LOGIC MODEL OF PEOPLE'S MIND TOWARD TSUNAMI EARLY WARNING

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***ABSTRACT*:** Two recent devastated tsunami generated by 9.0 magnitude earthquake, i.e. 2004 Indian Ocean (Sumatera) Tsunami and 2011 Tohoku Tsunami, have become the turning points not only for affected countries but also for international community. The 2004 event has made Indonesia, as well as other affected countries in Indian Ocean region, to put high priority for the development and establishment of tsunami early warning system (TEWS) under collaboration with the national, regional and international community. Adapting and improving existing technology for STRUCTURE component of warning system was intensively conducted. At the same time, enhancement of CULTURE component of the system has been done by promoting disaster risk reduction countermeasures to increase readiness of the city and preparedness of people at risk. Such efforts include mandate for local government to provide supporting infrastructure for conveying tsunami warning, emergency purposes, capacity building of government institutions in disaster prevention, increase preparedness of the people, and accommodate local knowledge/wisdom. Still, until completion stage of TEWS, the CULTURE component has yet been fully enhanced, compare to the other component. As it was tested by a number of tsunami occurrences, the people and city stakeholders of some national show case cities still have shown lacks of responses when strong shaking felt and tsunami warning/evacuation order issued. The evacuation processes went uncontrollable, i.e. traffic congestion, people panic and many other chaotic manners due to no officials in charge handling situation. Without any doubt, if *the expected scale of tsunami* were occurred, a massive loss of life would likely to be remained or even worse; then the effectiveness of tsunami warning and countermeasures implemented at those cities becomes a *critical question*. At the other hand, the 2011 Tohoku tsunami has also become the turning point for the Japanese government as well as its stakeholders to review all structural and non-structural countermeasures implemented to anticipate *the expected tsunami*, including enhancement of CULTURE component.

To challenge these issues and learning from the success and failure stories of 2011 event from the perspective of CULTURE component, the study presented in this paper has attempted to solve the problem using practical solution by developing a logic model of people's mind toward tsunami early warning. Holistic approaches have been used to identify and structure tangible and intangible factors, as well as restructure indelible factors that remain in people mind due to their exposure to disaster and countermeasures. Results of the study show a complex relation among these factors with some significant numbers as assisting and hindrance factors to slow process development of this component. In some case, it was worsened due to the fact that some assisting factors in one area were hindrance factors in other area. With the two case study cities, i.e. Padang and Cilegon, a numerical logic model was developed. Result of numerical analysis shows many surprised factors which *unexpectedly* influenced the people's mind to *immediately*, *delay* or *never* evacuate. Further research question is on how to have the right policy for the right needs for improving CULTURE component, implicitly led to improve the effectiveness of countermeasures implementation from local perspectives. The model presented in this paper is the core part of the "end to end" logic model, which is expected to be able to support local government and central government of Indonesia to identify the real problem and to develop the right policy for the right countermeasures in order to enhance overall goal of tsunami early warning *to safe as many people as possible*.

KEYWORDS: logic model, tsunami early warning system, principal component analysis

1. INCREASE OF TSUNAMI RISK AND ITS CHALLENGE FROM EARLY WARNING PERSPECTIVE

After the 2004 Indian Ocean tsunami, relentless devastated tsunami disasters generated by extreme magnitudes of earthquakes have still overwhelmed many coastal cities at tsunami prone zone in Indonesia as well as in other regions, i.e. Japan with recent experience with deadliest 2011 Tohoku tsunami. Serious heavy losses in *lives*, property, lifelines and infrastructures at those tsunami events has becomes *major concerns* and *turning points* not only for the affected government with the internal and external stakeholders from international, regional, national up to local level; but also for the scientific community.

At the aftermath of the 2004 event, the Government of Indonesia in cooperation with all stakeholders has put high priority to anticipate the impact of future tsunami by establishing an integrated Indonesian Tsunami Early Warning System (TEWS). This turning point is also based on two other factors, i.e. geodynamic position of Indonesia and increase of tsunami risk in coastal cities in Indonesia.

As located on the very active geological subduction zone and following the 9.0 magnitude Sumatera earthquake in 2004 which generated devastated Indian Ocean tsunami, it is expected that near-field tsunami are likely to occur in the near future in the outer west region of Indonesia due to increased tectonic tension that might cause to abrupt vertical up-thrust of sea floor after a century of seismic gap (Hillman, 2005). This was proven by a series of tsunami occurred in this region, i.e. Nias West-Sumatera April 2005, Pangandaran West-Java May 2006, Bengkulu West-Sumatera September 2007, Padang West-Sumatera September 2009, and Mentawai West-Sumatera October 2010. At the same time, the level of tsunami risk for cities located in tsunami prone zone has been increasing. Almost half of the 94 autonomous cities in Indonesia are susceptible to tsunami disaster; with the number of people at risk is not less than 20 million, in which the biggest population lives at this region. High vulnerability of people living in these cities are mostly due to some disadvantageous socio-economic factors, such as increase of urban population, poor city service, insufficient infrastructure for emergency responses, and level of poverty which often disables the ability for protection and coping to disaster.

Learning from the history of tsunami, the great number of victims in most events was generally caused by some factors. In addition to the factor of tsunami magnitude itself (earthquake epicenter, and tsunami height, speed and travel time, and inundation height at land), high number of victims were influenced by *ability* of the system to disseminate tsunami warning in accurate time and leaving sufficient time for people to evacuate, *slow response* to tsunami warning due to low awareness and readiness among people and government, and *abandonment* of local knowledge/wisdom on natural signs of tsunami (Rahayu et al, 2008).

