INTEGRATED LOGIC MODEL OF EFFECTIVE TSUNAMI EARLY WARNING SYSTEM

Harkunti Pertiwi RAHAYU

A dissertation submitted to
Kochi University of Technology
in partial fulfillment of the requirements
for the degree of

Doctor of Philosophy

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Department of Engineering
Graduate School of Engineering
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Abstracts

The two mega tsunami occurred in 2004 and 2011 in the Indian Ocean and Pacific regions were *beyond human expectation* in terms of its impact on human being and built environment. The extreme differences on the number of fatalities between these two disaster events were obviously due to the existence of tsunami warning system, public awareness and preparedness; beside this was also due to other parameters, such as parameters of susceptibility and capacity of affected area and physical characteristics of tsunami, i.e. earthquake magnitude, tsunami arrival time, tsunami height, run up, propagation at land, and inundation.

For Indonesia, the 2004 tsunami has been awakening milestone for the development of *tsunami early warning system* called ***Ina-TEWS*** which was completely established at the end of 2008 to protect people from future tsunami. Under intensive collaboration with the national, regional and international community, the hardware component of Ina TEWS known as STRUCTURE component aims for detecting, monitoring, processing, aggregation, simulation and dissemination information of potential tsunami to the CULTURE component and interface agencies. In the Culture component as also in the case of Japan, *the early warning to general public is mandated to regional and local government*, unless otherwise responsibilities are given to particular agencies by regulations. An extensive countermeasure of tsunami disaster risk reduction has been exercised in 7 national show case cities, however chaotic situation was still shown in the city during the occurrence of several tsunamigenic earthquake in the past 7 years; as if the tsunami warning system and the tsunami disaster risk reduction countermeasures implemented have no effect. This shows that the Culture component is a very critical element in the mechanism of TEWS.

The high number of Indonesian tsunami prone cities, almost 30%, the ability of tsunami warning reaching tsunami prone area until the last mile, as well as the complexity and level of vulnerability, capacity and resiliency of the tsunami prone area actually have made the CULTURE component becomes more critical; leading to questioning the effectiveness of tsunami early warning system itself. Using a holistic cognitive mapping to acquire and to structure the relation between physical phenomena, external factors and internal factors of people mindset toward the existence of *tsunami early warning system*, it is expected that the model

developed by this study, i.e. Integrated Logic Model of Effective Tsunami Early Warning System, could provide a complete logic model to base the policy making for assessing, building, improving, and evaluating the capacity of Culture component. Having a sound policy for disaster risk reduction countermeasures, reliable warning device, prepared government and responsive people; it is expected that the city will have an effective tsunami early warning system leading to saving people.

To obtain exhaustive and holistic knowledge from complex phenomena and/or factors associated with tsunami early warning system, two approaches of logic model are used in the process development of the model. First is *Physically Based Logic Model* – ***PBLM***, a methodology to acquire and structure the correlation of physical events/phenomena based on the up-to-date secondary data directly obtained from related institution and reconnaissance survey conducted after September 30, 2009 devastated earthquake. Second is *Tacit Knowledge Based Logic Model* – ***TKBLM***, a cognitive mapping methodology to acquire and structure the people's mind or thinking in responding tsunami early warning system by the use of the tacit knowledge which are formed by prior knowledge and/or heuristic knowledge.

To bridge the limitation of TKBLM approach, i.e. missing and unforeseen information, first the study improves methodology for logic model knowledge acquisition by introducing the use of *semi-open questionnaire based interview*. Even though it is time consuming but this methodology is able to explore more in-depth and detailed for all supporting and hindrance factors which includes the unforeseen ones that are indelible in people mind. It is also able to obtain more certain numbers of targeted data and information from the interviewee compare to questionnaire circulated by mail. Second, for the TKBLM numerical modeling, the numerical analysis was done using modification of *Principal Component Analysis* – ***PCA*** approach. It means that the PCA is used not only to structure and analyze the numerical correlation of all observed variables/factors among the members component of each level/cluster but also to uncover the unobservable variables/factors. However in order to have a complete TKBLM model of people mind mapping, there is no elimination or reduction for the least contributor factors as commonly done by standard approach of PCA's regression analysis.

Findings of the study are not only the two new methodologies as also discussed in above sections, i.e. first methodology in modeling the phenomena of tsunami early warning system in the form of Integrated Logic Model using combination of PBLM and TKBLM approaches and second methodology in knowledge acquisition, mapping and numerical analysis of people's mind using TKBLM approach. The findings of the study also include six output models developed.

1st Model is a *map of Functioning and Malfunctioning Indicators* developed during stage 1 - problem structuring. In-depth investigation was conducted to obtain any indicators associated with an end-to-end performance of tsunami early warning system in Indonesia, besides conducting direct observations on the chaotic performance of the preparedness indicators during September 30, 2009 earthquakes. These indicators were identified from four different areas/sources of Ina-TEWS, i.e. general scenario/scheme, Warning Information Dissemination Flow, Stakeholders, and several intensive documentations taken during the preparation and conducting the full scale of end-to-end tsunami drill at some national show case cities. The Problem structuring also shows that Culture Component is the most critical points to solve and play important role for achieving effective *tsunami early warning system.*

2nd Model developed during stage 2 of research study, i.e. modeling phenomena of effective tsunami early warning system in the form of integrated logic model, consists of integration of four phenomena, i.e. natural, socio, technical and physical phenomena. The integration is shown by layer logic models and floating model. There are four layer of logic model: Natural Phenomena model which include the correlation among primary and its collateral hazards of tsunami, Structural model describing the correlation of the hardware system. Cultural Component 1 called as the *Government Model* recognizes the correlation of all factors inside the government officials mind to response and take action when there is strong shaking with or without tsunami warning received, and Cultural component 2 called as People Model recognizing the correlation of all factors inside the people mind to response and take action when there is strong shaking with or without tsunami warning received.

3 rd Model developed during the stage 3 of the research study is the floating model that are described also as Preparedness Index. This is a model which consists of factors commonly affecting each layer. The model is developed using the principle of disaster risk assessment to analyze the secondary information of risk level and preparedness of the city at risk. The model complement to layer model aims for assessing the level of preparedness of the city at before the countermeasures intervention or after the intervention. This is very useful to assess also the level

of effort should be taken for increasing and improving the capacity of government (government model) and the people readiness (people model).

4th Model developed during the stage 4 of the study consists of layer model 1 and 2, i.e. Natural Phenomena model and Structural model, which are developed using the Physically Based Logic Model (PBLM). The detailing of these two logic model are based on the physical data obtained explained in previous section as well as based on the Functioning and mal-Functioning indicators.

To build TKBLM for 5th Model of Government and 6th Model of People, a comprehensive and time consuming city scale data acquisition is conducted under this study. Padang City was selected as case study city because of three reasons. First, the city is highly exposed to tsunami risk with frequent occurrences of tsunami-genic earthquake. Second, the city is the most fast growing city at the outer West part of Indonesia. Third, it is a leading city for its tsunami preparedness among national show case cities. The government official data was obtained through an in-depth semi-open questionnaire based interview conducted for officials who represent the local government institutions associated with the tsunami and disaster management at the city level as well as provincial level. While the people data were obtained through an in-depth semi-open questionnaire based interview conducted for general public from 14 tsunami risk zone/cluster. It is fortunate during the study that two major natural phenomena have stricken Padang City, i.e. devastated tsunami-genic earthquake occurred in September 30, 2009 and a Mentawai Tsunami occurred in October 25, 2010. To accommodate this window of opportunity, the data acquisition was divided into two timeline set of data. First data set consisted of 461 people and 20 government officials interviewed at the time after the devastated earthquake and prior to the tsunami. Second data set included additional interview for 61 people representing 2 out of 14 clusters conducting after the tsunami, some were re-interviewed.

In 5th Model and 6th Model, the detailing of the cognitive mapping is confirming the logic model ability to exhaustively recognize and structure the people mind set based on prior belief and/or heuristic rules in responding the tsunami warning. All foreseen and unforeseen of hindrance and supporting factors which are indelible or temporarily inherent in people mind were clustered and hierarchically structured as a logic model tree. There are 6 major clusters in this logic model recognizing both prior belief and/or heuristic belief, i.e. E - reasons for immediate, postpone or never evacuated after strong shaking, H -Hazard and Disaster Perception and Experiences, V -

Social Vulnerability and Capacity, T - Knowledge on Tsunami Risk and Triggering Event, CM - Disaster Risk Reduction Countermeasures and TEWS -Appreciation to Tsunami Early Warning System. Each cluster consists of several sub-cluster and/or factors/variables. The number of variables recognized in *government model* is about 515 variables structured in 6 clusters, i.e. 84 in Social Vulnerability and Capacity, 92 in Appreciation to Tsunami Early Warning System, 25 in Knowledge on Tsunami Risk and Triggering Event, 30 in Hazard and Disaster Perception and Experiences, 48 in reasoning for immediate, postpone or never evacuated after strong shaking, 223 in Disaster Risk Reduction Countermeasures and 13 in reasoning for evacuation. Meanwhile for *people model prior to tsunami, 500* factors were recognized, i.e. 87 in Social Vulnerability and Capacity, 60 in Appreciation to Tsunami Early Warning System, 9 in Knowledge on Tsunami Risk and Triggering Event, 29 in Hazard and Disaster Perception and Experiences, 184 in reasoning for evacuation, and 118 in Disaster Risk Reduction Countermeasures. For the *people model at the post tsunami*, *498 variables were* recognized, i.e. 86 in Social Vulnerability and Capacity, 60 in Appreciation to Tsunami Early Warning System, 9 in Knowledge on Tsunami Risk and Triggering Event, 29 in Hazard and Disaster Perception and Experiences, 183 in reasoning for evacuation, and 118 in Disaster Risk Reduction Countermeasures.

7th Model is the numerical model developed using regression analysis of principal component analysis (PCA). There are 7 *evacuation decision scenarios* used for the numerical analyses of people mind toward tsunami early warning system, i.e. people and government officials. These scenario show that there are two type heuristic decisions making, i.e. first decision making triggered by natural phenomena only in the case of strong shaking occurrence and second decision making triggered by combination of both natural phenomena and tsunami warning. These two decision making are combined with 3 expected outcome of prior belief based decision making, i.e. immediate evacuation, not immediate (postponed/delayed) evacuation, or never evacuation; as well as combined with other prior belief reasons for evacuation, i.e. plan or spontaneously. These prior belief decisions making are significantly influenced by many different type of hindrance and supporting factors as well as foreseen and unforeseen factors recognized and structured by TKBLM described.

The correlation among variables/factors of each cluster and among clusters of each scenario shows significant different pattern among the government and people model, as well as people model prior tsunami (people model 1) and people model post tsunami (people model 2). In scenario 1, i.e. immediate evacuation scenario triggered by the natural phenomena only, the correlation of upper variables (cluster) close to decision node in contributing to the evacuation decision are different between government model, people model 1 and people model 2. For the people model 1, the strong correlations are shown by V - Social vulnerability and capacity (21.28%), followed by T - knowledge on tsunami (20.65%), TEWS appreciation of people to tsunami early warning system (18.05%), E - reason for immediate evacuation (17.94%), H - hazard and disaster perception and experience (16.98%), and CM - tsunami disaster risk reduction countermeasures (5.10%). To compare, the people model 2 shows that the occurrence of tsunami phenomena even though minor one has influenced and shifted the degree of correlation among factors or variables to the heuristic decision making. For scenario 1, the people model 2 shows that strongest correlations contributed by H - hazard and disaster perception and experience (24.45%) and E- reason for immediate evacuation (22.45%). Meanwhile for the government model, the most significant contribution coming from V - social vulnerability and capacity (29.26%) and CM - tsunami disaster risk reduction countermeasures (22.53%). This shows that the mind thinking of government officials toward tsunami response are normative. Further analysis showing the degree of contribution among the variables in the same level/same of cluster and down to the root can be seen in Chapter 5 and 6 of this dissertation. The process development numerical analysis model is using the bottom up approach, while for the usage purpose is top down.

Detailed result of numerical model developed in this study is very useful to recognize how the people minds are influenced by their social status (job position), prior perception/belief to tsunami early warning system triggered by past experience and past information, and heuristic belief triggered by current external factors. The study also finds that prior belief based risk perception of the people toward disaster experience has limitation, as shown by the correlation among factors/elements between different group and different timeline of data acquisition. This numerical analysis performed is confirming the correlations among variables/factors in every level of the tree and in each cluster, as well as in the decision scenario. Then keeping all factors (no reduction), is conforming the holistic logic model.

To conclude that the outcome of the study is proving two original findings, i.e. the integrated logic model developed and the new methodology for the process development of logic model which is a new theory as a gate for better methodology in policy making.

It is expected that the model developed by this study will be a useful policy making tool for the city managers from tsunami prone area in Indonesia as well as in other region for achieving effective tsunami early system. In the future, the more frequent the model used, the more exhaustive the model. For future work, the model can be up-scaled for comparison analysis between cities from tsunami prone area for policy development and policy review at local, regional or national level.

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Finally, I would really like to say "thank you very much" for my big family in Bandung who always supported me to the right way and motivated me to do the best no matter what situation and condition. Last but not least, I would like to dedicate my dissertation for my son Ino.

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Introduction

Effective tsunami early warning system is an integration of natural, socio, technical and physical phenomena, aiming to save people as many as possible by alerting the *people at risk* with sufficient lead time to make decision for evacuation.

1.1. Background and Research Challenge

Less than a decade, two devastated mega tsunami generated by 9.0 – 9.2 magnitudes earthquakes have stricken the Indian Ocean and Pacific regions *beyond human expectation*, i.e. 2004 Sumatera-Andaman tsunami known as Indian Ocean tsunami and 2011 Great Tohoku Tsunami recognized as East Japan Tsunami. Not only their widespread devastated impacts in both regions, but also they become awakening milestones for the establishment and/or performance evaluation of tsunami early warning system at both regions especially for anticipating the *near-field tsunami*, i.e. tsunami stricken with limited elapsed time approximately less than 40 minutes.

The extremely high number of 2004 tsunami fatalities from Indonesia and other 14 affected countries in the Indian Ocean region was obviously due to ***no tsunami early warning system*** in place and ***lack of public awareness on tsunami***. Approximately 167,799 Indonesian died among 230,273 of total loss of life. The ***word tsunami*** hardly known that time in the region, however the absent of this tsunami awareness was surprising since Sumatra region has been stricken by big tsunami more frequent than other region in Indonesia. About 15.3% of total tsunami occurrence in Indonesia has occurred in this region (H. Latief et al, 2000), see also Figure 1.1 that the tsunami intensity and frequency of occurrence in multi-colored circles concentrated in the west coast of Sumatera. Even though the Indonesian Tsunami Catalog has listed that about 20 major tsunami events occurred in this region within period of 1770 to 2005, nevertheless most people in this region have forgotten the local wisdom about tsunami except the people from Simeulue Island, the closest area to the 2004 earthquake epicenter. Approximately 99.82% people in the island were saved because of local wisdom "*smong"*; only 6 people died among 3,368 total residents. The word *smong* literally meant as a "notice for potential tsunami" has been a legacy since the Sumatra tsunami in 1833 and 1907 (JICA, 2003; H. Yogaswara and E. Yulianto, 2010).

To illustrate the impact of 2004 tsunami, Figure 1.2 shows the famous Baiturrahman Mosque in Banda Aceh at the aftermath of tsunami.

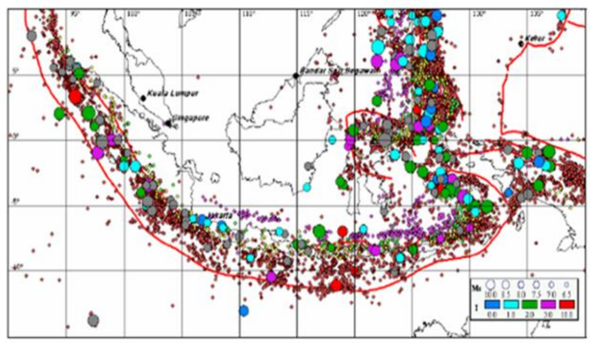


Figure 1.1 Location of tsunami occurrence (in big multi-colored circles) in Indonesian Archipelago (H. Latief, 2005)

Figure 1.2 Impact of 2004 Tsunami in Banda Aceh (Photo Courtessy of ITB Team)

To contrast, the 2011 event which was simultaneously broadcasted in real time with video footage has shown direct visual image of unforgettable natural phenomena's destruction to Japan coastal cities in this century caused by tsunami. Beyond that, this visual image may affect the *people mind* not only from the affected area but also around the globe, in terms of causing prolonged memory and increased people's perception toward tsunami risk, known also as prior belief. This 2011 tsunami has caused 15,550 people died and 5,344 missing (Japan National Police Agency by July 2011); yet the existence of *effective tsunami early warning system* has been proven to save the lives.

Table 1.2 shows that even though tsunami lead time were less than 20 minutes at some cities close to earthquake epicenter (i.e. Rikuzentakata, Kesennuma, Minamisanriku), the ratio of *the number of people saved* to *the number of people at risk* is still very high, i.e. 92.57% in average (sources: EERI, 2011) indicating that the tsunami destruction could have been even worse.

No	City	Population	Pop at Risk	% Pop at Risk	Death	% Casualties	% save	Tsunami Arrival
1	Rikuzentakata	23,000	16,640	72.35%	1,939	11.65%	88.35%	20
2	Kesennuma	73,000	40,331	55.25%	1,406	3.49%	96.51%	20
3	Minamisanriku	17,000	14,389	84.64%	901	6.26%	93.74%	25

Table 1.1 2011 Tohoku Tsunami Impact and characteristics at selected cities (Sources: EERI, 2011)

The aftermath of devastated destruction; the 2004 tsunami has become awakening milestone for the establishment of *tsunami early warning system* called ***Ina-TEWS*** to protect people from future tsunami. Under intensive collaboration with the national, regional and international community for the development of Ina-TEWS, the hardware component known as STRUCTURE component was built by adopting and adapting the existing technology used by Japan, USA and German in the Pacific TEWS and North Atlantic and Mediterranean TEWS.

The aims of the Structure component completely established at November 11, 2008 is for detecting, monitoring, processing, aggregation, simulation and dissemination information of potential tsunami to the CULTURE component and interface agencies, see also Figure 1.3. While in the Culture component of Ina-TEWS, as also in the case of Japan (Cabinet Office Government of Japan 2011) *the early warning to public is mandated to regional and local government*, unless otherwise responsibilities are given to particular agencies by regulation.

The revised grand scenario of Ina-TEWS after the Mentawai tsunami October 25, 2010 shown by Figure 1.3 describes the responsibilities of local government in conveying the tsunami warning to the community at risk or general public were represented by the city disaster management office (DMOs) and supported by the media in information dissemination (Ristek, 2010).

To complement with the development of Structure component, a series of extensive countermeasures of tsunami disaster risk reduction have been exercised in 7 national show case cities since 2005 to 2008, i.e. Padang, Denpasar-Bali, Cilegon-Banten, Gorontalo, Menado, Banda Aceh and Bantul, the location of these cities can be seen in Figure 3.3 of Chapter 3.

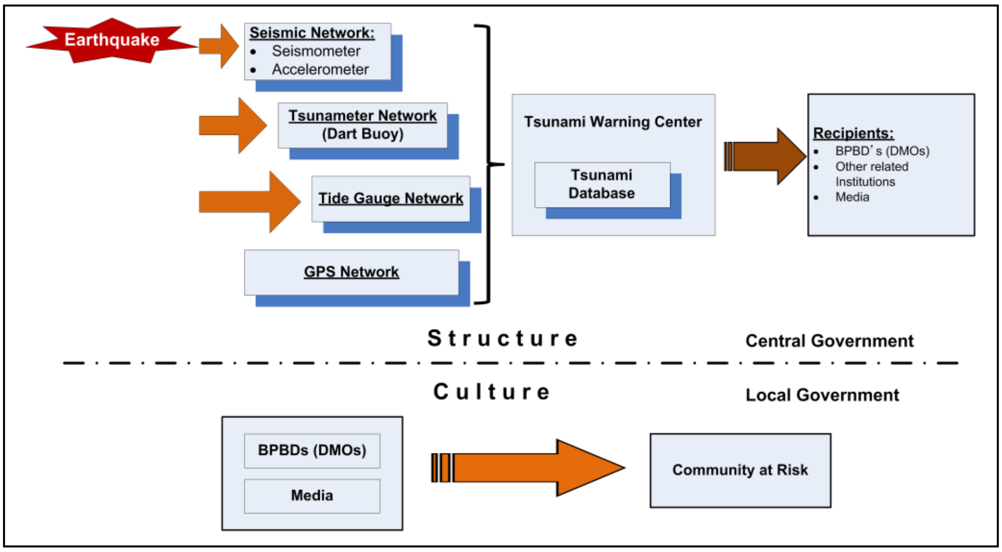


Figure 1.3 Revised Grand Scenario of Ina-TEWS (Sources: Ristek 2010)

To test the readiness of both the Structure and Culture components developed at these cities, a full scale of end-to-end tsunami drill or simulation were conducted. These tests reviewed that disseminating and conveying the tsunami warning were fully performed, the city officials were ready, and the people were responsive to evacuate to the designated shelter within the provided lead time known also as the golden time. In the contrary, when the city was really tested by natural phenomena, i.e. occurrence of several tsunamigenic earthquakes in these past 7 years, the chaotic situations were shown in the city. As if the existence of tsunami warning system established and implemented countermeasures have no effect. *This has challenged this study to investigate further, which was graphically described in Figure 1.4.*

During September 12, 2007 earthquake generated 3.6 m tsunami and September 30, 2009 with 0.8 m tsunami, the tsunami warning have been issued by the Structure component within less than 5 minutes which was compliance with the target of Ina-TEWS. However, the people were panic, evacuation processes failed, no official in place, and many designated vertical shelter collapsed due to the earthquake. The city mayor himself has attempted to convey the tsunami warning message through the radio station, however most supporting infra for conveying the tsunami warning were malfunction due to direct earthquake damage and electricity cut off affected by the earthquake (H.P. Rahayu, 2009; EERI, 2009). These infra included the siren, TV, radio, mosques speaker as praying caller also functioned for public announcement

(PA), mobile phone, fix phone, text message and some others. This shows that the critical problem of effective tsunami early warning remains at the Culture component.

