Flood Evacuation Behavior Analysis in Urban Areas

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Abstract: Flooding is a reoccurring natural disaster in Thailand and profoundly affects people's livelihood and economy. Understanding evacuation behavior is very important for flood preparedness planning. This paper aims to investigate the behaviors of urban inhabitants in traveling and evacuating before, during, and after the flooding. The questionnaire survey was conducted to interview the affected inhabitants in Hat Yai municipality as a case study. Applying logistic regression technique, the interview data are then used to develop two flood evacuation models, including evacuation decision model and evacuation mode choice model. The results reveal that gender, the number of adults and disabled persons are three significant factors influencing the decision making and the majority of evacuees prefer using private vehicles during the evacuation. The authors believe that the results would be helpful for local agencies in flood preparedness planning, and the concept of this study can be more rigorously applied to other areas.

Keywords: Evacuation Decision Model, Flood, Logistic Regression Analysis, Urban Area

1. INTRODUCTION

Flooding is a reoccurring natural disaster in Thailand and profoundly affects the city in terms of people's livelihood and economy. Figure 1 shows the statistics of flood situations in Thailand from 1990 to 2010. It illustrates that the number of casualties, including deaths and injuries, and the economic losses relatively fluctuate every year. However, the trend of the casualties and losses, especially during the last four years (2007-2010), increases significantly and reach the maximum at 16,339 million baht in 2010 (DDPM, 2012).

Hat Yai district, Songkhla province, is the center of business, commerce, and tourism in the southern Thailand. However, the city, located on the area downstream of U-Tapao canal basin, has been severely and repeatedly affected by flooding, a reoccurring natural disaster. The statistics of floods occurred in Hat Yai from 1990 to 2010 (DPMRC12, 2012), as depicted in Figure 2, reveals that the trend of deaths and economic losses rises up significantly in the last two years (2006 and 2010). Particularly, the number of deaths dramatically increases from 87 to 187 during these two years. Note that the economic losses presented in Figures 1 and 2 include the losses from people's properties and agricultural products only. The loss of human lives is not taken into account.

Although local authorities have put their efforts in flood prevention planning, seasonal floods repeatedly occurred and adversely affected the livelihood in urban areas. For example, the massive floods in 2000 and 2010 caused tremendous loss to Hat Yai people and the city economy. The risk of flooding continues to pose a big threat amongst the residents.

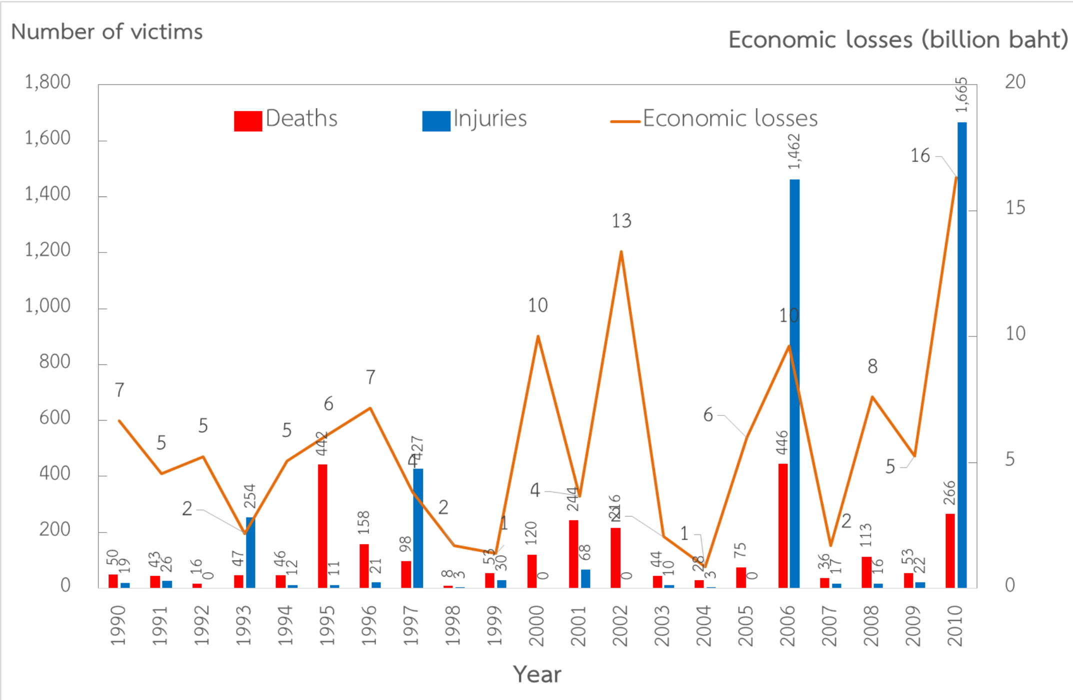


Figure 1. Flood situations in Thailand from 1990 to 2010
Source: DDPM (2012)

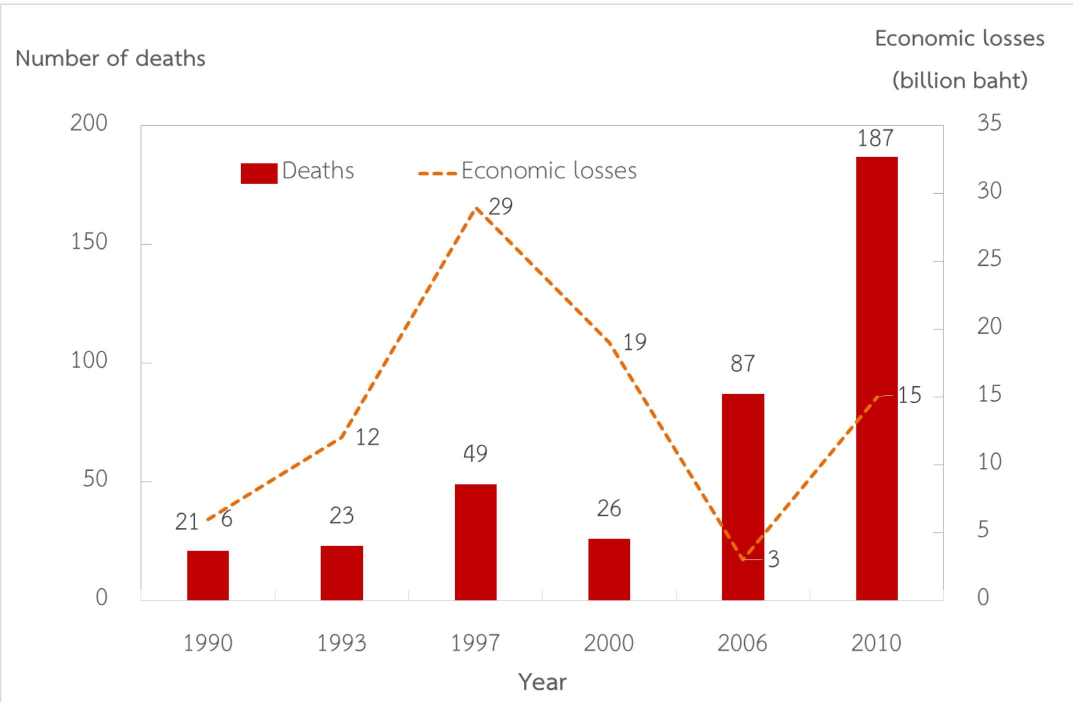


Figure 2. Deaths and economic losses from floods in Hat Yai district from 1990 to 2010
Source: DPMRC12 (2012)

Understanding the demand and behavior of travelers and transportation systems is very important for concerned agencies in disaster evacuation planning (Clarke and Habib, 2010). However, in Thailand the current transportation planning approaches for disaster evacuation are reactive and do not take this matter, especially the evacuee's behavior, into account thoroughly. This paper aims to investigate the behaviors of travelers and evacuees before, during, and after the flooding. A questionnaire survey was conducted on the samples of affected inhabitants in the area of urban Hat Yai as a case study. The paper also focuses on identifying the factors influencing the decision making in evacuation and transport mode choice. Applying logistic regression technique, the interview data are used to develop two flood evacuation models, including evacuation decision model and evacuation mode choice model. The results from this study would be helpful for local agencies in preparedness planning before, during, and after the flooding.