To follow up the government of Indonesia willingness to establish TEWS as a long term countermeasures investment, such intensives works were conducted from year 2005 to 2008 under collaboration with national and international community (institutions and experts) during the process development and deployment STUCTURE component, i.e. devices for monitoring, detecting, analyzing and disseminating tsunami warning to the interface agency and local government. In line with this, a series of countermeasures has been implemented to improve CULTURE component under collaboration with national, international and local community. This included capacity building for local government ability to receive warning of potential tsunami from central government then to convey to the people at risk in the form of *order for evacuation*, as well as other countermeasures that encouraged local government to provide supporting infrastructure for warning dissemination, evacuation and emergency response.

In addition to that, to *ensure* the accomplishment of TEWS objectives to protect people, a legal framework has been endorsed, i.e. enacted Disaster Management Law in 2007, followed by a series of implementing regulations mandatory for all level of government: to integrate disaster risk reduction countermeasures in planning and development, to restructure agency for disaster management at national, provincial and local level, to revitalize city/province's emergency operation center as central point in conveying warning of potential tsunami to the people at risk for evacuation.

By design, successful criteria of the establishment of TEWS in Indonesia can be described as follows (Rahayu, 2008):

1. to have reliable infrastructures to monitor, detect, analyze and disseminate the warning of potential tsunami in accurate time;
2. to have responsive and responsible government officials at the local and regional level to receive tsunami warning and issue order for evacuation in orderly manner to the people at risk;
3. to have responsive people;

This means that currently the CULTURE component plays vital role after the establishment of TEWS, in which a full responsibility should be envisaged by the local and regional government to implement countermeasures to achieve criteria 2 and 3. The scheme of liability sharing of TEWS in Indonesia between central government and local government can be seen in Figure 1, where the system consists of two main components, i.e. STRUCTURE and CULTURE.

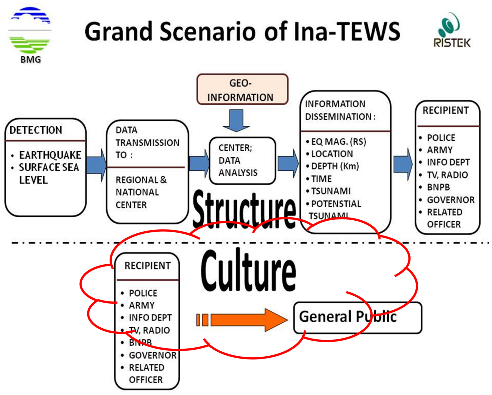


Figure1. The Scheme of Indonesian TEWS (*Courtesy of Ristek 2005*)

Tsunami is a very rare and unforeseen natural phenomenon to the local government, thus conducting physical and nonphysical development to have a tsunami safe city is very expensive and unpopular development policy comparing with to improve socio-economic problem, infrastructure and health facility. Even though it is mandatory for local government, unless they were chosen as national show case for tsunami ready city, the level of responsiveness to implement such countermeasures in reducing the susceptibility toward tsunami are likely low.

Hence, diversity of tsunami readiness of these coastal cities is found to be *critical issues* for achieving the effectiveness of the system established. It ranges from one end with comprehensive implementation of the countermeasures up to the other end with nothing has done yet due to the lack of funding and sufficient information on its potential hazard, vulnerability and capacity. In fact, the human being responsiveness, i.e. people and government official, from these cities toward the existence of tsunami early warning system in their area is *the **most** critical issue*. As shown during the occurrences of some significant events in this region following 2004 event previously discussed, many affected cities were in chaotic condition not only because of severe damages caused by strong shaking but also due to panic and uncontrollable evacuation situation, even though the warning system were performed perfectly in many events, where tsunami warning issued less than 10 minutes after the earthquake.

These critical problem issues have led to the research question of the study presented in this paper on *how effective the tsunami early warning system established in Indonesia, and how effective the countermeasures implemented at the CULTURE component in achieving the goal of the system* to save lives as much as possible. Further research question is on *how to increase the effectiveness of countermeasures implementation as consequence to the needs to have the right policy for the right problem at the right place*. The questions have been challenged and enriched by valuable lessons from success and failure story of two devastated events occurred in Pacific region during the study, i.e. Chile tsunami 28 February 2010 and 11 March 2011 Tohoku tsunami from the perspective of CULTURE component, i.e. how the existence of tsunami warning in Japan has been able to save a significant number of lives even for a *near field tsunami* with travel-time between 2 to 57 minutes.

This paper presents the rationale, research design, process development and result of the study, which attempts to solve the critical questions discussed by using practical solution to develop a logic model of people's mind toward tsunami early warning.

2. RESEARCH DESIGN

To answer the research questions discussed in section 1, *rationale* of this research study is to solve the problems encountered resulted from the establishment of TEWS with the *research objectives* as follows:

- *To find effectiveness of tsunami early warning system established in Indonesia, and how effective the countermeasures implemented at the CULTURE component in achieving the goal of the system to save lives as much as possible.*
- *To develop a practical solution model that can be used to increase effectiveness of countermeasures implementation as consequence to the needs to have the right policy for the right problem at the right place.*

In order to structure the people's mind, the model was developed based on logic model approach based on holistic data set obtained through exhaustive identification for the logical thinking of human being up to the unseen indelible factors inside the people's mind as well as people's understanding concerning their exposure, capacity and coping ability to tsunami disaster; and their trust to the existence of tsunami warning including willingness to evacuate.

A wide range of data set are expected from the target groups, i.e. government officials and people, from two case study cities in order to able to recognize and structure both issue of locality such as potential tsunami hazards and its collateral threat as well as its physical and social vulnerability, and the issue of generality such as susceptibility and capacity of human being to cope with disaster combined with their attitude and mindset as *regulator*, *executor* (government officials) or *general public* (people) in appreciating the needs to save their life as well other people from tsunami.