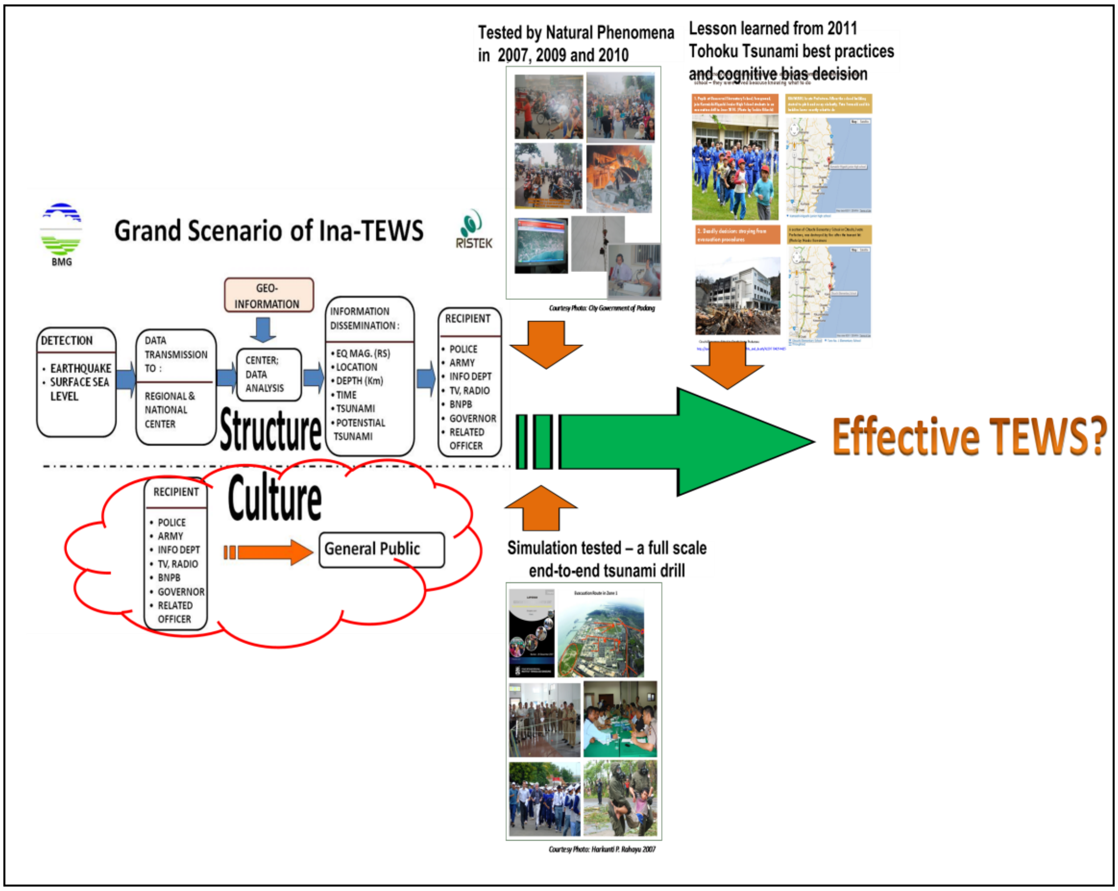


Figure 1.4 Research challenge for this study

In addition to that, the occurrence of Mentawai tsunami in October 25, 2010 showed that the Structure component was fully performed and able to issue the potential tsunami warning less than 5 minutes after the main-shock. Still, the Culture component once again failed to convey the tsunami warning to the people at risk, especially the last mile in this case the people living in Mentawai islands (the closest area to epicenter) who suffered devastated damages and loss of life (Ristek and BMKG, 2010).

Almost 30% of Indonesian cities are tsunami prone, i.e. 146 from 497 cities/regencies (Ristek, 2000). The complexity and diversity of city's vulnerability, capacity and resiliency as well as its tsunami hazard exposure have made the Culture component becomes more critical. Some guidelines for certain disaster risk reduction countermeasures have been published / endorsed by the Government of Indonesia, however these were not sufficient; and no such comprehensive model of Culture component as part of effective tsunami early warning system yet to be used to develop a tsunami ready city.

To better describe the important of the study, after the description of background and research challenge for this study, this chapter will present the basic definition, the study objective, the study area, the research approach and methodology, and the organization of this dissertation.

1.2. Basic Definition

The basic premise of the warning system is to detect impending disaster, to give the information to people at risk, and to enable those in danger to make decision and take action. For the tsunami, this simple definition in fact becomes very complex, since it links many expertise and institutions/organizations, as well as it needs responsibilities sharing between the central government and the local government, between the government and the private sectors, and between the government and the people; as expressed in the grand scenario of Ina-TEWS in the form of Structure and Culture components.

Meanwhile, the Tsunami early warning system as defined by terminology of UN-ISDR on disaster risk reduction is the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss (UN-ISDR 2009). This definition encompasses the range of factors necessary to achieve effective responses to warnings, where the people should be the important subject in the system not as the object. During the WCDR (World Conference on Disaster reduction) conducted in Kobe January 2005, it was stated that to be effective the early warning systems must be embedded in, understandable by and relevant to the communities which it serves. The warning information should be understood, timely, viewed as legitimate and ultimately responded by the diverse array of people at risk. At the beginning of the development of Indian Ocean Tsunami early Warning System, UN-ISDR has expressed a terminology of "end-to-end warning system" used to emphasize that warning systems need to span all steps from hazard detection through to community response.

Thus, as it is stated at the opening of this chapter, this study defines that ***Effective Tsunami early warning system*** is an integration of natural, socio, technical and physical phenomena, aiming to save people as many as possible by alerting the *people at risk* with sufficient lead time to make decision for evacuation.

1.3. Study Objectives

The objectives of this study are:

- To investigate and model the phenomena of effective tsunami early warning system established in Indonesia, which includes investigating how effective the countermeasures implemented at the CULTURE component in achieving the goal of the tsunami early warning system to save lives of all people at risk.

- To introduce the use of new approach for model development to recognize all underlying hindrance and supporting factors of the people mind toward the issue of effective tsunami early warning.

- To develop a tool which is able to :
    - Recognize holistic underlying hindrance and supporting factors to the effectiveness of TEWS established and the effectiveness of DRR countermeasures intervention implemented.
    - Assess or measure the level of tsunami preparedness of those tsunami prone cities to base the policy making for DRR intervention for supporting the Culture component of TEWS.
    - Review or develop new policy making for implementing countermeasures to build Culture component of TEWS.

1.4. Study Area

Padang is selected as the case study city for this research study because of three reasons. The city is exposed to the highest tsunami risk (see Figure 1.6) with frequent occurrence of tsunamigenic earthquake (see Figure 1.5), and it is the most fast growing city at the outer west part of Indonesia. The city is as one of leading city among national show case cities for its tsunami preparedness with its problem discussed previously in Section 1.2 of this chapter.

The risk profile of Padang is a very densely populated city located in the very active seismic activity as shown in Figure 1.5, where significant earthquake with magnitude above 7 are frequently occurred. The very high population density situated at low lying plain area has marked Padang as the city with highest tsunami risk in the world as shown by Figure 1.5 with 141,326 people/km^2 of population density. Risk indicator used in the map is population density of a strip along 2 km width from the coastline of all tsunami prone area in the world with elevation below 10 m, i.e. most severe (red color) above 75,000 people per km^2; severe (orange color) between 30,000 – 75,000 per km^2; and moderately severe (yellow color) below 30,000 per km^2.

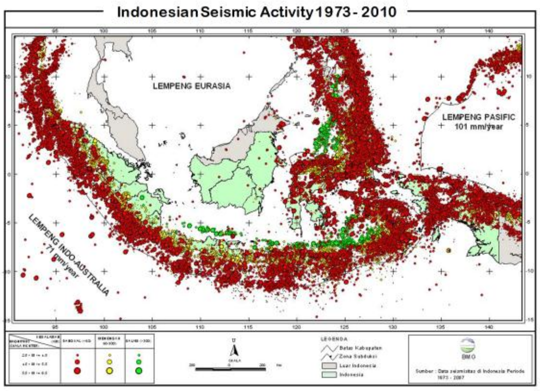


Figure 1.5 Indonesian Seismic Activity 1973-2007 (sources: BMKG)

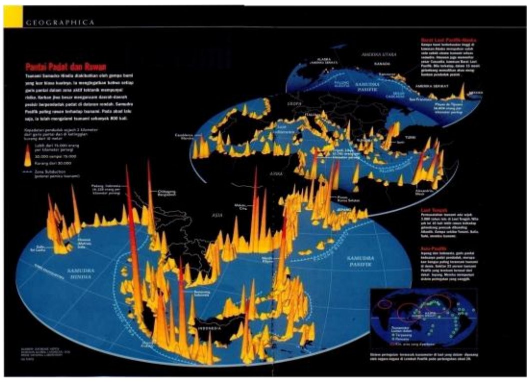


Figure 1.6 Tsunami Risk Exposure of Coastal City in the World (sources: Indonesian National Geographic March 2005 Edition)

With this highest population density, inadequate infrastructure for tsunami evacuation and some other factors of vulnerability; previous study (H. Latief and H.P. Rahayu *et al.*, 2007) on scenario based risk analysis and evacuation time estimate (ETE) for people of the Padang city shows that approximately 71.43% of 14 sub-sub-district (recognized in this study as cluster) are tsunami high risk. The scenario used for the analysis is based on 8 magnitude of earthquake, which generated tsunami with 27 minutes of estimated travel time, and with moderate assumption of 8 minutes for Structure component to disseminate tsunami warning and another 4 minutes time needed by Culture component to convey the warning to the public for evacuation. The result of analysis shows that among 14 sub-sub-districts located at the 5 km width of low lying coastline area, only 2 sub-sub-districts are in the tsunami safe zone, another 2 in high risk zone and 10 in very high risk zone (see also Figure 1.7 below).

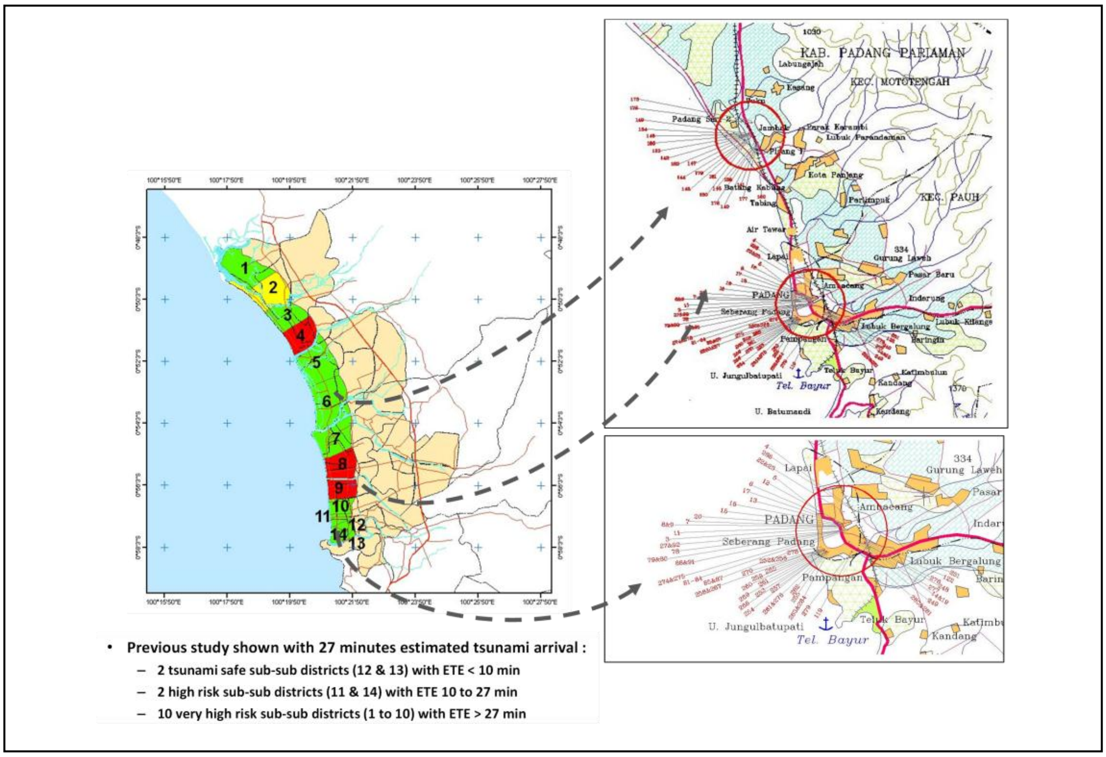


Figure 1.7 Study locations using the result of previous study on risk assessment for evacuation

However, the city government of Padang has put high effort to collaborate with local, regional, national and international community to build the city of Padang as tsunami ready city. Extensive disaster risk reduction countermeasures for tsunami have been implemented. Active community and stakeholders' involvement were shown during the implementation of the national tsunami drill. As previously discussed in Section 1.2 of this chapter, the critical issues of effectiveness of tsunami warning and countermeasures implemented become the focus to be solved under this study.

An in-depth and holistic approach of this study described in next section is used to acquire information from city government officials representing the disaster related institutions and people representing these 14 clusters.

1.5. Research Methodology and Hypothesis

To recognize the problem and to model the effective tsunami early warning system, an approach and methodology developed by this study is shown in Figure 1.8 below, which consists of several stages of study.

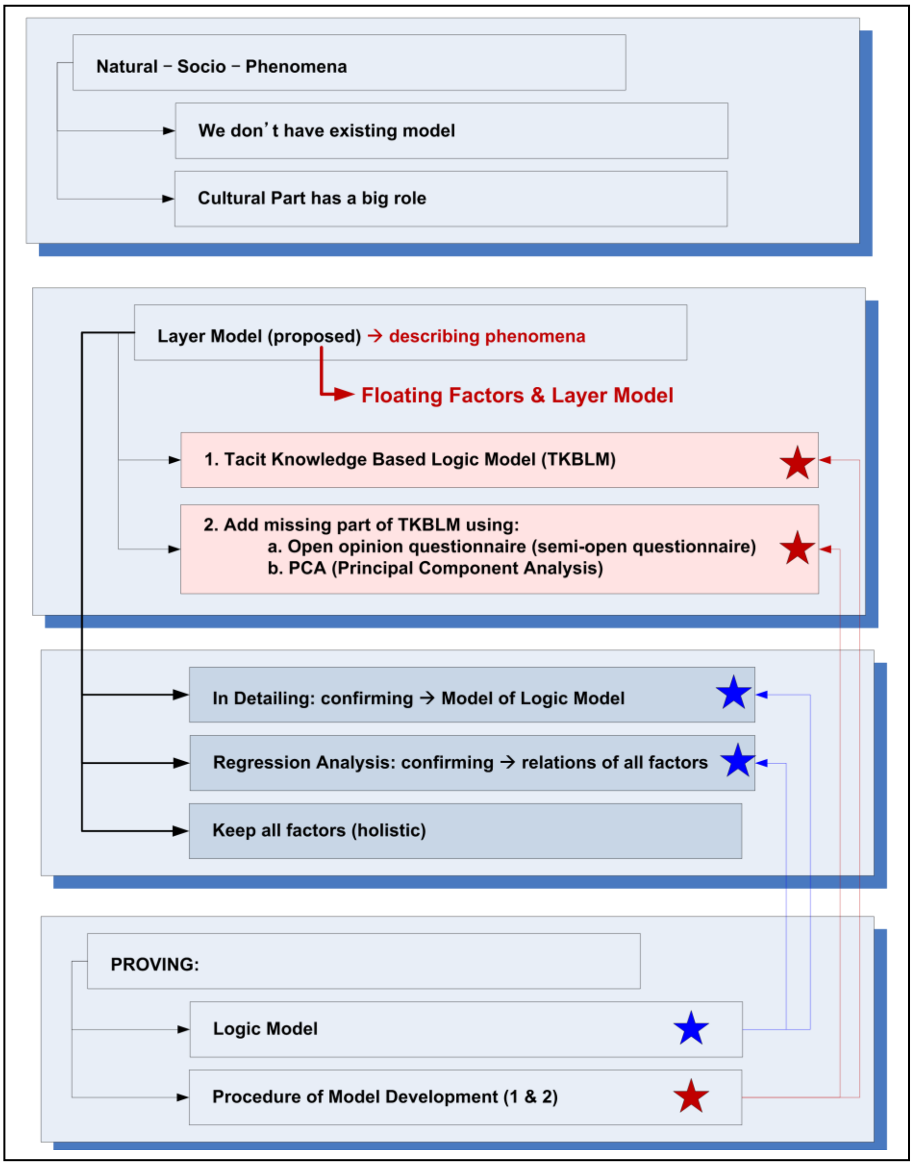


Figure 1.8 Research approach and methodology

In-depth investigation under this study was aimed to structure the problem of enhancing the effective tsunami early warning system established in Indonesia, which is described as the integration of natural, socio, technical and physical phenomena. It was found that not only the Culture Component has not yet fully developed, but also no existence of such model/standard and no thorough approach to recognize the problem exhaustively.

To describe better the integration of natural, socio, technical and physical phenomena as effective tsunami early warning, a logic model approach is used by this study. The logic model is a cognitive recognition method to acquire and structure the relation among these phenomena with external and internal factors of people mindset toward the existence of tsunami early warning system. The phenomena of effective tsunami early warning system is modeled as layer models and floating factors, named as Integrated Logic Model of Effective Tsunami Early Warning System.

The model is expected to be able to provide a complete logic model to base the policy making for enhancing the effective tsunami early warning system by having sound policy for disaster risk reduction countermeasures, reliable warning device, prepared government and responsive people leading to saving people.

For the development of the model, an exhaustive and holistic knowledge of complex phenomena and/or factors associated with tsunami early warning system can be recognized and structured by using two methods of logic model, i.e. *Physically Based Logic Model – PBLM* and *Tacit Knowledge Based Logic Model – TKBLM*.

The method of *PBLM* is a methodology to acquire and structure the correlation of physical events/phenomena based on the up-to-date secondary data directly obtained from related institution and reconnaissance survey conducted after September 30, 2009 devastated earthquake. The method of *TKBLM* is a cognitive mapping methodology to acquire and structure the people's mind in responding (heuristic judgment) to tsunami early warning system by the use of the tacit knowledge based on prior knowledge, social and physical influence, and access to information and appreciation to the warning system. Prior knowledge is the human perception toward tsunami disaster risk which is formed by previous direct experience and/or *trained* *experience,* for example tsunami drill. Meanwhile the heuristic judgment is an experience-based decision making for evacuation.

To bridge the limitation of TKBLM approach, i.e. missing and unforeseen information, there are 2 approaches have been used by this study. First the study improves *methodology for logic model knowledge acquisition* by introducing the use of *semi-open questionnaire based interview,* which is described in detail in Section 5.2 of Chapter 5 and Section 6.2 of Chapter 6. The advantage of this approach compare to ordinary logic model is its ability to explore more in-depth and comprehensive all supporting and hindrance factors including the unforeseen ones, which may indelible in people mind. In addition to that, it has certainty in obtaining the number of data and information from the interviewee compare to the questionnaire circulated by mail. However, more time consuming for data acquisition compare to ordinary logic model is the main disadvantage.

Second, the numerical modeling of TKBLM is done by adapting the *Principal Component Analysis* – ***PCA*** approach. In this study, there is no elimination or reduction for the least contributor factors as commonly done by standard approach of PCA's regression analysis. The PCA is used not only to structure and analyze the numerical correlation of all observed factors among the members component of each level/cluster, but also to uncover the unobservable factors.

1.6. Research Framework

There are *six output models* developed under this study in five stages of research study, see also Figure 1.9. These 5 stages of study are: stage 1 - problem structuring, stage 2 - modeling phenomena of effective tsunami early warning system in the form of integrated logic model, stage 3 - developing TKBLM models, PBLM models and Preparedness Index as floating models, stage 4 - conducting site survey, data coding, development of detailing logic model and development of numerical modeling using PCA (principal component analysis), and stage 5 - the result of the study. Meanwhile the 6 output models can be described as follows:

The 1st output model is a *map of Functioning and Malfunctioning Indicators* developed through in depth investigation on indicators associated with the *end-to-end performance* of tsunami early warning system during September 30, 2009 and September 12, 2007 tsunamigenic earthquakes. These indicators are identified from four areas, i.e. Ina-TEWS general scenario/scheme, Ina-TEWS Information Flow, Stakeholders of Ina-TEWS and documentation of preparing and conducting full scale of end-to-end tsunami drill in 2006 and 2007 at national show case cities.

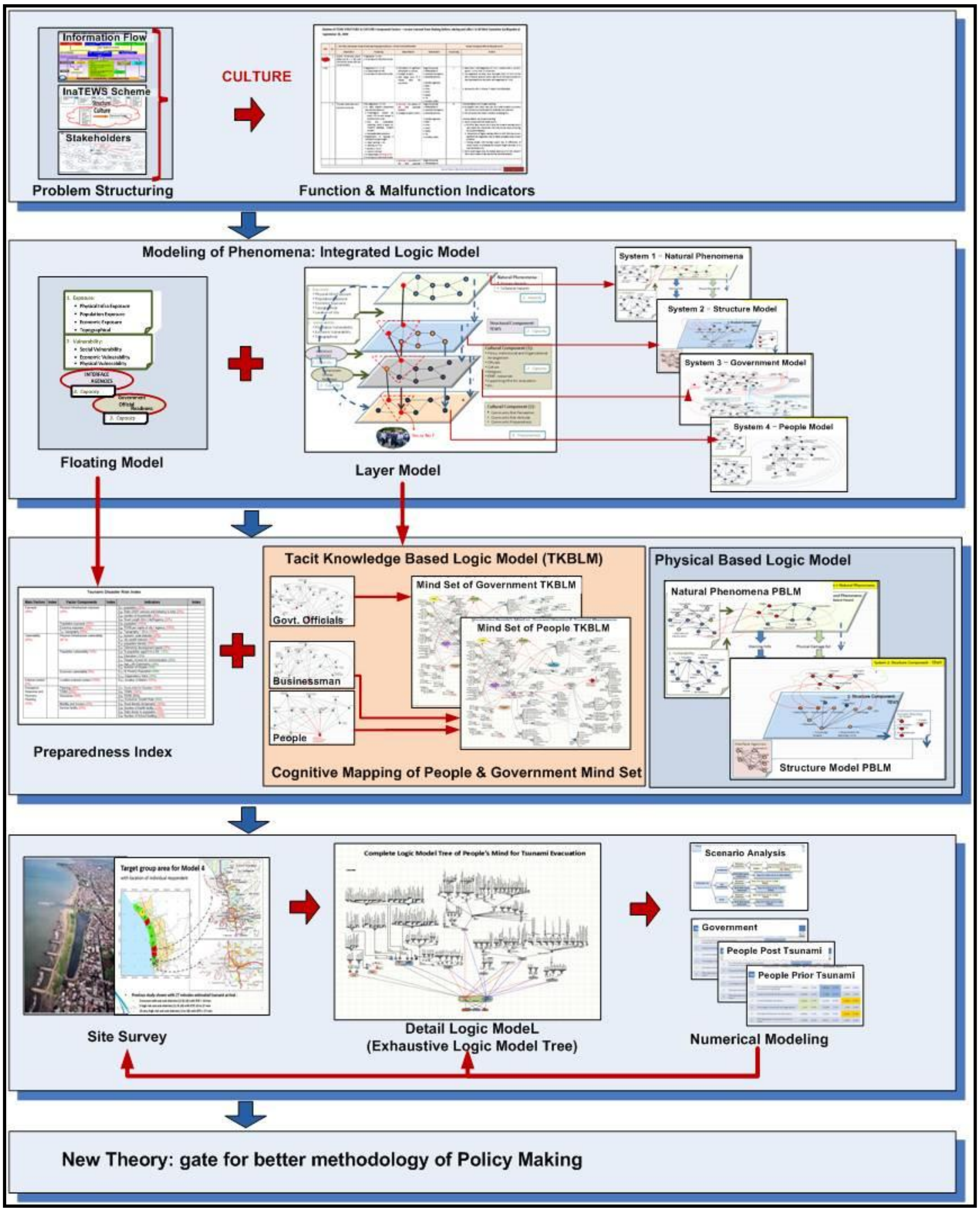


Figure 1.9 Research framework

The 2nd output model is the modeling of tsunami early warning phenomena as *Integrated Logic Model* which consists of integration of four phenomena, i.e. natural, socio, technical and physical phenomena in the form of layer logic models and floating model. There are four layer of logic model representing: Natural Phenomena model which include the correlation among tsunami primary hazard and its collateral hazards; Structural Component of tsunami early warning system which describes the correlation of the hardware system; Cultural Component 1 called as the *Government Model* which recognizes the correlation of all hindrance and supporting factors of the government officials mind in receiving, responding and taking action for duty to save people when strong shaking occurred and with and/or without tsunami warning received; and Cultural Component 2 called as People Model which recognizes the correlation of all hindrance and supporting factors inside the people mind to receive, response and take action when there is strong shaking with or without tsunami warning received.

