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EVALUATION OF STORM SURGE MAP FOR SAFETY IMPROVEMENT IN BANGKOK METROPOLITAN REGION, THAILAND

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ABSTRACT: Recently, there are a number of disaster occurred in several regions worldwide which might be caused of climate change effects. This damage alarmed many researchers to determine the possibility and risk. Bangkok Metropolitan Region (BMR) is low land area which is potentially flooding risk caused by river flood, flash floods and tropical storm in each year. Evacuation approach is necessary to response in disaster event, especially in low lying areas from the potential life-threatening effects of hazards to safe inland. According to study the local people's perceptions of storm surge in Amphoe Mueng, Samut Prakarn, the result was shown that most samples evacuate to outside Samut Parakarn area by their own vehicles and evacuate immediately when they have been warned from the government. This paper proposed two main objectives which area; 1) Evaluate Risk level of storm surge and relevant hazard in Bangkok Metropolitan Region (BMR) and 2) Evaluate potential evacuation by overlay between building density in Bangkok Metropolitan Region and road network. Geographic Information System (GIS) was employed to analyze hazard risk level with Spatial Analysis technique.

Keywords: Evacuation Routes, Storm Surge Risk, Spatial Analysis, Bangkok Metropolitan Area

INTRODUCTION

Disaster has affected to human settlement in many centuries, especially in recent decade. Many area that never effected by disaster had been effected. Because of the distortion of weather caused from climate change. Moreover, disaster event had occurred more frequently and dramatically from the last decade, one reason is from climate change and global warming which induced flash flooding, sea level rise and tropical storm in tropical area.

There are many researchers researched the probability of storm surge occurrences in Gulf of Thailand. Many researchers predicted the hazard area may cover to Pathumthani province. Although the government and related sectors had announced, planning for evacuation to safety area are not planned seriously. However, if was found that in the Thai context, the preparedness of local people is in the low level, but when they have been warned they will evacuate immediately by their own vehicle. Thus, there are probably chaotic evacuations, which get traffic jam and cause evacuation more difficulty.

This study was attempted to estimate evacuation demand during storm surge which occurred by focusing on shortest path, quickest path and population aggregation on plane that represent in current situation. Then, the result of analysis will be compared to development through regulation, to analyze future demand and suggest suitable for solve problems.

Donald and David (2006) had defined that storm surge is phenomenon that tidal wave had risen offshore by influence of high air-pressure and tropical storm. First occur by high wind speed gale on ocean surface which pressuring ocean surface that made dome water of surge. The damage of storm surge is depending on pressure, storm, tidal wave, rainfall. Not only storm surge could occur near coastline, but also occurred on big lagoon or large water area. Storm surge will be realized by people perception, because storm surge can only happened on severe storm sequence. However, most of the cased would concern to related hazards such as flashfloods, landslide and violent gale. Damage by storm surge is severe more than usual flooding because before storm surge happened; it must have heavy rain by severe storm and high pressure. Related problems can be made urban drainage system malfunction, damage by wind can destroy wooden houses.

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Warfield, C. (2009) had presented the absolute goals for disaster mitigation planning which trying to reduce damage caused by disaster as much as possible, the fundamental of disaster mitigation planning are listed as described in the following:

Preparedness – This step is planning to countermeasure risk or hazards that might be occur in the future. It concern with evacuation practice, early warning system, planning for counter measurement etc.

Response – This step is mitigate or operate for minimize disaster loss which concern on disaster aid, evacuation management, rescue etc.

Recovery – This step is operate or reconstruct failure system caused by disaster or construct basic needs such as temporary shelters, funding, medical care, etc.

Mitigation – This step is planning for minimizing loss as much as possible, it can be either structural measurement or non-structural measurement such as land use control, hazard risk assessment, indoctrination, etc.

Spatial analysis by using geographic information system (GIS) for analyze risk area could be performed by Multi-Criteria Decision Analysis (MCDA) This technique is adopted the overlay method and weight calculation for categorize and scoring in each separate grid.

