank, 2008). To meet this expansion, GTZ (2004) stated that many developing world cities are increasing the capacity of their road network, but often at the expense of the safety for the vulnerable road users. It still could not sustain the safety situation due to the evidence of the high number of people died and are injured unnecessarily in road crashes, with the consequential social, economic and health burdens imposing heavy constraints on sustainable development.

With this phenomenon, it is obviously seen that the task of managing urban growth has increased in both scope and complexity and has become one of the most important challenges of the 21st century (Millot, 2004). Without appropriate measurement, the situation may turn to be worse as Zhao (2009) stated that by 2050 nearly 70% of the world's population would live in cities by the projection of the United Nations Population Division (2007). The reality of this development indicates that urban areas would continue its growing rate, in particular in mega cities of developing countries with more infrastructure development. While infrastructure services provide more accessibility, people tend to build home and settle down in areas along highway, which raises consequences about road safety issues as well as efficiency of road utilization (World Bank, 2008). To get to the bottom of this problem, several researchers revealed the same questions for the need to address the guide for such rapid urban growth in a sustainable manner (Millot and Méditerranée, 2004; Thapa and Murayama, 2010; Iamtrakul and Pimonsathean, 2010). Thus, the growing burden of road injury and the substantial lost in term of societal and economic value for the mobility in the country is clearly a key challenge for the responsible agency which is immediately required as basic information of coordination among the various disciplines, institutions and organizations involved. The ultimate aim of this study is, therefore, attempted to provide an understanding about the influence of urban growth on road safety as an alternative approach for assessment of road safety in the case study of mega city, Thailand. The method consists in (i) identifying the situation of urban growth, (ii) analyzing this influence on road safety and (iii) studying the relationship between urban growth indicators and evaluating its impact on road safety with the policy suggestion of the specific problems which were identified.

SITUATION OF URBAN DEVELOPMENT AND ROAD SAFETY

Several studies had mentioned about the dynamic process due to the changes over its spatial and temporal dimensions which could modify the travel demand patterns and induced changes in transportation system (Shaw and Xin, 2003). Due to this reversible interaction between land use and transportation development, it requires an understanding of how the land use associate with urban growth. With its evolution, the new accessibility with more construction to accommodate new demand creates lot of impacts to several aspects of urban development, e.g., travel behavior, mobility pattern, safety aspects. Litman (2010) stated that the change in mobility can be described in term of per capita vehicle ownership and use, modal split, use of nonmotorized modes and accessibility by the people who are physically or economically disadvantaged. This study also explored the evidence to support the evolution of urban growth and safety situation in mega city, Thailand. The statistics from ASEAN Statistical Yearbook (2003) had revealed and showed an interesting fact that with the total area of the country of 513,120 km^2., the road development has been growing about 2 times within 10 years (1997-2007) as depicted in Fig. 1. Also, since then the first stage of the city's expressway system was constructed and completed in 1987 of 27.1 km. It is continued growth to provide alternative routes for people who might prefer to avoid the congestion in the city, especially for Bangkokians as of the total length of service is 198.4 km. until now. With this overwhelming situation of growth in the country, when the consideration is taken for the metropolitan areas, it was found that the growth have expanded due to continuous migration, far beyond its traditional jurisdictional boundaries. It was also known as greater Bangkok as of the high speed in growing of urban area further than the boundary of its surrounding which includes 5 adjacent provinces; Nonthaburi, Samutprakan, Pathumthani, Samutsakhon and Nakhonpathom. With the area of Bangkok Metropolitan Region of 7,761.50 km^2, the population was estimated to be approximately 12 million with the population density of 1,301.42 per km^2 (Fig. 2). To reveal the situation of urbanization

progress within the past 20 years (between 1988 and 2002).