The 3rd output model is the floating model described also as Preparedness Index, i.e. a model consisting of factors commonly affecting each layer. The model is developed based on the principle of disaster risk assessment to analyze the secondary information on tsunami risk level and the city preparedness toward tsunami. Beside as a supplement to layer model, this floating model can also be used to assess the level of city preparedness before and after the intervention of countermeasures. It can also be used to assess the level of effort needed for increasing and improving the capacity of government (government model) and the people readiness (people model).

The 4th output model is the layer model 1 and 2, i.e. Natural Phenomena model and Structural model, developed based on the Physically Based Logic Model (PBLM). The detailing of these two logic model as also explained in previous section are based on the physical data obtained and the Functioning and mal-Functioning indicators.

The 5th output model of government and 6th output model of people are developed based on TKBLM. Comprehensive and time consuming city scale data acquisitions are conducted under this study using in-depth semi-open questionnaire based interview on government officials representing city and provincial government institutions which related with tsunami and/or disaster management as well as on the people from 14 tsunami risk zone/cluster.

During the study, the occurrences of devastated tsunamigenic earthquakes in Padang on September 30, 2009 and a 12 m Mentawai Tsunami occurred in October 25, 2010 have made the study more complete in recognizing the real problem of enhancing the effective tsunami early warning system. To accommodate rare windows of opportunity, under this study the data acquisition for TKBLM are divided into two time-series data, i.e. first data acquired after the tsunamigenic earthquake before Mentawai tsunami and second data obtained after the tsunami. The first set of data consisted of 461 people interviewed from 14 clusters and 20 government officials interviewed. The second data consisted of 61 people re-interviewed representing 2 out of 14 clusters.

Detailing of the cognitive mapping in the 5^{th} model and 6^{th} model is confirming the logic model ability to exhaustively recognize and structure the people mind set using prior belief as well as heuristic rules in responding the warning and/or natural phenomena. All foreseen and unforeseen of hindrance and supporting factors which are indelible or temporarily inherent in people mind are well structured and hierarchical clustered in the forms of logic tree.

There are 6 major clusters developed in this logic model recognizing both prior belief and heuristic rules/judgment, i.e. *E - reasons for immediate, postpone or never evacuated after strong shaking, H -Hazard and Disaster Perception and Experiences, V - Social Vulnerability and Capacity, T - Knowledge on Tsunami Risk and Triggering Event, CM - Disaster Risk Reduction Countermeasures and TEWS - Appreciation to Tsunami Early Warning System*. Detailed of the process development of these two model are presented in Chapter 5 and Chapter 6 of this dissertation.

The 7^{th} output model is the numerical model developed using regression analysis of principal component analysis (PCA). There are 13 *evacuation decision scenarios* used for the numerical analyses of people (general people and government officials) mind toward tsunami early warning system. These scenario shows that there are two type heuristic decisions making using heuristic rules. First decision triggered by natural phenomena in this case is very strong shaking. Second judgment is the decision triggered by combination of both natural phenomena and tsunami warning. These 13 scenarios are developed by integrating these two scenarios with 3 heuristic rules (conditions of expected outcome of decision or judgment), i.e. immediate evacuation, not immediate (delay) evacuation or never evacuation; and with 2 other heuristic judgment, i.e. plan or spontaneously. Detailed of the process development of numerical modeling is exhibited in Chapter 5 and 6 of this dissertation.

1.7. Organization of Dissertation

The structure of this dissertation is basically can be divided into three main parts, i.e. research introduction, model development and conclusion. The organization of the dissertation is shown in Figure 1.10 and described further as follows:

PART I – RESEARCH INTRODUCTION AND STATE OF THE ART

- Chapter 1 – Research Introduction: outlines the study background which includes the the background and research challenges, the basic definition, the rationale and objective of study, the area of study, the research approach and methodology, the research framework and the organization of dissertation.

- Chapter 2 – The State of The Art for Effective TEWS: review all the existing and current works related for the area of effective tsunami early warning system, people centered early warning, countermeasures for tsunami preparedness, broader lesson learned from 2011 Tohoku tsunami.

PART II – DEVELOPMENT OF INTEGRATED LOGIC MODEL OF EFFECTIVE TEWS

- Chapter 3 – Problem Structuring and Model Development: showing the first stage of the logic model development through problem structuring and identification of TEWS functioning and malfunctioning indicator using the real phenomena test case on the case study city; then it is followed by the describing the process development of modeling the phenomena of effective tsunami early warning system in the forms of integrated logic model consisting 4 layer model and 1 floating model.

- Chapter 4 – Development of Preparedness Index and PBLM: showing the second stage of model development where the floating model is developed using the preparedness index approach based on the disaster risk assessment approach, this is followed by the development of the first two layer model using physically based logic model approaches, the two model are natural phenomena model and structural model.

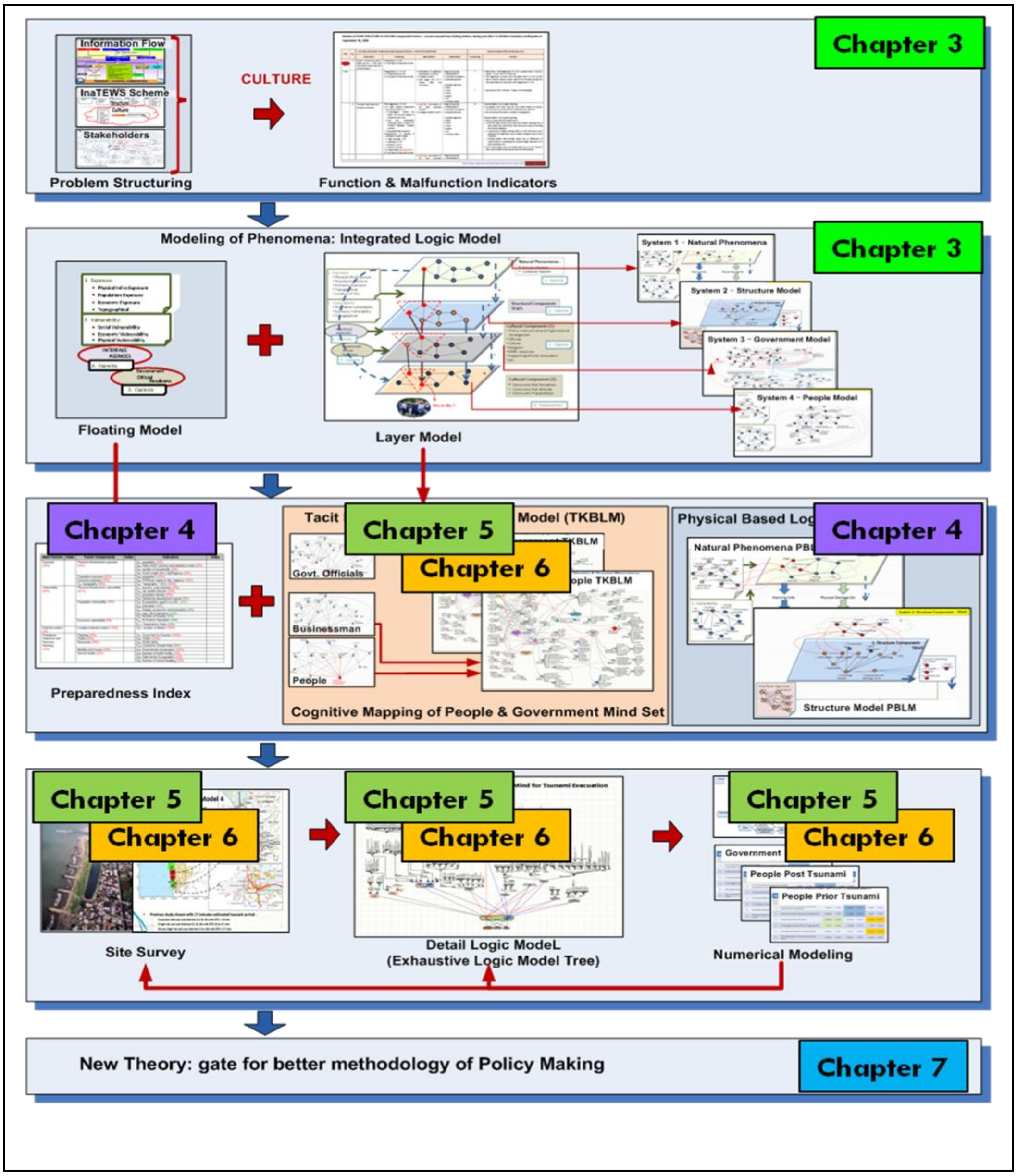


Figure 1.10 Organization of the dissertation

- Chapter 5 – Development of People Model - TKBLM (Layer 4): showing the process development of modeling the people mindset toward tsunami early warning system using the ability of logic model in conducting cognitive mapping of people mind to TEWS with tacit knowledge based logic model approach, there are two people model, i.e. one for model of people before intervention of natural phenomena tsunami and second model is for the same people after interrupted with tsunami phenomena, the steps of data acquisition and data coding is presented, followed by detailing the logic model in the format of tree-based logic model, and the last part to develop the numerical model for this people model logic model.

- Chapter 6 – Development of TKBLM of Government Model (Layer 3): showing the process development of modeling the government mindset toward tsunami early warning system using the ability of logic model in conducting cognitive mapping of government officials mind to TEWS with tacit knowledge based logic model approach, the steps of data acquisition and data coding is presented, followed by detailing the logic model in the format of tree-based logic model, and the last part to develop the numerical model for this government logic model.

PART III – RESEARCH FINDING AND FUTURE WORKS

- Chapter 7 – Research Findings and Future Work: proving of the research methodology and hypothesis. The study proved the process of describing the phenomena of effective tsunami early warning system as 4 layers model and 1 floating model. The use of integrated logic model for describing the phenomena is a fruitful approach for simulation of the natural, physical, socio and technological phenomena and for cognitive recognition of the people's mind toward the existence of tsunami early warning system. The numerical model developed based on two types of questionnaire-based interviews is proved to be able to analyze the correlation of all cognitive factors of the people's mind either as regulator and/or general public toward the existence of effective tsunami early warning system. The research methodology and the model developed are expected to be novel contributions for the area of policy making by providing better methodology for policy analysis for the policy development for achieving effective tsunami early warning system as well as for other area. In the future, the more implementation of the model in several different type of city and culture, the more complete and universal the model obtained.

Chapter 2

State of The Art of Effective Tsunami Early Warning System

2.1 Disaster Trends

Many countries in the tectonic subduction region in the world, especially in the ring of fire region have long concerned on the huge impacts that natural disaster especially tsunami have on the society in both developed and developing countries. Nearly a million people in the world have been killed over the last decade (2001 until 2010) from disasters caused by several types of natural hazards, i.e. storms, droughts, floods and earthquakes; however one third has died during the 2004 Sumatera Indian Ocean tsunami (EM-DAT, 2010).

For Indonesia region, geodynamic position as a meeting point of 4 major plates, i.e. Indo-Australia, Eurasia, Pacific and Philippines see Figure 2.1.a, has put Indonesian archipelago on a very high seismic activity with high occurrences of *tsunamigenic earthquakes* at both subduction area and/or major fault at the seabed. Tsunami Catalog for Indonesia as shown in Figure 2.1.c describes the statistics of tsunami occurrences with 20-year interval, where some high frequencies occurred between 1845 – 1865 (30 events), 1885 – 1905 (33 events), 1965 – 1985 (16 events) and 1985 – 2005 (21 events) (H. Latief and S. Hadi, 2007).

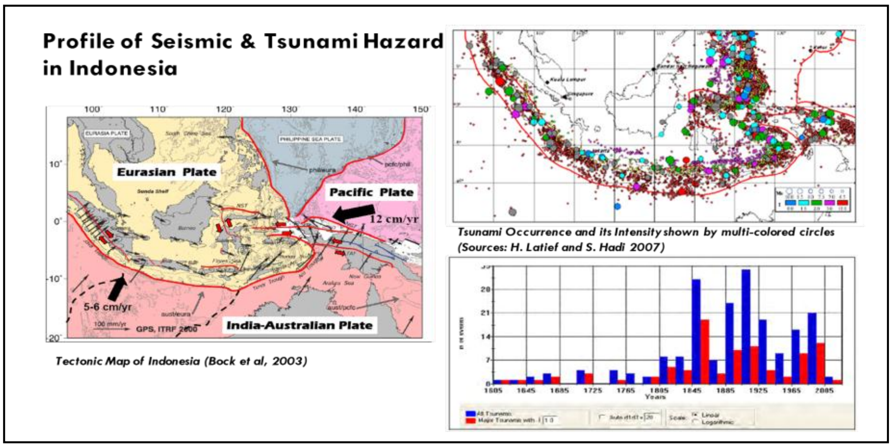


Figure 2.1 Profile of seismic and tsunami hazard in Indonesia

The distribution and intensity of these tsunami occurrences can also be seen in Figure 2.1.b as multi-colored circles, i.e. dark blue representing low tsunami intensity (scale I to IV) up to the dark red representing very high tsunami intensity (scale IX to XII); where the scale is classified based on the tsunami impact and the tsunami height. Within 1965-2010, there were 15 *major tsunami* events, with the average of occurrence about 1 in every 2.5 year (A. Muhari and Immamura, 2007).

These mean that Indonesia archipelago is highly exposed toward major tsunami threat which should be considered carefully in the development planning, as it is known that the tsunami disaster always has long-term impacts on recovery, rehabilitation and reconstruction on the built environment, economic growth and development especially on the developing countries where capital resources are limited.

In addition to that, the trend of urban-centered natural disaster, i.e. natural disaster affecting urban area, has been increased in these three past decades. The complexity and dynamic change of the urban area have significantly contributed to the level of disaster affected cities in Indonesia. Among those urban-centered disasters in Indonesia, the one causing most severe impact on number of people death in the last two centuries is tsunami disaster (BNPB, 2010), see also Figure 2.2 below. From years to years, the tsunami disaster seemed significantly increased in terms of number people killed and level of damages.

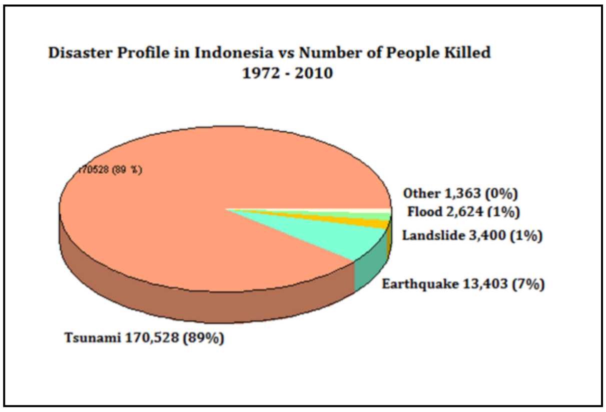
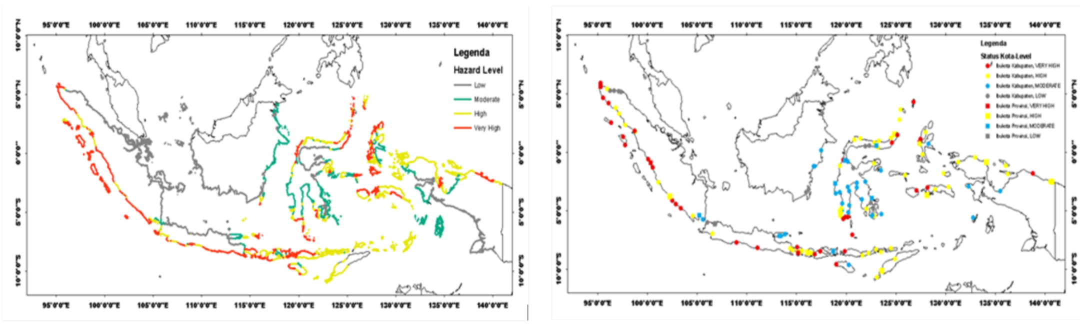


Figure 2.2 Disaster impact on number of people killed within 1972-2010 (source: Inventar 2012)

According to Indonesian Tsunami Risk Map (Ristek, 2009), there are almost 30% of Indonesian cities, i.e. 146 out of 457, are prone toward tsunami, ranging from low tsunami risk up to very high. About 36 cities are classified to be very high risk, meanwhile 58 cities to high risk, 36 cities to moderate risk and 16 cities to low risk. Most cities with very high tsunami risk are located in west coast of Sumatera, i.e. 14 cities/regencies. The criteria used for this risk classification is the tsunami hazard map developed based on two tsunami parameters (i.e. tsunami height and tsunami travel time) and generic vulnerability parameters of coastal cities, i.e. population and infrastructures at both city level including regency capital city. Figure 2.3 below shows both the tsunami hazard map and the distribution of tsunami risk cities/regencies in Indonesia.



Indonesian Tsunami Hazard Map

Map of Tsunami Risk for Coastal Cities in Indonesia

Figure 2.3 Indonesia tsunami hazard map and city tsunami risk (source: Ristek, 2009)

Considering the tsunami disaster risk is defined as the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between tsunami hazards and vulnerable conditions as well as the people capacity and ability to cope with the disaster as adapted from UN-ISDR (2004a).

Therefore, the geodynamic and geographical position of Indonesia discussed above coupled with the dynamic changing and complexity of high populated cities in Indonesia has created those classified cities at risk are profoundly exposed to tsunami disaster risk, leading to increasing the number of people at risk. Almost half of Indonesian coastline, i.e. 54,716 km[1] which is also the second longest in the world after Canada (Wikipedia 2012), are susceptible to tsunami disaster with not less than 20 million people living in those coastal cities/regencies are threatened by tsunami.

These disaster risks are then compounded by increasing number of emerging cities and changing demographics profile as the consequences of autonomous policy (decentralization) in year 2000 and other vulnerability factors related to technological and socio-economic conditions, i.e. unplanned urbanization, development and illegal settlement within high-risk zones, and insufficient infrastructure for emergency response purposes.

In addition to that the city vulnerability is also increasing due to more people tend to live on hazard prone area illegally. The poor are often forced to live in disaster prone area and marginal area; with limited coping ability then they become the most severe affected every time disaster occurred; where the main obstacle for the preparedness are come from the level of poverty which commonly disables the abilities for protection. The greater the number of people suffered, the higher the potential national economic damaged. Since protecting the citizen for the threat of disaster has always been the state function, thus having *better risk management* becomes one measure of *good governance* for any high risk countries (K. Sierra, 2006).

As lessons learned from most Japanese people in responding the warning during 2011 Tohoku tsunami, adequate *early warning systems* coupled with *better preparedness* and *response* mechanism are recognized as the best way in reducing the number of loss of lives. On the other hand the 2004 tsunami showed the worse case of the nonexistence of tsunami early warning system. Thus no matter how dynamic and progressive the state of the art of early warning mechanism has been achieved, the effectiveness of the early warning system can only be enhanced if it involves the whole stakeholder's participatory, i.e. the government, the people and the other stakeholders.

2.2 Challenges for Tsunami Early Warning System

Despiteful destructive impact, for Indonesia the occurrences of 2004 Sumatera-Andaman Indian Ocean mega tsunami actually has been triggering event for the establishment of tsunami early warning system, while and 2011 Tohoku mega tsunami has provided valuable lesson learned for the evaluation of tsunami early warning system established especially for its performance in anticipating the *near-field tsunami* as well as for the *tele-tsunami*.

Figure 2.4 shows tsunami travel time of these mega tsunamis and its widespread effect both as *near-field-tsunami* and *tele-tsunami*. For the case of near-field tsunami, the 2004 tsunami has hit Banda Aceh City and surrounding area within 30 minutes, while 2011 tsunami has stricken some cities of Miyagi and Iwate province within 20 to 25 minutes. Here it shows that for both phenomena, the existence of effective tsunami early warning is critical either as *national tsunami warning center* (NTWC) for near-field tsunami or as *regional tsunami warning provider (RTWP)* to other affected countries for tele-tsunami (Ristek, 2010).

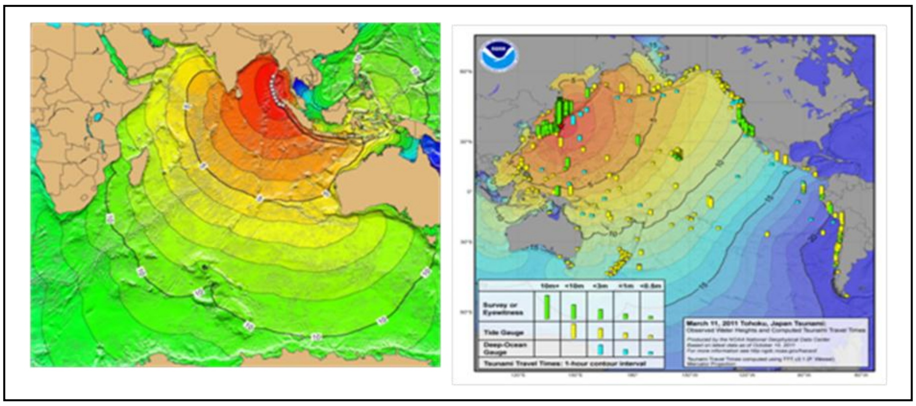


Figure 2.4 Tsunami travel time map for the 2004 Indian Ocean tsunami and 2011 Tohoku tsunami. The number tags represent hours after the initial event (NOAA, 2011).

To challenge the above natural disaster risk issues in general, in these past two decades several extensive disaster risk reduction initiatives have taken place in Indonesia as international commitment to the Yokohama Strategy 1994. It has provided landmark guidance on reducing the disaster risk and the impacts of disaster, which was then followed by the Hyogo Framework of Action 2005 where tsunami early warning becomes the central issues of the disaster risk reduction countermeasures for building the nation resilience (see Figure 2.5).

In fact from 2005 till now, the numbers of people affected and economic losses caused by natural disaster were still increasing. The *substantial issues of disaster risk reduction have often been oversight*, such as the issues of *recognizing real problem and reducing underlying risk factors* in building resilience and ensuring systematic action to address disaster risks in the context of sustainable development and building resilience.