Case Study Location:

To accomplish the rationale and objectives of this research study, the case study cities, i.e. Padang City and Cilegon City, are selected from those six national show case cities based on further selection criteria, i.e. level of tsunami hazard/threat, susceptibility and countermeasures implemented either by their own local government or external stakeholders such as national and international community. Figure 2 shows location of the case study cities among the national show case cities in Indonesian seismicity map. These cities has been chosen to host the national end-to-end tsunami simulation (full scale tsunami drill for city level) as commemoration to national disaster 26 December 2004, i.e. Padang in 2005, Denpasar-Bali in 2006, Cilegon in 2007, and simultaneous four cities in 2008 at Banda Aceh, Manado and Gorontalo and Bantul.

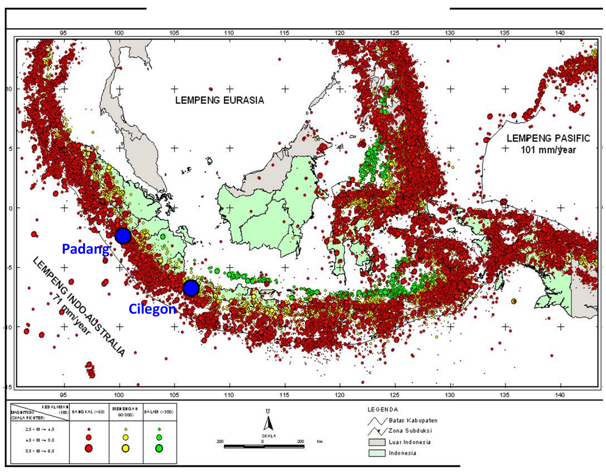


Figure 2. The location of Case Study Cities in the Map of Indonesian Seismicity 1973-2010 (Courtesy of Ristek 2010)

Data Acquisition:

From preliminary work done for this research, many tangible and intangible factors were found to become assisting and hindrance factors to the effort of enhancing CULTURE component. To obtain an exhaustive and holistic data set, to ensure the quality and the quantity of the response within certain time limit and to reduce misinterpretation, missing information and low response from target groups, the *primary data acquisition* was designed using *semi open questionnaires based interview* format for the two target group, even though this kind of survey needs to mobilize a great number of surveyor to obtain large number of sample within a limited time.

The first target group was people at risk (people who live in tsunami prone cluster or neighborhood), which are divided further based on the cluster (sub-subdistrict) they live, gender and social status (working people, house wife, students). The second target group was government officials whose work related with disaster management, i.e. emergency operation center, disaster management agency, planning department, health department, public works department, and community empowerment department.

Meanwhile, *secondary data* are required for recognizing and structuring the problem issues and drafting the questionnaire for obtaining primary data. These included technical data obtained from city planning department, meanwhile socio-economic and socio-culture data obtained from 2010 City Statistical Data. In addition to that, previous and preliminary works were conducted at the beginning of the research study, i.e. reconnaissance investigation on physical and socio economic damage in Padang affected by September 2009 earthquake and preliminary interview. Important information obtained from the survey were many tall building/houses designated and mandated by local regulation (Mayor decree) as the vertical evacuation shelter were heavily damaged during the earthquake. These designated shelters were located in densely populated area, in which average *estimated time for evacuation* (ETE) was less than sufficient time for evacuation which is *travel time of expected tsunami* approaching the area minus the needed for tsunami warning dissemination. Result of previous work done for Padang City on the 14 cluster showed that average ETE with obstacle during day time is *44.43 minutes* and without obstacle is *17.77 minutes*, meanwhile *expected* tsunami travel time approaching the land is *22 minutes* from the warning issued (Rahayu et al, 2007).

After 2004 event, Padang City has been the focus of international and national scientific community with wide range of research/project interest to study and to implement many countermeasures for anticipating the big tsunami which *expected* to occur at any time in the near future, as also discussed in section 1 of this paper. However, the 2009 event has tested that Padang City with population of one million was not really ready to cope with the *expected* tsunami.

Preliminary interview was randomly done on some social group, i.e. fishermen, business man, government officials, students, house wife and a few people working in the informal sectors, who were affected during the devastated September 2009 earthquake. Result of the interview was used to recognize and structure the situation happened during the events, what they did and what was their reasons not to evacuate for tsunami after the strong shaking. This information combined with secondary data and tacit knowledge was used not only to draft the questionnaires but also to design the process of primary data acquisition. Prior to the primary data acquisition, the questionnaires developed were randomly tested by interviewing *sample of the target group*. This pretest was aimed for refining the questionnaires and helping the surveyor to have the same skill and techniques in fishing out as much as possible the indelible factors which remain in the people's mind, the *semi-open questionnaire* is very much useful to expect more unforeseen factors during the survey.

For Padang case study, the target group were further defined based on the cluster they live called sub-subdistricts from tsunami risk zones, i.e. 14 clusters with 20 to 40 sample per cluster. Location of each respondent was also tag using the GPS to show its individual location and the distant from the shore lines, see also Figure 3. The objective of using this mechanism is for recognizing whether the *time and space* of individual human being will affect their mind and attitudes.