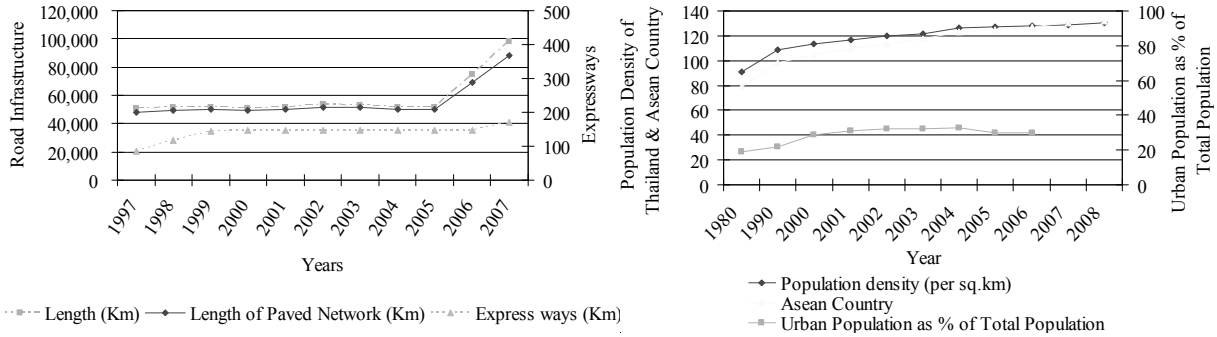


Fig. 1 The development of infrastructure and population growth in the country

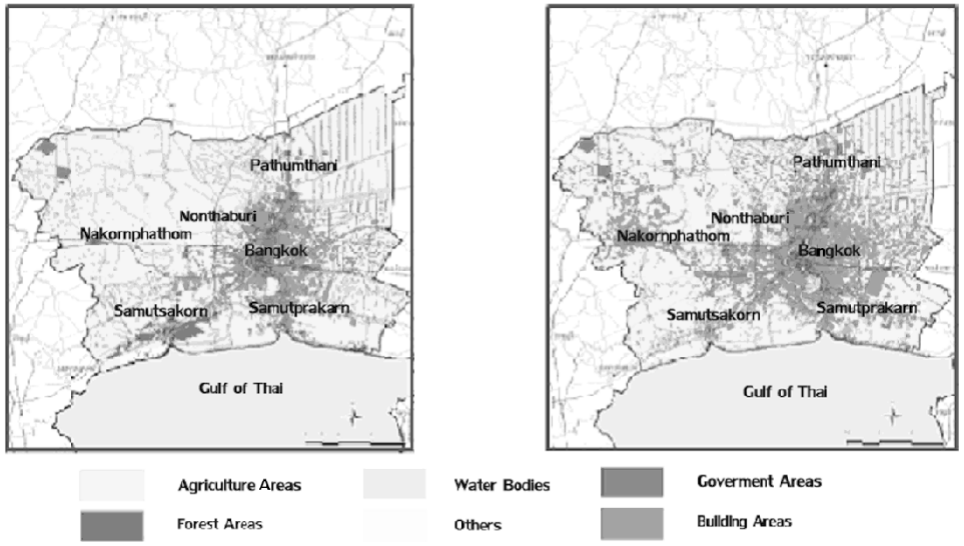


Fig. 2 Expansion of urban areas in Bangkok and its vicinities
Source: The second revision of Bangkok Metropolitan Comprehensive Plan, 2006

However, due to the weak enforcement of planning and control measures, Perera et al., (2007) stated that the rapidly increasing in term of population density cause the losing of some agricultural land and expedite urban sprawling to almost all sides of the city including the adjacent provinces. Furthermore, Rujopaharn (1999) also criticized that Bangkok was failed to decentralize its growth since the 5th National Economic and Social Development Plan (1982-1986) by allocating almost 20 billion baht for only road an expressway projects with BMR. It was also found, although the 6th Plan (1987-1991) recommended the more systematic and integrated approach to provide the linkage of physical planning of an infrastructure investment, however, it had been still arising in the problems of financial capability to cope with the existing dilemma (Kaeokungwal, 1990). Fortunately, during the 7th Plan (1992-1996), the second revision of Bangkok metropolitan land use plan was established to emphasis on the more coordination between land use and transportation plan by proposed a multi-nodal metropolitan with a ring of sub-centers. This is consistent with the suggestion from Cladera et al. (2009) that a metropolitan area could therefore be seen as one comprising urban sub-systems, characterized by greater or lesser degrees of monocentrism. During the 8th Plan (1997-2001), the first MRT line was completed in 1999 and operated by recognizing as the Bangkok Transit System (BTS) or Sky Train (Green Line) with a total length of 22.9 km. (IMAC, 2005). However, with the limited service of transit line and the more investment program for 1,000 km. of road and expressway project instead of financing a mass transit network of 260 km. during the 9th Plan, Bangkok and its vicinities have been continuously dominated by the roads-oriented development with the unsolved traffic congestion crisis (Rujopaharn, 2003). It is crystal clear that the urban sprawl has become the main influence to the settlement along the network expansion. The more use of private car which rises to the question of road safety as undoubtedly depicted in Fig. 3. This problematic has become the challenges of sustainable development, although the similar trend of decreasing in accident rate of the country, Bangkok and its vicinity. It is counted about 64 % in 1998 and reducing to 47 % in 2007, while the regional provinces were about half of the total number of accident during 1998 and 2007.

Furthermore, the number of serious accident which cause of death in the provincial area has been in the stable rate. It was found that the number of death in this area was continue rising from 6 % to 11 % during the same period.