This paper consists of the following five sections. Section 2 presents literature reviews, then the methodology is described in Section 3. Section 4 shows and discusses the results. Finally, Section 5 concludes the paper and gives some recommendations for future research.

2. LITERATURE REVIEW

Murray-Tuite and Wolshon (2013) comprehensively reviewed the research works on evacuation modeling and simulation for roadway transportation planning and operations. Various studies are related to evacuation modeling: the forecast of evacuation demand, the distribution of evacuation demand with different travel patterns, and the assignment of evacuation demand with various transport modes to regional/local road networks to reach safe destinations. The research on an evaluation of management strategies or policies are also discussed in their paper.

Hasan *et al*. (2011) developed a random-parameter hazard-based model to capture hurricane evacuation timing by individual households. The model was developed upon the hazard-based model (Bhat, 1996) by considering the choice of departure time depending on the risk perception, the household characteristics, and the built environment features. The results from their research revealed that the variables related to household location, destination characteristics, socio-economic characteristics, evacuation notice and household decision making were significant factors highly affecting the departure time. de Jong and Helsloot (2010) remarked that not only the socio-economic characteristics, but also the communication and information which had significant effects on the response during flooding exercise.

Charnkol and Tanaboriboon (2006) and Charnkol *et al*. (2007) investigated the tsunami evacuation behavior of permanent and transient residents from two massively affected areas in Thailand, the Phuket and Phang-nga provinces. They also developed the evacuation models, based on binary logistic regression technique, in order to estimate the number of evacuees. The reaction times to tsunami evacuation warning of the evacuees for quick and slow response groups were also investigated in their research. These information can be applied to improve the existing tsunami evacuation management in Thailand.

From the literature, several researchers have investigated the characteristics of evacuation demand and developed evacuation models both simple and complex for evacuation planning and operations on road networks. However, the more complex we develop the models, the more difficult we face in model calibration and validation (Murray-Tuite and Wolshon, 2013). Due to limitations in existing transport models and data availability in Hat Yai, in this paper we decide to focus on the development of simple flood evacuation models based on logistic regression analysis for long-term evacuation planning instead of dynamic response operations.

3. METHODOLOGY

3.1 Study Area

The study area as shown in Figure 3 covers a total of 102 affected communities (zones) which can be integrated into four major areas (zone groups) following Hat Yai flood preparedness plan (Hat Yai Municipality, 2011). Each zone group is bounded based on geographic and demographic characteristics of Hat Yai urban area. In addition, different areas have different probabilities of being flooded. This probably influences the individual's decision in different areas. The four areas cover 25 zones (10,798 households), 24 zones (15,548 households), 26 zones (14,797 households), and 27 zones (15,641 households), respectively.

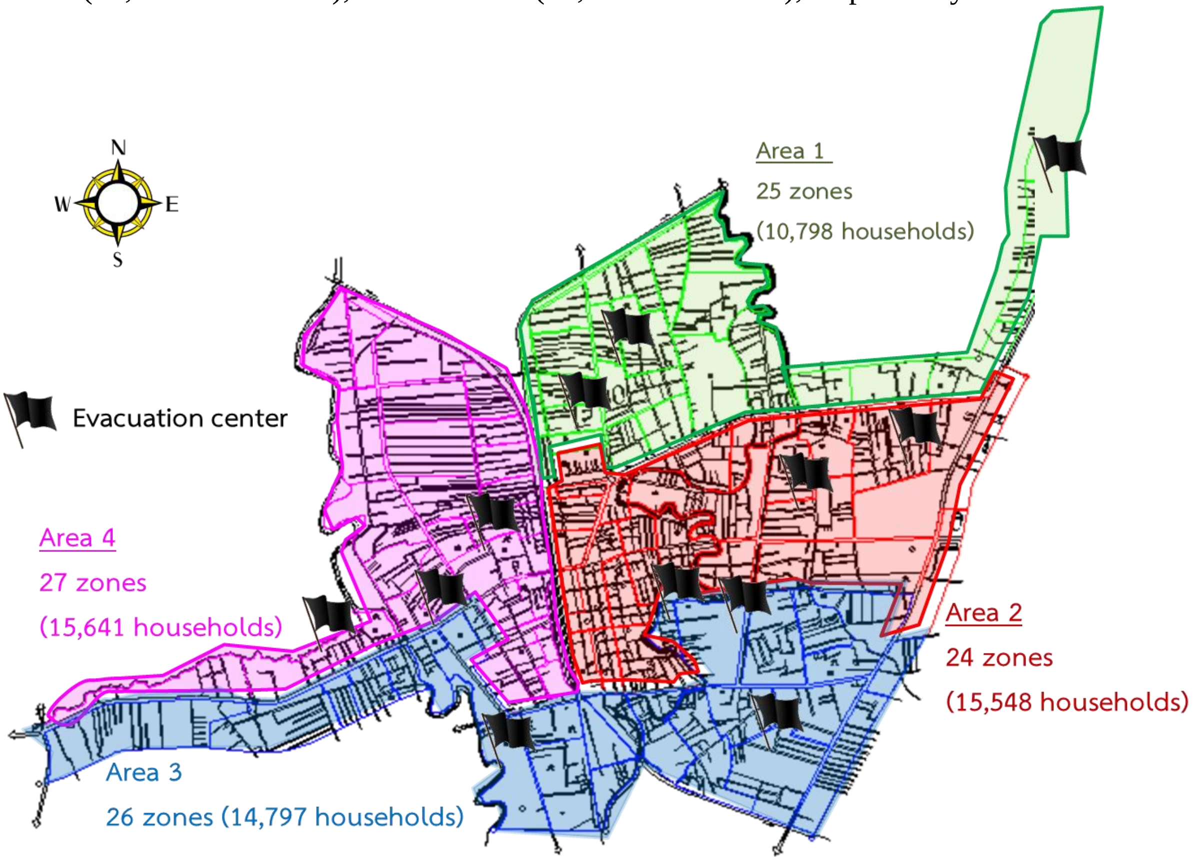


Figure 3. The study area

3.2 Data Collection and Questionnaire Survey

The data required in this study are classified into two groups including 1) socio-economic data and 2) travel and evacuation behavior data. For the first group, the 2011 data are mainly obtained from Hat Yai municipality office. For the behavior data, a questionnaire was developed to investigate the behaviors before, during and after the flooding from past experiences. The questionnaire consists of three main parts.

The first part is about general information of a respondent including gender, age, occupation, salary, number of household members, vehicle occupancy, and the address of home and working place. The second part is to investigate the travel behavior and trip chain during normal days. The trip purpose, transport mode, and trip rate are also included in this section. The last part addresses the behaviors before, during, and after the flooding. Before flooding, respondents were asked where they got the source of flood information, and the warning time required for evacuation preparedness. During the flood, they were asked whether they had evacuated, the reasons to evacuate or not, the level of flooding when evacuate, transport modes and destination choices, and the reasons for choosing the mode and destination. After the flood, they were interviewed about the recovery period, facilities needed for recovery, and the supports from local governments.