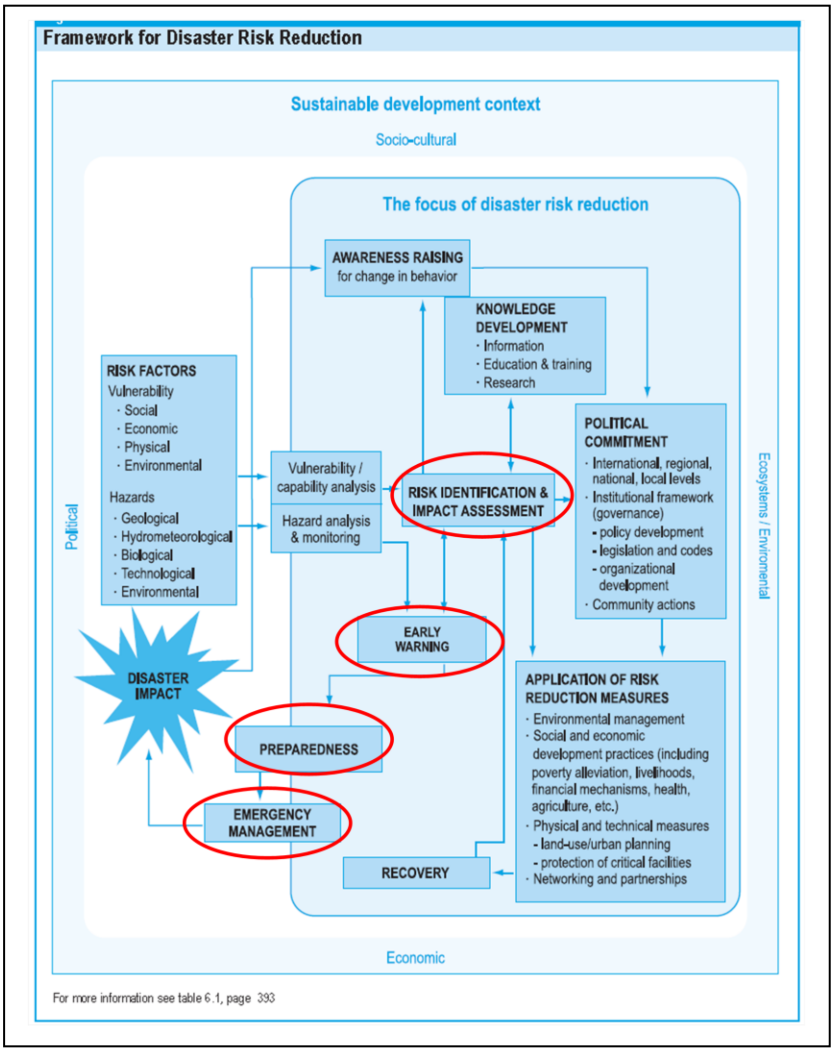


Figure 2.5 UN-ISDR strategy for disaster risk reduction (source: UN-ISDR, 2004a)

In many cases the official policy of government in reducing tsunami risk often *did not address the deep causes of vulnerability* (Ben Wisner *et al*., 2003), but rather emphasized on technical measures to control tsunami impact through populist policy, such as implementing structural mitigations countermeasures and one-way public awareness campaign. It is very often that some countermeasures implementations were donor-tailored, which were not suitable to the local needs. For example: building inefficient vertical tsunami shelters that cannot be used for daily needs of surrounding people, and unsustainable public education program which confused the target people.

However, the most critical issue which challenged this study is that among identified problems faced by tsunami prone area in several cities, lack of timely and proper response toward the warning is a major concern. This leads to the needs for the soundly *effective tsunami warning system* that able to disseminate warning with sufficient lead time for those people at risk to make decision for evacuation to save their own lives.

2.3 Effective Tsunami Early Warning System in International Appreciation

Early warning system could be simply defined as a mechanism to observe potential disaster, to make available that information to people at risk, and to enable those in danger to make decision and take action (J.H. Sorensen, 2000). This simple definition for the area of tsunami hazard threat in fact is very complex. The classical system generally include 3 main elements of *early warning chain*, i.e. understanding and mapping the hazard; monitoring and forecasting impending events; processing and disseminating understandable warnings to authorities and people/population, and undertaking appropriate and timely actions in response to the warnings (UN-ISDR, 2004a).

Currently, the early warning systems for natural hazards are found to be increasingly perceived as an integral component of disaster risk reduction program, involving a broad spectrum of actors, since it has been address in UN International Strategy for Disaster Reduction shown in Figure 2.5. It is shown that the early warning countermeasures cannot stand alone. It has direct correlation with risk assessment, preparedness and emergency response management shown in red circled and indirect relation with the rest countermeasures in the strategy framework to reduce the disaster risk.

Prior to the event of 2004 Sumatera Andaman /Indian Ocean tsunami, the international appreciation toward *early warning system – EWS* initiatives were mainly focused on the climate and volcanic hazards; except among Pacific regional communities leaded by Japan and US which has established *Pacific Tsunami Warning System – PTWS* since 1968. The initiatives for promoting and integrating the early warning system as an essential component in the disaster risk reduction countermeasures and in the culture of disaster resilience has been encouraged by the UN General Assembly and initiated by the *UN International Decade for Natural Disaster Reduction – UNIDNDR* for the period of 1990 to 1999. This lead in the acknowledgement of its importance in the *1994 Yokohama Strategy and Plan of*

Action for a Safer World, endorsed at the *UN World Conference on Natural Disaster Reduction – UNWCNDR* in Yokohama 1994. Such acknowledgment could be seen in the principle no 5 which relates to early warning, i.e. early warnings of impending disasters and their effective dissemination are key factors to successful disaster prevention and preparedness.

Later after 2004 tsunami, during the *UNWCDR* ‐ *World Conference on Disaster Reduction* in Kobe 2005, the *International Strategy for Disaster Reduction - UNISDR*, i.e. the successor to the *UN-IDNDR*, has introduced a stronger focus on vulnerabilities and emphasized the needs to integrate disaster risk reduction into sustainable development. During this World Conference, the *Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters* has been addressed, in which *risk assessment* and *early warning* has been acknowledged as one of the five priority of action for reducing the disaster risk.

During the 2005 Kobe world conference, the initiatives for early warning system has been appreciated to be more necessary and relevant to reduce natural disaster risk especially tsunami to compare with they were firstly conceived in 1994. Several international initiatives tried to promote the tsunami early warning system, i.e. establishment of regional tsunami early system for Indian Ocean - *IOTWS*, which was expected to become the second regional tsunami early warning system in the world after PTWS. However due to political matter overruled socio-technological matter, the *IOTWS* has never been similar to *PTWS*. It becomes only a network of several national tsunamis warning center of Indian Ocean countries.

Other initiative was the establishment of *UN-ISDR Platform* for *Promoting the Early Warning System – PPEW*; with specific recommendations to call countries to develop *people-centered early warning systems*. In line with the PPEW initiatives, the *tsunami early warning system* has been defined as *the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response* (UN-ISDR, 2004a). This is then refined in the UNISDR Terminology (2009) as *the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a* *hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.*

Meanwhile the second concepts which has been proposed by PPEW basically consisting of four interacting elements (UNITED NATION, 2006), namely: (i) risk knowledge, (ii) monitoring and warning service, (iii) dissemination and communication and (iv) response capability, as shown in Figure 2.6 below. The existence of these four elements is not in a logical sequence, but each element has direct multi-way linkages and interactions with other elements. To take analogy to the grand scenario of the TEWS, these figure shows 3 component of 4 elements are Culture component; meaning it stressed more on the Culture than Structure.

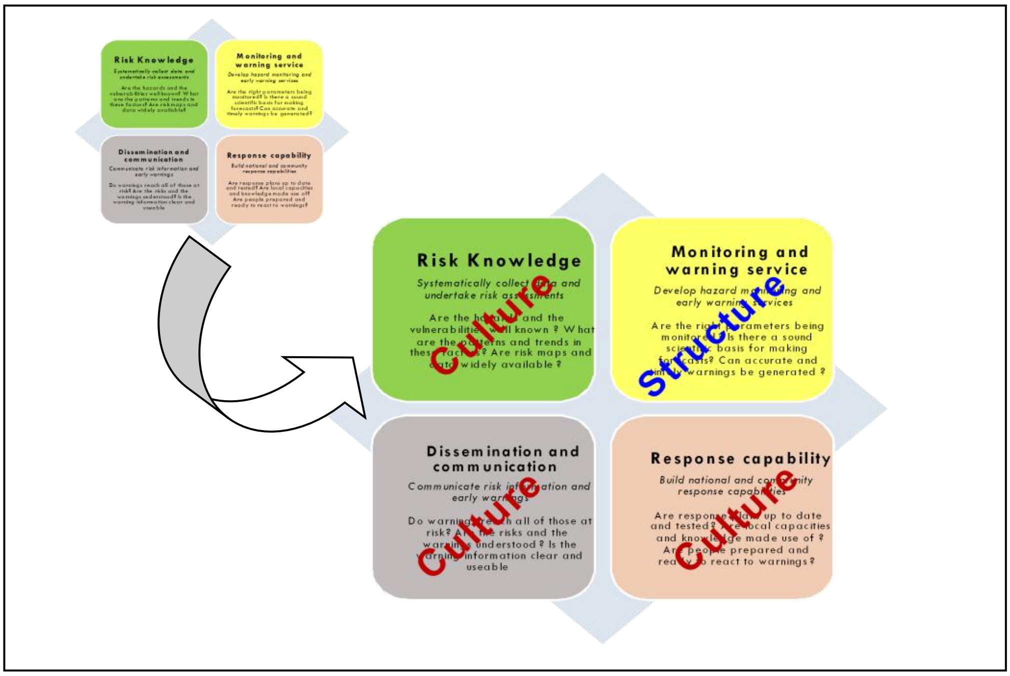


Figure 2.6 Four elements for effective Early Warning (PPCEW) - down load by October 1, 2011 (http://www.unisdr.org/2006/ppew/whats-ew/basics-ew.htm)

This definition encompasses the range of factors necessary to achieve *effective responses* to warnings, which are expressed in the concept of *end-to-end warning system* and the concept of people-*centered early warning system*.

The element of risk knowledge consists of the knowledge of all relevant hazards, and of vulnerabilities of people and society related to these hazards. The element of monitoring and warning service includes the technical capacity to monitor hazard sources (generator), to predict hazard phenomena, and to issue warnings. The dissemination and communication element covers the dissemination of warnings which is acceptable and understandable by those people at risk as prior preparedness information. Then, the response capability element contains knowledge, plans and capacities for timely and appropriate action by authorities and the people at risk.

Currently the element of monitoring and warning service is the most well recognized as part of the early warning system practices, but experience has shown that technically high-quality predictions by themselves are insufficient to achieve the desired reduction in loss of lives. The human factor in early warning systems is very significant. Failures in early warning systems typically occur in the communication and preparedness elements, as well as failure in respect to risk knowledge, i.e. a lack of full public and political appreciation (Twigg, 2002).

To sustain four elements over long run, it is necessary to have strong political commitment and durable institutional capacities, which in turn depend on public awareness and an appreciation of the benefits of effective warning systems. Such the case after the 2004 tsunami the public awareness and political support is often high immediately, such moments should be capitalized to strengthen and secure sustainability of early warning systems otherwise the political will and euphoria will be evaporated after some time.

Some relevant development frameworks for promoting tsunami early warning system were Agenda 21, multilateral environmental agreements, Barbados Plan of Action for Small Island Developing States, and Johannesburg Plan of Implementation. Mostly, all of these initiatives tried to call for actions to expand, deepen and strengthen local, national and international initiatives to develop early warning in particular and disaster risk reduction in general, as *critical tools* for promoting sustainable development and poverty reduction for the developing countries.

Other than that, the international conferences on early warning, i.e. EWC-I 1998, EWC-II 2003 and EWC-III 2006, have addressed *guiding principles* for the development of early warning systems which implicitly outlined related program on early warning to reduce disasters using proposed technical considerations, strategic issues and institutional requirements and made specific recommendations for strengthening early warning systems, including the incorporation of early warning into policy and development frameworks, a greater emphasis on the social factors in early warning systems and mechanisms sustaining dialogue and collaborative action among key stakeholders.

However, to be effective, the early warning systems need to have not only a sound scientific and technical basis, but also a strong focus on the people exposed to risk, and with a systems approach that incorporates all of relevant factors in that risk, whether arising from natural hazards or social vulnerabilities, and from short-term or long-term processes (R. Basher, 2006). As also accommodated in EWC II (2004) to be effective and complete, an early warning systems must be *both* technically systematic and people-centered.

Existing paradigm to model early warning systems is that the use of linear model-based early warning systems as opposed to previous techno-centric concepts. The linear model emphasizes necessity to have all element of the early warning chain in place and connected. Two works on this approach, first is *most common current view of early warning systems* comprising of a simple warning chain, i.e. a linear set of connections from observations through warning generation and transmittal to users. The characteristic and limitation of linear model are presented in Table 2.1 below.

The second is the *end-to-end concept* aiming to make forecasts and warnings more relevant and useable to the end-users. Even though this existing end-to-end linear concept is an advance, however it has several limitations, such as:

a) focus still tends to remain on *hazard*, with less emphasized on *vulnerabilities, risks and response capacities*
b) different hazards are handled by separate independent technical institutions, with few synergies or mutual benefits being sought
c) expert dominance lead to difficulties in user appreciation, i.e. warning content, warning uncertainty, nature of false alarms and necessary responses to different types of warnings,
d) lack of engagement or empowerment of those people at risk in development and operation of warning system,
e) a tendency by end-users (people) to lack any sense of ownership in the system and to mistrust experts and authorities

f) lack of systematic mechanisms to improve system through incorporation of knowledge, experience and feedback from users and those at risk, and

g) lack of public engagement and recognition tends to lead to lack of political and budgetary support for warning system

No	Steps	Main characteristic	Factors involved	Needs and challenge
1	assessment	baseline risks	time and space characteristics of tsunami-genic sources and vulnerabilities thereto	uncertainty and inadequate data, such as: on submarine geology, coastal bathymetry and social vulnerability
2	monitoring	initial state	seismicity, sea level, visual observations	ocean observations needed; tsunamet expensive to establish and maintain
3	system models	time-evolving	seismic or other forcing, ocean wave generation and propagation, bathymetry and coastal topography	wave propagation models for far-field events if ocean-state data are availabl statistical models based on seismic dat for near-field events
4	predictions	probabilistic	need time-space estimates of wave train structure, run-up, inland penetration, turbulence; intrinsic uncertainty and probabilistic nature of estimates	very rapid assimilation of data; high 'false' alarm rate for seismicity-based warnings; little time to review and revise warnin experience limited by the infrequency events
5	impact	complexity	human settlements have high spatial and behavioral complexity	inundation models require extensive data and evaluation; impacts depend c response
6	response	complexity	multiple warning channels; human behavior depends on knowledge, belief, experience, preparedness, practice, emotion, etc	preparedness strategies; control of warning channels; discounting of low frequency risks; high cost of false alar need for very fast response

Table 2.1 Example of linear model characteristics and limitations: tsunami early warning systems

As stated at the opening statement of this thesis in Chapter 1, to have better understanding toward the phenomena of the tsunami early warning system, this study defines the ***Effective Tsunami early warning system*** as an integration of natural, socio, technical and physical phenomena, aiming to save people as many as possible by alerting the *people at risk* with sufficient lead time to make decision for evacuation, see also.

Then to better describe the phenomena of the system, the effective tsunami early warning system is modeled using the logic model approach which is able to recognize and structure all the challenges faced by the tsunami early warning system practices. Detailed of process development of the model are presented in the next part of this dissertation.

2.4 Current Status of Tsunami Early Warning System in Indonesia

The 2004 tsunami has been a *wake-up call* for Indonesia for the establishment of *tsunami early warning system* called *Ina-TEWS* to protect people from future tsunami. The Government of Indonesia has put high priority for the development of *Ina-TEWS* which was completely established at the end of 2008. The system consists of two main components, i.e. the hardware component known as STRUCTURE component and Culture components; see also the grand scenario of *Ina-TEWS* in Figure 2.7.

To support the development, deployment, operation, and maintenance of *Ina-TEWS*, hence a set of legal framework was endorsed, i.e. disaster management law and its related government regulations. The establishment tsunami early warning system and the enforcement of these legal frameworks are as part of the Indonesian Government's international commitment for Hyogo Framework of Action (HFA) 2005-2015 to build the resilience of nation and communities toward natural disaster.

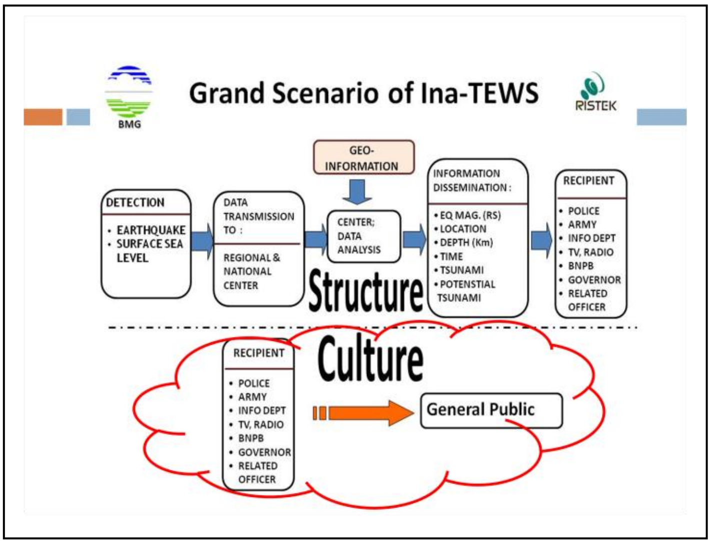


Figure 2.7 The Ina-TEWS Scheme (Sources: Ristek 2008)

Under intensive collaboration with the national, regional and international community for the development of Ina-TEWS, the STRUCTURE component was built by adapting and improving the existing technology of tsunami early warning system from Pacific Tsunami Early Warning System - PTWS. The aim of this component is for detecting, monitoring, processing, aggregation, simulation and dissemination of the information for potential tsunami, see also Figure 2.7 above. By the use of *a multimode communication device*, i.e. radio internet (substituted by digital video broadcast), internet, SMS, fax, and phone, the warning of potential tsunami is disseminated to the CULTURE component, which is addressed to Disaster Management Offices (DMOs) at local government including some related interface agencies, i.e. media and DMOs at provincial government (H.P. Rahayu *et al.*, 2007; 2008).

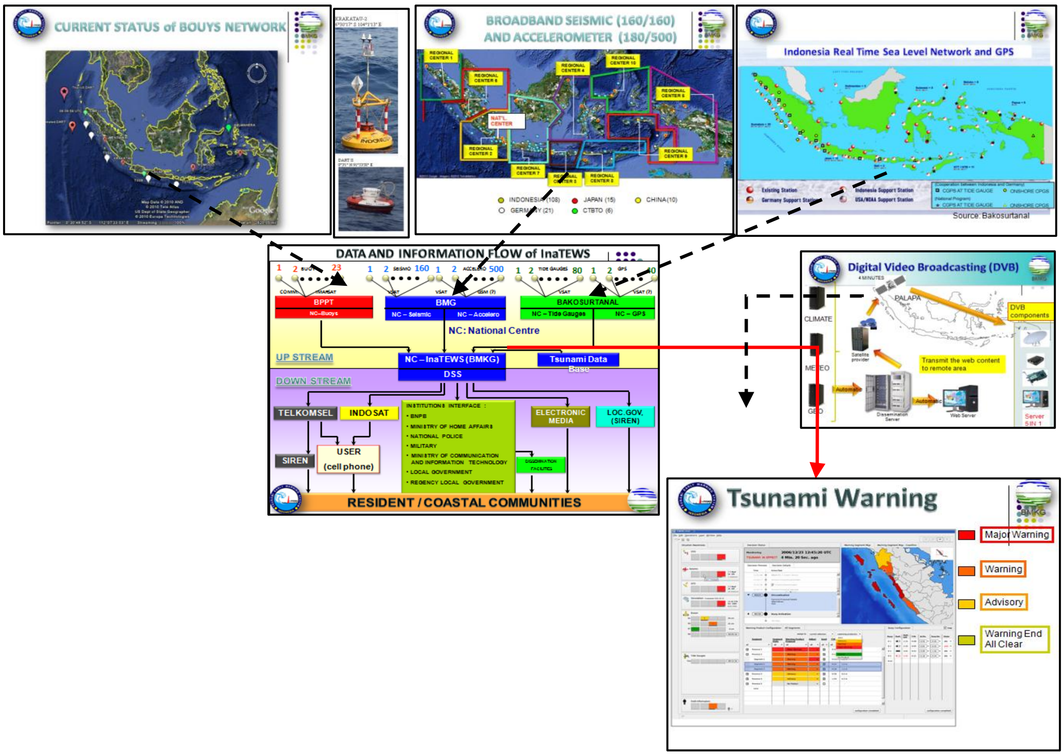


Figure 2.8 Current Status Ina-TEWS by December 2011 (Sources: BMKG 2010)

The current status for the Structure component can be seen in Figure 2.8. It shows the hardware capacity of the system for detecting the seismic parameter using seismometer and accelerometer networks, tsunami phenomena using tsunameter using dart buoy network, GPS and tide gauge network; then analyzing using the DSS and Tsunami Database; followed by dissemination of the tsunami warning to local government (DMO) using multi-mode networks of communication.

The content of warning using the international standard format, i.e. consisting of 4 categories: *major warning* (red color) for expected tsunami height above 3 m, *warning* (orange color) for expected tsunami height between 1-3 m, *advisory* (yellow) for expected tsunami height below 1 m, and *end* or *all clear* (green color) for lifting up the warning sequences. This international standard of warning format and content has become debatable issues during the 2011 Tohoku tsunami among practices and scientist in tsunami early warning system. For the case of mega tsunami, the major warning could be misled the end-user (government officials and the people) since in fact tsunami height could way above 3 m.

While in the Culture component of Ina-TEWS, as also in the case of Japan (Cabinet Office Government of Japan 2011), *the early warning to public is mandated to regional and local government, unless otherwise responsibilities are given to particular agencies by regulations*. This shows a responsibility sharing between national and local government. The national government has developed and deployed the hardware for Structure component, meanwhile the local governments of those tsunami risk cities are expected to provide the supporting infrastructure to convey the warning and for evacuation.

For the first purpose, the supporting infrastructure may vary from high tech such as networks of smart tsunami siren up to local knowledge such as mosque speakers etc. For the evacuation purposes, the infrastructure may vary depending on the city's economic condition, such as from good and sufficient evacuation routes, sign board and vertical shelter up to nothing existed.

During the development stage of the Culture component, several extensive countermeasures of tsunami disaster risk reduction have been promoted and exercised in 7 national show case cities from 2005 to 2008 aiming for increasing the city readiness and its community preparedness of tsunami prone area. These cities, i.e. Padang in West Sumatera, Denpasar in Bali, Cilegon in Banten, Gorontalo and Manado in North Sulawesi, Cilacap in Central Java, Bantul in Yogyakarta and Banda Aceh, are expected to be the role model city for tsunami prone area in Indonesia. Example of implemented disaster risk reduction countermeasures for Culure component can be seen in Figure 2.9.

However, the local governments from other tsunami prone cities were showing their willingness to invest the countermeasures to protect their citizen from tsunami threats. This willingness was addressed on the Declaration of Agreement of City/Regency Governments during the Earth Day in year 2007 (H.P. Rahayu *et al*., 2007; 2008). In the declaration the countermeasures needs for developing Culture components of Ina-TEWS are explicitly extended and written to include 10 mandatory tasks, as shown in Table 2.2.