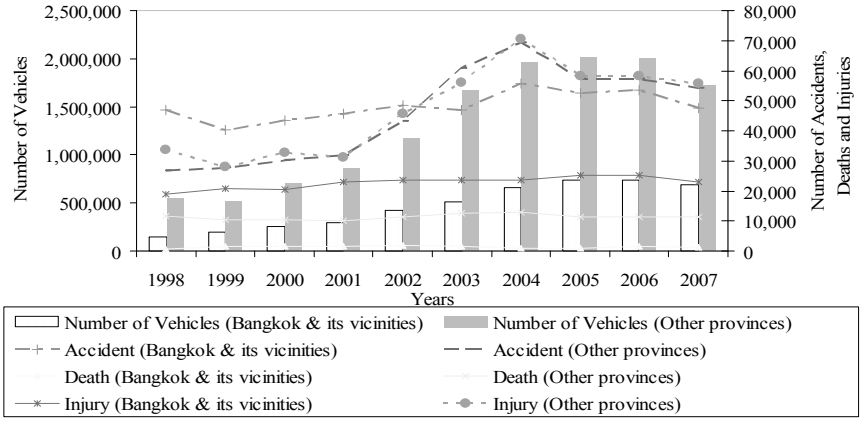


Fig. 3 Situation of Road Accident in Bangkok and Its Vicinities
Source: The Royal Thai Police, 2008

This unacceptable negative effects of urbanization, thus calls for an urgent look into the consequences of urbanization in bangkok and its vicinities. Subsequently, it is undeniably to set up the strategic planning to secure long-lasting improvements in road safety.

DETERMINATION OF RISK AREA INFLUENCED BY URBAN GROWTH

3.1 Preliminary Determination of Risk Area Influenced by Urban Growth of Bangkok and its Vicinities

As a capital city of Thailand, Bangkok and its vicinities were recognized as fast growth cities. For an in-depth understanding of the situation in this mega city, the preliminary analysis is required to select the most vulnerability area consequences as a result of urban growth by taking into consideration of three main driving factors into the analysis, e.g. physical conditions, economic opportunities, demographic growth together with plans and policies. The ranking method was then employed to perform the screening of the selected study area to input into further analysis. The overview of input data was derived on the basis of the calculation of the changes in average annual growth rate by gathering a substantial amount of data compiled from varied sources in Bangkok (e.g. Department of Public Works and Town & Country Planning, 2008; Department of Provincial Administration, 2008; National Statistical Office of Thailand, 2008). The changes in the built up area of Bangkok and its vicinity can be depicted in Fig. 4 and their changes were also determined by the different aspects of growth, e.g. infrastructure demands (ground water, electricity and educational service) to demonstrate the most potential area based on the situation of urban growth along with road safety to set an objective assessment to clarify the spatial features of the growth and its influencing to traffic safety problems. The study area was selected based on the technique of overlay and the ranking method which had been suggested by several researches due to its simplicity as a straightforward allocation of the importance points and unit weighting to the indicators (Schoemaker and Waid, 1982; Pitz and Mckillip, 1984). The approach of weighted multiplication was derived to determine suitable selected area of road safety caused by the expansion growth of its development. The analysis of the risk area associated with the phenomenon of sprawl was then analyzed by the multi-aspects data obtained from various sources and applying with the weight of analysis. The weight calculations were obtained from the interview of urban and transportation planning experts, practitioners, local planners and government officials regarding the policies of urban development and road safety in Bangkok. The preliminary result of analysis in term of the annual average percentage of normalization growth rate at different perspectives, e.g. built up area, density, no. of fatality due to road accident is represented by risk score which can be shown in Table 1.

Additionally, based on an integrating approach of geographic information system (GIS), the assessment on the effects of road accident by the growth of cities can be presented by the application of spatial analysis. Fig. 5 demonstrate the results through its weight of the importance index of risk factors. This is useful for illustration of the risk areas together with the unsuitable urban transportation development which can be explained the different level of risk in different color. Then, Bangkok and five vicinity areas were examined; Samutprakarn, Pathumthani, Samutsakorn, Nakornpathom and Nonthaburi during period of changes between 1988 to 2007. This study also applied the spatial overlay operation to develop alternative method which allow for examine the relationship of all effects of growth indicators interact with safety problem (physical, demographic and economic factor) in the study area as illustrated in Fig. 5. The highest value of calculation revealed that Pathumthani was selected as the most influence area. The selection of risk area was derived from the average of normalization value among three