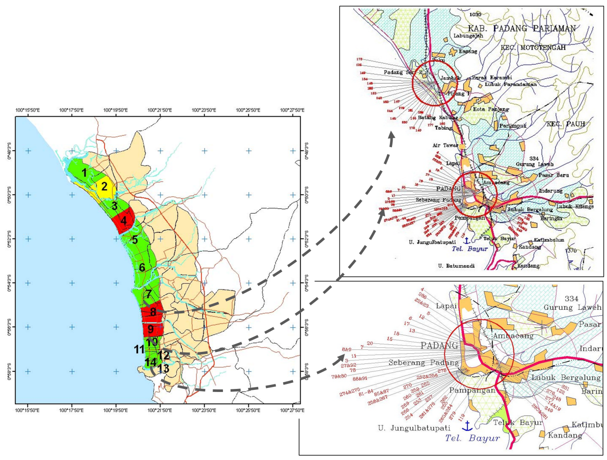


Figure3. Location of the survey at 14 clusters and example of GPS location of individual respondent

Primary data acquisition conducted July 2010 (post Padang EQ Sept 30, 2009) has covered 50 pretest samples during the first batch for pretest, and then 300 samples represented 14 clusters. In addition to this number, there were 61 samples obtained from the interview conducted in November 2010 after the Mentawai tsunami in 25 October 2010. This sample represented cluster 8, 12, 13, and 14 of the target area with some same respondent. The rationale of conducting this was to identify how different their mindset and attitude before after the occurrence of significant tsunami.

Meanwhile for Cilegon City primary data acquisition and pretest was conducted starting from 15 August 2010. Target group for Cilegon was divided into the industrial worker from two out of four industrial zones in Cilegon City, and general public from 2 sub-subdistrict selected as countermeasures implementation during the national tsunami drill conducted in 2007. The mechanism of the survey in Cilegon City is to achieve the research study objective. Both information taken from respondent from the Padang City and Cilegon City are used for the development of logic model and to construct the qualitative and numerical model presented in the next section.

Survey Results

Results of the survey in Padang City and Cilegon City showed the significant different in the demographic condition of samples. As also shown in Figure 4, sample of Padang City is dominated by 62% female between 19 to 50 years old with majority education level high school, working in informal sectors, followed by house wife and public servants including teacher., however only 13 % has participated in training and tsunami drill. This was really surprised as the first national show case for tsunami ready city. Meanwhile sample of Cilegon City dominated by 64% male 19 to 40 year old, with majority education background high school and university and working in manufacture sectors, and only 5 percent participated in tsunami training and 18% in tsunami drill, most training participated was in industrial and emergency rescue training in the factory they work.

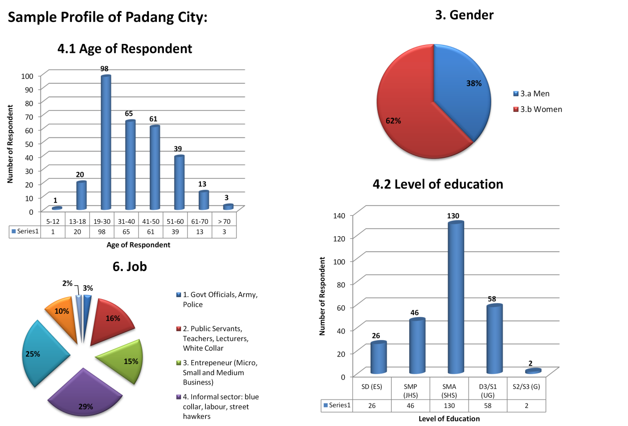
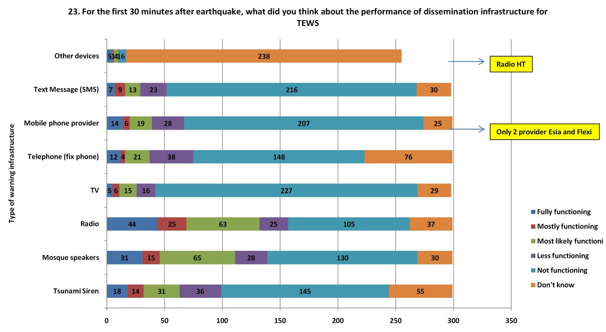


Figure4. Profile of Padang People



	Tsunami Siren	Mosque speakers	Radio	TV	Telephone (fix phone)	Mobile phone provider	Text Message (SMS)	Other devices
Fully functioning	18	31	44	5	12	14	7	5
Mostly functioning	14	15	25	6	4	6	9	1
Most likely functioning	31	65	63	15	21	19	13	4
Less functioning	36	28	25	16	38	28	23	1
Not functioning	145	130	105	227	148	207	216	6
Don't know	55	30	37	29	76	25	30	238

Figure5. Appreciation toward Warning Dissemination Device

Meanwhile, people appreciation to the performance of dissemination device for conveying the message of warning based on their experience during the strong shaking can be seen in the Figure 4 that according to Padang people that radio transistor (44%) was the most effective device for this matter, followed by the mosque speaker (31%) and tsunami siren (31%), other devices were very low due to severe damaged from the earthquake, i.e. mobile phone, fix phone, and TV.

3. STRUCTURING THE PEOPLE MIND AND BEHAVIOR IN TSUNAMI EVACUATION

The factors structured based on the holistic and exhaustive data set obtained from primary data acquisition are 487 variables, which consist of 448 observable variables and 39 latent variables. The direct relationship of these variables was structured following the people logical thinking flow and their behavior in disaster situation which were recognized from the sample was structured as shown in Figure 5. The mindset of the people of Padang in disaster situation and the way in responding natural phenomena (strong shaking) and tsunami warning before their decision to evacuate, to delay evacuation or never to evacuate were presented in this diagram.