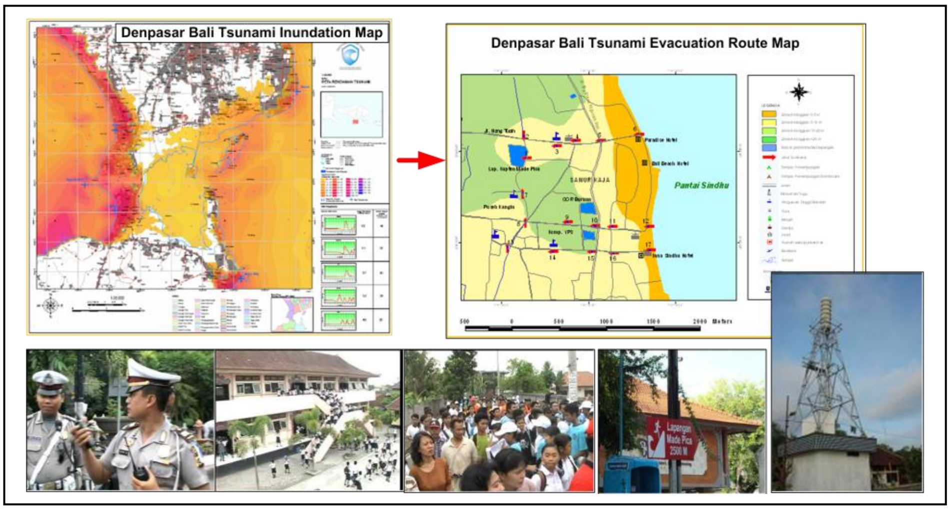


Figure 2.9 Tsunami DRR countermeasures in Denpasar Bali (Sources: H.P. Rahayu 2006)

1. *Secure tsunami detection equipment in their jurisdiction area*
2. *Prepare risk map (inundation map) including standard operating procedure for evacuation*
3. *Prepare tsunami evacuation route and tsunami shelter*
4. *Deploy tsunami evacuation sign boards*
5. *Establish crisis center or command center at city level*
6. *Conduct tsunami drill regularly*
7. *Deploy tsunami warning sirens*
8. *Build or designate tsunami shelter*
9. *Mainstream/integrate the disaster risk reduction countermeasure into spatial planning*
10. *Mainstream/integrate the disaster education into school local curriculum*

Table 2.2 Ten mandatory task of local government for culture component (Sources: H.P. Rahayu 2007; 2008)

In fact, during the exercise at these national show-case cities in the period of 2005 - 2008, most countermeasures implemented have been only focused on the preparation of *end to end tsunami early warning simulation* known also as *full scale tsunami drill*. Such countermeasures included fulfillment of task 2 up to 8. However, as mentioned in Chapter 1 that prior to 2004 Sumatra-Andaman Indian Ocean tsunami there were no existence of tsunami knowledge and low capacity toward tsunami preparedness.

Therefore the countermeasures exercised in those national show case cities was within various range depending on the political will of the local government and its stakeholders to support the national tsunami drill. The most common countermeasures conducted were public education, government and community training, action planning both at city level and neighborhood level, beside by the help from national government jointly with university to prepare scientific based tsunami inundation map, evacuation route map, evacuation sign boards, setting up the *standard operation procedures – SOP* for *emergency operation center - EOC* at *city disaster management office - DMO*.

The aim of the *end to end tsunami early warning simulation* is to test linearly the performance of Ina-TEWS starting from the STRUCTURE component (under authority of Indonesian Tsunami Warning Center as part of BMKG – Agency for Meteorology Climatology and Geophysics) to CULTURE component (under authority of local government), i.e. starting from detecting, obtaining, analyzing and disseminating the information of potential tsunami reaching all targeted people at risk.

This simulation was up-scaled in the regional level. Such simulation conducted to test the performance of the Indonesian Tsunami Warning Center as Tsunami Warning Provider to the region, i.e. at the level of Indian Ocean Region known as *IO-Wave* end-to-end simulation and at the level of ASEAN recognized as *ARDEX*. In addition to that, the role of Culture component in enhancing the goal of Ina-TEWS in saving life has been also socialized to all local government of tsunami prone region through national technical guidelines, local regulations, presidential decree and disaster management law.

However, the chaotic situations were still shown in many cities during the occurrence of several tsunamigenic earthquakes in these past 7 years; as if the existence of tsunami warning system and implementation of disaster risk reduction countermeasures having no effect. These earthquakes occurred in 2005, 2007, 2009 and 2010 actually has generated from minor tsunami at the city of Padang to major tsunami at some cities in the west coast of Sumatera, see also the tsunami warning issued for these event in Figure 2.11.

The readiness of the government officials and responsiveness of the people were tested in real scale. No officials performed their duty during the critical hours after the strong shaking, the city was chaos due to people panic, evacuation not to follow the procedure as exercised in tsunami drill, and only 1 out of 9 tsunami warning siren functioned. Description of real situation during the disaster events to contrast situation during simulation tested are presented in Figure 2.10.

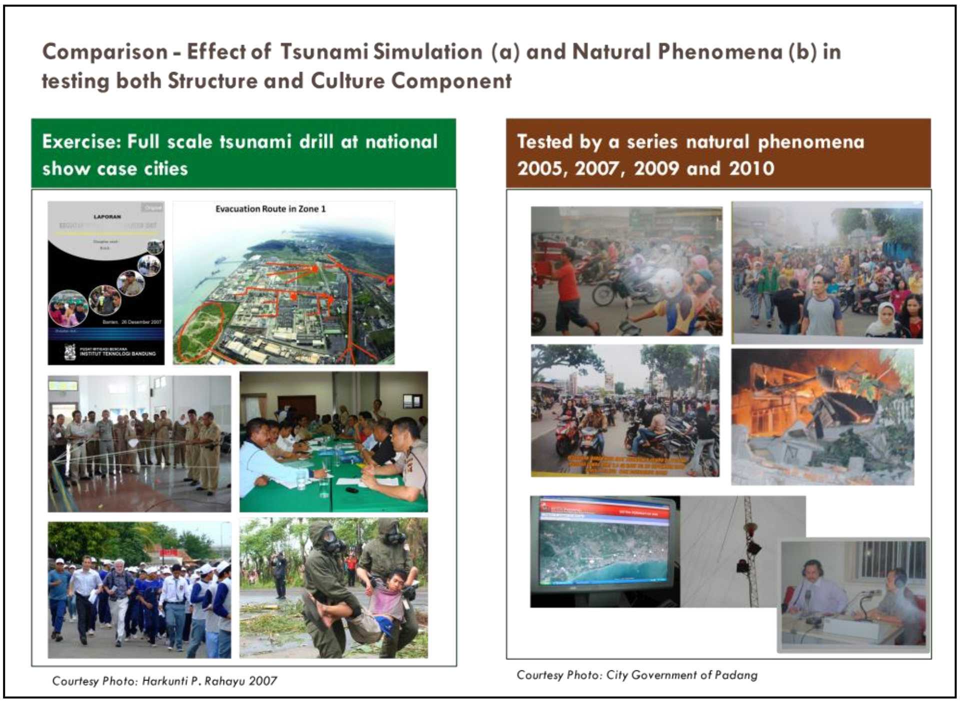


Figure 2.10 Effect of simulation tested and naturally tested in the city of Padang

Meanwhile at the beginning stage of Ina-TEWS development, there were some disadvantages of false warning or malfunction of siren in the City of Banda Aceh (the ground zero of the 20-4 tsunami) which created huge public confusions thus led to big distrust by the public to the system. However, in since 2007 the performance of the hardware or Structure component has been improving.

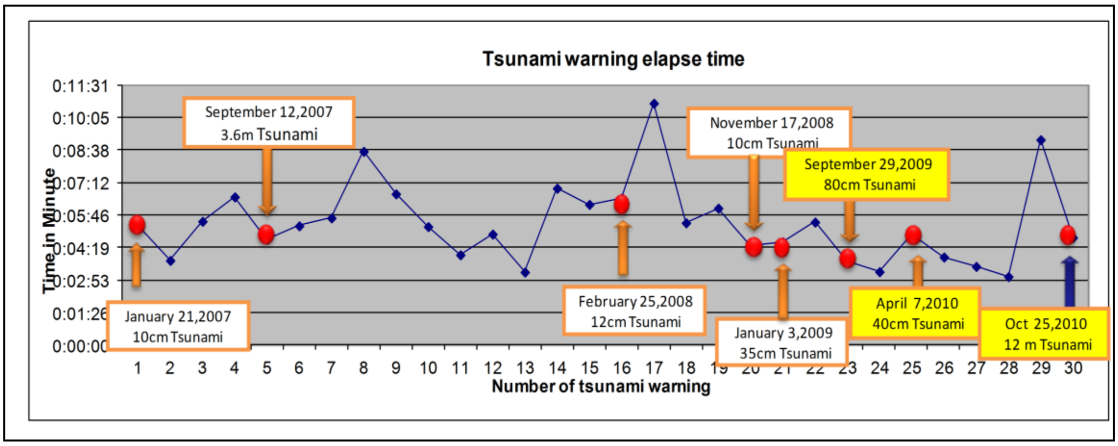


Figure 2.11 Performance of structure component (Sources: BMKG 2010)

To contrast with the performance of Culture component during these natural events the mechanism of issuing the tsunami warning with sufficient lead time was fully performed by Structure component. First warnings have been disseminated to local, media and interface agencies in average about 5 minutes after the main shocks. As recorded the performance of Structure component in these past two years was able to issue the warning within 2’53” to maximum of 10’5” leaving sufficient lead time to the government official to convey the warning as shown by Figure 2.11.

By looking at the current status and the challenges and obstacle found during the 7 years of operation of Ina-TEWS, both effectiveness of tsunami early warning system established and countermeasures intervention conducted for the development of Culture component *has become the research question for this study.* The 3 criteria of effective tsunami early warning system are necessary to be investigated further, i.e. ability and sustainability of the system to disseminate the potential warning accurately with sufficient lead time, readiness of local government and supporting infrastructure to receive and convey the warning to all people at risk by issuing the order for evacuation, and responsiveness of the people to the warning to save their lives (H.P. Rahayu *et al*., 2007; 2008).

2.5 Lesson Learned from 2011 Great Tohoku Tsunami

After 2.5 years of the completion of establishment for tsunami early warning in Indonesia, the 2011 Tohoku tsunami becomes an important wake up call for reviewing the tsunami early warning system in Indonesia. What would be happened if the same magnitude of earthquake and the same intensity of tsunami were occurred again in Indonesia? Were the Structure and Culture component performed and complement as expected? How many people responded to the warning? How many people could be saved? How the performance of the the government officials? Were there any impacts of the disaster countermeasure implemented to save the people? What most appropriate supporting devices for conveying the warning? These questions emerged since the 2011 Tohoku tsunami occurred during the completion stage of this study.

Beyond a deep grief for the victim of 2011 Tohoku tsunami, there are countless valuable lessons from the performance of tsunami early warning system in Japan especially the Culture component of the system as well as the advantage and disadvantage impacts of disaster risk reduction countermeasures intervention to save people that can be learned by this study to enrich the process development to model an effective tsunami early warning system using integrated logic model approach.

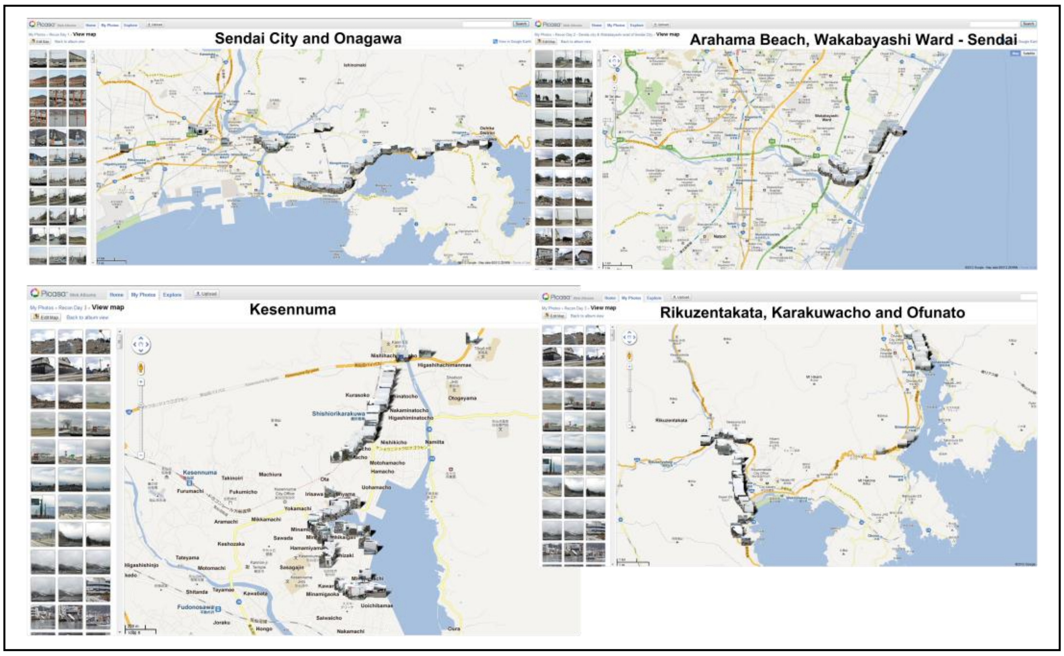


Figure 2.12 Location of reconnaissance survey for Tohoku, April 6-10, 2011

In this section, the discussion on the learning from best practices and lesson from the 2011 Tohoku tsunami focuses on several issues that related to these 3 points of view, i.e. *Tsunami Warning and People Perception*, *Public and Formal Tsunami Education*, *Role of Government*, and *Paradigm Shift in Susceptibility*. The information reviewed for this study were based on brief reconnaissance survey in several affected cities in Miyagi and Iwate prefectures done 3 weeks after the disaster and investigated on line data and secondary data regarding the 2011 Tohoku tsunami, as well as related information on the legacy of Japanese culture in disaster risk reduction countermeasures. Location of reconnaissance survey is shown in Figure 2.12 conducted on April 6 to April 10, 2011.

This covered Sendai City; Onagawa; Wakabayashi Ward included Arahama Beach a coastal residential area; Ishinomaki; Kesennuma a big fishery port, central business district and residential area devastated by tsunami; Karakuwacho used to be a small beautiful coastal town located at the outmost northern area of Miyagi prefecture between Kesennuma and Rikuzentakata with almost all area washed away by tsunami, see also Figure 2.13; Rikuzentakata a relatively big fishing port town badly affected by tsunami; Ofunato another important fishing port having similar situation and condition with Rikuzentakata.

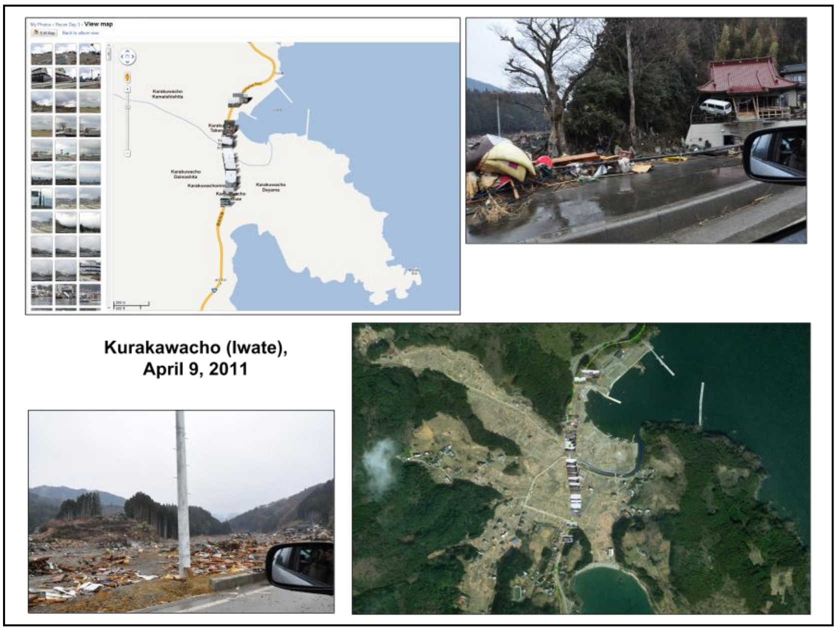


Figure 2.13 Karakuwacho Town, April 9, 2011

2.5.1 Tsunami Warning and People Perception

The 2011 tsunami actually has been a long awaited event which has been used for capacity building for city and people preparedness in the region, where historically this area have been stricken by major tsunami many times. Even though this 9.0 magnitude tsunami was far above the anticipated magnitude of 8.0, still there are many best practices and lesson from the viewpoint of tsunami early warning and appreciation of people that can be learned.

Several valuable and important ones discussed in the next few paragraphs are starting from the success performance of early warning to deal with the near-field tsunami, followed by the good practices of the warning to reach the last miles including the existence of supporting infrastructure for conveying the warning, the controversial debate regarding the needs for reviewing the warning content, up to the positive and negative appreciation of the people to the warning which are influenced by their prior belief. The summary of best practices and important lessons for this area are listed in Table 2.3 below.

<u>Tsunami Warning & People Perception:</u>

1. ***Tsunami warning system Structure component*** **-** ability to issue the warning for near field tsunami in 3 minutes after main shock with sufficient lead time.
2. ***Tsunami warning system Culture component*** **-** Able to reach the last mile by continuous broadcasting via TV, radio, internet/webpage, customized information sharing via community FM, and community self-help in the form of volunteer based firefighting organization.
3. ***Controversy debate on content of major tsunami warning*** **–** the controversy debate among scientist and practice of disaster manager regarding the need to revise the warning as to accommodate if the mega tsunami with tsunami height far above 3 m. Just looking at the warning where estimated tsunami height 3 m and more, the people at risk often *taking wrong decision*, see also *wrongful decision* taken at Kamaishi School
4. ***People appreciation to tsunami warning*** – **s**hown by high number of people responded to the warning and saved, in average about 92.57% of people at risk from saved (EERI Report November 2011).
5. ***People mis-perception to tsunami risk*** – beside due to family/personal reason, some people did not evacuate due to *feel safe mis-perception*, *cognitive biases* (systematic error) on *fatal judgment, undermining the warning content, etc.*
6. ***Short memory of people to disaster*** **–** an analogy can be taken by looking at the public interest and media on the disaster, less than few weeks the interest were declined. For example in Twitter tweets counts on Japanese disaster conducted by some research.

Table 2.3 Identified best practices and lesson from the performance of tsunami warning system

Besides, there is high accomplishment of ability to issue the tsunami warning within 3 minutes after the earthquake's main shock and leaving sufficient lead time for the people at risk to make decision for evacuation. This is the best practices for the countries that are prone to near field tsunami such as Indonesia; the first wave came to the closest cities to the earthquake's epicenter was between 20 to 25 minutes, see also Table 1.2 of Chapter 1. The first updated warning was issued in the following 25 minutes, and continuously broadcasted for about 51 hours 09 minutes until lifted by 17:58 a.m. JST on March 13, 2011. The lifted up warning issued until all the regions of Japan are all clear from this tsunami, where Okinawa was the the farthest one. Figure 2.13 shows the first warning and the all clear warning (lifted up) issued by JMA (http://www.jma.go.jp/jma/en/2011_Earthquake.html).

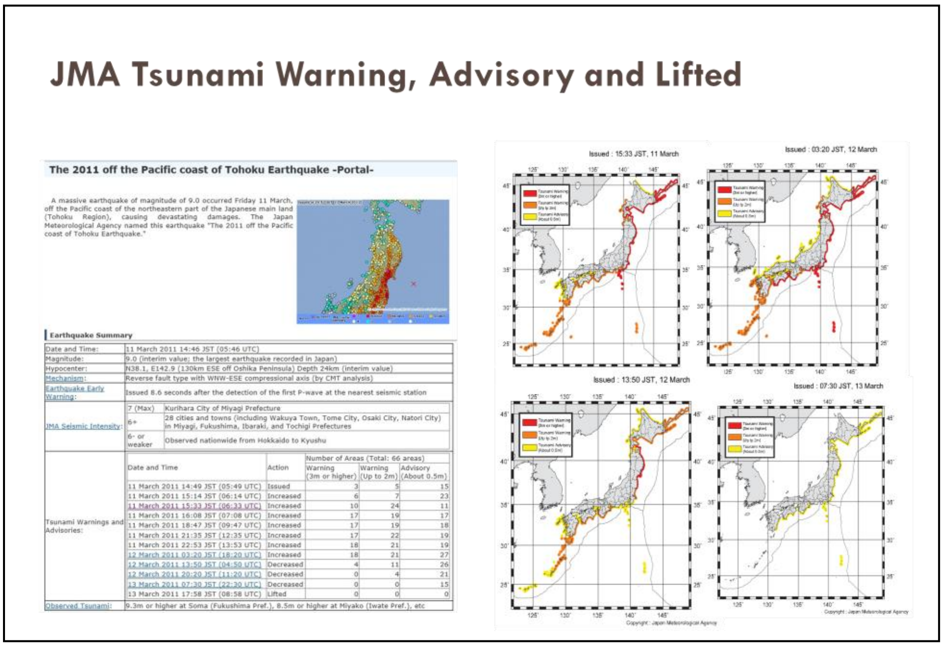


Figure 2.14 Performance of structure component (Sources: BMKG 2010)

Supporting infrastructure used in reaching the people at risk: Meanwhile at the down end of warning system mechanism, what is called Culture component in the Indonesian Early Warning System – Ina TEWS, there are several best practices in reaching the people at risk especially the last mile during the 2011 event. Not only real-time and continuously broadcasted via TV, radio and JMA webpage, but there are also other multi mode dissemination infrastructure used in real time, i.e. J-ALERT by the central government to disseminate real-time warning to all municipalities and conveyed by the City Disaster Management Office (DMO) to the people by wailing the siren and public announcement speaker (PA). Example of J-Alert at Kochi City Disaster Management Office can be seen in Figure 2.15.

In addition to that, there are other best practice of conveying the warning at the grass root level, i.e. the existence of customized information sharing via Community FM, community self-help organization such as *volunteer based firefighting organization*, and spontaneous neighbor, family and friends. The Community FM proved to be very effective to transfer government information to community during the event (Asahi Shimbun).

These kinds of needs for customized information sharing between the affected people and the government is very important and can be elaborate further for *tailored need radio programs*.

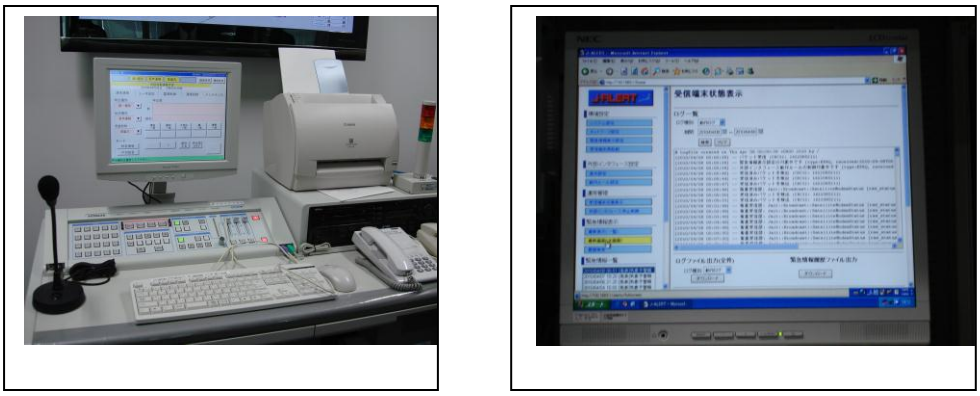


Photo: H.P. Rahayu.