Xu (2007) has shown his concept on temporary shelters based on Vitae system is aimed to provide temporary shelters for relief which are difference types, function and definitions which depend on each country, major characteristics such as well-known place, large area, ease to access and sense of public place. Some countries categorized level of temporary shelter into 4 levels (Household level, Neighborhood level, Community level and Regional level) Temporary shelter concept on Vitae system can be divide in three parts which contains 1) Survivability 2) Vitality and 3) Conviviality. Every temporary shelter contains these concepts but emphasizes one concept and lead that concept to another aspect which shown in Fig. 1

Many researchers had researched and analyzed the possibilities of storm surge occurrences in Bangkok Metropolitan Area and nearby provinces and found that the coastline area are risky to suffer due to storm surge in higher level, the wave might be surge 3 meter height and spread in the whole area because the physical characteristic. Moreover, this area can be suffered by severe flash flooding and drainage failure, traffic congestion. Thus, evacuation to safety area should be operating urgently during severe flash flood before congestion.

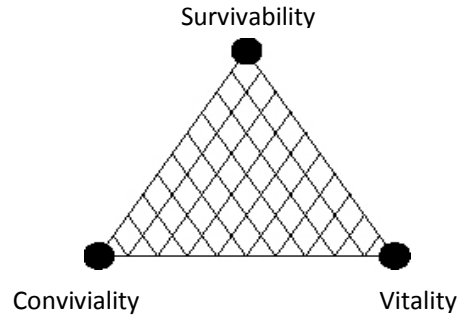

Fig. 1 Temporary shelter on Vitae system
Source: Xu (2006)

Other problem which affected to drainage system is tidal wave because current drainage situation is flowing storm water to Chao Phraya River directly, when the tidal water is rising, it always flow to inland area.

Raungratanaamporn (2009) had studied the perception on evacuation perception of local people who live in Amphoe Mueng Samut Prakarn province. This is the province which located on southern of BMR and located shoreline which confront to Gulf of Thailand. In evacuation behavior, people would perceived to evacuate immediately when they know or has been warned, they chose to evacuate by their own vehicle, and they expected local government to accommodate them by fundamental services. This has shown in Fig. 2.

According to the choosing destination of evacuees to evacuate when storm surge in Samut Prakarn province the study was shown that most evacuees had chosen to evacuate to other area, but some of them had chosen to

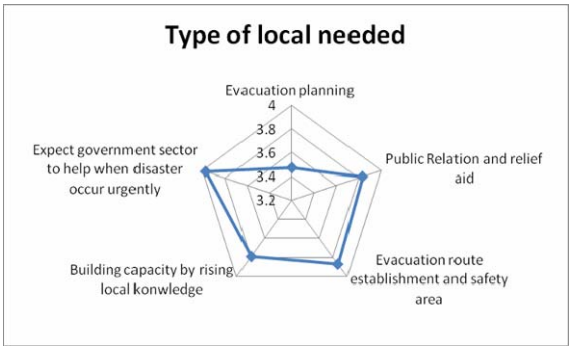

Fig. 2 Type of local needed
Source: Raungratanaamporn (2008)

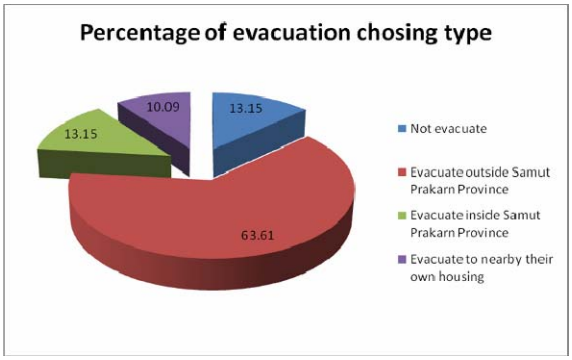

Fig. 3 Percentage of evacuation choosing type
Source: Raungratanaamporn (2008)

stay in risk area. Because they thought storm surge is hardly to occur which presented their lack of awareness, especially, they have no idea to evacuate. This can be shown in Fig. 3.

STUDY AREA

This study area was covered Bangkok and 6 nearby provinces. This study area is situated in Bangkok Metropolitan Region (BMR), the grouping territory between Bangkok and nearby provinces (Pathumthani, Nonthaburi, Nakorn Pathom, Samut Prakarn and Samut Sakorn) as shown in Fig. 4.

Physical characteristic of BMR is low-flat land which sloped from north to central. The prior land use is agriculture but nowadays this area had been changed to urbanized area. This location is potential to flood plain area because these areas is the major basin in central region and normally drain storm water from north to Gulf of Thailand in the southern area of BMR in Fig. 5.

