Behavioural choices in evacuations during floods: a preliminary study in Metropolitan Area of Valencia, Spain

Azarel CHAMORRO OBRA[1], Wisinee WISETJINDAWAT[2], Motohiro FUJITA[3]

[1]Research student, Department of Civil Engineering, Nagoya Institute of Technology
(Gokiso, Showa, Nagoya, Japan 466-8555, Japan)
E-mail$_1$:cju83505@stn.nitech.ac.jp
E-mail$_2$: azchaob@cam.upv.es
[2]Assistant Professor, Department of Civil Engineering, Nagoya Institute of Technology
(Gokiso, Showa, Nagoya, Japan 466-8555, Japan)
E-mail: wisinee@nitech.ac.jp
[3]Professor, Dept. of Civil Engineering, Nagoya Institute of Technology
(Gokiso, Showa, Nagoya, Japan 466-8555, Japan)
Fujita.motohiro@nitech.ac.jp

The Metropolitan Area of Valencia (in the Mediterranean coast of Spain) suffers yearly heavy rains due to a cut-off low phenomenon called "Cold Drop". There are historical records showing that floods due to long return period downpours led to catastrophic situations. Until now, the flood management in the region has been analysed from an economic impact perspective. Even though the economic analysis is important and necessary, the humanitarian perspective analysis is required to plan future events preparedness and response. This paper aims to model the behaviour choices of the inhabitants of the region in case of the issue of an evacuation alert due to long return period flood inundations. To do so, a questionnaire survey has been conducted to ask the inhabitants of the region as a case of study. A total of six hundred responses from inhabitants have been analysed by using logistic regression models. A model for each of the four main variables has been developed. Results have shown the threat awareness and the family attributes as the most important variables to influence choice decisions during evacuation. Taking into consideration the obtained results, it could be possible to establish a draft plan in order to improve local government response for future flood events.

***Key words**: Behaviour choices, Cold Drop, Valencia, floods, evacuation*

1. INTRODUCTION

In the Metropolitan Area of Valencia (MAV), floods historically represent one of the most hazardous natural disaster (after heat waves and droughts) in terms of injured and casualties[1]. Evacuations due to natural disasters have not been previously considered, thus no evacuation management and prevision of shelter areas have been considered for disaster plans.

The MAV is populated by more than one and a half million inhabitants, being the third most populous urban area in Spain. The region is located in the Central Valencian Depression, which is the largest coastal plain in the Spanish Mediterranean coast. This alluvial plain is surrounded by mountain ranges and crossed by several rivers and gullies. The most important of these rivers is the Turia River. The majority of the rivers are usually dry and water flows only when heavy rains fall. Near the coast there is a lagoon called "Albufera", which is the lowest place in the basin and the largest lagoon in the Iberian Peninsula. Most of the flow coming from the area drains to this lagoon, which surroundings are commonly flooded.

As it is common in coastal plains, there are many precedents of floods. Most of the floods are due to a yearly heavy rain commonly called "Cold Drop" (also known as "DANA"). Eventually, this cut-off low phenomenon leads to important floods in the

MAV and causes important damages. For instance, from 1321 to 1957, 48 flood events were reported[2]. The most catastrophic event ever reported happened in October 1957, when a Cold Drop phenomenon caused the river to overflow into the city. Two thirds of the total population of the city were affected and 81 official casualties were reported. After this massive flood the course of the river was diverted to the current place and the capacity was greatly increased.

In order to protect the urban areas, in the last 40 years the public administrations have greatly improved the territorial plans and infrastructure. From 1985 to 2003 the regional government invested more than 130 million Euros (175million US$) in flood defence works[3]. However, highly vulnerable areas around the largest gullies are still being vulnerable for medium return periods (50 to 100 years) because of the high population density.

The flood impact in the MAV has been traditionally analysed from an economic perspective. PATRICOVA[3] analysed the damage of inundations in the region, but there is no specific mention to the inhabitants that may be threatened in the MAV. Legislation for the Civil Defence include a state[4] and a regional[5] directive to apply in case of hazard. However, those studies do not mention any prevision of shelters or special instructions to evacuate the population that could be affected by long return period floods.