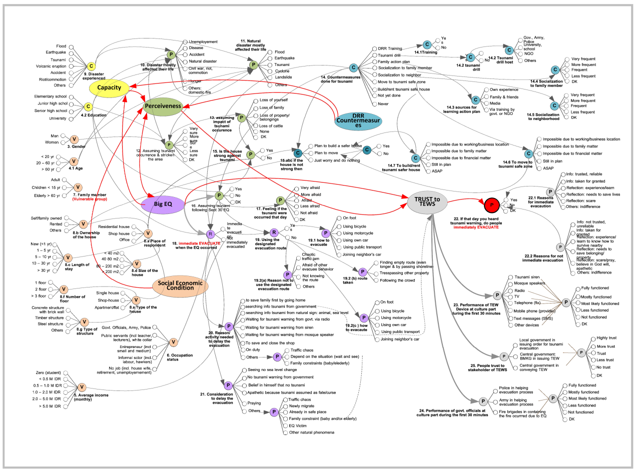


Figure 5. Structuring the problem and the people's mind in tsunami disaster situation

Some important variables that assisting or hindrance the people's willingness was shown by the high and low capacity of people in terms of socioeconomic and socio-culture factor are: knowledge and skill regarding tsunami preparedness countermeasures obtained from the public education or training.

Meanwhile the ability to cope disaster in terms DRR countermeasures intervention participated by the people, as well as their knowledge and appreciation toward existence of the infrastructure for evacuation and emergency purposes, such as warning siren and other device, route for evacuation, evacuation shelters and many other factors, their trust to the government or community leader, last but not least is the indelible factors to base their rationale for making decision before taking action to evacuate.

4. DEVELOPMENT OF LOGIC MODEL OF PEOPLE'S MIND TOWARD TSUNAMI EARLY WARNING

Based on the previous diagram shown in Figure 5, then the logic model is constructed by simplifying the diagram of relationship among those observable and latent variables. Through the logic model, these two type variables can be easily recognized and the relationship between and among those variables are best presented.

The 448 observable factors derived from the primary data acquisition are structured in the form of logic model tree with 39 latent variables as intermediate layers in the logic model tree. The relationships among these 448 observable factors as shown in Figure 5 were structured further in simplified format as hierarchical or parallel order like a tree (called as logic model tree) as shown in Figure 6 and Figure 7. Figure 6 shows a complete Logic Model Tree of People's Mind toward Tsunami Early Warning, while Figure 7 is the core model of the Logic Model showing relationship among latent variables.

In Figure 6, the logic model is presented nodes which characterized by some identity as shape, color and with ID number or not. An oval shape is upper layered latent variables; a round shapes with ID number are second and/or third layered latent variables. Meanwhile the observable variables are characterized in solid round shape at the bottom of logic model's tree or as the root node of the tree.

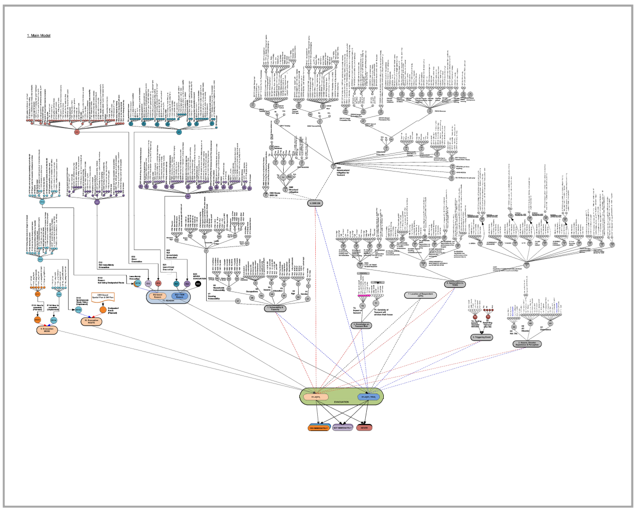


Figure 7. Logic Model Tree of People's Mind toward Tsunami Early Warning

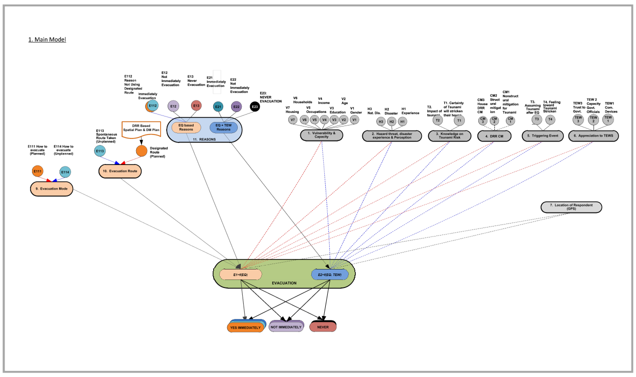


Figure 8. Core relationship diagram (Latent Variable) of Logic model of People's Mind toward Tsunami Warning

The color of those shaped nodes shows the substantial relationship needed to represent their role in the scenario analysis of this numerical model. The grey colors show that these grey nodes are as *external factors* of the people's mind that become assisting and/or hindrance factors to the peoples' mindset for taking decision in the disaster situation. For example the socio-economic factors which influenced the level of people's susceptibility then implicitly will affect their coping ability and/or perception toward any disaster; then these will contribute to the people's decision making for responding the disaster situation whether to immediately, delay or never evacuate. These grey factors always considered in the numerical analysis of *every scenario of numerical logic model* that will be presented in the section 5. To compare, the color variables characterized the internal factors which indelible in people mind which strongly influenced the people's decision process to response to any emergency/critical situation. These factors emerged mainly based on some direct or indirect experiences in any disaster situation. These colorful variables show a unique contribution to analysis in e*ach scenario of numerical logic model.* In this paper, to better describe the color based relationship of the nodes, the logic model consists of two *constellation of relationship* among all factors which influence the peoples' mind toward tsunami warning system.