The questionnaire survey was conducted by randomly selecting 1,600 affected samples in the study area (400 samples for each zone group). The number of sample size was calculated using elementary sampling theory (Yamane, 1967) at 95% confidence level. The samples were personally interviewed by the trained staffs at their home or community areas. The survey was conducted from July 2012 to January 2013.

3.3 Development of Evacuation Models

In this paper, a logistic regression technique was applied to develop the evacuation models, including evacuation decision model and evacuation mode choice model. In general, logistic regression analysis, an extension of multiple regression, is to determine a relationship between outcome (dependent) variable and predictor (independent) variables (Dayton, 1992; Hair *et al.*, 2006). Logistic regression analysis can be classified into two types: binary and multinomial. Binary logistic regression is used when the outcome variable is dichotomous (e.g. evacuate = 1 and not evacuate = 0), whereas multinomial logistic regression is applied when the value of outcome variables that can be classified is greater than two groups (e.g. evacuate mainly by walking = 1, private vehicles = 2, and public vehicles = 3). The predictor variables considered in modeling and their descriptive statistics analyzed from the survey data are presented in Table 1.

In the regression analysis, a linear predictor function $y(m,i)$ of a set of p predictor variables $x_{p,i}$ for the individual i has outcome m can be expressed as

$$y(m,i) = \beta_{0,m} + \beta_{1,m}x_{1,i} + \beta_{2,m}x_{2,i} + ... + \beta_{p,m}x_{p,i} \tag{1}$$

where

$\beta_{p,m}$ is the regression coefficient related to the pth variable and the mth outcome.

In this paper, the evacuation decision model was developed by applying binary logistic regression. Let $\boldsymbol{\beta}_m$ and $\mathbf{x}_i$ be the sets of regression coefficients and predictor variables, respectively. The probability of an individual choosing to evacuate (m = 1) can be formulated as a logistic function as

$$\begin{aligned} \Pr(Y_i = 1) &= \frac{e^{\boldsymbol{\beta}_1 \cdot \mathbf{x}_i}}{1 + e^{\boldsymbol{\beta}_1 \cdot \mathbf{x}_i}} \\ &= \frac{1}{1 + e^{-\boldsymbol{\beta}_1 \cdot \mathbf{x}_i}} \end{aligned} \tag{2}$$

whereas the probability of the individual choosing to not evacuate (m = 0) is $1 - P(Y_i = 1)$.

Table 1. Predictor variables and their descriptive statistics from the survey data

No.	Predictor variables	Classification (Parameter coding)	Zone Group Area 1	2	3	4	All
1	Gender (GEN)	▪ Male (GEN=1)	49.8%	39.5%	50.8%	55.8%	46.1%
		▪ Male (GEN=2)	50.2%	60.5%	49.2%	44.2%	53.9%
2	Age (AGE)	▪ <= 20 years old (AGE=1)	12.0%	11.2%	8.5%	7.8%	9.7%
		▪ 21-30 years old (AGE=2)	31.5%	42.8%	43.3%	39.4%	39.7%
		▪ 31-40 years old (AGE=3)	23.8%	21.5%	22.9%	25.5%	23.4%
		▪ 41-50 years old (AGE=4)	17.7%	13.2%	15.8%	16.0%	15.6%
		▪ 51-60 years old (AGE=5)	9.5%	9.5%	8.7%	9.5%	9.3%
		▪ > 60 years old (AGE=6)	5.5%	1.8%	0.8%	1.8%	2.3%
3	Occupation (OCC)	▪ Unemployed (OCC=1)	6.7%	3.5%	6.0%	5.5%	5.5%
		▪ Student (OCC=2)	23.2%	1.8%	22.8%	25.2%	25.6%
		▪ Business (OCC=3)	18.1%	13.3%	18.9%	20.7%	18.9%
		▪ Worker (OCC=4)	13.5%	5.3%	14.1%	15.8%	14.0%
		▪ Housewife (OCC=5)	8.5%	14.5%	7.7%	9.2%	10.2%
		▪ Agriculture (OCC=6)	3.6%	12.8%	3.9%	3.8%	3.8%
		▪ Government (OCC=7)	21.5%	17.8%	22.1%	16.5%	18.3%
		▪ Retired (OCC=8)	4.9%	31.0%	4.5%	3.3%	3.7%
4	Household income (INC)	▪ No income (INC=1)	19.5%	26.0%	27.8%	24.8%	24.5%
		▪ < 5,000 baht (INC=2)	10.3%	10.0%	11.3%	10.3%	10.4%
		▪ 5,000–9,999 baht (INC=3)	18.0%	17.0%	17.0%	15.0%	16.8%
		▪ 10,000–14,999baht (INC=4)	19.8%	22.0%	19.8%	18.8%	20.1%
		▪ 15,000–19,999baht (INC=5)	14.5%	15.5%	14.8%	22.0%	16.7%
		▪ 20,000–24,999baht (INC=6)	6.3%	4.3%	4.3%	5.5%	5.1%
		▪ 25,000–29,999baht (INC=7)	5.5%	4.2%	4.0%	1.5%	3.9%
		▪ > 30,000 baht (INC=8)	6.1%	1.0%	1.0%	2.1%	2.5%
5	No. children <12years old (CHILD)	▪ Continuous variable (mean)	0.75	0.56	0.70	0.59	0.65
6	No. adults <=60years (ADULT)	▪ Continuous variable (mean)	2.13	2.29	2.14	2.21	2.19
7	No. elderly >60years old (ELDER)	▪ Continuous variable (mean)	0.37	0.36	0.49	0.33	0.39
8	No. disabled persons (DISABLE)	▪ Continuous variable (mean)	0.05	0.02	0.04	0.04	0.04
9	Vehicle ownership	▪ No (VEH=0)	6.5%	4.5%	7.0%	4.5%	5.6%
		▪ Yes (VEH=1)	93.5%	95.5%	93.0%	95.5%	94.4%
10	Time of evacuation	▪ Immediately after warning (TIME = 1)	74.1%	80.3%	84.1%	74.6%	78.3%
		▪ Flood level < 0.5 m. (TIME = 2)	17.9%	11.2%	10.8%	15.3%	13.8%
		▪ Flood level 0.5-1.0 m. (TIME = 3)	5.8%	4.5%	3.0%	7.6%	5.2%
		▪ Flood level > 1.0 m. (TIME = 4)	2.2%	4.0%	2.1%	2.5%	2.7%

For the evacuation mode choice model, multinomial logistic regression was applied to develop the model. Let m = 1, 2, and 3 be the main transport modes for evacuation, which include walking group, private vehicle group (motorcycle, passenger car, and pickup car), and public vehicle group (tuk tuk, songthaew, minibus, and bus). To obtain the multinomial logistic regression model for M possible choices, one outcome (i.e. private vehicle group) is fixed as a pivot and then the other M-1 choices can be evaluated against the pivot choice. The probability for the evacuee choosing M-1th transport mode can be calculated from

$$\Pr\left(Y_i = M-1\right) = \frac{e^{\boldsymbol{\beta}_{M-1}\cdot\mathbf{x}_i}}{1+\sum_{m=1}^{M-1} e^{\boldsymbol{\beta}_m\cdot\mathbf{x}_i}}. \tag{3}$$

In Table 1, note that four groups of household member are classified, including the children less than 12 years old (5th variable), the adults less than or equal to 60 years old (6th variable), the elderly over age 60 years (7th variable), and the disabled persons (8th variable). In this paper, the adult group consists of youths (12-22 years old) and working people age 23-60 years. This group is combined based on the assumption that they can evacuate by themselves, compared to the other three groups who require special cares. However, the group of youths should be considered separately in future research.