The flooding caused by storm surge in central region can be occurred not only coastal area but may also occurred in large water area in Fig. 6 which shown the risk area from storm surge risk and relevant hazard.

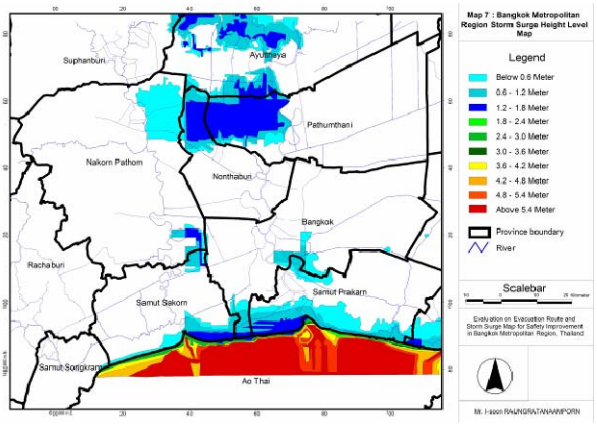

Fig. 6 Storm surge risk area in BMR
Source: Supharatid (2009)

The Road networks in Bangkok Metropolitan Region in nowadays are grid pattern which grid densely in central of BMR and sprawl to nearby region such as north, each and west, which can be depicted in Figs. 7 and 8.