The first constellation of the upper layer latent variables shown in colorful nodes consists of 3 variables, i.e. *evacuation mode of transportation* which consists of *transportation mode used to evacuate by plan* and *transportation mode used to spontaneously evacuate*; *evacuation route* which consists of *spontaneous route* and *designated route* (official route in city master plan); *reason for evacuation* which consists of *earthquake based reasoning* and *combination of earthquake and tsunami warning based reasoning*, where each of these two variables is divided further into *reasoning for immediate evacuation*, *to delay evacuation* and *never evacuation*.

The second constellation shown in grey nodes consists of 7 variables, i.e. *tsunami triggering event* which consists of *assuming tsunami following the* *strong shaking* and *feeling toward tsunami stricken; knowledge for tsunami and its risk* which consists of knowledge on *impact of tsunami* and *certainty of tsunami might stricken* their house; *DRR countermeasures* which consists of *tsunami safe house countermeasures, structural tsunami mitigation countermeasures*, and *nonstructural tsunami mitigation countermeasures*; *appreciation to TEWS* which consists of *trust to government*, appreciation to the *capacity of government officials*, appreciation for *communication devices* for conveying warning; *vulnerability and capacity* which consists of *vulnerable group* containing *gender*, *ages*, *households*, then *capacity* containing of *education*, *income*, *occupations*, and *housing vulnerability*; *disaster direct experience and perception* which consist of *experienced to disaster*, perception to *natural disaster* threat and impact, perception to *any disaster* and impacts; and *GPS based location of the respondents*.

Then, all relationship of the 448 observable variables was hierarchically and/or horizontally structured under each related floating variables in the forms logic model tree with two constellation relationship.

5. DEVELOPMENT OF NUMERICAL LOGIC MODEL

As discussed in Section 4 of this paper, to accommodate the unique and common relationship contribution among those observable and latent variables, the numerical model analysis is designed to use a scenario based analysis. There are seven scenario designed to develop the numerical logic model, as shown in Figure 8. The seven scenarios basically consists of two natural situation prior to tsunami events for the city has had the tsunami early warning deployed, i.e. the earthquake based decision process and the combination of earthquake and tsunami early warning based decision. Then they are further described in three type of outcome decision scenario, i.e. immediate, delay and never. However, the immediate evacuation can be represented further for the situation and condition of the City readiness to expected tsunami, i.e. plan and spontaneous evacuation procedure. Plan procedure here means that the procedure taken will follow the City Emergency Action Plan prepared for Tsunami and other expected disaster, which consist of the designated route for evacuation and procedure of evacuation not using cars or vehicles in high populated area/clusters as well as other factors such as the official in charged “who is doing what” in emergency situation.

Thus each scenario represents each nature of relationship among all assisting, hindrance, indelible and latent factors which influence in decision making process of the people both either as general public as well as the government officials (regulator and/or executor).

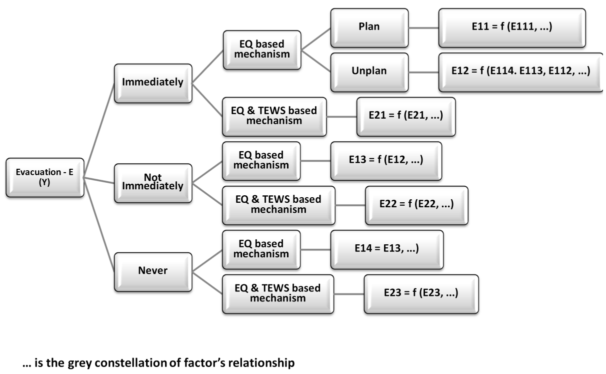


Figure 9. Seventh Scenario of Numerical Analysis of the Numerical Logic Model

The formula derived from the seven scenario based numerical analysis can be presented as follows (Figure 9). Due to limited spaces in the paper, the grey constellation only by the very upper of its latent variables, while color constellation represented by both upper and mid layer of latent variables.

$$\mathrm{E} = \mathrm{f}\,(\mathrm{E}_1, \mathrm{E}_2)$$

$$\mathrm{E} = \mathrm{f}\,(\mathrm{E}_{11}, \mathrm{E}_{12}, \mathrm{E}_{13}, \mathrm{E}_{14}, \mathrm{E}_{21}, \mathrm{E}_{22}, \mathrm{E}_{23})$$

Scenario I (1 to 4) – EQ based Evacuation (E1) :

$$\mathrm{E}_{11} = \mathrm{f}\,(\mathrm{E}_{111}, V_i, H_i, T_i, CM_i, TEWS_i)$$

$$\mathrm{E}_{12} = \mathrm{f}\,(\mathrm{E}_{114}, \mathrm{E}_{113}, \mathrm{E}_{112}, V_i, H_i, T_i, CM_i, TEWS_i)$$

$$\mathrm{E}_{13} = \mathrm{f}\,(\mathrm{E}_{12}, \mathrm{E}_{112}, V_i, H_i, T_i, CM_i, TEWS_i)$$

$$\mathrm{E}_{14} = \mathrm{f}\,(\mathrm{E}_{13}, \mathrm{E}_{112}, V_i, H_i, T_i, CM_i, TEWS_i)$$