4. RESULTS

In this section, the data obtained from the secondary sources and the questionnaire survey are analyzed. The results are given in the first two subsections. The last subsection presents the evacuation models developed in this paper. The details are as follows.

4.1 Household Characteristics

4.1.1 Household size

Household size and member characteristics are factors that significantly influence the individual's decision on flood evacuation and can be used to estimate the number of evacuees. Figure 4 shows that the average household sizes, classified by four resident groups (children, adult, elderly, and disabled persons), in four areas are similar. The majority is the adult group (2.13, 2.29, 2.14, and 2.21 persons per household), followed by the children group (0.75, 0.56, 0.70, and 0.59 persons per household), the elderly group (0.37, 0.36, 0.49, 0.33 persons per household), and the disabled person group (0.05, 0.02, 0.04, and 0.04 persons per household). From these results, a number of household sizes in the four areas can be calculated at 3.30, 3.23, 3.37 and 3.17 persons per household, respectively.

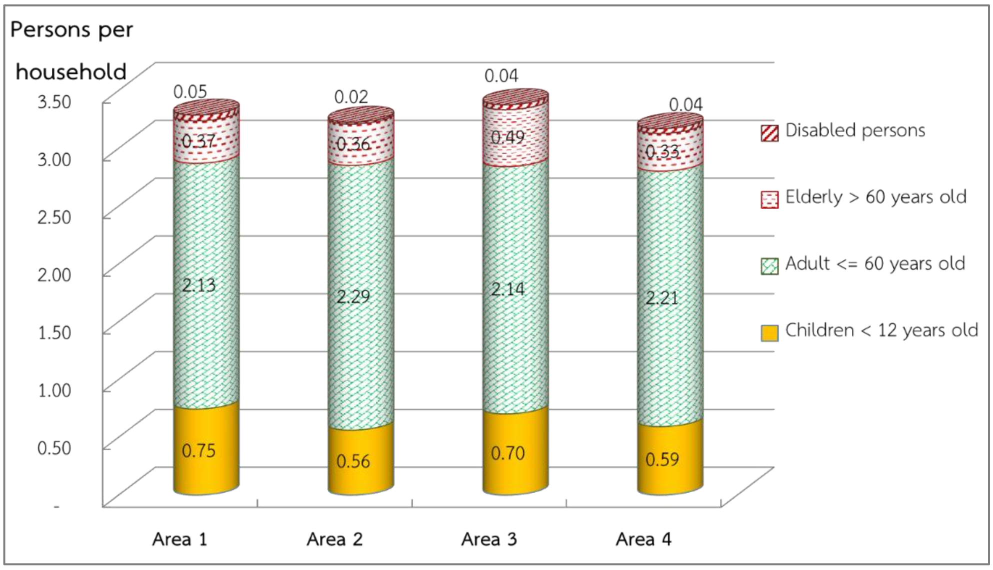


Figure 4. Average household size by residents

4.1.2 Vehicle ownership

Figure 5 shows the average numbers of vehicle ownership per household in the four areas. In this study, five types of commonly used vehicles are considered, including bicycle, motorcycle, passenger car, pickup car, and van. It is found that motorcycle is most popular in all the four areas with 1.25, 1.09, 1.06, and 1.29 vehicles per household, respectively. The second common vehicle is pickup car of which the ownerships are 0.43, 0.38, 0.41, and 0.34 vehicles per household, respectively. The third preference vehicle is passenger car of which the ownerships are 0.33, 0.37, 0.38, and 0.33 vehicles per household, respectively. The fourth prevalent vehicle is bicycle of which the ownerships are 0.33, 0.19, 0.26, and 0.28 vehicles per household, respectively. From the figure, least common use vehicle is van (0.01, 0.04, 0.06, and 0.02 vehicles per household, respectively). The vehicle least ownership would affect individual’s decision making on transport use for evacuation. These information can also be applied to estimate a number of vehicles moving on the roads during evacuation period.

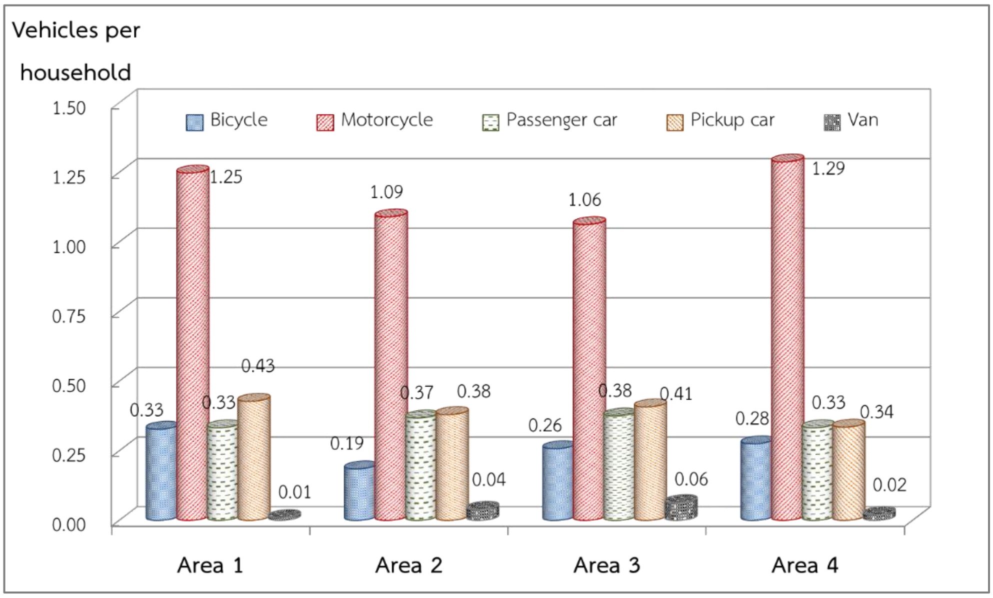


Figure 5. Average number of vehicle ownership

4.2 Evacuation Behaviors

As mentioned earlier, the evacuation behaviors were investigated for three time periods including before, during, and after flooding. The results are presented as follows.

4.2.1 Before flooding

Respondents want local agency to announce the flood warning time for evacuation preparedness in advance. Table 2 shows that the mean values of the warning time obtained from all areas are moderately similar ranging from14.27 to 17.56 hours, while the values of the standard deviation of the warning time are almost the same (3.30-3.76 hours). On average, the people need more than half a day (15.82 hours) for their evacuation preparedness. This information is useful for the local agency to provide sufficient warning time to the people.

Table 2. Warning time required for evacuation preparedness (in hours)

	Area 1	Area 2	Area 3	Area 4	All areas
Mean	14.27	16.83	14.63	17.56	15.82
Standard deviation	3.30	3.68	3.31	3.76	3.54

4.2.2 During the flood

Figure 6 shows the percentages of evacuation timing, classified by four time periods: immediately after flood warning, flood level lower than 0.5 m., flood level 0.5-1.0 m., and flood level 1.0-1.5 m. Note that the three water levels of the flooding are categorized based on historical flood data. However, a flood level higher than 1.5 m. is not reported here because there is no data from respondents. These three flooding levels were used in the questionnaire to allow a respondent to perceive flooding situation nearby his/her house obviously.

In Figure 6, people in all areas preferred to evacuate (55.75-59.00 %) rather than not evacuate (41.00-44.25 %). On average, 42.75 % of the people did not want to evacuate, whereas those who chose to evacuate totaled 57.25 %. Regarding the evacuee group, 44.81 % evacuated immediately after the flood warning signal given by local authority, 8.00 % evacuated when the flood level is lower than 0.50 m., 3.00 % evacuate when the flood level is 0.5-1.0 m, and 1.44 % evacuate when the flood level is 1.0-1.5 m.

