

MODELING THE DECISION OF EVACUATION FROM TSUNAMI, BASED ON HUMAN RISK PERCEPTION

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1. Introduction

After great improvements on early warning system technology for tsunami during the past decades, and also many mitigation programs in coastal communities around the world, still some people decide not to evacuate from a dangerous situation such as a tsunami threat (Imamura, 2009; Katada et al., 2005). Most of survivals who did not evacuate mentioned as a reason for no evacuation the fact that the sea did not retreat, no information or warning confirmation came, he/she considered him/herself in a safe place already, etc. (Hoppe and Setiyo, 2010). The lack of recognition of the risk in which they were involved resulted on a non evacuation decision.

In this study, a new approach for start time evacuation decision modeling in tsunami events is presented. The decision process relies on the Risk Perception Level (RPL) as the driven variable of human behavior in emergency situation. RPL was addressed in three stages (Pre-decision, Decision-making and Action), through questionnaire surveys. Also, techniques and theories of Reference Risk, Prospect Reference Theory, Subjective Judgment Matrices and Bayesian Learning were used as tools to construct a suitable Risk Perception Framework for Tsunami Evacuation Decision.

2. Objective

The purpose of this study was to develop a start time evacuation model based on risk perception, experience, warning information, social influence and time pressure.

3. Methodology

Risk Perception is defined as the subjective judgment of a risk. It is an idea of how risk is the situation; feelings of safety or fear emerge at this moment.

According to Figure 1, the three stages are:

Pre-decision Stage is the non threatening scenario or situation in which an individual holds a fearless condition against any kind of hazard which is not occurring at the moment, however an idea or perception q_0 of how risk could be the situation, is present under the *what if...* idea of been involved in such hazard.

Decision-making Stage refers to all the decision making processes of an individual, when the risk perception q_K is rising until it gets to the next stage called Action Stage.

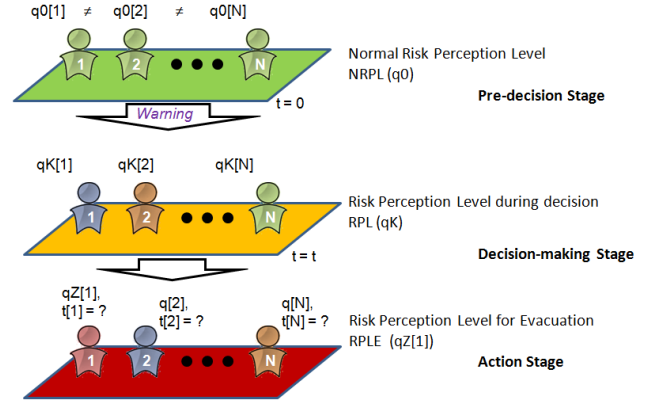


Figure 1: Stages of Risk Perception

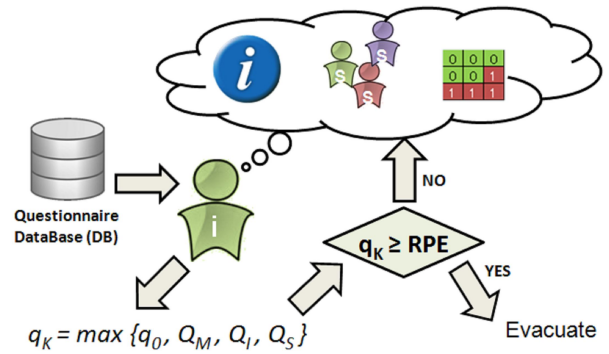


Figure 2: Individual Behavior

Action Stage is the moment when the individual cannot stand anymore the actual perceived risk level q_Z and a protective action (e.g. evacuate) has to be performed, taking the whole decision process into an end.

The individual behavior, as shown in Figure 2, explains the process of decision, where a database (DB) of parameters obtained from questionnaire surveys – q_0 and RPE among them – becomes the input of the model and the warning information Q_I , social information Q_S and spatial risk Q_M are the feedback of a new posterior risk assessment q_K . Decision of evacuation is made when the current risk outweighs the risk perception level for evacuation RPE .