criteria which influence on the study area. Finally, the calculation result of risk score of this area was about 0.73 which represented as the highest value, followed by Nakhon Pathom (0.64) and Samut Prakan (0.42), respectively, as shown in Table 1. When considering on the changes of physical aspect, although, Pathumthani was found that built-up areas slightly increased by 5.64% at annually from 132.48 km^2 in 1988 to 282.01 km^2 in 2007, its demographic changes represents the largest value among the other growing provinces in comparison. The preliminary result also demonstrated the high and more concentrated of settlement is related to the development zones. This is due to the goal of provincial development plans which includes education and research center, technology development and supports those communities with land for residential and employment developments. Its role was also designed to serve economic growth in the future which indirectly creates a center of migration to the province in the highest rate of 3.28 %. In fact, there are many researches already mentioned about the missing application caused by inadequate knowledge to maintain the quality of infrastructure services, especially highway and road network for safety confidence (Rujopakarn, 2003; GTZ, 2004; Millot, 2004). As expected, the significant evidence in term of people died as a consequence of road crashes was found to be annually average about 5.59 % which represents the highest growth. This might be due to several factors induced by the rise of proximity to city streets in land development as it is represented the highest growth in term of density of population of 654,701 people in 2001 to 896,843 people in 2007 (area of 1,526 km^2). Additionally, the number of housing had been increasing from 282,275 units in 2001 to 427,051 units in 2008. As a consequent, changes in housing development are one of the main pressures to increase in the need for long distance travel, in particular travel between the city centre and suburban area with their private trips. When considering the location of Pathumthani as an influenced area, it is located in the northern of Bangkok and situated by the access of major highways connected to the north and northeastern region of the country. Paholyothin highway plays an important role as the main road to provide accessibility to the residential and the employment in this area as the main trip attraction which are consisted of employment sectors, residential areas and academic institutions including Thammasat University (Rangsit Campus), Navanakorn Industrial Zone, Thai Market, etc. However, during peak hour for both morning and evening, it also brings about the problem of traffic congestion and safety problem as a general view of this area. Furthermore, with the consideration of the development plans at national, regional, sub-regional, provincial and municipality level, Pathumthani as a selected area for input to the further analysis could be also viewed as the prevalence of the satellite town of educational institution and industrial area. This represent its high growth rate which is consistence with the previous study about the occurrence of the growth had been redeployed in the satellite towns rather than in the central town (Millot, 2004). Meanwhile, the evolution of road safety in the area should be studied in more comprehensive approach to create an effective linkage of this urbanization leading to a conclusion on the effects of road safety point of view. The suggestion for further development plans could be shaped in the more efficiency of commuting attraction which simultaneously strengthens the safety aspects in achieving urban sustainability development. 3.2 Analysis of Urbanization Pattern of the Risk Area

The study area was selected to input into further step of analysis which was represented its strong growth of the most dynamic province in term of physical, economic and demographic changes. This area is also predominantly affected by the tragic outcome of road casualties. However, to analyze road safety situation in the study territory, the accident data had been accessed from several sources, e.g. the hospital, police and highway district of Pathumthani records. The files list of accidents was collected during year 2001 to 2006 of 2,812 records. Although, the accident statistics revealed that the number of accident is slightly increasing from 1,184 cases in 2001 to 1,190 cases in 2006, the number of fatalities is about 61.5 % increasing from 169 persons in 2001 and the number of injuries is approximately 90 % higher than in year 2001 (643 persons). Fortunately, the locations of accidents were recorded with its related attribute of accident location, vehicle involvement, type of damage, etc. which could be used to facilitate the methodology of this study. Based on this approach, the outcome is necessary to be explored to make a distinction between accidents occurring in the different intensity of growth and the level of risk based on severity analysis. The aerial photographs and the different layer of data in the form of a geographic information system (GIS), at the different periods available over the past 6 years (2001 – 2006) were utilized as base map. The aim was to pinpoint growth in the urban territory and notably the occurrence of accident on the basis of this expansion over the period. Firstly, the identification of changes of the urban surface area was performed for two different years due to the availability of aerial photograph of year 2000 and 2004. This study also applied the remote sensing data to input into the analysis by derived from satellite based data by Landat5 of the thematic mapper (TM) sensor data and Landsat 7 of the enhanced thematic mapper plus (ETM+) sensor data (Suksa-ard et al., 2010). Two data sets of Landsat TM/ETM+ images, in 2000 and 2004, were utilized to investigate the morphological changes in land cover. The 2000 image was registered into 1: 4,000 topographic maps of Patumthani province. And Transverse Mercator geo-referenced, the TM image was then co-registered to ETM+ image with the resulting of the acceptable standard deviation values ranging from 0.13 to 0.24 pixels. Process evaluation of the land cover change was categorized by utilizing the landsat satellite image. Then, this study applied the remote sensing to obtain the description of building density with a spectral transformation called “urban index transformation” with

the assumption of high pixel value indicated the built-up area intensively. The build up area and the vacant land could be categorized together with the urbanize index as shown in equation (1) (Kawamura et al., 1996).

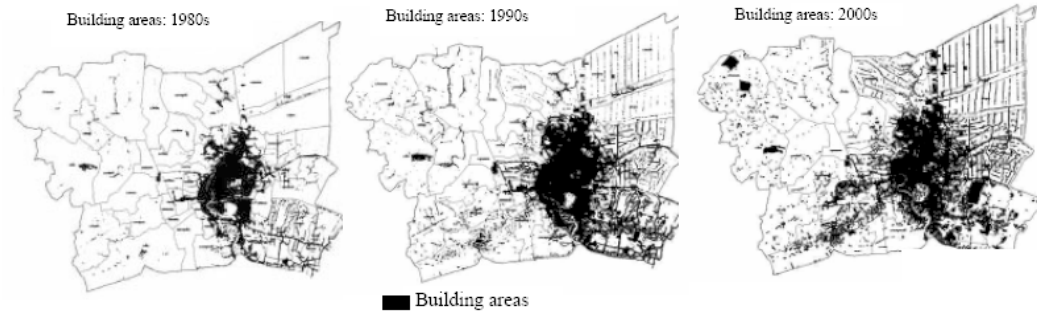


Fig. 4 The growth of building areas in Bangkok and its vicinities
Source: Department of City Planning, Bangkok Metropolitan Administration, 2005