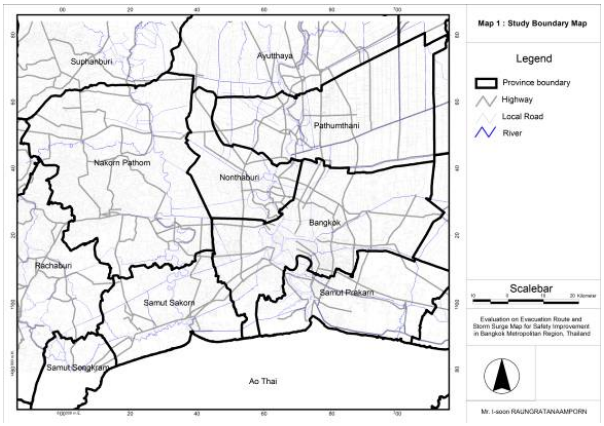

Fig. 4 Study area

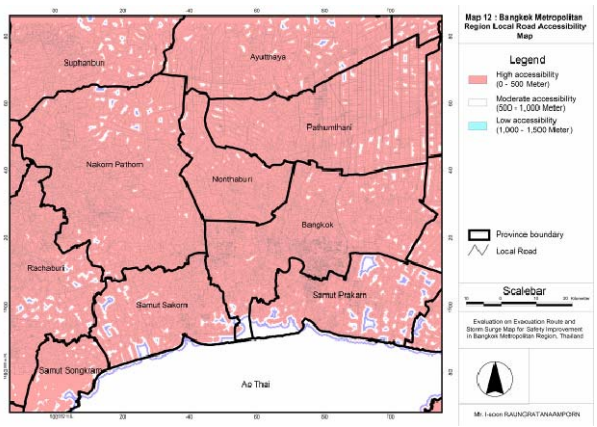

Fig. 7 Local Road Accessibility in BMR

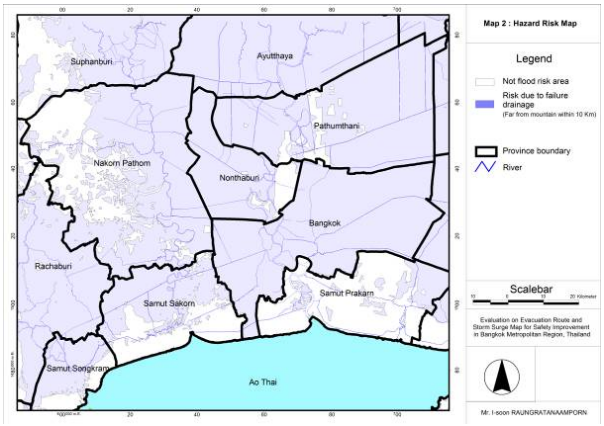

Fig. 5 Flood risk area in BMR

Fig. 8 Highway Road Accessibility in BMR

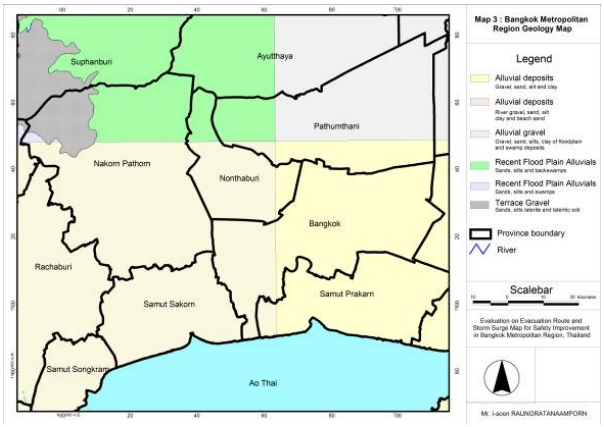

Fig. 9 Geology in BMR

Bangkok Metropolitan Region is located in central region which the geology is alluvia deposit area. Some area are in trouble with poor drainage which can be shown in Fig. 9.

METHODOLOGY

This study used Geographic Information System (GIS) to analyze storm surge and related hazard risk area by spatial analysis (Using model builder) to analyze the potential risk of storm surge in BMR. This study analyzed potential between positive factors and negative factors to analyze storm surge risk level by using spatial analysis and using factors grouping which can be separate into positive factors which is shown in Fig. 10.

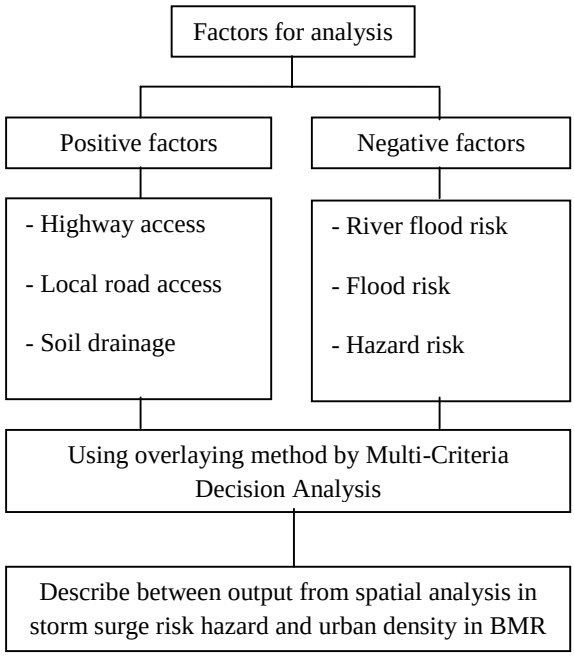

Fig. 10 Conceptual diagram in this study

The score or value used in this study are balancing between summation value both positive factors and negative factors which can be describe in Table 1.

This analysis used Model Builder TM to analyze the level of storm surge hazard risk in Bangkok Metropolitan area with Multi-Criteria Decision Analysis (MCDA) by ranking factors of positive factors and negative factors, then convert all factors to grid and overlaying by using arithmetic overlay. Weight on each factor was considered on risk possibility, power of destruction, major positive factor are considered as reduction damage in case of drainage, accessibility and taking least risk when compared with another attribute at same layer. The model can be shown by flowchart in Fig. 11.

RESULT

After analyzed by using MCDA to analyze the storm surge risk in Bangkok Metropolitan Region (BMR), the result of analysis showed that BMR are risk due to storm surge and relevant hazard in low level. But some area

Table 1 Factors using to analyze storm surge hazard risk in central region

Factor	Value
Highway	+ 5
Local road	+ 1
Main river	- 3
Soil drainage	+ 4
Flood risk area	- 1
Hazard risk area	- 2
Surge risk area	- 10
Coastal characteristic	+ 4
Erosion risk area	- 1
Forest characteristic area	+ 3

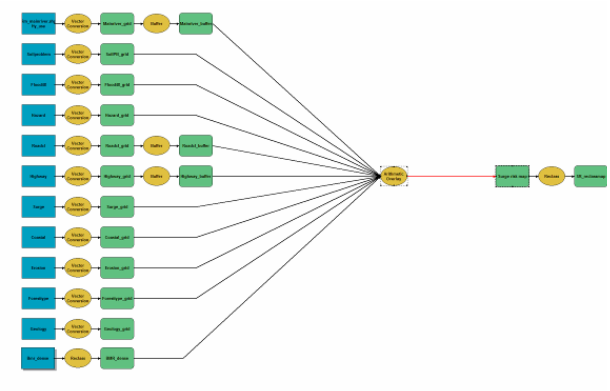

Fig. 11 Multi-Criteria Decision Analysis in this study

especially the area near Chao Phraya River is risk to storm surge and relevant hazard in moderate level. This study result can be depicted in Fig. 12.