From the interview, it was also found that the people don’t want to evacuate because they worry about their property (40.64 %), believe that evacuation centers provided by local agency are uncomfortable (31.75 %), and worry about their elderly or children (27.61 %). On the other hand, the reason for those who evacuated immediately was that based on their past experiences the floods in the urban area could be return within a few days so they wanted to move their vehicles, especially passenger cars, to adjacent safe locations as soon as possible.

Regarding the number of evacuees, Table 3 shows that on the average there are 2.75 evacuees per household when the flood level is less than 0.5 m., followed by 2.66 evacuees per household (immediately evacuated), 2.48 evacuees per household (the flood level is 0.5-1.0 m.), and 2.43 evacuees per household (the flood level is 1.0-1.5 m.). These results can imply that the number of evacuees per household decrease when the flood level rises up. The results can be applied to estimate a total number of evacuees during the evacuation time periods. This information is very useful for evacuation planning.

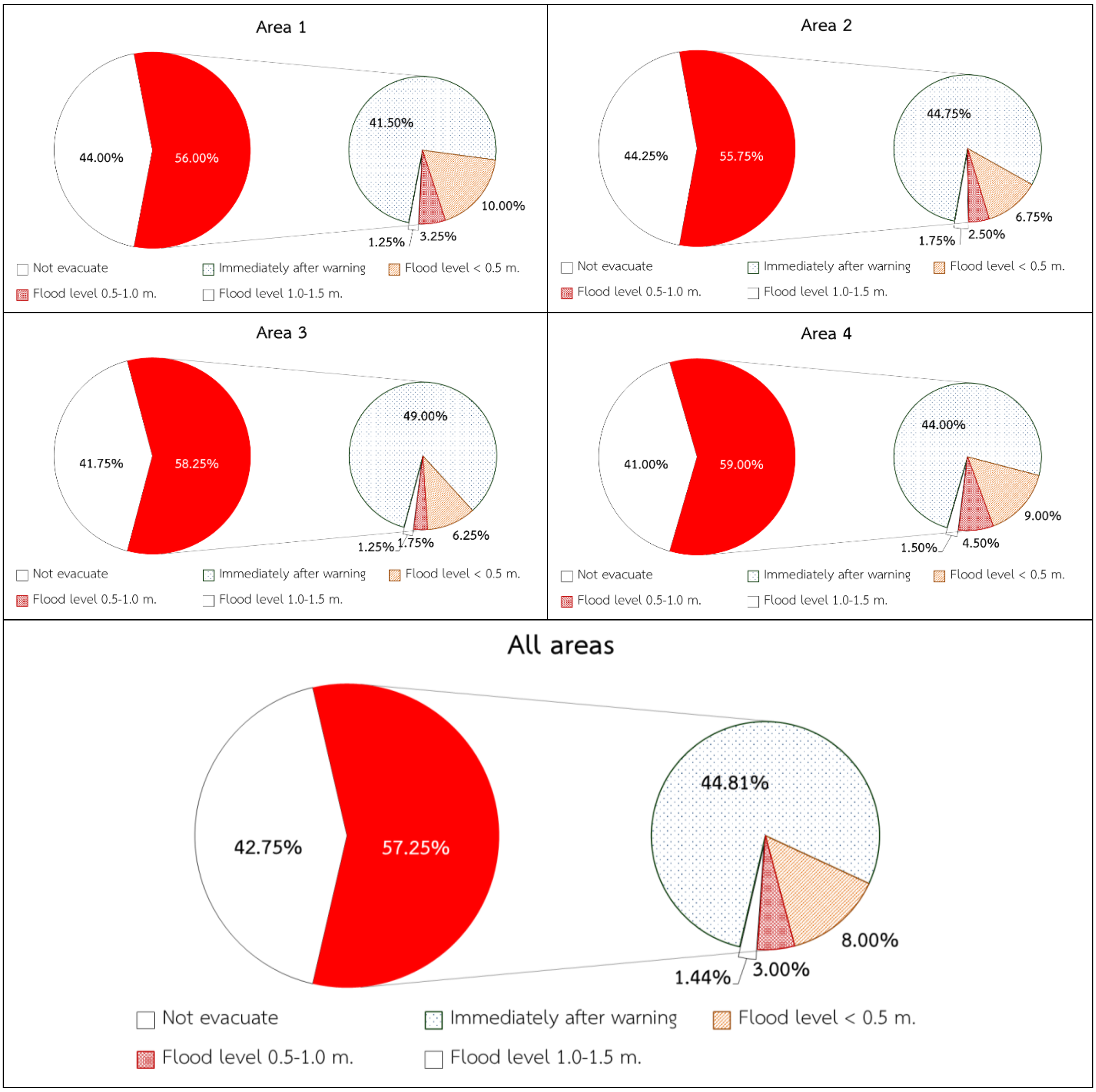


Figure 6. Percentages of evacuation timing

Table 3. Number of evacuees per household (in persons)

	Area 1	Area 2	Area 3	Area 4	All areas
Immediately	2.62	2.64	2.81	2.58	2.66
Flood level < 0.5 m.	2.50	2.88	2.80	2.91	2.75
Flood level 0.5-1.0 m.	2.25	2.13	1.50	3.06	2.48
Flood level 1.0-1.5 m.	2.60	2.67	2.60	1.80	2.43

Regarding the destination of evacuation, this study focus on two main destinations: evacuee relative's house (outside the study area) and public evacuation centers (inside the study area). However, some evacuees possibly visit other places, e.g. assembly point, shopping store, or office, before going to evacuation centers. Figure 7 shows that only 28.31 % of the evacuees left Hat Yai to their relative's house in other areas, whereas 71.69 % preferred going to the public evacuation centers, provided by local government, as the final destination. Considering the second group: 37.75 % went to the evacuation center directly.

25.69 % went to the assembly point first and moved to the center later. 3.50 % visited their relative's house first, then went to the assembly point, and finally traveled to the evacuation center. 2.44 % first went to shopping at nearby stores, then went to the assembly point and the evacuation center in that order. 2.31 % dropped by their office first, then went to the assembly point, and moved to the evacuation center.