Figure 2.15 J-Alert of Kochi City Disaster Management Office

High appreciation to tsunami warning: However, the people appreciation to tsunami warning was very high, this can be shown by the number of people responded to the warning and saved. In average, about 92.57% of people at risk from the most severe affected cities were saved, i.e. Rikuzentakat, Kesennuma and Minamisanriku see also Table 1.2 of Chapter 1 (EERI Report November 2011). An interviewed based assessment conducted following the 2011 event shows that in average about 49% of people from Iwate, Miyagi and Fukushima Prefectures have heard tsunami early warning that day, but not paying attention to the content of warning message (such as tsunami height), because about 40%-47% people busy with evacuation, 14%-20% people not hearing any warning information from the city Disaster Management Office, around 5%-12% people having electricity cut off, 1%-10% cell phone not functioning, and 3%-10% just being ignorant to the warning (Yamazaki Noburo, 2011 with source: National Fire Agency, JMA and Cabinet Office, Nov 2011).

This high number of 40%-47% people evacuate based on the warning and not paying attention to the detail warning information has argued the controversy debate about the need for revision of tsunami warning content. It was recognized that *tsunami early warning issued promptly, but underestimated tsunami heights at the first warning might have affected people's behavior to make decision for evacuation*. Other interviewed-based assessment on 25 respondent at the affected area presents that a high percentage of people responded to the warning and evacuated (JICA 2011), i.e. 62% people immediate evacuation and 38% not immediately. The reasons for delaying the evacuation were: confirming family members' safety, not consider tsunami higher than dyke, back home cleaning after earthquake, based on experience, and did not consider tsunami at all.

Early warning system is effective when it is properly perceived: Although there was an early warning issued immediately, often people misperception toward tsunami risk occurred. Such as people underestimated the height of the tsunami due to repeated occurrences of earthquakes, then a *feel safe misperception* prevailed. Other than that, the attitude of taking for granted or taking the knowledge blindly of public education or tsunami drill may create cognitive biases (systematic error) leading to fatal judgment. This can be seen at the case of Okawa Elementary School in Ishinomaki, Miyagi Prefecture, where 74 children died or went missing after being caught in the tsunami while evacuating since time has been consumed for the assembled the student as the trained procedure for evacuation, see Figure 2.16.

Other example due to misperception is about wrong judgment taken at school evacuation is at Togura Junior High School in Minami-Sanriku of Iwate Prefecture. The school building actually was designated as one of evacuation shelter in the neighborhood area. However the teacher worried about building damaged due to 9.0 magnitude earthquakes, then students were assembled at the school grounds instead. The tsunami struck while the students were there, one girl died after being caught up in the wave (Asahi Shimbun). It is clear here that during critical situation people need for p*roper perception* to make decision for necessary actions.

Photo: Shinichi Iisuka

Figure 2.16 Okawa Elementary School in Ishinomaki, Miyagi Prefecture in the March 11 tsunami

***Short memory of people to disaster*:** Other important lesson is about the memory of people toward disaster. Even though no formal scientific based assessment has been conducted following the 2011 event, there is popular assessment conducted on the public interest and media on the disaster in time line on Twitter tweets counts on Japanese disaster conducted on Twitter tweets counts on Japanese disaster (source: http://twitter.com/). In less than few days the interest were sharply declined, and re-emerged if there was other issues such as occurrence of strong aftershocks and further damage of Fokushima nuclear power plant etc. Figure 2.17 shows that after a month from the main shocks the euphoria interest of common people were decreased.

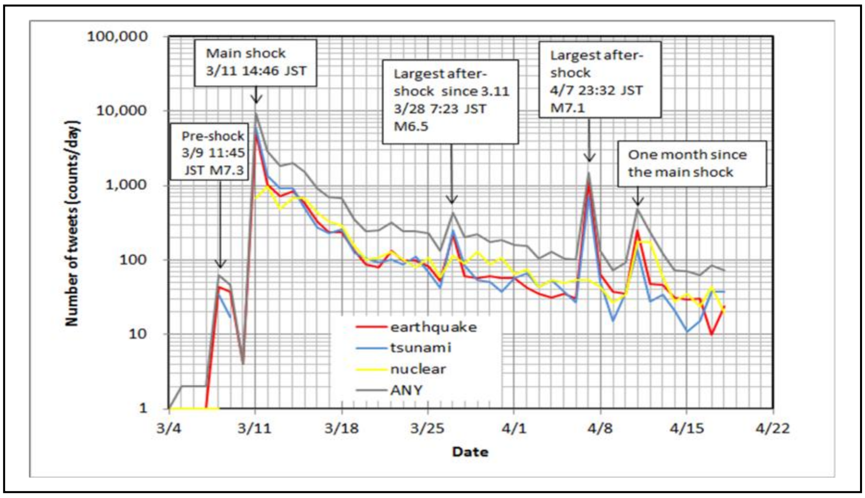


Figure 2.17 Short memory of people toward disaster shown by twitter on interest for 2011 Mega disaster (source: http://twitter.com/)

To summarize, between tsunami early warning and people perception to worse tsunami risk, the root causes of ***controversy debate*** among scientist and disaster manager practices in the scientific forum and/or media regarding the need to revise the warning content as to accommodate the mega tsunami height which is far above 3 m. As admitted by head of JMA Akira Naga, it is difficult to transfer such kind of technical information to general public; therefore as added by Fumihiko Immamura that the scientist numbering warning information is Natural Science, but how to make general public/people reading the number is difficult problem and need more research on social science. This debate was then expanded to the need for socialization to local government and general public to have better understanding about the meaning of height for 3 different tsunami parameters, i.e. estimated tsunami heights as stated in Tsunami Warning, tsunami inundation, and tsunami run up. Tsunami height refers to the gap in sea level raised by tsunami from the normal sea level. Tsunami run-up height is the elevation in which tsunami runs up from waterfront toward inland ranging from as the expected tsunami height released in the warning to maximum around quadruple. For the society equipped with good warning mechanism the people often did not have any idea about the last two parameter of tsunami phenomena, which in fact to be the most affected parameters to their lives. By only relying on the warning with estimated tsunami height 3 m and more, the people at risk will *taking wrong decision*, see also wrongful decision taken at Kamaishi School discussed in the next section.

2.5.2 Public and Formal Tsunami Education

Identified best practices and lesson learned the area of *Public Education* and *Disaster Prevention for Education* are listed in the following Table 2.4.

Mainstreaming disaster risk reduction into both main curriculum and external curriculum are the best practices to increase preparedness, leading to the increased of *prior belief* in risk perception. ***Success impact of regular tsunami drill*** conducted every *Sept 1* in Iwate Prefecture for commemoration of *Great Showa Sanriku Tsunami 1933* is shown by the fact found in Kamaishi city student who were saved almost 99.98% students are saved, i.e 5 student death among a total of 3,000 students (1,927 Elementary School and 999 Junior High School) even though the city was stricken by 10 m tsunami. When the school building started to pitch and sway violently, pupils at Unosumai Elementary School, foreground, join Kamaishi-Higashi Junior High School students started evacuation promptly and voluntarily following their experience of evacuation drill conducted in June 2010 (Asahi Shimbun). Several other areas performed regular disaster drills on *March 3* for the day of 1933 *Great Showa Sanriku Tsunami*, which was just one week before the disaster. See Figure 2.18.

Photo: Toshio Kikuchi

Figure 2.18 Pupils at Unosumai Elementary School, foreground, join Kamaishi-Higashi Junior High School student in an evacuation drill in June 2010 (2nd row).

Public and Formal Tsunami Education :

1. ***Socialization to local government and general public*** - to have better understanding about the meaning of height for different tsunami parameter, i.e. *estimated heights of tsunami* as stated in Tsunami Warning, *tsunami inundation*, and *tsunami run up*; as well as the ***temporal and spatial differences*** showing the sequence of largest wave. In many cases for the society equipped with good warning mechanism having no idea about the last two parameter of tsunami phenomena (tsunami inundation height and tsunami run up) which was actually the one that affected their lives.
2. ***Disaster Prevention for Education –*** the best practices shown in mainstreaming disaster risk reduction into both main curriculum and external curriculum to increase preparedness, leading to the increased of *prior belief* in risk perception, to contrast with *fatal judgment* due to *cognitive bias,* that will be worthwhile to make the best of tsunami education.
3. ***Intensive public education and drill -*** seemed very effective to save many people, many positive impacts of tsunami drill done to save their live (good story from evacuee). In contrary, many elderly used to be the most active participants for the drill and town watching activities were the one who washed away.
4. ***Advantage and disadvantage of simultaneously broadcasted video footage on Mega tsunami to the public –*** able to increase *prior belief* leading to the increase of tsunami risk knowledge and risk perception of the people of Japan and around the globe, in the other hand a *psychological effect* called the *anchoring heuristic* will influence the people mind to underestimate the unsafe level of tsunami height. As found that by the 2010 Chilean tsunami, roughly *70 percent* identified that a *10-foot (3.05 m)* tsunami is a hazard with *60 percent* willing to *evacuate* in the event, but after the 2011 Tohoku disaster only *45 percent* of respondents realized that a 10-foot tsunami was unsafe with only *31 percent* willing to evacuate (Satako, 2011).
5. ***Local Wisdom from ancient era*** – among uncountable local wisdom on disaster risk reduction countermeasures have saved many people during the 2011 Tohuku tsunami, i.e. local culture of "tendenco" saved many people's lives**,** *memorial stone marker* as crude tsunami warning system from the ancient has saved *some* people lives in many places in Tohoku area, the culture of Dissemination of information to future generations through *storytelling* to the school children from the old people, and the legend of Inamura (rice sheaves) has been legacy on for the countermeasures of prevention for tsunami disaster. Not to mention ***local wisdom on infrastructure measures*** from ancient, i.e. the construction of dyke an many region in Tohoku region, man-made hill in Kamogawa city, and vegetative buffer zone in Kamaishi after 1611

Table 2.4 Identified best practices and lesson from public and formal tsunami education

Beyond the controversy of many tsunami-hit schools found to have inadequate evacuation school action plan, there were a great number of school children were saved due to taking right decision to evacuate. From the tsunami stricken school, about 40 % of 56 elementary and junior high schools did not specify evacuation areas in their school disaster-prevention manuals, about 21 tsunami-damaged schools failed to provide adequate information on evacuation destinations, while 11 had their students remain in the school buildings after the earthquake (Asahi Shimbun on line, downloaded November 29, 2011).

Some example of right decision taken based on prior belief formed by trained experiences are shown by students in Kamaishi saved because of learning from a Gunma University Professor who advising the students to keep on evacuating higher and higher without stopping whenever hearing tsunami warning and/or wailed siren. An example of deadly decision but saving student lives showing by a decision straying from evacuation procedures shown when a section of Otsuchi Elementary School in Otsuchi Iwate Prefecture destroyed by fire following the strong earthquake, a teacher was bravely to lead the student to evacuate through undesignated routes and places.

This shows best lesson on the ability to take *sound judgment* based on intuition and/or knowledge in any emergency situation by that will be worthwhile to make the best of tsunami education; to contrast with the *fatal judgment* due to *cognitive bias* formed by systematic error shown by disaster wrong decision taken in Togura Junior High School in Minami-Sanriku Iwate Prefecture discussed in previous section. Other than that, there is strong need to review the School Disaster Prevention Manuals (Asahi Shimbun) based on the survey conducted during July to August for investigation on education boards, where only 66 education boards from 47 prefectures and 19 *seirei-shitei-toshi* cities (a government-ordinance-designated cities with population of 500,000 or more) participated. The 2011 event has prompted these education boards to put priority for tsunami as disasters to prepare for.

Vast majority of education boards currently review school manuals on *crisis management manuals* and *disaster preparedness education*. About *90 %* officials consider *building students' abilities to make sound judgments on their own in emergency situations*, since many student swept away by tsunami because *too much time elapsed in the process of trying to evacuate them*. Hence, the education board encourage that, *schools should put priority on making sure students flee immediately to evacuation areas, when an earthquake with an intensity level of 5 or higher on the*

Japanese scale of 7 occurs, not assembling in schoolyards and calling out a list of names. The education boards of some prefectures with long coastlines (Wakayama, Toyama, Kagawa, Oita and Miyazaki) have *strengthened the crisis management manuals to deal with tsunami*, meanwhile Aichi Prefecture plan *to strengthen their disaster preparedness education so that children can judge and act appropriately under any circumstances*.

Intensive public education and drill seemed very effective to save many people. Many positive impacts of tsunami drill done to save their live (good story from evacuee). In contrary, many elderly used to be the most active participants for the drill and town watching activities were the one who washed away (A. Muhari, 2011). ***Advantage and disadvantage of simultaneously broadcasted video footage on Mega tsunami to the public*** – is a good public education tool to increase *prior belief* leading to the increase of tsunami risk awareness, knowledge and perception of the people of Japan and around the globe. In the other hand, a *psychological effect* called the *anchoring heuristic* will influence the people mind to underestimate the unsafe level of tsunami height. As found that by the 2010 Chilean tsunami, roughly *70 percent* identified that a *10-foot (3.05 m)* tsunami is a hazard with *60 percent* willing to *evacuate* in the event, but after the 2011 Tohoku disaster only *45 percent* of respondents realized that a 10-foot tsunami was unsafe with only *31 percent* willing to evacuate (Satako, 2011).

Local Wisdom from ancient era, there are uncountable local wisdom on disaster risk reduction countermeasures have saved many people during the 2011 Tohuku tsunami. First is the local culture of ***tendenco*** have saved many lives, which actually emerged after 1896 major earthquake and tsunami where many people wanted to look for their family and neighbors after the tsunami. The deep meaning of this culture is built on the *mutual trust*; people were taught to be evacuated with the trust and belief that their family members will also take proper shelter. Other best practice of local wisdom is that a crude tsunami warning system from the ancient was proven saving lives, i.e. dundreds of memorial stone marker from the ancient marked the Japan coast line. Collectively these stone markers form a basic tsunami warning system for Japan. Some stone marker came from 600 year ago, see Figure 2.19.

Others just simply showed the evidence of past tsunami; reminding people *not to build any housing below the marker*, or just showing daily reminder such as *if an earthquake come beware of tsunami*. However, many facts show that many people have forgotten these local wisdoms, for example one memorial stone marker in Kessenuma mentions that *always to be prepared for unexpected tsunamis; the prioritize lives over your possession and valuables*. Some people follow advice, but many just went back to save valuables after shakings stop, then they were washed away by tsunami.

Dissemination of information to future generations, in several areas frequently hit by tsunami, the dissemination of past experiences conducted through *storytelling* to the school children from the old people, which is considered as an important educational tool. Last but not least, the legend of ***Inamura*** - rice sheaves (Cabinet Office – Disaster Prevention Group) has been the legacy on for the countermeasures of prevention for tsunami disaster. Not to mention ***local wisdom on infrastructure measures*** from ancient, i.e. the construction of dyke an many region in Tohoku region, man-made hill in Kamogawa city, and vegetative buffer zone in Kamaishi after 1611 Keicho tsunami. Most judgment for evacuation was based on prior belief formed by *trained experiences*, i.e. training.

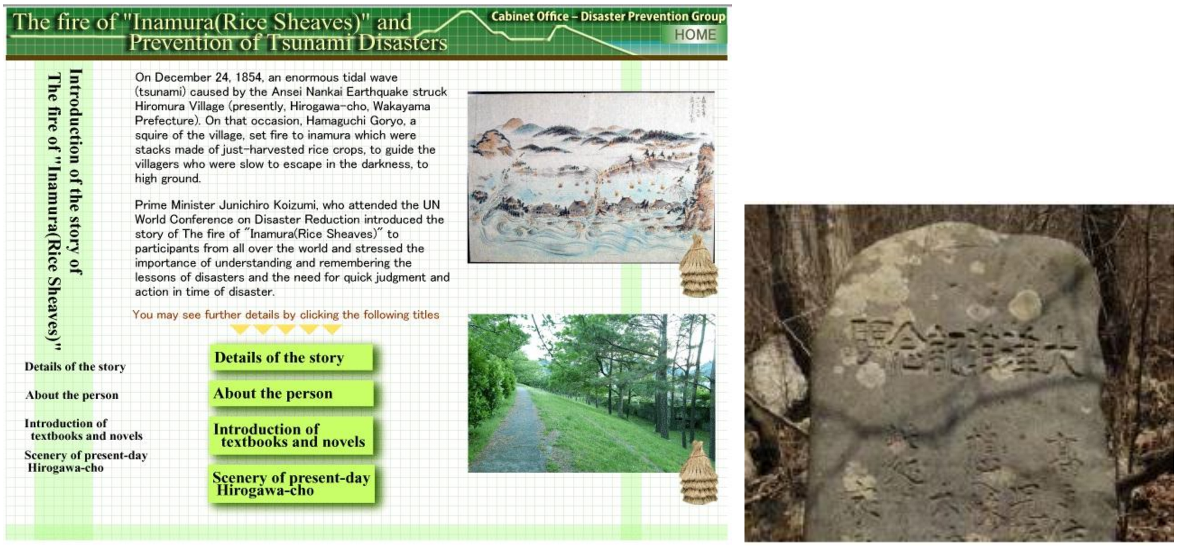


Figure 2.19 Example local wisdom and ancient era

2.5.3 Role of Government and Paradigm Shift in Susceptibility

The ***strong role of many local governments***, i.e. *City Disaster Management Office,* in conveying the tsunami warning to save people by non-stop wailing sirens and public announcement speaker (PA) to order people for evacuation, seems very effective. A heroine of tsunami early warning, Ms. Miki Endo of Minamisanriku City Disaster Management Office, becomes legacy in this area of tsunami early warning. Figure 2.20 shows the condition of Minamisanriku City Disaster Management Office at before and after tsunami stricken (sources: website of Minamisanriku City). Other valuable lesson learned is a shifting paradigm for the composition of vulnerable group of people at risk. Common composition prior to 2011 tsunami, it consists of 4 groups, i.e. children below 15 years old, elderly above 60 years, women and difabel (people with different ability).

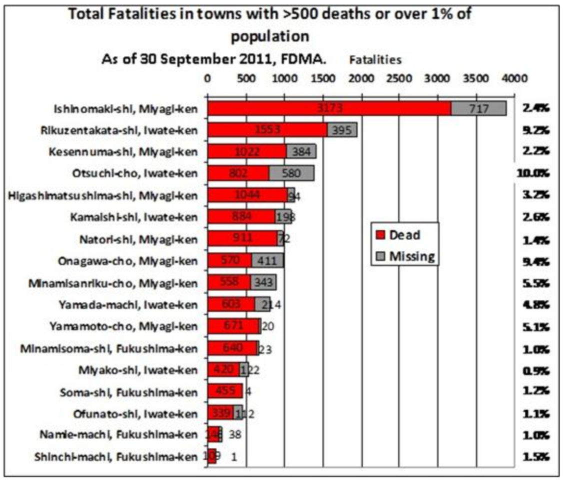
<u>Role of Government and Paradigm Shift in Susceptibility :</u>

1. ***National Government's first response on day one*** **-** very quick as tsunami warning simultaneously transmitted to municipalities using **J-ALERT** within 3 minutes and Emergency Disaster Response Headquarters established within 28 minutes after the earthquake.
2. ***Role of local government*** – government officials responsibility shown by the tsunami heroine from Minamisanriku City Disaster Management Office who becomes the legacy in disaster management best practice, i.e. Ms. Miki Endo
3. ***Paradigm shift in demographic susceptibility (vulnerable target group)*** **-** The 2011 Tohoku tsunami the biggest portion of fatality was the elderly, i.e. total for elderly 60 year old and above was 65% and the children below 20 years old was the smallest about 6%. The most vulnerable target group elderly and working class age, due to some physical and responsibility reasons; while exclusion of *school children* from vulnerable group is as the good impacts of mainstreaming tsunami education into school curriculum and program.
4. ***Location of critical facilities and evacuation shelter*** - public facilities such as the nursing hospital in underestimated inundated area, causing elderly become the most severe victims; over 1001 designated evacuation site was hit by tsunami and several inundation maps were underestimated (Asahi Shimbun).

Table 2.5 Identified best practices and lesson on role of government and paradigm shift in susceptibility

Figure 2.20 Minamisanriku Disaster Management Office before and after 2011 Tohoku Tsunami (Source: Minamisanriku City)

Such the case of 2004 Sumatera tsunami, the highest victim were children below 20, with approximately 43% in West Aceh District – Indonesia and 44.6% in Ampara District – Srilanka. To compare, the impact of 2011 Tohoku tsunami on the 3 most affected prefectures, the victim from children below 20 years was 6.0%; meanwhile the biggest number of fatalities was elderly above 65 years old with contribution about 65%, followed by working age people, see also Figure 2.21 and 2.22 below.



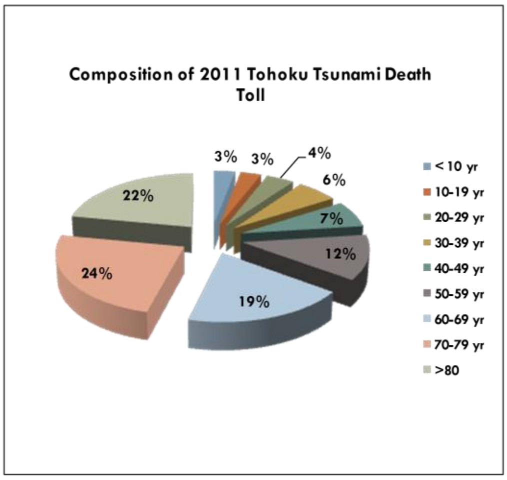


Figure 2.21 Fatalities by cities over 1% population, http://earthquake-report.com/2011/10/ 02/japan-tohoku-earthquake-and-tsunami-catdat-41-report-october-2-2011/

Figure 2.22 Composition of fatalities by group (Sources: Prime Ministry and Cabinet Office http://www.kantei.go.jp/foreign/incident/index.html)

Other critical issues associated with city land use planning, many critical facilities, i.e. school, and nursing hospital for elderly are located in the inundation area and very close to shore line. Even though with the best structural countermeasures with multi stories building, the elderly and school children are commonly to be as the most vulnerable one during any disaster situation. Not only that many multi stories nursing hospital for elderly located in high tsunami risk zone were designated as the vertical tsunami shelter were badly inundated. The underestimate tsunami risk scenario for the development plan has made a lot of misjudgment in emergency response management. Example of susceptible conditions found in Arahama beach of Wakabayashi Ward – Sendai shown the Figure 2.23 taken during the survey.