Based on the land use in MAV the vulnerability in cities near the most hazardous gullies has been quantified[6]. This vulnerability has been implemented in the available cartography (ARPSI[7]). Furthermore, the expected rainfalls for different return periods have been estimated in previous researches[8].

Despite the large number of previous works about the economic impact, there is no work related to the humanitarian damages. On account of this, the population affected by a return period of 500 years was estimated by this author. By using demographical and geographical data, two possible scenarios were considered for the same return period of time: an optimistic scenario when people who live in the first floor and detached dwelling, and a pessimistic scenario when the inhabitants living in a whole building affected by flood. The affected population for each scenario was estimated at 23,000 and 73,000 inhabitants, respectively.

Evacuation behaviour during floods in developed countries has been analysed by many researchers. Manuel Fidalgo[9] analysed behaviour during emergency situations in Spain. It was shown that people who have experienced hazards are more likely to move and react against disasters. Bateman and Edward[10] claimed that "women are more likely to evacuate than men because of socially constructed gender differences (…) and perceived risk". When comparing earthquake and flood evacuation behaviour, Yuling Liu[11] claimed that it is necessary to raise awareness of disaster at community levels for an appropriate citizen response. The importance of the information provided by the government about disasters in evacuations was also studied during the National Dutch flooding exercise[12]. Moreover, flood vulnerability reduction with a lack of communication about the potential consequences of flooding leads to low perception of flood risk[13].

The first step to develop an evacuation plan is to know how inhabitants would react in such case. This work proposes a study of behavioural choices during evacuation due to flood in the MAV. It is aimed to find relationship between significant variables and analyse how they affect decisions. Due to the new situation that would be for inhabitants of the MAV, it has been considered that a safer attitude would be to follow the instructions from emergency authorities. Then, deciding to evacuate is stated as the safest decision.

2. METHODOLOGY

For this preliminary analysis, data was collected by means of an Internet survey. The sample was compounded by anonymous students and staff from the School of Civil Engineering (ETSICCP) of the Universitat Politècnica de València. The sampling unit is an individual living in the MAV. From a total of 870 received, 612 responses were accepted within the 14 days that the Internet questionnaire was available to be filled out. This sampling methodology belongs to convenience sampling, a non-probabilistic sampling technique. However, due to the high number of responses received, the sample was considered to be representative of a random sample for high literacy and young population strata in the MAV.

The survey was divided into 26 questions in 5 groups: personal attributes, decisions before hazard, decisions while evacuating, decisions while staying and opinion. For questions related to the family unit, individuals below 15 years old were considered children and those who are above 65 years old were considered elders. The situation described was an evacuation alert issued by emergency authorities due to forecasted long time heavy rain in the MAV. Floods for 2 or more days are expected. Respondents are initially in their homes have 12 hours from the moment of the alert issue to the

downpour. Few well-known places in the area have been shown as shelters for those who wanted to go to them when evacuating.

A logistic regression model was used to develop the models for the main decisions: evacuation decision, destination, transportation and departure time. Since the three first decisions have two possible choices, a binary model has been used. In this kind of model, value 1 means that the choice *x* is selected and, otherwise value *x* is not selected. For departure time decision a multinomial logistic regression has been applied. In both analyses no constant have been calculated, then the fixed value α_0 has been considered as zero (same initial probability for every choice). Then, the utility function for the decision U_y taken by one individual is shown as follows:

$$U_y = \propto_{1,y} x_1 + \propto_{2,y} x_2 + \cdots + \propto_{n,y} x_n$$

The probability function for the decision *y* for one individual can be formulated as:

$$\mathrm{P}(y) = \frac{1}{1 + e^{-U_y}}$$

3. RESULTS

As it is expected from a sample that is compounded by students and staff of the university, most of the responders are young people. 86% of the individuals are below 30 years old. Moreover, everybody is supposed to have high level of studies. As a consequence, following results represent young and high literacy strata in the inhabitants of the MAV.

In order to explain the behaviour choices in the evacuation before downpour, four main decisions have been chosen. The hit ratio of the logistic regression models is higher than 60% (medium accuracy) for "evacuation" and "departure time" decision. For the decisions of "Going to a shelter" and "Leaving by car" the hit ratio is higher than 75% (high accuracy), so it can be considered that every model is reliable enough to extract conclusions for a preliminary study.