According to building density analysis and evacuation between road network and built-up area in Bangkok Metropolitan Region the result shown that highest building density are located on central of BMR especially Bangkok, eastern of Nonthaburi and central of Samut Prakarn. And major highways are spread to north, east and west region. Some parts of that highway network have cluster of buildings along it especially highway which goes to eastern region that shown in Fig. 13.

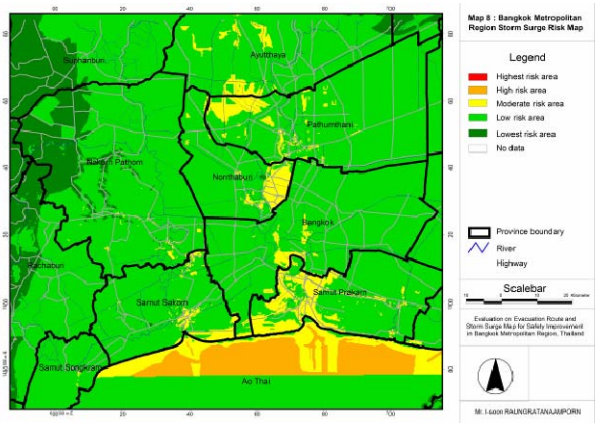

Fig. 12 Storm surge and relevant hazard level in BMR

Table 2 Area of storm surge and relevant hazard in BMR

Risk level	No. of Grid	Area (Km^2)
Highest level	-	0.00
High level	6,157	384.81
Moderate level	15,172	948.25
Low level	148,333	9,270.81
Lowest level	16,068	1,004.25

Output grid cell size is 250*250 Meter

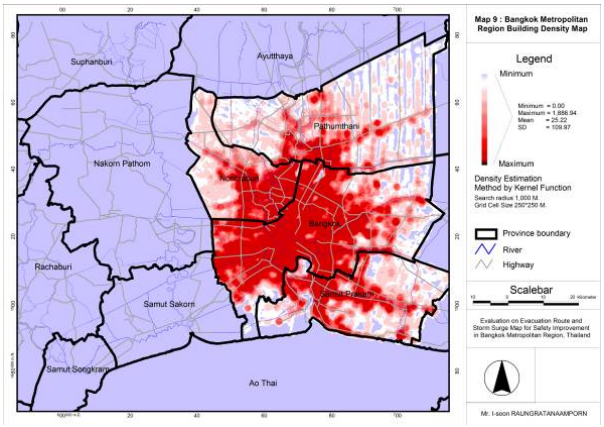

Fig. 13 Building density in BMR

According to estimate number of evacuees, this section has the estimated number of evacuees by using shortest path analysis, was calculated number of buildings in each square kilometer grid and assigned destination point on major arterial or expressways. The shortest path in GIS was adopted to estimate the number of evacuees which calculated by average household size. And then calculate by aggregating number of evacuees who evacuate to the north (In bound), otherwise was design as out bound which can describe in 3 provinces below.

Samut Prakarn Province

There are 10 assigned destination points which located on major arterial or expressway. After estimation by using shortest path analysis, most evacuees tends to evacuate to inbound area because the assigned destination point to exit Samut Prakarn province is the shortest point. Some of evacuees tend to approach assigned destination point in outbound direction to Cha Chiang Sao province or Chonburi province. The number of evacuees can be shown in Table 3.