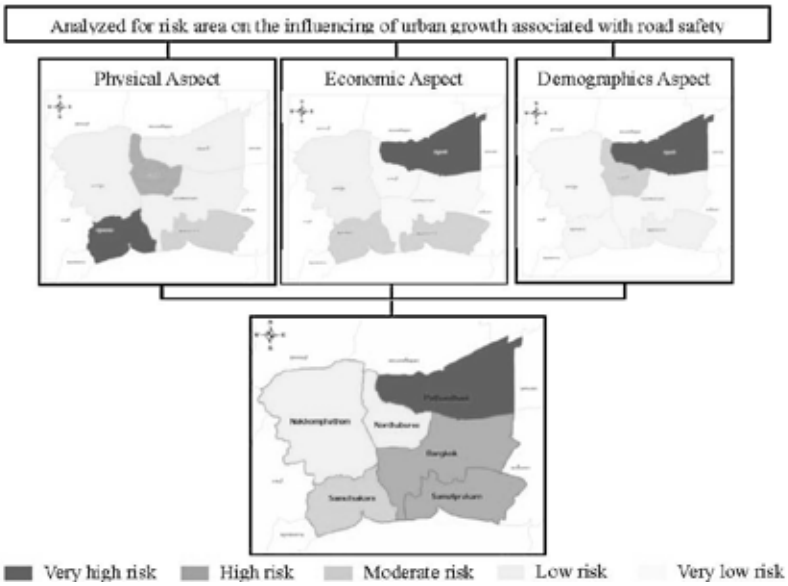


Fig. 5 The selected study area base on the weighted derivation by ranking method

Table 1 The screening of risk area of Bangkok and its vicinities influencing by urban growth

Area	Buit Up Area (km^2)			Density (Person/km^2)			No. Of Fatality (Person) due to Traffic Accident			Risk Score
	1988	2007 %		1997	2007 %		1997	2007 %		
Bangkok	609.52	841.68	1.90	5,680,380	5,716,248	0.06	1,582	1,499	-0.48	-0.0029
Samutprakarn	172.61	247.01	2.16	995,838	1,126,940	1.20	186	282	4.69	0.4206
Pathumthani	132.48	282.01	5.64	654,701	896,843	3.36	169	273	5.59	0.7254
Samutsakorn	79.99	105.27	1.58	428,814	469,934	0.87	98	148	4.64	0.3792
Nakornpathom	45.05	333.65	32.03	781,138	830,970	0.58	202	294	4.14	0.6375
Nonthaburi	79.35	141.83	3.94	859,607	1,024,191	1.74	128	139	0.78	0.2601

$$UI = \left(\frac{SWIRsChannel - VNIRsChannel}{SWIRsChannel + VNIRsChannel} + 1 \right) \quad (1)$$

Where *SWIR* (Short wave infrared) channel is represented of band 5 and *VNIR* (Visible and Near Infrared) channel is corresponded to band 2.Base on this application, then, the urban growth can be determined between 2001 and 2006 with the study area of 1,520 km^2. It was then divided into smaller size of the total of 431 grid block of cell size of 4 km^2 (2 km. x 2 km.) of space between them. GIS application was then employed for further analyze and overlay of different attributes which were digitized and geo-referenced. The detail of determinants which were included for spatial investigation can be described as follows;

- Growth Factors:
  - *Physical Characteristics*: land use (commercial, industrial and warehouse, institution, education, religion, residential, mixed use), access to

infrastructure service (electricity, water supply, education), build up and vacant areas;
- *Transportation Characteristics*: hierarchy of road (arterial, collector and local road), traffic volume (high, medium, low), road network (section, intersection, curvature), conflict (crossing, diverging, merging);
- *Economic Characteristics*: GPP, income, employment
- *Demography Characteristics*: number of population, density of population, household size, immigration and emigration.

▪ Road Safety Factors:
- *Accident Characteristics*: number of accident, number of fatality and injury;
- *Severity of accident and hazardous location*.

This procedure allows for the superposing of the photographs along with the GIS attribute data, then the comparison among different urbanization pattern can be evaluated at the combination of three levels of both distinctive of growth factors and road safety factors (high, medium and low). To quantify the influences of explanatory variables on the urban expansion incorporate with road safety, this paper performs the analysis as described in the following steps;

1. Analysis of a single layer of growth factor, such as physical characteristic, transportation characteristics, economic and demographic characteristic.
2. Perform the severity analysis by adopting the severity index (*SI*) which could be described as economic losses of victims on accident in term of monetary. The monetary value of person saved from the fatality and prevented from injury and of the property prevented from damage could be determined. This allows the final selection of the specific area of problem which represented the value of high, medium and low. It was derived based on the reliability of the magnitude from the result of severity analysis (Jica, 1987; Kankajit, 2002; Charnkol et al., 2006).
3. Identify all possible combination of growth and road safety factors. This indicates the relative magnitude of each grid cells and accounts for prioritize (also called sorting) by grouping of data divided into mutually exclusive classes and the number of occurrences in each class of high, medium and low.
4. Evaluate the pattern of urbanization against the changes in a set of spatial variables. This analyzes take into account for sorting effects, including its tendency as to provide a clear scenario of urban growth patterns and their consequences in road safety situation.

