Basic study on Human Behavior for Tsunami Evacuation Simulation using Multi Agent System

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1 Introduction

Evacuation models are a modern approach in tsunami risk management; however evacuations are performed by real human beings, thus human behavior is one of the important characteristics that an evacuation model must consider. Several videos from Indian Ocean tsunami 2004, and recently Samoa 2009, show a late reaction of people against tsunamis, even they can watch the incoming tsunami wave. This can be explained through human behavioral aspects (Imamura, 2009), in this study risk bias expressed in the Risk Perception Index controls the behavior for start evacuation and stress condition in emergence situations.

2 Objective

Simulate some aspects of human behavior during tsunami evacuation scenarios and perform a sensitivity analysis for the assessment of the level of participation of each variable in the model output (casualty estimation). Variables in consideration are: warning coverage, risk perception index, energy, tsunami arrival time and runup..

3 Model characteristics

Multi Agent System paradigm is used for the individual human behavior simulation. An open beach of 0.4km shoreline and 1km inland with 2% slope was developed for tsunami simulation. Input variables are: Number of agents (population), maximum value for energy and risk perception index for initial conditions, tsunami arrival time, and the percentage of population receiving the first warning coverage (% of population with warn message).

4 Model behavior

Once the initial condition input variables are set, the model will present N number of agents randomly located in the beach space, warning percentage W% of N will be represented as blue agents (the ones who hold the warning message), others stay color red, ocean receding - tsunami natural warn - gives a special warning to agents near the sea (agents color green). Agents with no warn receive the message from blue or green agents if they pass 10m nearby.

When the model is running, every agent performed the behavior shown in Figure 1, and decide their own start time evacuation, own goal (refuge in high ground), speed is increased or decreased according to individual energy and crowd density. Agents with very low energy will not be able to increase speed anymore and the speed is fixed to a minimum assumed value of 0.5m/s. Tsunami arrives after T min set in the input panel with a 100km/h velocity to a maximum set run-up (R). Casualties in this model are defined as agents under inundation level of 2m (probably dead or injured). (Figure 2)

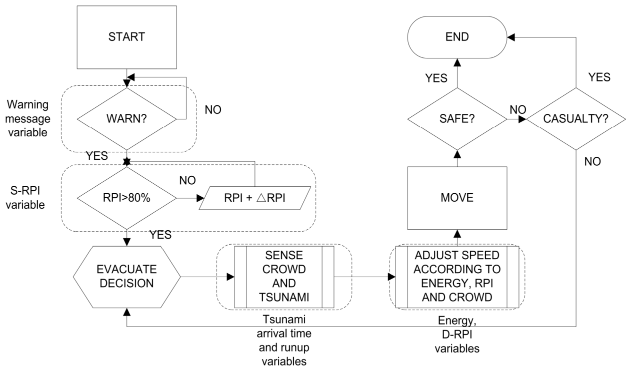

Figure 1 Agent behavior

5 The Risk Perception Index (RPI)

In this study, RPI is considered as the main variable for human behavior simulation in emergence situation. Each agent starts the simulation with a randomly given RPI less than the set in the input panel. This condition represents the Static Risk Perception Index (S-RPI), which holds the experience and knowledge on tsunamis by the agent in a normal situation. When warning message is received, the agent decides to start his/her tsunami evacuation based on his actual value of S-RPI, otherwise waits until the risk perception increases. Dynamic Risk Perception Index (D-RPI) plays the main role in speed variation -also energy and crowd condition- during evacuation process. D-RPI represents the fear and stress of the evacuee in emergence situations.

Through this variables agents decide their own response, when S-RPI increases above an assume value of 80%, the agent starts the evacuation. RPI increases with time and tsunami approaching (at sight). Also RPI is a triggered for speed acceleration or “shock” condition (over stress condition, being disoriented).