For every decision, the model for the choice which is considered to be value 1 has been developed. Results are shown in Table 1.

Table 1 Model results

Dependent variable	Independent variable	α	T value
Model 1: Evacuation Decision			
U_1: Evacuating	*Being a female*	0.6328	3.720
	Being high informed	0.4829	1.990
	Living in Valencia City	0.2937	2.150
	Living below 4 th floor	0.3326	2.130
	Have experienced floods	-0.3766	-2.430
Hit ratio: 63.22%		**N= 609**	
Model 2: Destination			
U_2: Going to a shelter	*Having Children*	-0.8844	-3.774
	Having elders	-0.5191	-2.154
	Floods for more than 4 days	0.3556	5.659
	Being aware of threat	-1.0310	-2.521
Hit ratio: 77.66%		**N= 376**	
Model 3: Transportation			
U_3: Leaving by car	*Going with the family*	2.2590	9.223
	Picking up a relative	0.4725	1.686
	Living in Horta Sud	1.4680	1.717
	Going to a shelter	-2.9530	-9.698
Hit ratio: 82.12%		**N= 376**	
Model 4: Departure Time			
U_4: Early departure	*Going with the family*	2.2520	4.431
	Being a female	1.7870	2.313
	Being well-prepared	-1.3280	-2.013
	Being aware of threat	2.1890	1.908
U_5: Regular departure	*Go with the family*	3.2800	6.620
	Being a female	1.4850	1.935
	Being well-prepared	-1.4450	-2.254
	Being aware of threat	2.0100	1.754
Hit ratio: 65.42%		**N= 376**	

(1) Evacuating decision

Two possible choices have been set for the decision of evacuating: "Evacuating" (1) or "Stay home" (0). From a total of 609 responses, 376 people (62%) assured that they would evacuate in the situation stated in the survey. In this first model all the accepted responses were analysed. However, in the next models (destination, transportation and departure time) only the people who decided to move will be considered as sample.

The model for "Evacuating" decision explains 63.22% of the data of the survey (medium accuracy). Regarding the T-test results, every variable have significance at 95% confidence level. "Being a female" is the most influential condition to take the decision of evacuating. The only condition value is shown in the variable "Have experienced floods", which means that people who "have experienced floods" will not be likely to move (-0.3766). In this decision, 60% of the surveyed responded that they would evacuate.

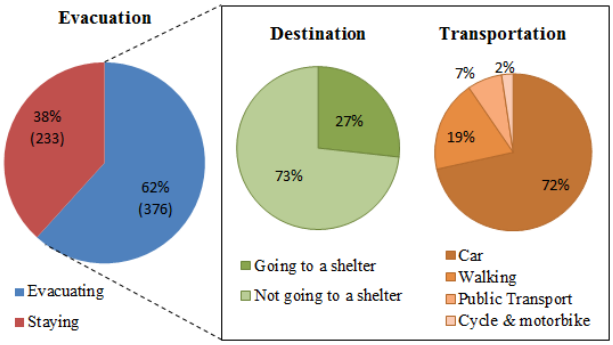

Figure 1 Survey main results

(2) Destination decision

For those who decide to evacuate, destination decision has been set in two possible choices: "Going to a shelter" (1) or "Not going to a shelter" (0). This last choice includes any other destination than shelters, such as relative or friend's house, no specified destination, etc. From survey results (Figure 1) it is shown that 27% of the respondents would go to a shelter if evacuating.

The only variable that encourages people to take the decision of going to a shelter is "Floods for more than 4 days", which is interpreted as they do not have any other place to evacuate. The other three conditions remain negative with values more than double the positive variable in case of "Having children" (-0.8844) and "Being aware of threat" (-1.031).

(3) Transportation

Survey results show that most of the people would move by car (figure 1). The majority of the people who would not move by car (the remaining 28% of the interviewees) would move on foot or by public transportation. For the transportation decision model, two possible choices have been considered: "Leaving by car" (1) or "Not leaving by car" (0). Many different choices can be evaluated in transportation decision, such as "leaving on foot", "by car" or "public transportation". However, from the point of view of evacuation management, the most interesting mean of transport is the automobile. This model only analyses leaving by car, so other mean of transports are included in the value 0 (not leaving by car).