RESULTS OF ANALYSIS

This approach then enabled for the evaluation of urbanization pattern of different level of risk in the selected study area since the changes of urban growth could be observed during the period 2001–2006. This is to pinpoint the combination of different intensity level of urban growth associated with road safety by the territory studied. Indeed, the built-up areas between the study periods were mainly made up of mostly residential housing (56.18 %). For the second most building type, which creates a major attraction for population growth in this area is an industrial sector. It can also be observed a certain sprawl of this study area as most of the housing and employment nodes are mainly made up along the main highway. The result as shown in Fig. 6 indicated that as its role of the satellite towns, which had strong population growth, also induce a strong expansion in built-up areas. Based on the analysis as previously determined, the finding revealed the dark color cells represented the high value of analysis which were selected for the nine combinations to assess the association pattern of growth and safety aspects (Table 2). It is apparently evidenced that the location of the high growth and high risk area (*HG-HR*) is located in the area of high density of building in different type of urban activities which is concentrated near to the allocation of transport infrastructure and center of employment area on the west side of the urban fringe of Bangkok. The majority of land use in this area is industrial sector (57 %), follow by the residential and mixed use sectors (mixture between residential and commercial in the same area) of 28 % and 6 %, respectively. Density also plays an important aspect to form urban development which is found to have a significant impact on the travel patterns of people in this neighborhood area. Although, there is some mixed land use which should reduce motorized travel, conversely it deteriorates the congestion as of private vehicle usage in this area, especially the morning and evening peak hour as there is the availability of major highway no. 3312 with 6 lanes. On the other hand, considering the low growth and low risk area (*LG-LR*), the low density of area represents the low intensity of land use activity which also induces a low traffic. It can be seen that the allocation of road infrastructure in this area is highway no. 2019 with 2 lanes for serving the majority use of resident (92 %) as illustrated in detail of Table 2. Finally, the urban expansion as urbanization has become a key issue to sustain the road safety provision which the finding is obviously shown the affect transportation patterns in many ways – through increasing densities and concentration, through mixed use development, through housing location, and through establishing the real integration of transportation and land use plan for the availability of services. Base on this approach, the dimension of driving factor could be graphically presented in Fig. 8 for further clarify the roles of each factor competes with the others in the different pattern of urbanization. Additionally, the influence of socio-demographic pressure on the changes of the physical conditions could be simple examined by inclusion of experts' perceptions through the participation of concerned authorities or local government officials in the process of evaluating the driving factors and minimized the risk as a result of traffic accident. The quantification of these contributing

roles in changing the land use patterns is an important piece of information that would contribute to impact of road safety while understand future urban growth processes.