Figure 2.23 Example of susceptibility: Critical land use planning for critical facilities

Other facts shown by many elderly did not leave the house for evacuation even though there was sufficient elapsed time for evacuation. This was contrasted with their active involvement in many tsunami educations and tsunami drill, not to mention their own direct experience to tsunami occurred in the past. Figure 2.24 shows the study on the distribution of deaths vs. density of population at risk based on the residential address, the highest evacuee population and the highest number of fatalities are from shore-lines area, where the biggest proportion of fatalities are elderly followed by working age group shown by yellow color. Only small number of children under 14 years old shown by green color have affected by the tsunami.

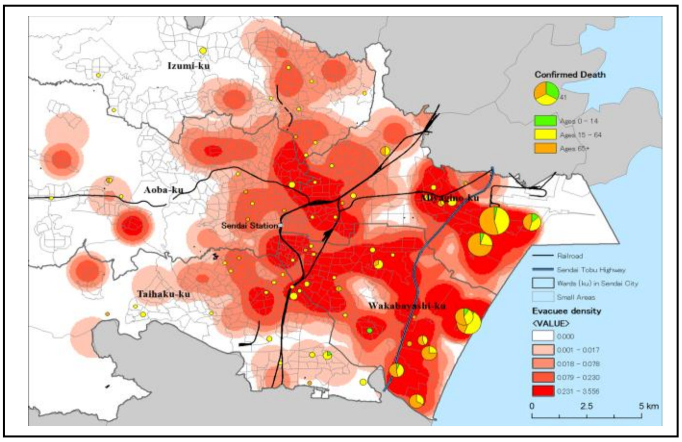


Figure 2.24 Distribution of deaths and densities of evacuees at their residential address in Sendai City (Isoda, 2011)

2.6 Summary

As the old Japanese counsel says "a disaster strikes when it is forgotten", which emphasizes on three messages, i.e. an unimaginably long recurrence period of hazard, a hazard may become a disaster if people are not prepared for it, and forget. Learning from best practices and its failure from 2011 Tohoku tsunami to review the existence of Ina-TEWS and to solve foreseen and unforeseen problem of enhancing effective tsunami early warning could make a better prepare for tsunami.

Based on the in depth review of the disaster trend in Indonesia, it challenges for tsunami early warning system, the state of the art effective tsunami early warning system in the international appreciation, the current status of tsunami early warning system in Indonesia by 2011 as well as its hindrance factors and problem, and the valuable lesson and best practices learned from 2011 event, this study recognize that a necessity to put people not as the object but as the subject positioned in the center of tsunami early warning system, not at the front or the top nor at back or the bottom.

Here it does not meant physically positioned in the center, but it is more to put the people as the main focus to be recognize their needs, understanding and capacity in developing the effective tsunami early warning system. The people under this study are not only the general public who is the end user and the one who need to know their ability to perceive, their understanding about the warning and their right to know the right things. The people also include the government officials, and other stakeholders of the system. It is a very complex issue to model, as previous mentioned in Chapter 1 that logic model is the most reliable approach to portray the problem, which will be discussed in the next chapter.

Chapter 3
Problem Structuring and Model Development

3.1 Introduction

As discussed in Chapter 2, the tsunami warning system is a complex and dynamic area. Some school of thoughts has attempted to improve the practice of the natural hazard warning system (including tsunami) from some angles. Majority of scholar in this area viewed the warning system as a *high-techno center* which emphasizing more on the technology capability to issue the warning with high accuracy and real time. Some attempted to introduce both *off- and near-shore sensors* used simultaneously to build an *efficient TEWS* especially for near field tsunami (L.K. Comfort *et al*., 2011, G. Bellotti *et al*., 2009). Others have viewed the system from *people center* with expected easy access to the information and good preparedness own by the people at risk, such as proposed by PPEWC – UNISDR (PERI, 2006; F. Thomalla, 2009; F. Thomalla *et al.*, 2008). Moreover UN-Secretary General encourage for a broader context of global multi-hazard EWS in the world (UN-SG, 2006).

In other perspective, some conceived the system as a top down, simple and linear warning chain (J.H. Sorensen, 2000), from central government to the people. Some considered as bottom up approach, emphasizing involvement of community to identify needs, patterns of vulnerability and to develop the legitimacy. However, this community based early warning system commonly work for slow-onset hazard (flood) not for sudden-onset hazard (tsunami), unless supported at higher levels by appropriate scientific and analytical capacity and policy frameworks; or unless it was cultivated in subculture of people at risk, such as in the case of Nishiki Town at Mie Prefecture which have strong *disaster cultivated subculture* and *mutual trust* in strengthening local tsunami warning system (M. Takahashi *et al.,* 2008).

From the Structure component, the current success of Ina-TEWS as a technology is shown by its ability in issuing tsunami warning within 5 minutes. However, its outcome is measured socially to the extent for preventing and/or reducing damage to lives and property. Ina-TEWS therefore adopts both structural focused on high-techno center and cultural approaches focused on government and people at risk.

After three years of development and another 3 years of establishment, the challenges of tsunami early warning system in Indonesia, and lesson from 2011 Tohoku tsunami; this study believes that there should be a *shifting paradigm* in *viewing the practice of tsunami early warning system*. The system should be viewed as a multi facet, complex and dynamic phenomena. There is no dichotomy of viewing the system; both component, i.e. structure and culture, are equally significant for tsunami prone cities especially for anticipating the short travel time of near-field tsunami. However, several external factors related with the physical and socio-economic susceptibility have significantly affected the performance of the two components during 2005, 2007, 2009 and 2010 events in the case study city.

Thus, this study attempts to describe these problem issues by defining the system to be effective should be as an integration of natural, socio, technical and physical phenomena, aiming to save *people at risk* by alerting them with sufficient lead time to make decision for evacuation.

Common practice of policy development in disaster management area assumes that solving the problems are purely objective oriented conditions obtained by determining the facts in a given case. This naive view often fails to recognize that the same facts may be interpreted in different ways by different stakeholders. This leads to the thought of structuring problem as a critical stage in recognizing problem issues before providing problem solution, since a policy solution is the output of problem solving which depends on proficiency/capability of problem structuring (W.M. Dunn, 2008).

Therefore to recognize holistically the problem issues of *effective tsunami early warning system*, this study introduces the use of logic model approach for acquiring and structuring the problem associated with the natural, socio, technical and physical phenomena. The advantage of this model is able to capture in-depth mindset of people toward some issues, and mindset of multi-level stakeholders with multi-disciplinary approach and a wide range of human being capacity and capability in perceiving tsunami threat, tsunami warning, coping ability, and appreciation to the government and/or other stakeholders.

3.2 Method Description

Initially logic model is defined as a systematic visual knowledge representation of people mind to resources they have, activities they plan, and outcome they expect (S. Nasu, 2007). Currently, there is a wide range of logic model methodologies used to acquire and represent the people mind. Some scholar has worked on an interview based cognitive mapping to develop the logic model. Others assumed logic model as an application of problem structuring method based on interview surveys and cognitive maps among identified stakeholders (H. Kato *et al.*, 2007).

According to R. M. Kitchin (1994), cognitive mapping is a process composed of a series of psychological transformations by which an individual acquires, stores, recalls, and decodes information about the relative locations and attributes of the phenomena in his everyday spatial environment. General belief sees that cognitive mapping explaining and leading not only to the understanding of spatial behavior, but cognitive map is a mental building which is explicit, analogical, metaphorical or hypothetical that actually influences behavior. It shows a strong correlation between mind of people and physical and non-physical environment surrounding the human being that influences the decision to act or behave.

Some other scholar assumed the knowledge representation can be structured by using *physically based logic model - PBLM*; where knowledge acquisition is based only on physical data/information and no interview involved (S. Nasu (2011), personal communication). Most of works on logic model have emphasized the interviewed based survey, which is followed by questionnaire based survey (T. Kariya and S. Nasu, 2009; T. Kariya, 2008). Here, the information obtained for structuring the problem issues are purely based from the thought, knowledge and/or perception of people being interviewed with regard to some issues and/or willingness. Thus this study sees current trend of logic model as *a new theory of problem structuring method which is based on interview surveys and/or cognitive maps.*

However for structuring problem of the effective tsunami early warning system characterized by multi facet, complex and dynamic phenomena; two types of logic model method are introduced and used in this study. These are Physically Based Logic Model – PBLM and Tacit Knowledge Based Logic Model – TKBLM. The

PBLM is a non-interviewed based knowledge mapping. The method of *PBLM* is used in this study to acquire and structure the correlation of physical events/phenomena based on the up-to-date secondary data directly obtained from related institution and reconnaissance survey conducted after September 30, 2009 devastated earthquake.

Meanwhile the TKBLM is a modification of common logic model with the use of tacit knowledge in structuring the problem issues. The method of *TKBLM* is a cognitive mapping methodology to acquire and structure the people's mind in responding (heuristic judgment) to tsunami early warning system by the use of the tacit knowledge based on prior knowledge, social and physical influence, and access to information and appreciation to the warning system. Prior knowledge is the human perception toward tsunami disaster risk which is formed by previous direct experience and/or *trained experience*, for example tsunami drill. Meanwhile the heuristic judgment is an experience-based decision making for evacuation. Detailed methodology of these two logic model in structuring problem are presented in Figure 3.1 and 3.2.

The two figures present overall view of research methodology developed by this study:

First is to recognize problem situation.

Through in-depth investigation at both components of the system, i.e. Structure and Culture, and the performance of both component during the 2005, 2007, 2009 and 1010 events; exhaustive problem issues were identified. This was followed by examining any related susceptibility, capacity and resiliency factors that hindered and supported the performance of both components during those events. It was found that not only Culture component not yet fully developed, but also no existence of such model/standard and no thorough approach to recognize problem issues exhaustively.

Second is problem structuring and logic model development.

To describe the phenomena of effective tsunami early warning system which integrate natural, socio, technical and physical aspects; an integrated logic model has been developed by this study consisting of integrated 4 layer model and 1 floating model. The first two layers and floating model were developed using PBLM, while the remaining two are based on TKBLM. To bridge the limitation of TKBLM, i.e. missing and/or unforeseen information, two further approaches used at this stage of the study, i.e. improvement of information acquisition and using Principal Component Analysis to keep all factors instead of eliminating them.

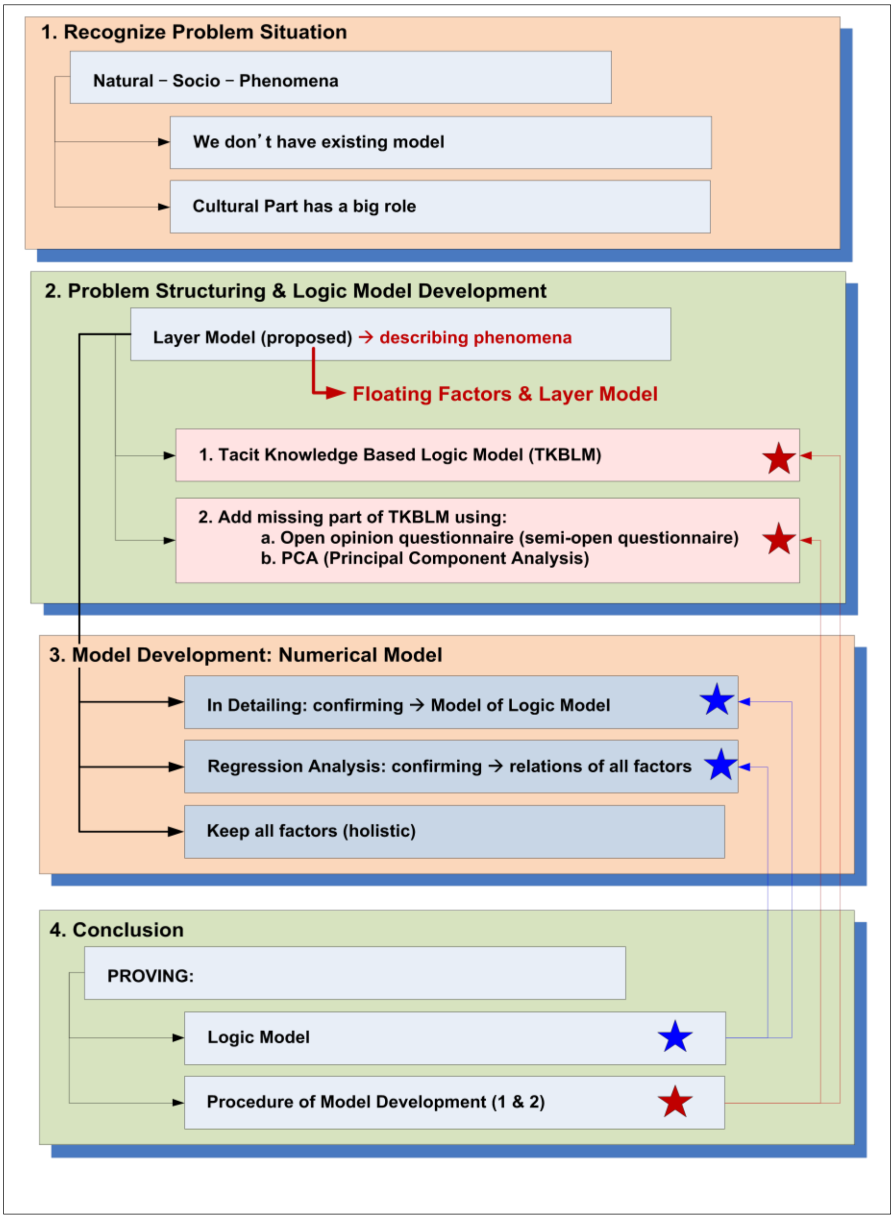


Figure 3.1 Research Methodology

The *first improvement* is to introduce the use of *semi-open questionnaire based interview survey*, which is used for logic model's knowledge acquisition. The advantage of this improvement is the ability to explore more in-depth and comprehensive all supporting and hindrance factors including the unforeseen ones, which may be indelible in the people mind. In addition to that, it has more certainty in obtaining the target amount of data and information from the interviewee compare to the questionnaire circulated by mail, but it is more time consuming if a large data set required. This is because it needs to interview people on one to one basis. Based on this data obtained, the cognitive mapping can be performed. There are two stages of interview based survey to structure the problem issue using the TKBLM. Details of data acquisitions are discussed in the next section.

Second improvement is to keep the model set holistic, the numerical modeling of TKBLM is done by adapting the *Principal Component Analysis – **PCA*** approach with no elimination or reduction for the least contributor factors as commonly done by standard approach of PCA's regression analysis. The PCA is used not only to structure and analyze the numerical correlation of all observed factors among the members component of each level/cluster, but also to uncover the unobservable factors.

Third is numerical model development.

Detailing in structuring problem is confirming the ability of the two logic model approaches used to model the phenomena of effective tsunami early warning system. While the use of regression of PCA is conforming the relationship among all recognized factors and/or variables. Then using PCA in keeping all variables and/or factors is conforming for modeling a complete and holistic phenomenon, however small the contribution in the relation among the variables and/or phenomena as entity they are still significant to be recognized in the map. As it has been discussed in that the characteristic of the effective TEWS phenomena is dynamic and multifaceted. Thus the smallest contributor to perception of people minds to make decision for evacuation for example, may change in the future.

Fourth are the findings of this study.

Findings of this study are not only the two new methodologies as also discussed above sections, i.e. first methodology in modeling the phenomena of tsunami early warning system in the form of Integrated Logic Model using combination of PBLM and TKBLM approaches and second methodology in knowledge acquisition, mapping and numerical analysis of people's mind using TKBLM approach. The findings of the study also include six output models developed; see also Figure 1.8 Research Framework of this study.

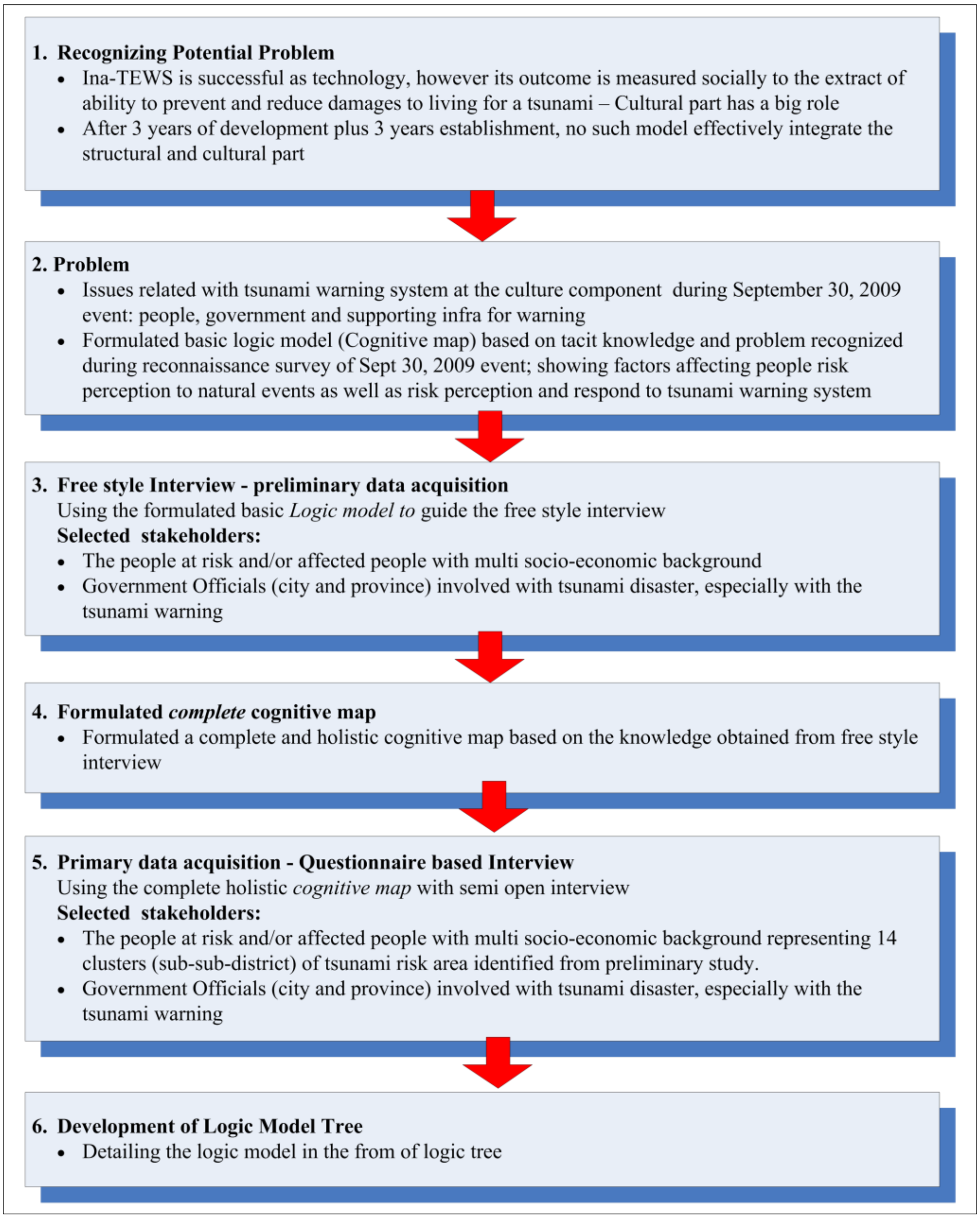


Figure 3.2 Methodologies for Problem Structuring

By limiting the focus of the study on the roles of Indonesian Tsunami Early Warning System only as a National Tsunami Warning Center – NTWC and not to include its role as Regional Tsunami Watch Provider - RTWP, then the practice, policy, facts, potential risk and other factors associated with the issues of why the warning not effective during the 2005, 2007, 2009 and 2010 event in the case study area and what the criteria of effectiveness and/or ineffectiveness are recognized and structured based on national and local context. The five stages of process of structuring and restructuring the problem starting from recognizing, acquiring, mapping, reacquiring and improve mapping are summarized in detail by Figure 3.2.

3.3 Case Study City

3.3.1 Rationale for Selection

To accomplish the rationale and objectives of this research study, Padang is selected as the case study city among those six national show case cities for tsunami preparedness (Figure 3.3).

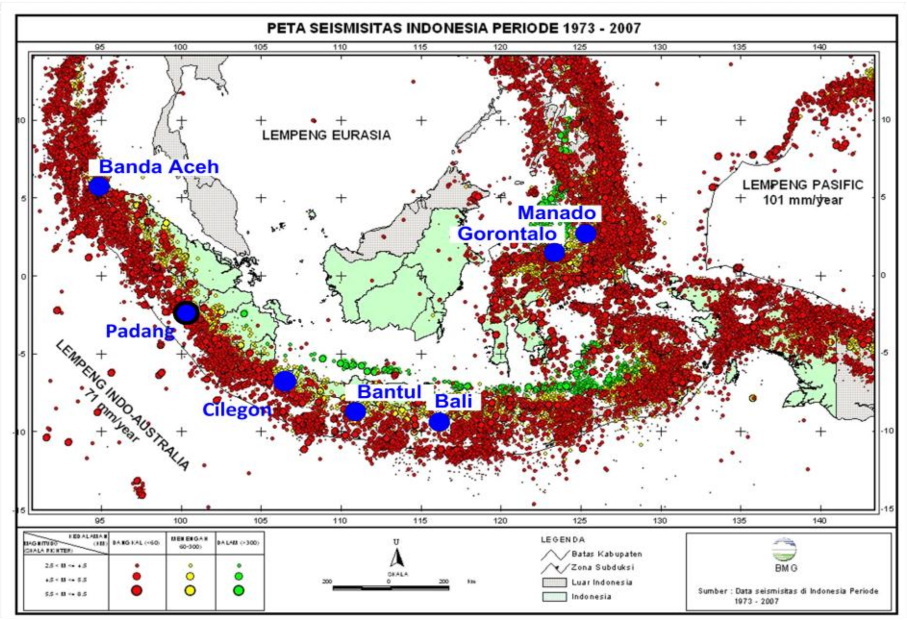


Figure 3.3 Location of Case Study City among National Show-Case City in the Map of Indonesian Seismicity 1973-2010 (Courtesy of BMKG 2007)

They are Padang-West Sumatera, Denpasar-Bali, Cilegon-Banten, Banda Aceh, Bantul-Yogyakarta, Gorontalo and Manado in Sulawesi. These cities has been chosen to host the national end-to-end tsunami simulation (full scale tsunami drill for city level) as part of 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. However, Padang city is selected because of fulfillment of further selection criteria, i.e. level of tsunami hazard/threat, susceptibility and countermeasures implemented either by their own local government and/or external stakeholders such as national and international community. Figure 3.3 shows location of the Padang as case study city among the national show case cities in Indonesian seismicity map.

3.3.2 Profile of the City of Padang and Susceptibility

Profile of tsunami hazard of Padang City are presented in this section, followed by the discussion on the level of susceptibility including capacity, coping ability and the disaster risk reduction countermeasures intervention.

a. Geographical Situation

Figure 3.4 Administrative Boundary of Padang City (Sources: BNPB 2012, photo: H. Latief, 2007)

Padang City is the capital of West Sumatera Provinces and the fastest growth city at the west coast of Sumatera - outer west of Indonesian archipelago. The administrative area is about 694.96 Km^2, where 21.51% of area (149.50 Km^2) is below 25 m. Most of central business districts – CBDs and densely populated area are located in this low land area along the ocean coastline area. Administratively, it consists of 11 sub-districts with 104 sub-sub-districts (village level), see Figure 3.4.

b. Socio-economic vulnerability

Padang is a melting pot city, people from several different ethnic group background come from surrounding, i.e. Solok, Padang Pariaman, and Pesisir. The Padang people are known as religious people with high respect on the norm and custom value. The religious ethnic factor seems to be the strong capacity factors to anticipate and respond to disaster threat such as tsunami; however this could also be antithesis unless the public education and public awareness dissemination handled carefully.