Scenario II (1 to 3) – EQ & TEWS based Evacuation (E2)

$$\mathrm{E}_{21} = \mathrm{f}\,(\mathrm{E}_{21}, \mathrm{E}_{112}, V_i, H_i, T_i, CM_i, TEWS_i)$$

$$\mathrm{E}_{22} = \mathrm{f}\,(\mathrm{E}_{22}, \mathrm{E}_{112}, V_i, H_i, T_i, CM_i, TEWS_i)$$

$$\mathrm{E}_{23} = \mathrm{f}\,(\mathrm{E}_{23}, \mathrm{E}_{112}, V_i, H_i, T_i, CM_i, TEWS_i)$$

Figure 10. Formula of Seven Scenario used to develop Numerical Logic Model Tree

The rationale used to perform the numerical analysis of the numerical model development is described and discussed as follows:

Among statistical methods, the nature of the model where the relationship among observable and latent variables in many different characteristics of each variable, then the model developed is better analyzed using a combination approach of principal component analysis (PCA) and logic model. The model does not use the whole process/philosophy of principal component analysis, where it should aim to reduce less significant factors in the constellation relationship among observable variables as well as with the latent variables. Thus model is only use half process of the principal component analysis to structure the main component (latent variables), which is a linear combination of some observed variables. The numerical analysis is then conducted from the bottom (root nodes) of the logic model tree going up until the final outcome, which is the decision of action to respond the symptom in tsunami event, i.e. the strong shaking and/or the early warning system.

The numerical analysis for using principal component analysis is then calculated using PCA facilitated by SPSS 19 program. Final result of the analysis as shown in the following formula and figure discussed below:

From the disaster perception experience and perception aspect (Hi), Figure 10 and 11 shows the logic model tree and numerical analysis result at those levels.

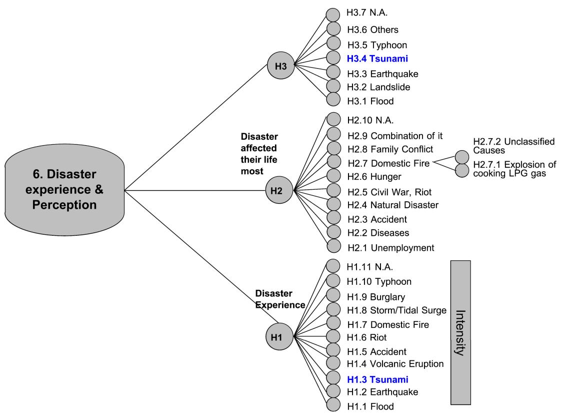


Figure 11. Numerical Logic Model Tree for the aspect of Hi – Disaster Experience and Perception

H=0,602898(H1)+1,26547(H2)+0,971114(H3)

H1=3,640299(H1.1)+ 3,957815 (H1.2)+5,027433 (H1.3)+5,027707 (H1.4)+4,213959 (H1.5)+4,414796 (H1.6)+5,527384 (H1.7)+4,40903 (H1.8)+5,484045 (H1.9)+5,558043(H1.10)

Figure 12. Numerical Analysis result for Hi

This shows that for Padang people that the most contributable relationship among the observable variables to model of decision making is that at the upper level of Hi, direct experience toward any disaster including the man-made disaster was the most influence to the model followed by the people perception toward disaster impact, and the lowest contribution was from the direct experience toward natural disaster including tsunami and earthquake which is supposed to be threat for them. The coefficient of its contribution is as follows:

H = **0,602898**(H1)+**1,26547**(H2)+**0,971114**(H3)

From the aspect of impact of the countermeasures, i.e. tsunami drill, to the model can be described in Figure 12 and 13. Result analysis shows in Figure 13 that there is 0 coefficient relationship shown by CM123, i.e. effectiveness of tsunami drill to their decision. This is because the numerical analysis described as sample for discussion is the analysis based on the data acquisition prior to Mentawai tsunami, called as data phase 1 and 2 only. At the analysis of Data phase 3, i.e. data collected after Mentawai tsunami from the same cluster show some significant coefficient relationship for this factor.

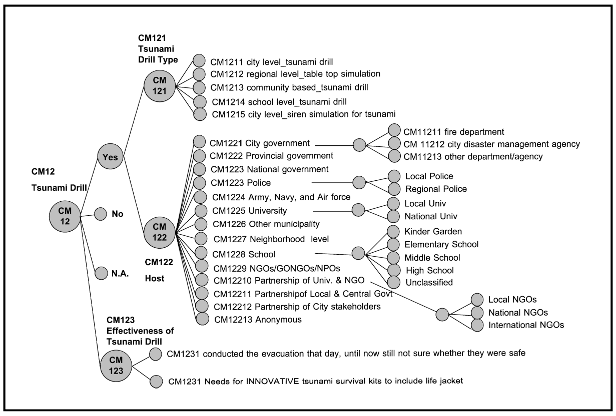


Figure 13. Numerical Logic Model Tree for the aspect of CMi – Tsunami Drill as Countermeasures implemented

CM1.2 =0,799(CM1.2.1)+0,799(CM1.2.2)+0(CM1.2.3)

CM1.2.1=-1,26135(CM1.2.1.1)+0,753193(CM1.2.1.2)+0,75817590(CM1.2.1.3)-0,3948390(CM1.2.1.4)+1,16667(CM1.2.1.5)

CM1.2.2=1,224316(CM1.2.2.1)+2,22804(CM1.2.2.2)+2,625545(CM1.2.2.3)+1,33022(CM1.2.2.4)+1,180915(CM1.2.2.5)+1,458496(CM1.2.2.6)-1,18296(CM1.2.2.7)+1,218627(CM1.2.2.8)+0,600958(CM1.2.2.9)+2,625545(CM1.2.2.10)+1,509522(CM1.2.2.11)+1,682725(CM1.2.2.12)-0,44644(CM1.2.2.13)

CM1.2.3 =0,708(CM1.2.3.1)-0,708(CM1.2.3.2)