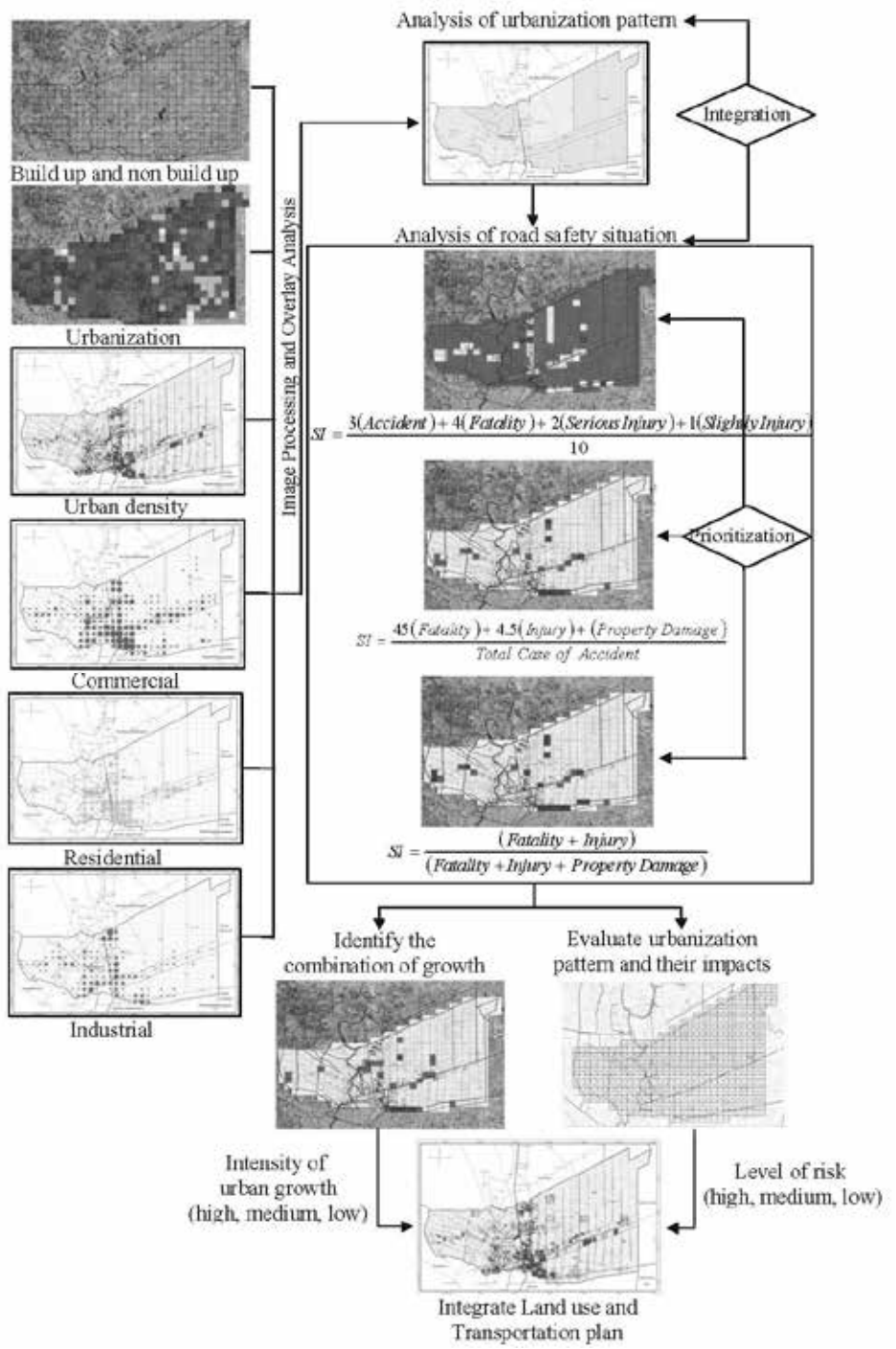


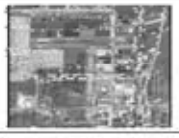
Fig. 6 The analysis of urbanization pattern and their impacts on road safety

CONCLUSIONS AND RECOMMENDATIONS

This paper has contributed to improve the understanding of urbanization pattern and road safety in mega city of Thailand, Bangkok and its vicinities. The analysis presented the appealing point of the dynamic change between the urban expansion and road safety which involves in many driving forces such as demographics and economic development. These revolutionizes also significantly transform the spatial pattern in Bangkok and its vicinities during 1980s and 2002. These changes were driven by three main driving factors which are influenced by physical conditions, economic opportunities and demographic growth, including plans and policies. This study aims to cope with the rapidly growth of urban area which has resulted to the changes in travel practice and strong influences on road safety by proposing an unconventional method. Base on this useful

methodology, the impact of urbanization could be investigated more precisely with application of aerial photographs and geographic information system. This is not only helps to illustrate the complexity of the urban expansion phenomenon, but the result of analysis also clearly revealed the negative effects on the deterioration of urban development in the current transformation context. Undeniably, the implications of urban growth management for sustaining the road safety situation become tremendous challenges to the issue of policy practice for concern stakeholders in various sectors to coordinate and efficiently implement in order to reduce the number and severity of road crashes within the circumstance of the urban development.

Table 2 The analysis of risk area on the comparison between urban growth factors and road safety factors

Intensity of Urban Growth	Level of Risk	Major Land Use (percent)				Aerial Photo	Road Characteristics		
		R	F	M	I		Description	ROW/ Road Width	No. Of Lanes
HG	HR	28	57	6			Highway No. 3312, Klong 6	18/14, 9/6	6,2
	MR	39		8	45*		Highway No.1, Bangkan and Nongsue road	18/14, 7.5/6	6, 2
	LR	53		8	14**		Highway No. 2005, Chumratpattana	8.5/7, 7.5/6	2,2
MG	HR	79		5	11		Highway No.347, Thammasat road and rural road	17/12, 7.5/6	4,2
	MR	88		2			Highway No. 3059, rural road	7/6, 7.5/6	2, 2
	LR	84	4		7*		Highway No.305, rural road	7/6, 7.5/6	2, 2
LG	HR	53		8	14**		Highway No.3012, rural road	18/14, 6/6	6, 2
	MR	92		2			Highway No.9, rural road	7/6, 6/6	2, 2
	LR	51		5	6**		Highway No.2019, rural road	7/6, 6/6	2, 2

Note: *Academic,**Religion, R= Residential, F=Industrial/Factory, M= Mixed Use, I=Institution

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REFERENCES

Bener, A., Abu-Zidan, F., Bensiali, A., Al-Mulla, Al. and Jadaan, K. (2003) Strategy to Improve Road Safety in Developing Countries, Saudi Med J, Vo. 24 (6), 603-608.

Charnkol, T., Iamtrakul, P. and Kowtanapanich, W. (2006) Identification of Hazardous Location Using Information System Application, Journal of the Faculty Senate, The Academic Division, CRMA, 152-165.