Table 3 Estimate evacuees to assigned destination point in Samut Prakarn province

Assigned destination point	Direction	No. of evacuees
Route 3139	Inbound	20,906
Sukhumvit	Inbound	178,374
Suksawat	Outbound	179,272
Srinakarin	Inbound	354,337
On Nut	Inbound	12,439
Karnchanapisek	Inbound	175,280
BKK-CHON motorway	Inbound	24,090
BKK-CHON motorway	Outbound	15,437
Bang Na – Trad	Outbound	87,745
Sukhumvit	Outbound	63,227
Total		1,111,107

Average household size is 2.34 persons/unit

Table 4 Estimate direction and number of evacuees in Samut Prakarn province

Direction	No. of route	Estimate evacuees
Inbound	6	765,426
Outbound	4	345,681
Total		1,111,107

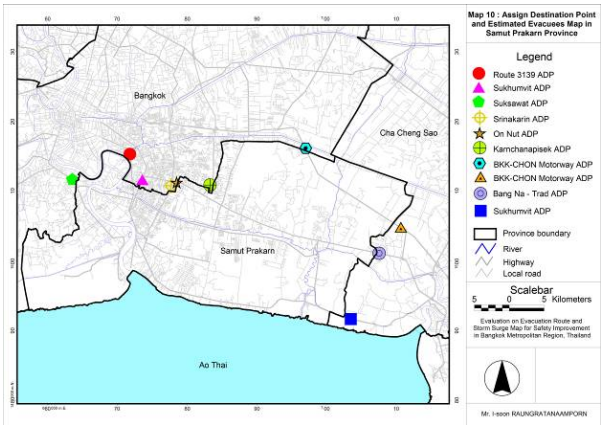

Fig. 14 Assigned destination point in Samut Prakarn Province

Bangkok

In this case, some evacuees who were tended to evacuate inbound was calculated as people who live in Bangkok and also have to evacuate in shortest route. In this case, the estimation was divided into two calculation are 1) Number of estimated evacuees who lives in Bangkok and 2) Number of evacuees whose evacuate inbound from Samut Prakarn province.

There are 11 assigned destination points in Bangkok. After estimation by using shortest path, most evacuees tend to evacuate to assigned destination point in west direction to Nonthaburi Samut Sakorn and Nakorn Pathom province because there are many buildings on the north and north-west in Bangkok (See Fig. 13) which have the shortest path to assigned destination point. The number of evacuees can be shown in Table 5.

After calculated the number of evacuees who tends to evacuate from Samut Prakarn province in inbound direction, then aggregate the number of people who live in Bangkok and evacuate to assigned destination point. The number of evacuees can be shown in Table 6.

Table 5 Estimate evacuees to assigned destination point in Bangkok

Assigned destination point	Direction	No. of evacuees
Phetchakasem	West	134,459
Boromrachachonnee	West	22,816
Eakachai	West	91,166
Rama II	West	121,295
Karnchanapisek	North	143,743
Ngam Wong Wan	West	491,562
Chaeng Wattana	West	100,203
Paholyothin	North	83,604
Eastern Ring Road	North	224,624
Route 3841	East	420
Suvinthawong	East	100,640
Total		1,514,532

Average household size is 2.44 persons/unit

Table 6 Aggregation evacuees from Samut Prakarn province and Bangkok

Assigned destination point	No. of evacuees (SPK)*	No. of evacuees (BKK)	Total
Phetchakasem	-	134,459	134,459
Boromrachachonnee	-	22,816	22,816
Eakachai	-	91,166	91,166
Rama II	-	121,295	121,295
Karnchanapisek	-	143,743	143,743
Ngam Wong Wan	566,056	491,562	1,057,618
Chaeng Wattana	-	100,203	100,203
Paholyothin	-	83,604	83,604
Eastern Ring Road	175,280	224,624	399,904
Route 3841	-	420	420
Suvinthawong	24,090	100,640	124,730
Total	765,426	1,514,532	2,279,958

Average household size is 2.34 persons/unit

Table 7 Estimate direction and number of evacuees in Samut Prakarn province

Direction	No. of route	Estimate evacuees
North	3	627,251
East	2	125,150
West	6	1,527,958
Total		2,279,958

Aggregated only inbound direction

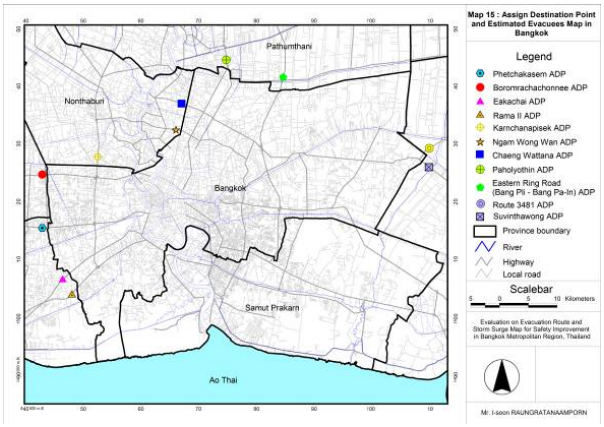

Fig. 15 Assigned destination point in Bangkok

Pathumthani Province

There are 13 assigned destination points which located on major arterial or expressway. In this case, the assigned destination points are regional destination to evacuate in this study, which leads in three directions, north, east and west. After estimation number of evacuees who live in Pathumthani tended to evacuate to evacuees who live in Pathumthani tended to evacuate to outside BMR by north direction because there are 9