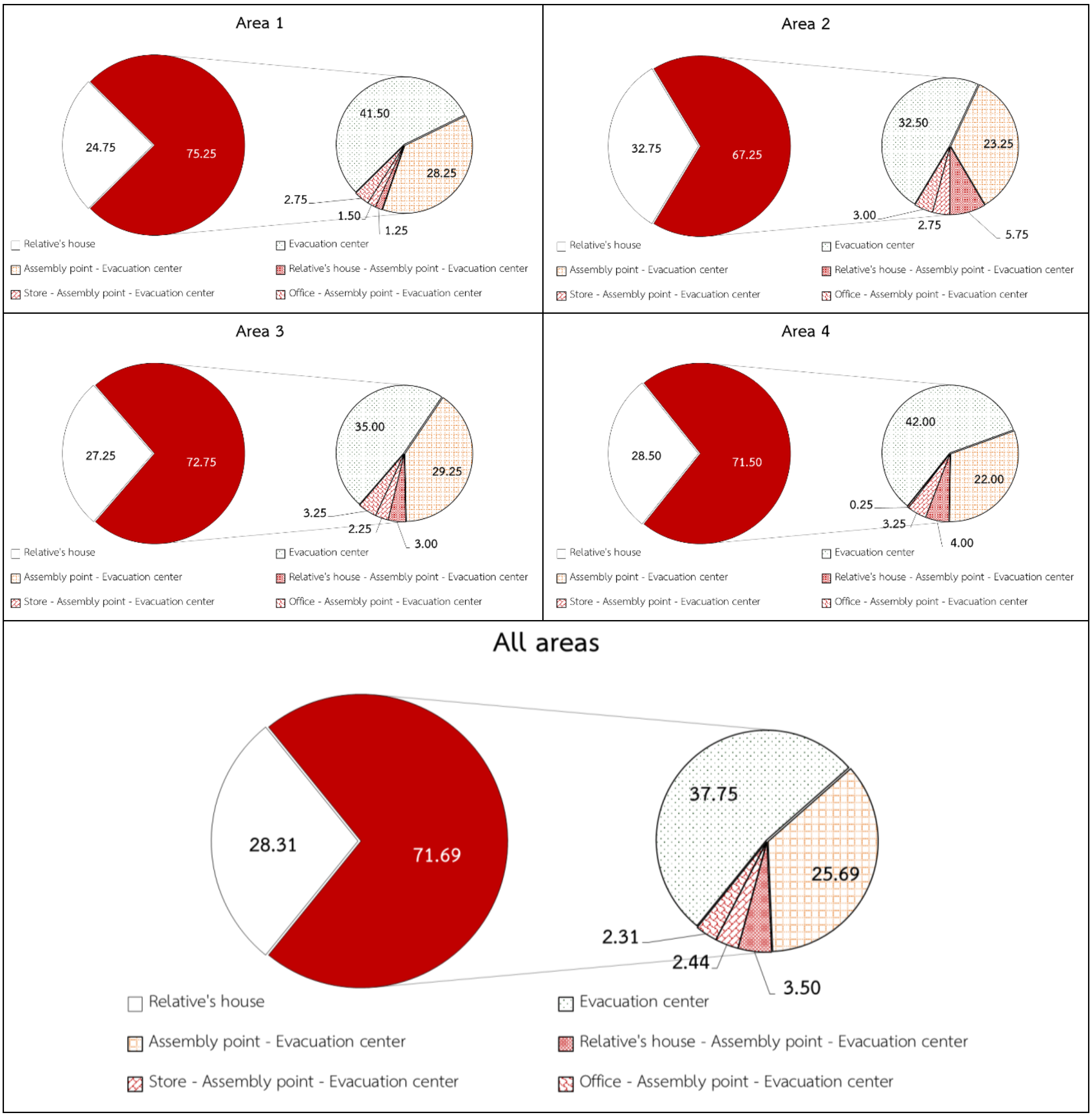
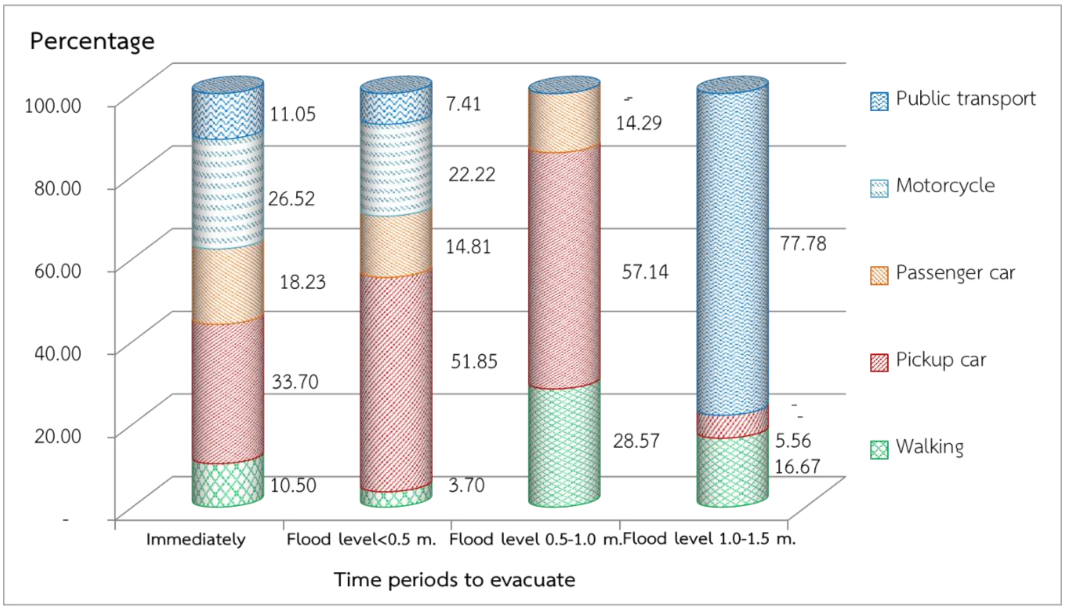


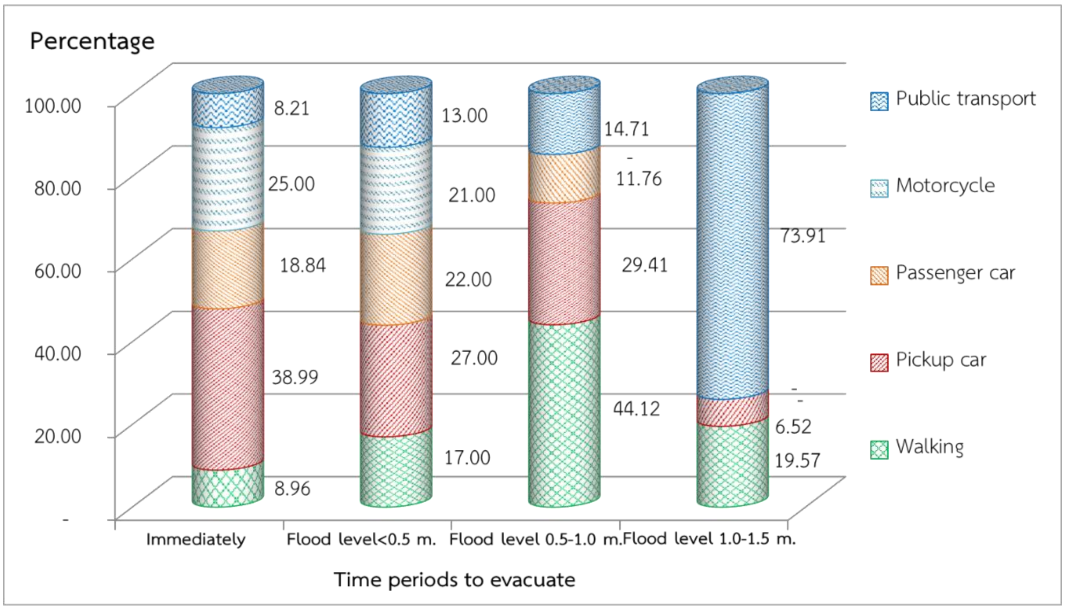
Figure 7. Evacuation destinations

Regarding the means of transport mainly used for evacuation classified by the four time periods (in Figure 6) and the two final destinations (in Figure 7), Figure 8a) shows that pickup and passenger cars were the top two means of transport that the evacuees mainly used for the evacuation to their relative's house before the flood level was higher than 1.0 m. 33.70 % evacuated immediately. 51.85 % evacuated when the flood level was lower than 0.5 m. 57.14 % evacuated when the flood level was 0.5-1.0 m. After the flood level was higher than 1.0 m., it was difficult for the evacuees to travel by smaller vehicles (i.e. pickup car, passenger car, and motorcycle). Therefore, 77.78% of the evacuees used public transports (bus and minibus) for the evacuation. 16.67% traveled by walking. A minority (5.56 %) traveled by off-road pickup car. Note that typical public transports (tuk tuk, songthaew, minibus, and bus) operated regularly when the flood level was lower than 0.5 m. After that special public transports (minibus and bus) were serviced by local evacuation agencies.