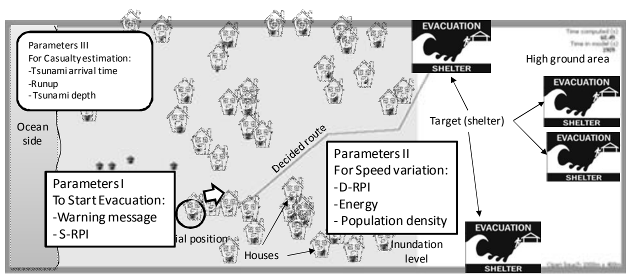

Figure 2 Variables at model

6 Sensitivity analysis

Whilst there are many approaches to sensitivity analysis (Saltelli et al. 2000), this proof of concept is limited to a one-at-a-time (OAT) design. Table 1 shows the variables and range for the different simulations. Base condition for fixed parameters is assumed at the mean value of each variable. A total of 15 times simulation per scenario was conducted over the whole range in the 6 main variables, finally, using graphical methods for sensitivity analysis, trends in scatter plots of casualty estimation output results are describe in Figure 3.

i (id)	Parameter	Definition	Range	Unit
I		To Start Evacuation		
1	S-RPI	Static Risk Perception Index (initial condition)	0 – 100	%
2	Warning coverage	% of population receiving warning at initial condition	0 – 100	%
II		For Speed Variation		
3	D-RPI (dR)	Dynamic Risk Perception Index (risk increment)	0.2 – 1.0	%
4	Energy	Maximum Energy value at initial condition	50 – 100	%
III		For Casualty Estimation		
5	Tsunami Arrival Time	Time of arrival for killer wave	0 – 60	min
6	Run up	Maximum elevation for tsunami wave	2 – 10	m

Table 1 Model parameters and range

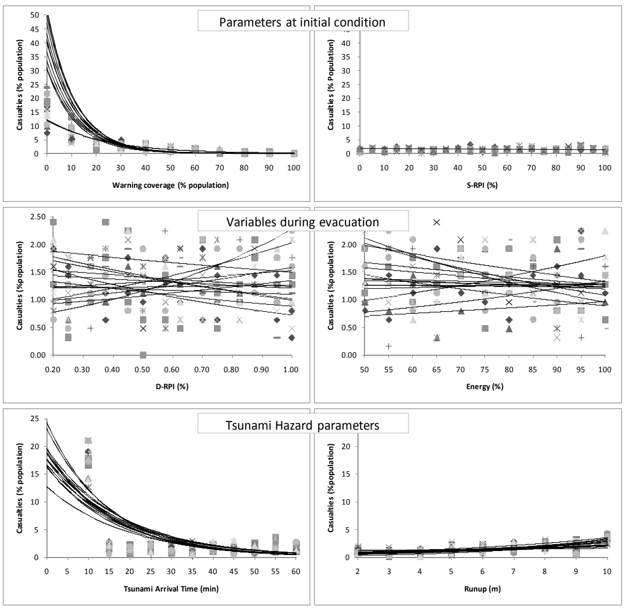

Figure 3 Output scatter plots

7 Discussion

Parameters at initial condition

It is clear that the parameter “warning coverage” has an important participation and effect on casualty estimation output in this model. More people warned faster, means more minutes available for start evacuation decision and evacuation process, thus, in a rational behavioral response, fewer casualties are expected.

Variables during evacuation

Although the model has an acceptable behavior in the analysis of initial conditions parameters and tsunami hazard parameters, the variables of interest for this study (D-RPI and Energy), which controls the speed behavior of evacuees, show a random trend. For that reason, calibration of behavioral conditions in the model will be assess through real data from questionnaires and experimental test in a selected community. Then we can determine the real contribution of these variables in the total evacuation time and also the casualty estimation.

Tsunami Hazard parameters

The tsunami arrival time has an important effect on casualty estimation. In this model, over 15min arrival time is less sensitive for casualty output.

8 Conclusions

Human behavior was simulated through the Multi Agent System paradigm using agent-based modeling. Moreover, we conducted a sensitivity analysis using graphic methods and one-at-a-time (OAT) approach for the evaluation of some parameters in tsunami evacuation models. Warning coverage has an important participation and effect on casualty estimation output in this model. Forecast and warning messages for tsunami evacuation measures are of high importance for casualty prevention.

Although the model is driven by the Energy and the Risk Perception Index, which we introduce as Human Behavior variables for the Tsunami Evacuation simulation, results are still preliminary, and calibration of these variables is part of a future work using real data from questionnaires and other psychological methods.

Acknowledgments

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