Table 8 Estimate evacuees to assigned destination point in Pathumthani province

Assigned destination point	Direction	No. of evacuees
Route 3111	North	71,337
Karnchanapisek	North	1,350
Route 3309	North	8,226
Route 347	North	74,891
Paholyothin	North	198,690
Eastern Ring Road	North	30,870
Route 4001	North	18,346
Route 3261	North	14,115
Route 5026	East	1,340
Rang Sit – Nakorn nayok	East	66,220
Lum Lukka	East	47,977
Bang Bua thong – Suphanburi	West	3,159
Route 346	West	22,040
Total		558,561

Average household size is 2.14 persons/unit

Table 9 Aggregation evacuees from Bangkok to Pathumthani province

Assigned destination point	No. of evacuees (BKK)*	No. of evacuees (PTT)	Total
Route 3111	-	71,337	71,337
Karnchanapisek	-	1,350	1,350
Route 3309	-	8,226	8,226
Route 347	-	74,891	74,891
Paholyothin	83,604	198,690	282,294
Eastern Ring Road	-	30,870	30,870
Route 4001	-	18,346	18,346
Route 3261	-	14,115	14,115
Route 5026	-	1,340	1,340
Rang Sit – Nakorn nayok	-	66,220	66,220
Lum Lukka	224,624	47,977	272,601
Bang Bua thong – Suphanburi	-	3,159	3,159
Route 346	143,743	22,040	165,783
Total	451,971	558,561	1,010,532

*Aggregated only north direction

Table 10 Estimate direction and number of evacuees in Bangkok and Pathumthani province

Direction	No. of route	Estimate evacuees
North	8	501,429
East	3	340,161
West	2	168,942
Total		1,010,532

*Aggregated only north direction

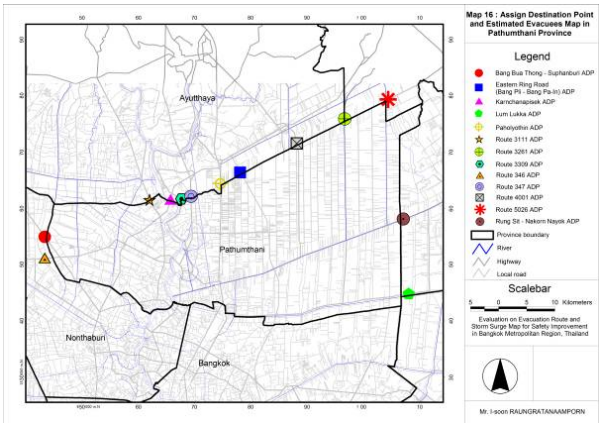

Fig. 16 Assigned destination point in Pathumthani

assigned destination points on the north direction. The estimate evacuees can be demonstrated in Table 8.

After calculated the number of evacuees who tends to evacuate from Bangkok to Pathumthani province in north direction, then aggregate the number of people who live in Pathumthani province and evacuate to assigned destination point with the shortest path. The number of evacuees can be shown in Table 9.

CONCLUSION

Overall of risk level caused by storm surge in this region are low level, some area are classified in the moderate risk level, especially seashore and coastal area. Because there are primary areas suffer from flashflood not only than storm surge. One reason to make the output of storm surge risk of Bangkok Metropolitan Region in low level is the positive factors such as local road network accessibility, geology characteristic and drainage. Furthermore, the other positive factor to palliative potential of hazard such as quick drainage and evacuate to safety area or highland more easily.

In terms of evacuation when overlay between road network and building density, this study demonstrated that the major arterial such as Paholyothin road and Ngam Wong Wan road are play as a major road of circulation in central region across central of BMR. The analysis revealed that people who live in southern part of BMR, especially Samut Prakarn province should evacuate from BMR to eastern region instead of evacuate to northern region or central region because people who live in Bangkok may decide to evacuate to north of Bangkok Metropolitan Region, central region or northern region.