Claera, J. R., Duart, C. R. M. And Moix, M. (2009) Urban Structure an Polycentrism: Towards a Redefinition of the Sub-centre Concept, Urban Studies, 46(13) 2841-2868.

DOH (2007) Traffic Accident on National Highways, Department of Highway.

de Sherbinin, A., Balk, D., Jaiteh, M., Pozzi, F., Giri, C., & Wabbebo, A. (2002). A CIESIN thematic guide to social science applications of remote sensing. Columbia University, New York, NY. <http://sedac.ciesin.columbia.edu/tg/guide_main.jsp>. Accessed 25.12.03.

GTZ (2004) Sustainable Tranport: A Sourcebook for Policy-makers in Developing Cities Module 5b, Urban Road Safety, Deutsche Gesellschaft für Technische Zusammenarbeit. Germany.

Iamtrakul, P. and Pimonsathean, Y. (2010) Impact of Urban Factors on Road Accident in Bangkok, Thailand, Lowland Technology International Journal, Vol.12, Issue 2, June 2010.30-40.

IMAC (2005) The Intermodal Services Integration for the Improvement of Mobility, Accessibility, Sustinability and Livelihood for Bangkok Metropolitan Region (BMR) and Surrounding Area, Office of Transport and Traffic Policy and Planning (OTP), September 2005.

JICA (1987), Traffic Safety, Study on Road Improvement, Rehabilitation and Traffic Safety in Bangkok, Final Report, Japan International Cooperation Agency, Volume IV, 1-34.

Kaeokungwal, C. (1990) National urban development policy and financial strategies for infrastructure expansion in Thailand. Symposium on Urban Development and Transportation in Bangkok, Bangkok.

Kankajit, C. (2002) The Application of GIS for Development of Traffic Accident Database System: A Cse Study of Hadyai, Songkhla, Master Thesis of Prince of Songkhla University, Thailand.

Kawamura , M., Jayamanna .S.,Tsujiko, Y. (1996) Relation between social and environmental conditions in Colombo Sri Lanka and the Urban Index estimated by satellite remote sensing data, Internatonal archived of photogrammetry and remote sensing, 1996, Vol XXXI, part B7 (commission VII), 321-326.

Litman, T. (2010) Land Use Impacts on Transport: How Land Use Factors Affect Travel Behavior, Victoria Transport Policy Institute With Rowan Steele, www.vtpi.org.

Liu, Z. and Yang, X. (2005) Use of Sattle-derived Landscape imperviouseness index to Characterize Urban Spatial Growth, Computers, Environment and Urban Systems, 29, 524-540.

Millot, M. (2004) Urban Growth, Travel Practices and Evolution of Road Safety, Journal of Transport Geography, 12, 207-218.

Millot, M. and Méditerranée, C. (2004) The Influence of Urban Planning on Road Safety, European Transport Conference, Strasbourg, France, 4-6 October, 2004.

Perera, R., Permana, A.S. and Charoentrakulpeeti, W. (2007), Promoting Reduction in Travel Demand in Transport Sector of Asian Cities, Air Pollution Control in the Transportation Sector: Third Phase Research Report of the Urban Environmental Management Project, IGES (Hayama), Japan.

Pitz, G., F. and Mckillip, J. (1984) Decision Analysis for Program Evaluators. Contemporary Evaluation Research Series 7., Beverly Hills, SAGE.

Rujopakarn, W. (1999) Study on transport investment in Bangkok Metropolitan Region during the 8th National Economic and Social Development Plan (1997-2001). Journal of the Eastern Asia Society for Transportation Studies (EASTS), 3(4), 7-21.

Rujopaharn, W. (2003) Bangkok Transport System Development: What Went Wrong?, Journal of the Eastern Asia Society for Transportation Studies (EASTS), Vol.5, October, 3302-3315.

Schoemaker, P. and Waid, C. (1982) An Experimental Comparison of Different Approaches to Determining Weights in Additive Utility Models, Management Science, Vol. 28 (2), 182-196.

Suksa-ard, P., Iamtrakul, P. an Srivanit, M. (2010), Influence of Road Development and Land Cover Change on Urban Heat: A Case Study of Pathumthani, Thailand, Journal of Society for Tranportation and Traffic Studies (JSTS), Vol.1, No.2, 49-63.

Thapa, R. B. and Murayama, Y. (2010) Drivers of urban growth in th Kathmandu valley, Nepal: Examining the efficacy of the analytic hierarchy process, Applied Geography, 30, 70-83.

World Bank (2008) Thailand Infrastructure Annual Report, Bangkok.

Xin, X. and Shaw, S. (2003) Integrated Land Use and Transportation Interaction: a Temporal GIS Exploratory Data Analysis Approach, Journal of Transport Geography, 11, 103-115.

Yang, X. (2003) Remote sensing and GIS for urban analysis: An introduction. Photogrammetric Engineering and remote Sensing, 69(9), 937, 939.

Zhao (2009) Sustainable Urban Expansion and Transportation in Growing Megacity: Consequences of Urban Sprawl for Mobility on the Urban Fringe of Beijing, Habitat International,1-8, In press.