Similar to Figure 8a), Figure 8b) shows that 14.71 % and 73.91 % of the evacuees used the public transports provided by local agencies for their travel to the evacuation centers when the levels of flood were 0.5-1.0 m. and 1.0-1.5 m., respectively. The results obtained from this part can be applied to forecast a number of vehicles traveling on the road network, and consequently used to assess the traffic impact in the study area.



a) Evacuate to relative's house



b) Evacuate to evacuation centers

Figure 8. Means of transport mainly used for evacuation

4.2.3 After the flood

Figure 9 shows that most of the evacuees (70.00 %) returned to their home immediately after the water receded. 21.38 % took 1 day to return to normal life whereas the rest of them waited for longer time periods: 5 days (3.81 %), 7 days (2.81 %) and 3 days (2.00%). Regarding flood recovery time, Figure 10 shows that on the average 40.08 % of the people required 1-2 weeks to return to normal life, 28.03 % needed less than 1 week, 12.57 % took 3-4 weeks, 10.82 % required 1-2 months. For a minority, a return to normal life occurred after 3-6 months (3.97 %) and for some over 6 months (4.53 %).

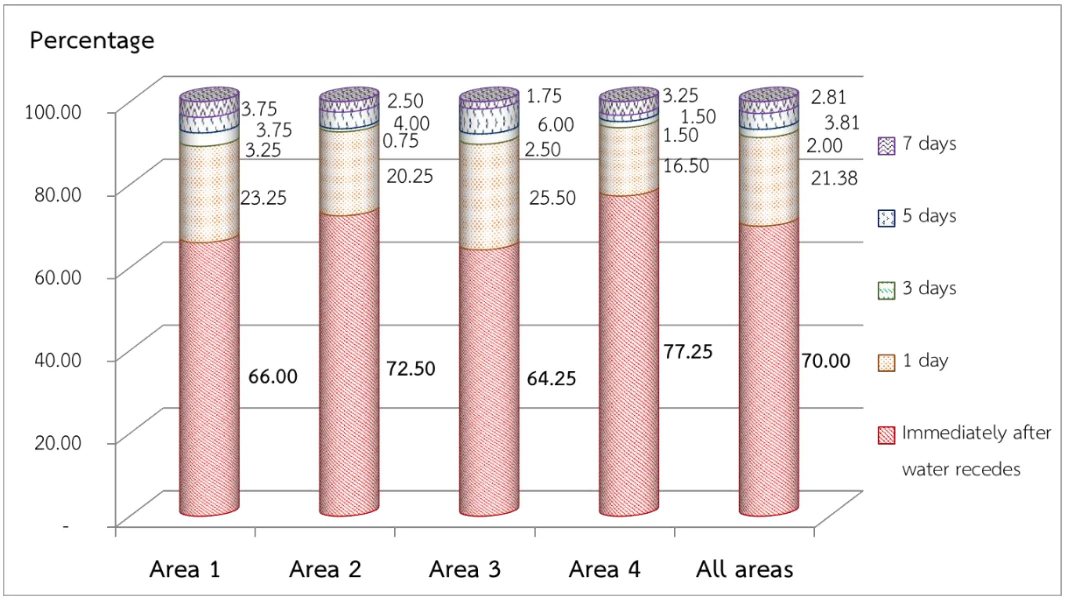


Figure 9. Time periods to return home

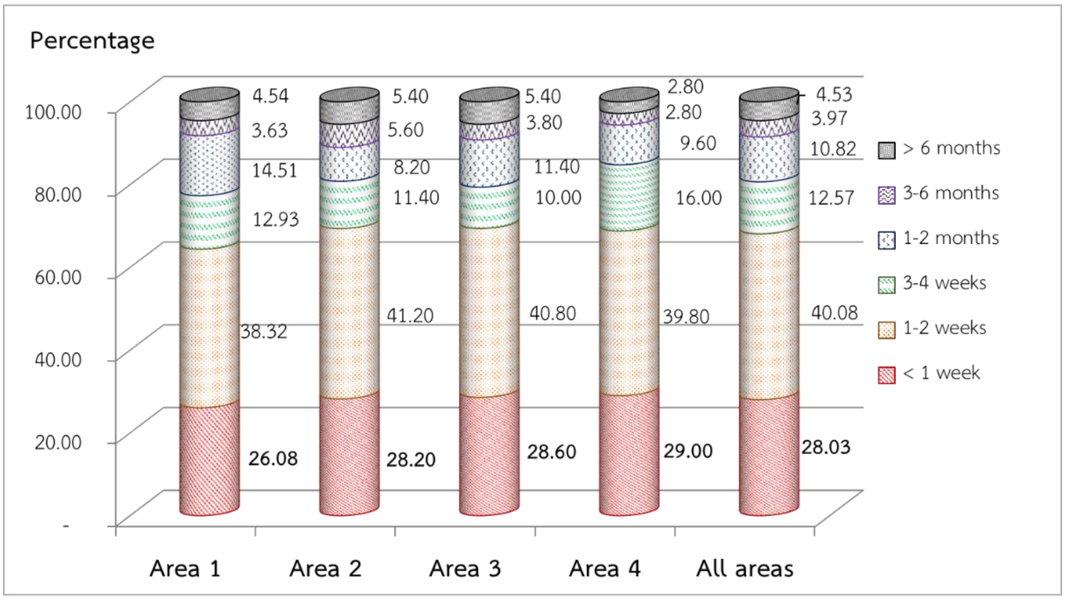


Figure 10. Recovery time periods

4.3 Flood Evacuation Models

4.3.1 Flood evacuation decision models

A flood evacuation decision model was developed based on the assumption that individual's characteristics (i.e. gender and age) and household's characteristics (i.e. income, no. children, no. adults, no. elderly, no. disable persons, and vehicle ownership) influenced on the individual's evacuation decision making (evacuate = 1, not evacuate = 0). By applying binary logistic regression, six evacuation decision models, classified by occupation, can be developed significantly. The results are presented in Table 4. In this study, the goodness of fit of the models is assessed by Hosmer-Lemeshow test, Cox and Snell R^2, Nagelkerke R^2, and the percent correctly predicted. It is found that the models fit the survey data reasonably well.

Table 4. Flood evacuation decision models by occupation

Predictor variables	Model E1: all occupations		Model E2: unemployed		Model E3: retired	
	β	Sig.	β	Sig.	β	Sig.
Constant	1.140	0.032	0.056	0.983	0.005	0.992
Gender	-0.363	0.023*	-	-	-2.111	0.070**
Age	0.138	0.046*	0.764	0.028*	-	-
Household income	-	-	-	-	-	-
No. children	-0.2310	0.043*	-	-	-	-
No. adults	0.241	0.012*	-	-	-	-
No. elderly persons	-0.218	0.051**	-1.549	0.066**	-	-
No. disabled persons	-	-	-	-	-	-
Vehicle ownership	-0.612	0.093**	-	-	-	-
Hosmer& Lemeshow Test (Sig.)	0.122		0.622		0.126	
Cox and Snell R^2	0.533		0.236		0.283	
Nagelkerke R^2	0.712		0.319		0.388	
Percent correctly predicted	60.1		71.1		68.0	
Predictor variables	Model E4: business		Model E5: worker		Model E6: government	
	β	Sig.	β	Sig.	β	Sig.
Constant	-1.835	0.146	1.725	0.099	0.293	0.843
Gender	-	-	-1.101	0.010*	-	-
Age	0.636	0.004*	-	-	-	-
Household income	-	-	-	-	-	-
No. children	-0.586	0.092**	-	-	-0.653	0.046*
No. adults	0.562	0.029*	-	-	0.987	0.004*
No. elderly persons	-0.989	0.008*	-	-	-4.124	0.003*
No. disabled persons	-	-	-	-	-1.987	0.009*
Vehicle ownership	-	-	-	-	-	-
Hosmer& Lemeshow Test (Sig.)	0.303		0.144		0.069	
Cox and Snell R^2	0.227		0.091		0.167	
Nagelkerke R^2	0.303		0.121		0.240	
Percent correctly predicted	67.1		66.0		77.4	

- Not relevant; * Significant at 95% confidence level; ** Significant at 90% confidence level.