According to shortest path analysis, most people who live in Samut Prakarn province tend to evacuate themselves to inbound assigned destination point because many building are settled near Bangkok and its

peripheral. There are many major regional road networks such as Sukumvit road and Srinakarin road which assigned as a Samut Prakarn province destination point for evacuate due to storm surge disaster. In case of Bangkok, Kanchanapisek road and Ngam Wong Wan road are major evacuation route especially evacuees who live in west and central part of Bangkok. Some evacuees may choose assigned destination point such as Paholyothin or Eastern Ring Road (Bang Pli – Bang Pa – in) instead of travel to assigned destination point which located in west direction. In case of Pathumthani province, most evacuees from Bangkok and Samut Prakarn province tend to evacuate to assigned destination point which located on west direction, some of them may evacuate to north direction. Because Karnchanapisek, Eastern Ring Road (Bang Pli – Bang Pa – In) and Paholyothin are the regional road network which can be used to north and northeastern region. Totally the evacuees may evacuate outside 3 study areas are approximately 3.5 million persons. However, this estimation was excluded commuters, which may raise number of evacuees due to hazard sequence.

Assigned destination point in this study were assigned for calculate the number of evacuees to evacuate outside study area which determine on major artery and expressway, evacuees may evacuate to outside risk area through local road, but in many cases in evacuation phase, many civilians tried to evacuate outside risk area through major road or expressways because there are wider than local road, more lanes, well-known and ease to evacuate. In this study, some of route might be unable to use as a major evacuation route due to hazard sequence because it might be used by many evacuees influence by shortest path. Thus, evacuation route planning should be concern on holding capacity or established special or temporary route for evacuate due to storm surge disaster sequence.

From this study, planning for evacuation in Bangkok metropolitan region should be individually planned for each province or districts. People who live in urban fringe area can evacuate immediately or should prepare themselves during early warning from local government, before people who live in high density area evacuate. It can avoid traffic congestion while evacuation had begin. Some highways were constructed as a layer of road network like an expressway which can be used as evacuation route to evacuate during storm surge event. Another approach for mitigate is urban land use control, current situation in urban planning in Thailand is lack of evacuation planning, the area which high density are more difficult to evacuate than lower density area. In case of high density area, especially in urban area should establish evacuation zone instead of trying to evacuate people as much as possible. Moreover, evacuation practice,, establish evacuation sign, early warning system in local and regional announcement, upgrade and check road capacity are the part of critical evacuation planning, which leads to achieve goals of regional evacuation.

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REFERENCES

Cova, T.J. and Church, R.L. (1997). Spatial Evacuation Analysis Project. Retrieved from http://www.ncgia.ucsb.edu/~cova/seap.html.

Hyndman, D. and Hyndman, D. (2006). Natural Hazards and Disaster. Thomson Higher Education. 10 Davis Drive. Belmont, California, United State of America.

Jafari, M., Bakhadyrov, I. and Maher, A. (2003). Technological Anvances in Evacuation Planning and Emergency Management: Current Stste of the Art. Retrieved from http://cait.rutgers.edu/files/EVAC-RU4474.pdf.

Raungratanaamporn, I. (2009). Mitigation of Storm Surge Plan: A Case study of Amphoe Mueng, Samut Prakarn Province.

Supharatid, S. (2009). The Servers and Possibility of Storm Surge Occurance and Coastal Flooding. Retrieved from http://www.thaidisaster.com/index.php.

Warfield, C. (2009). The Disaster Management Cycle. Retrieved from http://www.gdrc.org/uem/disasters/1-dm_cycle.html.

Xu, W. (2007). Development of a Methodology for Participatory Evacuation Planning and Management: Case Study of Nagata, Kobe. Retrieved from http://repository.kulib.kyoto-.ac.jp/dspace/bitstream/2433/49136/1/xuwei20070830.pdf.

Xu, W., Okada, N., Hatayama, M. and He, C. (2005). A Diagnosis Model for Disaster Shelter Planning from the Viewpoint of Local People --- Case Study of Nagata Ward in Kobe City, Hyogo Prefecture, Japan. Retrieved from http://www.dpri.kyoto-u.ac.jp/dat/nenpo/no50/ronbunB/a50b0p24.pdf.