The choice of leaving by car model highlights unequal results. "Going with the family" and "Going to a shelter" conditions have a very high importance in taking the decision or not, respectively. As it can be deduced from t-value, both values have an almost perfect correlation with the decision (significance above 99.99%). On the other hand, "Living in Horta Sud" (administrative division) and "Picking up a relative" variable have a statistical significance at 90%. In comparison, the last variable is more than three times less important to dissuade people from taking the car.

(4) Departure time

For the departure time decision model three possible choices have been considered: leaving until 10 hours (1), from 10 to 2 hours (1) and from 2 hours before the downpour starts (0). From now, the choices will be stated as "Early Departure", "Regular Departure", and "Late Departure", respectively. According to this definition, survey results have been gathered in these three groups (figure 2).

In order to consider more than one choice, a multinomial logistic model has been developed. In this multinomial model, variables are common for every choice (specific variables). The highest value for a variable establishes the most likely choice. In case of all the values being negative (for a same variable), the most likely decision is the choice which utility function has not been calculated. Then, the model attributes (such as hit ratio or sample size) are the same, no matter which choice is evaluated.

According to the model results, individuals who fulfil "Being a female" (1.787) and "Being aware of threat" (2.189) conditions prefer an early departure. However, in case of "Going with the family" individuals strongly prefer to move from 10 hours to 2 hours before. Individuals who consider themselves as "Being well-prepared" tend to "late departure", due to the confidence of being prepared for the situation; they wait until the last moment.

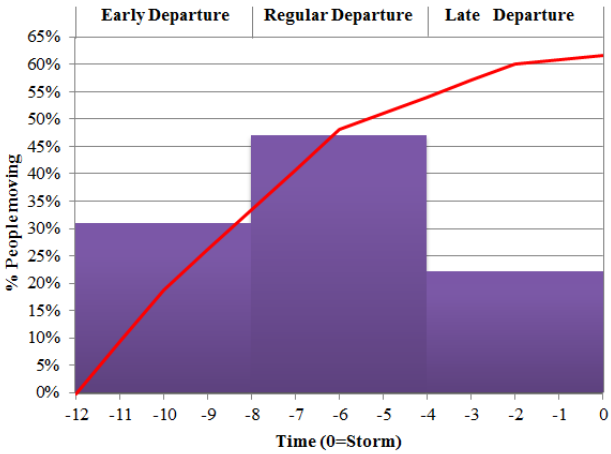

Figure 2 Departure time survey results: The red line represents the accumulated departures for the initial sample (including those who do not move).

4. DISCUSSION

As was noticed in other studies, stated preferences that are based on personal perception, such as "Being aware of threat", "Being high informed" and "Being well-prepared", have been shown to be key variables in most of the analysed models. Awareness level is especially crucial for going to a shelter and departure time decisions. The important weight of these variables shows the importance of training the population and increasing the information about floods. Nevertheless, "Have experienced floods" is not a condition that encourages people to evacuate as was expected. This can be explained if it is considered to be a result of the young age of most of the responders: most of the individuals have not experienced major inundations.

The most important personal attributes are sex and those related to family characteristics. Females are prone to have safer attitudes, such as evacuating more and faster than males. In general, large families (i.e. those who have children or elders) have a well-defined pattern once they have decided to evacuate.

5. CONCLUSION

In this study, models for four key decisions during evacuation due to floods have been made. Applying logistic regression models for the main decisions, the most influencing variables related to each model have been found. The results show that few variables were found to be almost related with the possible choices taken during evacuation. Also, high threat perception and provided information have been revealed as key factors to influence decisions.

For the target population (young and high level of studies people), a well-defined reaction in case of evacuation issue has been highlighted. From observed results it has been concluded that evacuation and shelter preparation should be included and evaluated in future emergency plans. Despite the fact that this study cannot be applied for all the inhabitants of the MAV, it provides a good starting point from which analyse flood hazards in the MAV from the point of view of transportation and emergency response in future researches.

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