From all six models presented Table 4, it is found that different occupations have dissimilar significant influence factors. However, the household income is not a key influence factor in all model. Regarding the model E1 analyzed from all occupations, the model is significant to gender, age, no. children, no. adults, no. disabled persons, and vehicle ownership. The negative coefficient of gender variable implies that male prefer to evacuate more than female. As we expected, the children and elderly persons are the groups requiring special cares. The negative coefficients of these two groups mean that the larger number of children or elderly persons staying in a household the lower chance the individual would evacuate. On the other hand, the positive coefficient of age implies that older people prefer not to evacuate. The positive coefficient of adult variable means that the higher number of adults the higher probability they would evacuate together.

4.3.2 Evacuation mode choice models

Evacuation mode choice models by time and destination of evacuation were developed to capture the factors that influenced evacuee's choosing the transport means, including walking, private vehicles (i.e. pickup car, passenger car, and motorcycle), and public vehicles (i.e. tuk tuk, songthaew, minibus, and bus). Multivariate logistic regression technique was applied to develop the models. The models were analyzed by setting the group of private vehicles as a pivot choice and the results are presented in Table 5 and Table 6.

Table 5. Evacuation mode choice models by time of evacuation

Transport means for evacuation	Predictor variables	Model M1: Evacuate immediately		Model M2: Flood level < 0.5 m.	
		β	Sig.	β	Sig.
Walking	Constant	-0.562	0.679	0.681	0.385
	Gender	1.015	0.014*	-	-
	Age	-	-	-0.498	0.080**
	Income	-	-	-	-
	No. children	0.663	0.013*	-	-
	No. adults	-	-	-	-
	No. elderly persons	-	-	0.777	0.100**
	No. disabled persons	-	-	-	-
	Vehicle ownership	-1.527	0.000*	-1.897	0.017*
Public transport	Constant	-0.061	0.970	-0.736	0.336
	Gender	-	-	-	-
	Age	-	-	-	-
	Income	-	-	-	-
	No. children	0.487	0.092**	-	-
	No. adults	-	-	-	-
	No. elderly persons	-	-	-	-
	No. disabled persons	-	-	-	-
	Vehicle ownership	-2.440	0.090**	-2.447	0.004*
Cox and Snell R^2		0.122		0.144	
Nagelkerke R^2		0.169		0.188	

- Not relevant; * Significant at 95% confidence level; ** Significant at 90% confidence level.

Table 5 shows the two mode choice models based on time of evacuation. However, the two time periods of evacuation (evacuate immediately and flood level < 0.5 m.) can be used to develop the models because the sample sizes of the other time periods are small. For those who evacuated immediately, the model M1 reveals that gender, no. children, and vehicle ownership were three significant factors affecting transport mode choice. The model implies that female preferred walking more than male. In addition, the larger number of children the higher probability evacuees chose walking or public vehicles, compared to the private vehicles. The negative coefficient of vehicle ownership means that an evacuee preferred using his/her own vehicle(s) instead of walking or using public vehicles. When the flood level was higher than 0.5 m., the negative coefficient of the age in the model M2 implies that an elderly evacuee preferred walking. The negative vehicle ownership in the two models means that the higher number of vehicles owned the higher the chance he/she would use his/her vehicle instead of walking or public vehicles.

Table 6 shows the other two mode choice models based the two evacuation destinations: relative's house and evacuation center. The model results are similar to the previous models. However, the mode choice models classified by the two destinations are not significant to the evacuation time and the number of elderly persons. The positive coefficients of disabled persons mean that people would prefer larger public vehicles (e.g. bus) compared to smaller private vehicles.

Table 6. Evacuation mode choice models by destination of evacuation

Transport means for evacuation	Predictor variables	Model M3: Relative's house		Model M4: Evacuation center	
		β	Sig.	β	Sig.
Walking group	Constant	-3.365	0.001	0.467	0.624
	Gender	-	-	-	-
	Age	-	-	-	-
	Income	-	-	-	-
	No. children	-	-	0.613	0.081**
	No. adults	-	-	-	-
	No. elderly persons	-	-	-	-
	No. disabled persons	1.943	0.013*	3.313	0.006*
	Vehicle ownership	-	-	-3.697	0.000*
	Time to evacuate	-	-	-	-
Public transport group	Constant	-2.324	0.000	-0.106	0.913
	Gender	-	-	-	-
	Age	-	-	-	-
	Income	-	-	-	-
	No. children	-	-	0.852	0.014*
	No. adults	0.543	0.021*	-	-
	No. elderly persons	-	-	-	-
	No. disabled persons	-	-	3.815	0.001*
	Vehicle ownership	-1.087	0.025*	-3.621	0.000*
	Time to evacuate	-	-	-	-
Cox and Snell R^2		0.164		0.209	
Nagelkerke R^2		0.180		0.288	

5. CONCLUDING REMARKS

This paper presented the analysis of factors affecting urban inhabitant's decision making on evacuation action before, during, and after the flooding. The survey was conducted in Hat Yai municipality as a case study. The study was divided into three main parts, including the investigation of household characteristics, the analysis of evacuation behaviors, and the development of evacuation models. The results of the first part revealed the number of members and vehicles in household. The second part presented the behaviors of evacuees before, during, and after the flooding. Before the flooding, people require about fifteen hours for evacuation preparedness. During the flooding, it was found that 57.25 % of the people want to evacuate to safe places. The number of evacuees was 2.66, 2.75, 2.48, and 2.43 persons per household for the cases of immediate evacuation, flood level < 0.5 m., flood level 0.5-1.0 m., and flood level 1.0-1.5 m., respectively. Regarding the destinations of evacuation, 71.69 % of the evacuees went to the evacuation centers provided by local agencies, whereas 28.31 % went to their relative's house. It was also found that most of the evacuees used private vehicles (pickup car and passenger) as the major means of transport for the evacuation to both destinations. This may cause traffic problems during the critical period. After the flooding, most of the evacuees (70.00%) returned to their home immediately after the water receded. Considering the recovery time, on the average 40.08 % of the affected people needed 1-2 week to return to normal life. The third part of this study developed two types of flood evacuation model by applying logistic regression analysis. The first type was to determine the factors influencing decision making of individuals by occupation on the evacuation. From all occupations, it was found that gender, age, no. children, no. adults, no. disabled persons, and vehicle ownership were the significant factors. The second type was to investigate the factors affecting the evacuation mode choice. It was found that no. children, no. disabled persons, vehicle ownership were the significant factors. The results and models developed can be applied to estimate the travel demand of evacuees, improve current and propose new efficient means of transport to meet the demand and needs. Finally, the authors believe that the concept of this study can be more rigorously applied to propose disaster management systems before, during, and after flooding in other urban areas in developing countries. Future related works should focus on an introduction of time series in flood evacuation modeling for flood preparedness planning.

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