Figure 14. Numerical Analysis result for CMi

Other example of countermeasures implementation:

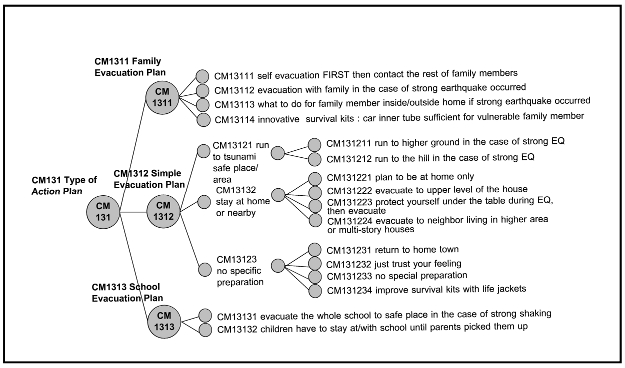


Figure 15. Numerical Logic Model Tree for the aspect of CMi – Tsunami Drill as Countermeasures implemented

CM1.3.1=0,360602(CM1.3.1.1)+1,174876(CM1.3.1.2)+0,756694(CM1.3.1.4)

CM1.3.1.1 =1,392272(CM1.3.1.1.1)-1,04951(CM1.3.1.1.2)-0,00122(CM1.3.1.1.3)-0,2798(CM1.3.1.1.4)

CM1.3.1.2.1 =0,865416(CM1.3.1.2.1.1)-1,10294(CM1.3.1.2.1.2)+0,348731(CM1.3.1.2.1.3)

CM1.3.1.2.2 =-0,58776(CM1.3.1.2.2.1)+0,830484(CM1.3.1.2.2.2)-1,11132(CM1.3.1.2.2.3)+0,869601(CM1.3.1.2.2.4)

CM1.3.1.2.3 =-0,79574(CM1.3.1.2.3.1)+0,6245212(CM1.3.1.2.3.2)-0,83616(CM1.3.1.2.3.3)+1,145069(CM1.3.1.2.3.4)

CM1.3.1.2 =0,758752(CM1.3.1.2.1)+(CM1.3.1.2.2)-0,75875(CM1.3.1.2.3)

CM1.3.1.3 =0,708(CM1.3.1.3.1)-0,708(CM1.3.1.3.2)

Figure 16. Numerical Analysis result for CMi

Final formula for the seven scenarios of people of

Padang City is presented as follows (see Figure 16 below):

EM I-1=0,727(E1.1.1)+0,727(E1.1.4)
RouteI=0,755(E1.2)+0,755(E1.3)
ReasonII=0,707(E2.1)+0,707(E2.2)
E1.1.2=0,157607(E1.1.2.1)+1,037238(E1.1.2.2)+0,275481(E1.1.2.3)+1,320126(E1.1.2.4)+1,175652(E1.1.2.5)-1,005873(E1.1.2.6)+1,007612(E1.1.2.7)-0,860445(E1.1.2.8)
E1.1.3=-0,959307(E1.1.3.1)+1,256198(E1.1.3.2)+0,021713(E1.1.3.3)+1,109065(E1.1.3.4)+1,271672(E1.1.3.5)+0,885772(E1.1.3.6)+0,888436(E1.1.3.7)
E1.2=2,22947(E1.2.1)+2,419261(E1.2.2)+0,416974(E1.2.3)+2,201485(E1.2.4)+0,853319(E1.2.5)+0,658239(E1.2.6)+1,567195(E1.2.7)-2,0927(E1.2.8)
E1.3=1,218394(E1.3.1)+1,056613(E1.3.2)-0,68263(E1.3.3)+0,687394(E1.3.4)-0,37326(E1.3.5)+0,445409(E1.3.7)-0,71339(E1.3.8)+0,396846(E1.3.9)-0,50092(E1.3.10)+0,271772(E1.3.11)+1,817094(E1.3.12)
E2.1=0,423837(E2.1.1)+1,263105(E2.1.2)+1,369486(E2.1.3)-0,40385(E2.1.4)+0,876517(E2.1.5)-0,131232(E2.1.6)+1,416397(E2.1.8)
E2.2=0,829491(E2.2.1)+0,895839(E2.2.2)+0,993029(E2.2.3)+0,361358(E2.2.5)+1,01(E2.2.6)+1,375249(E2.2.7)-0,59076(E2.2.8)+1,357042(E2.2.9)+1,236615(E2.2.11)-0,05837(E2.2.12)+0,919507(E2.2.13)

7. CONCLUDING REMARK

Result of the numerical analysis for people of Padang based on Prior and Post Mentawai tsunami occurred during the data acquisition show, there were many hindrance factors that was not effective in the implementation. For example the national tsunami drill and many other scale of drill performed starting from school level, neighborhood level until city level has not covered the community at risk. There are still many people being left out from the countermeasures, which mean there is a need for bridging mechanism for these countermeasures to be able to reach majority of people at risk.

Thus this numerical logic model can be used as the basis to develop the right policy for creating the tsunami safe city for solving the right need for people of Padang at this moment. It is recommended this assessment should be conducted in periodic interval, i.e. prior to the development of five yearly master plan of the city, using the logic model tree developed.

The logic model tree is very useful not only for the reassessment of case study cities, i.e. Padang City and Cilegon City, but also could be used to asses other tsunami prone area in Indonesia.

To have more global logic model of people mind in the regional or international level toward the tsunami early warning system and their readiness to tsunami threat, it is the challenge for this study to be tested in other country. The more the tested, the more complete the model set and the better to be used for the assessment tools and for the basis for the policy analysis and policy development.

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