4. Overview of study area

The October 3rd, 1974 event, in front of La Punta had a magnitude of 8.0 and a local tsunami height of 1.6 m (Espinosa et al., 1977; Langer and Spence, 1995). From this day, no big seismic activity has been reported so far in front of la Punta area. A possible seismic gap might be located in this area,

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threatening La Punta and other coastal cities with a future big earthquake and tsunami. Therefore, a risk perception survey was conducted in a group of 137 respondents. The conducted questionnaire addressed three main objectives; (1) To obtain a value of Risk Perception Level in a natural or normal state of affairs (q_0); (2) To estimate the Risk Perception Level for Evacuation Decision (q_Z), and (3) To identify sample's evacuation knowledge, experience and individual perspectives.

5. Traditional model of departure estimation times

Tweedie et. al (Tweedie et al., 1986) used a methodology based on probabilistic mobilization time curves for estimating times required for the partial or total evacuation of an emergency planning zone (EPZ). An evacuee mobilization time curve is also called a traffic loading curve and is defined as the timing of evacuee response or traffic departure time. The mobilization curve based upon the Rayleigh probability distribution function is of the form:

$$F_t = 1 - \exp\left(-\frac{t^2}{T}\right) \quad (1)$$

where F_t is the percentage of the population mobilized by time t , and T is a parameter the analyst can adjust, to control both the slope of the traffic loading curve and also the maximum time at which all evacuees are assumed to have mobilized. As we observed, shape and value of T are assumed by local stakeholders' opinion when stated intention of evacuation from the population has not been collected. For this study, questionnaire data helped on giving the mobilization curve a more realistic shape by using the original definition of the Rayleigh distribution, where the parameter T equals $2\sigma^2$ and an estimation of the parameter σ is:

$$\hat{\sigma} = \sqrt{\frac{1}{2N} \sum_{i=1}^N t_i^2} \quad (2)$$

where N is the number of respondents with estimated time t_i .

6. Results and Discussion

We ran the model and compared the output predicted time of decision with the time of decision argued by the respondents and a common predicted method from emergency planning (Tweedie et al., 1986).

Figure 3 shows the perceived time of decision from a group of respondents (Questionnaire line), the model output (Model line) and a traditional approach for preparation times before evacuation (Mobilization curve). A Normalized Root Mean Square Error (NRMSE) of 26% for the model and 50% for the traditional distribution shows an improvement on the predicted method proposed here. Also, a successful Wilcoxon test ($H_0 : \mu_Q = \mu_M, p = 0.178 > \alpha = 0.05$) was performed to confirm the reliability of questionnaire data and model outputs. Contrary to traditional models for Start Time Evacuation which are based on directly information from survey data of past experiences, residents estimations or expert opinions, where a simple and unique scenario can be simulated, here a mathematical based framework model integrated with survey parameters allows for a different situation of modeling in an individual and cooperative dynamic simulation with an emergent behavior.

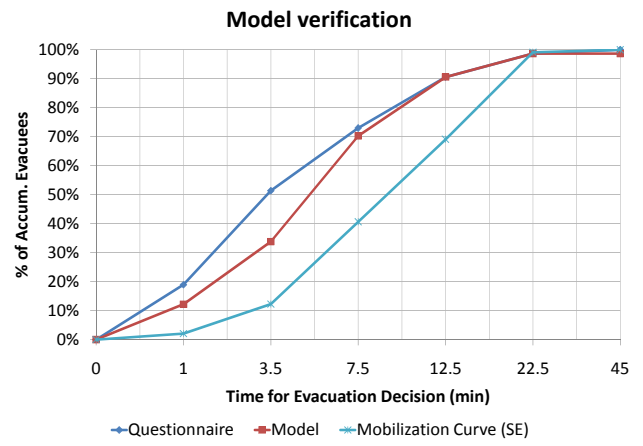


Figure 3: Model output vs Questionnaire

7. Conclusions

Assisted by the techniques and theories mentioned in the introduction, a proposed model for Start Time Decision of Evacuation based on Risk Perception was presented and compared with questionnaire responses. The capability to predict similar times of evacuation decision from the sample group, gives a promising future to the model.

Acknowledgments

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