In disaster situation, different ethnic group may not respond similarly to disaster threat, warning or sign depending on its historical experience and the cultural traits. As studied by J.C. Gaillard *et al.* (2008) on the correlation between ethnicity and experience to tsunami and the disaster subculture, it shows that the ethnic of Simeuleu which had historical experience to tsunami and made the disaster issues into subculture were 99.99% saved. Others ethnic who had experiences but not taking disaster as subculture have made wrong decision, washed away by tsunami while collecting fishes at the beach. The biggest lost were found at the people living in the urban area such as Banda Aceh who has no experience and no disaster subculture. With several experiences to historical major and even mega tsunami in Padang and/or West Sumatera region see Tsunami catalog (H. Latief, 2005); a disaster subculture is expected to be there leading to a sound existence of public awareness and preparedness.

However by looking at the behavior of Padang City people in responding the event of 2005, 2007, 2009 and 2010 earthquakes, this thought becomes one of several major questions to this study. Although causing only minor tsunami at Padang City, it seemed there was no awareness and no preparedness have been implemented. Is there any correlation between experience and the prior belief (disaster subculture) and the reaction of the people?

Other socio-economic vulnerabilities are represented by several classical demographic vulnerability factors such as, i.e. population density per sub-district, total number of children below 15 year old, elderly with age above 60 years old and women. Figure 3.4 shows that the bigest portion of population is about 58% of school children between 6 to 19 year old. Other vulnerable group is about 8% of infant < 5 year, and

4% of elderly above 60 year. It is also shown that the population ratio of men and women is almost the same, i.e. 51% to 49%.

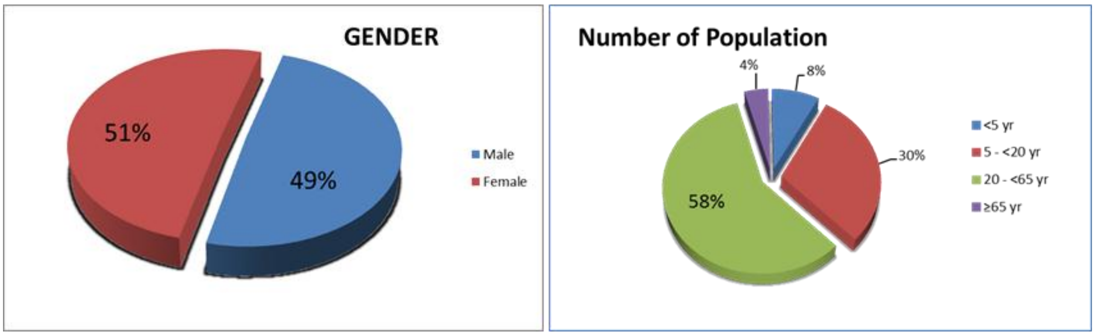


Figure 3.4 Demographic Profile of Padang City in year 2009 (Sources: BPS 2009)

Padang City is also known as an education city, the leading in Sumatera Island. There are 425 unit elementary school with approximately 94,566 students; 74 Junior High School with 36,243 students; 46 Senior High School with 26,571 students; 48 Vocational School with 17,327 students; and 46 universities with 3 state universities with total student body about 55,137.

The school building strength in Padang have been tested during 2009 earthquake, after being hit by a series of major earthquake in almost every two year, i.e. 2005, 2007 and 2009. Many school building were devastated and collapsed. Tragically most of these schools have been designated under the local regulation, i.e. Perda 2007, as the vertical evacuation center. This big population of students which correlates with number of school building which are not seismic and tsunami resistant may put the students especially school children more at risk if tsunami occurred during school hours to contrast with the case of 2011 Tohoku tsunami.

By year 2009, the 3 highest population density of sub-districts exceeded 8,800 people per km^2. They are Padang Timur, Padang Barat, and Padang Utara with density of 10,860; 8,859; and 9,593 consecutively; in which central bussiness districts for Padang city located. Meanwhile from the total population per subdistricts, the biggest population are in subdistrict Koto Tangah with 166,033 while Kuranji with 123,771 and Lubuk Begalung with 109,793. From the population growth rate, Sub-district of Koto Tangah, Lubuk Begalung, dan Kuranji located at the outskirt of city were sharply increased in this past decade, see Figure 3.5 below.

No	Sub-District	Population		Total Population	Population Density per Km2
		Men	Women		
1	Bungus Teluk Kabung	12,237	12,180	24,417	242
2	Lubuk Kilangan	22,138	22,414	44,552	518
3	Lubuk Begalung	55,869	53,924	109,793	3,552
4	Padang Selatan	31,775	32,683	64,458	6,427
5	Padang Timur	43,208	45,302	88,510	10,860
6	Padang Barat	31,425	30,585	62,010	8,859
7	Padang Utara	33,265	44,244	77,509	9,593
8	Nanggalo	29,272	30,579	59,851	7,416
9	Kuranji	60,559	63,212	123,771	2,156
10	Pauh	27,815	27,031	54,846	375
11	Koto Tangah	84,952	81,081	166,033	715
Total		432,517	443,235	875,751	1,260

Table 3.1 Population by Sub-districts for Gender and Population Density (Source: BPS, 2009)

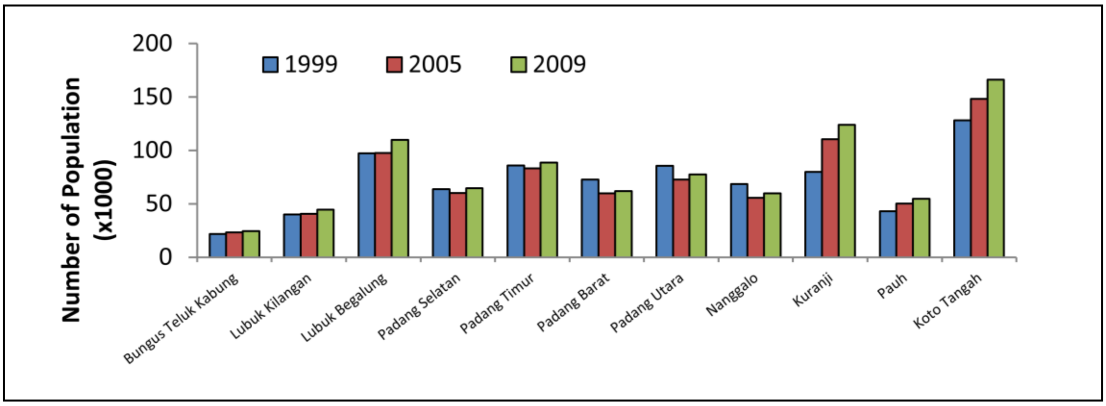


Figure 3.5 Number of Population by Sub-District of Padang City in 1999, 2005 and 2009 (Source: BPS, 2009)

3. Critical Facilities

In health services, there are health facilities consisting of 26 hospitals, 77 health center, 69 clinic, 159 pharmacies, 104 drug-stores, and 12 health laboratories (BPS, 2009) In term of economic facilities, there are 26 bank, i.e. 13 public bank and 13 private bank, 3 main markets with 71,374 m^2 area and 44,298 building coverage, 8 Supporting markets and 7 local markets.

Due to such tsunami hazard and susceptibility factors, previous study (H.P. Rahayu and H. Latief, 2007) on assessing the time needed for evacuation in Padang City, described in next section of Padang Risk Profile, shows that about 30% of city were exposed to tsunami risk. The wide area of high tsunami risk zone and several natural obstacles for evacuation, such as rivers, has urged the Mayor of Padang issues a mandate for all multistory public building designated as vertical tsunami shelters, no exclusion for schools, government office, hotels and many others. However, during the September 30, 2009 many of them were collapsed due to the strong shaking. Some examples of the critical facilities damages photo taken during reconnaissance survey are shown in Figure 3.6.

Hotel

Hospital

School

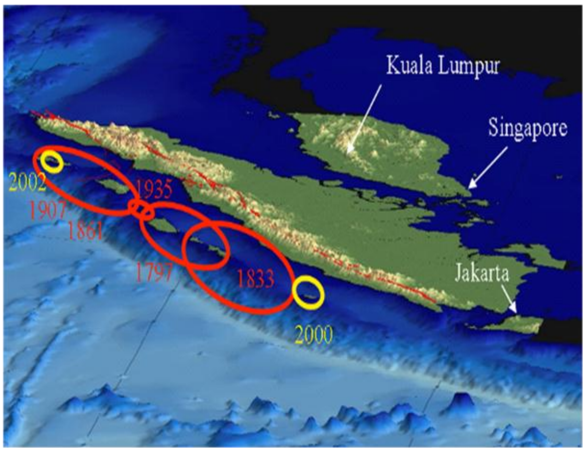
Government office

Figure 3.6 Critical Facilities Damages due to September 30, 2009 tsunamigenic earthquake (Source: H.P. Rahayu Photo 2009)

3.3.3 Tsunami Hazard Profile of Padang

As it has been highlighted in Chapter 2 regarding the disaster trend, the location of Padang is highly exposed to the potential sources of tsunami hazard, which is located in front of tectonic sub-duction area of Java Trench. The map shown in Figure 3.7 regarding the major and mega seismic activities since 1861 till 2002 states that a major or mega tsunamigenic earthquake is expected in the near future, bigger than the 2009 or 2010 events. The table in Figure 3.5 describes the History of Tsunami Event in West Coast of Sumatera.

Several different tsunami hazard maps of Padang prepared by some national and international scientific communities, since Padang scientifically known as the highest tsunami risk in the world (National Geographic, 2005) with high potential of tsunami occurrence in the near future. The maps consisted of inundation map with uniform roughness of land-use (soil, mangroves, street networks and infrastructures), inundation map with spatially distributed roughness, and inundation map that integrate real conditions (buildings, houses). The map recommended by the Mayor's Regulation (Perwako) to be used for the revision of City Spatial Planning document (RTRW) and disaster risk reduction master plan – DRRMP can be seen in Figure 3.8.



Year Month Date	EQ Magnitude	H(m)	Casualties (People)	Affected Area
1797 02 10	8.4	Very High	300	W. Sumatera, Padang, Sipora-Pagai
1799		16		Sumatera
1818 13 18				Bengkulu
1833 01 29	9			W. Sumatra: Padang, Priaman, Sipora-Pagai
1833 11 24				Bengkulu
1843 01 5-6		High	Many	N. Sumatera: Barus Is., G. Sitoli, Nias
1847				Great Nicobar island
1861 02 16	8.4		50	Sumatra: Batu Is., Nias Is.
1861 09 25			thousands	Sumatra: Padang, Indrapura, Nias
1864				W. Sumatra: Padang, Batu
1881 12 31				Andaman, Nicobar island
1883 08 26	Volc	35	36,000	Sumatera: Sunda St., Java,
1904 07 04				W. Sumatra: Siri-siri
1907 01 -			thousand	Sumatra : Western Coast, Simelue_Nias
1908 02 06				W. Sumatra
1909 06 03	7.3		200	Sumatra: Kerinci-Jambi
1928 03 26	Volc			S. Sumatera: Sunda St., Lampung,
1935 12 28				N Sumatera: Batu Island
1936 03 01	7.0		110/479	Sumatra:
1941				Andaman
1967 04 12	6.5	Very High		N Sumatera: Sigli
2004 12 26	9		300,000	Aceh, Andaman, Nicobar
2005 03 28				Nias
2010 10 25				Mentawai

History Tsunami Event in West Coast of Sumatera (Sources : D. Natawijaya, 2005)

Figure 3.7 Potential Tsunami Sources (Sources: D.H. Natawijaya, 2005 and H. Latief, 2005)

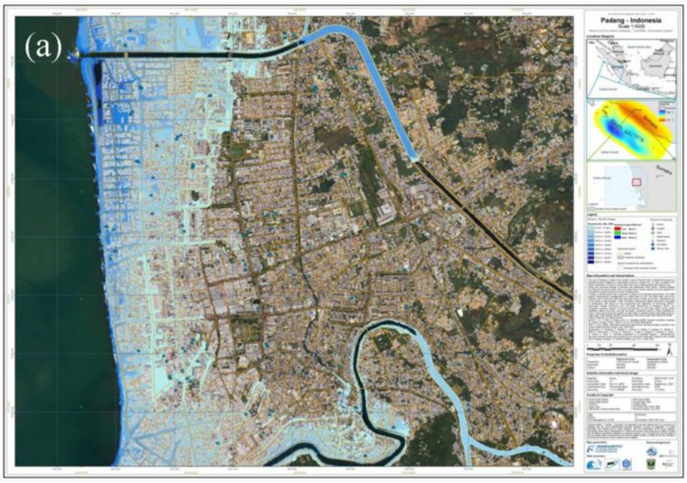


Figure 3.8 Example of Official Tsunami Inundation Map

Aside from this controversial debate about the tsunami hazard map, for recognizing the tsunami risk profile of Padang City this study used the tsunami hazard map produced by H. Latief (2008) and Tsunami Hazard Index for all municipality in Indonesia issued by Ristek 2009 (I.W. Sengara and H. Latief, 2009). The index is based on the criteria of tsunami height for each tsunami prone cities in Indonesia. Table 3.2 shows that the Padang city has very high tsunami risk level as well as very high seismic risk level among the 6 national show case cities.

6 National show case cities with level of Earthquake and Tsunami Hazard Risk

Area Name	City / Regency	Province	EARTHQUAKE		TSUNAMI		
			PGA	Risk Level	Hmax (m)	Tmax (min)	Risk Level
Banda Aceh	Kota Banda Aceh	NAD	0.35	Very High	11.1	15	Very High
Padang	Kota Padang	West Sumatera	0.40	Very High	10.5	31	Very High
Anyer-Carita	Kota Cilegon	Banten	0.20	High	4.4	141	Moderate
Cilacap	Cilacap	Jateng	0.15	High	10.1	29	Very High
Denpasar	Kota Denpasar	Bali	0.20	High	9.3	37	Very High
Gorontalo	Kota Gorontalo	Gorontalo	0.34	Very High	1.2	38	Moderate

Sources: Ristek 2009

Table 3.2 Tsunami Hazard Index of National Show Case Cities (sources: H. Latief et al 2009)

3.3 Data Acquisition

A comprehensive data acquired from Padang City was in the forms of primary data collected based on TKBLM methodology and secondary data needed to form the PBLM. Detailed methodology for both knowledge acquisition and types knowledge data obtained are described in Figure 3.9.

3.3.1 Primary Data Acquisition:

An in-depth primary data with wide range of data set are acquired from the target groups, i.e. government officials and people, from the case study city. Primary data acquisition in this study called as TKBLM data acquisition aims for recognizing all factors that hinder and/or supporting the people's mind toward tsunami warning and toward natural events of tsunamigenic earthquake. There are 3 stages of acquisition with expected 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.

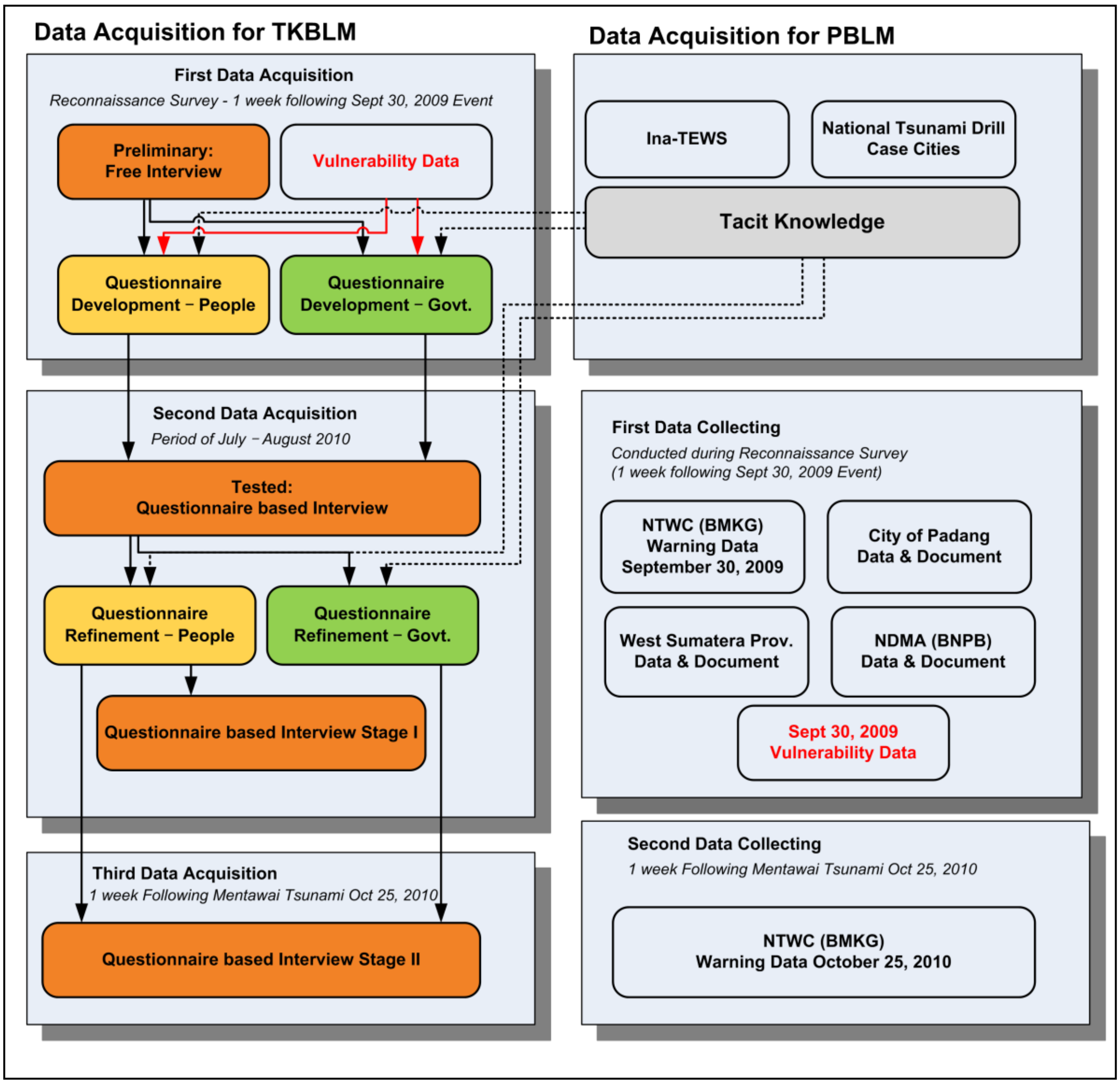


Figure 3.9 Data Acquisition for both TKBLM and PBLM

a. *First Stage of Data Acquisition:*

The first data acquisition aims for structuring the preliminary problem issues from the affected people and studying from the damage affected by 2009 event. During this stage, two types of data collecting conducted as part of *reconnaissance survey* were at October 9 – 14, 2009 (9 days after the September 30, 2009 event). The data acquisitions were: vulnerability assessment and free style preliminary interview. These two acquisition method were needed as the basis to preliminary structuring problem.

Vulnerability assessment conducted by recognizing the damages using visual and checklist method. The target assessment were: first was at all critical facilities such as schools, hospitals, government offices, malls, markets, hospitals and some other multi stories buildings designated as vertical evacuation shelters; second was any type of collapsed houses including shop-houses in the area of highly dense population as well as the high tsunami risk area identified during previous study.

Preliminary interview was conducted on several target groups among the victim of the 2009 event, i.e. general people, fisherman, businessman, and government officials on duty or off duty during the event. A free style interview was used for recognizing any factors that hinder or support the people's mind or thoughts regarding the threat they faced during the shaking and hearing tsunami siren wailing, what they thought and did. The people interviewed were 6 general public (fisherman, waitress of the hotel, taxi driver, office boy, students, and faculty members of University of Andalas), 1 businessman (hotel owner); while the 7 officials included the Mayor of Padang city, head of planning department, head of fire brigades, doctors and medical staff of hospital, staff of civil defense, head of disaster management office, and ordinary staff from city hall.

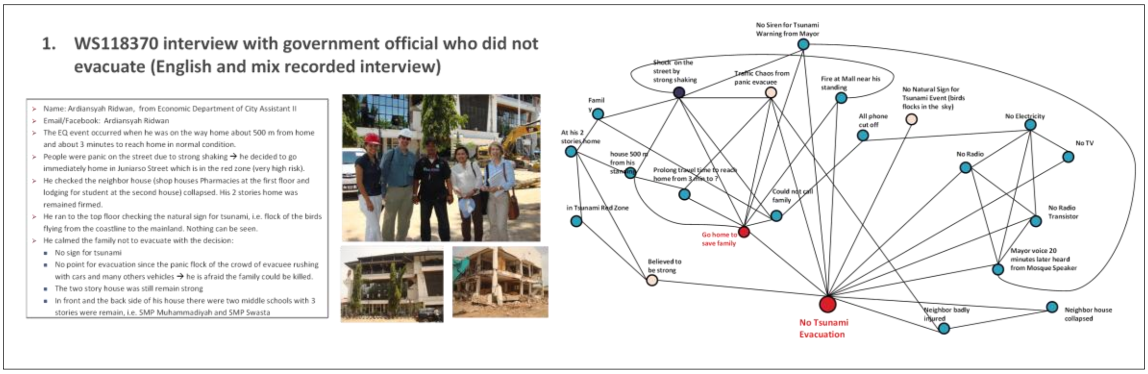


Figure 3.10 The Preliminary Interview and Cognitive Map of Government Officials

Based on these two data types, *a preliminary cognitive map* was structured. Initially there are three type of preliminary cognitive map structured based on clustering the interviewee, i.e. general people, business man, and government officials, consecutively shown by Figure 3.10, 3.11 and 3.12.

First free-style interview was conducted with government official who did not evacuate, i.e. Mr. Ardiansyah Ridwan from Economic Department of City Assistant II. The interview was in dual languages English and Bahasa and recorded (WS118370, 2009a). The EQ event occurred when he was on the way home about 500 m from home and about 3 minutes to reach home in normal condition. People were panic on the street due to strong shaking, then he decided to go immediately home in Juniarso Street which is in the red zone (very high risk). He checked the neighbor house (shop houses Pharmacies at the first floor and lodging for student at the second house) collapsed. His 2 stories home was remained firmed. He ran to the top floor checking the natural sign for tsunami, i.e. flock of the birds flying from the coastline to the mainland. Nothing can be seen. He calmed the family not to evacuate with the decision since there was no sign for tsunami, no point for evacuation since the panic flock of the crowd of evacuee rushing with cars and many others vehicles. He is afraid the family could be killed. The two story house was still remaining strong. In front and the back side of his house there were two middle schools with 3 stories were remain, i.e. SMP Muhammadiyah and SMP Swasta.

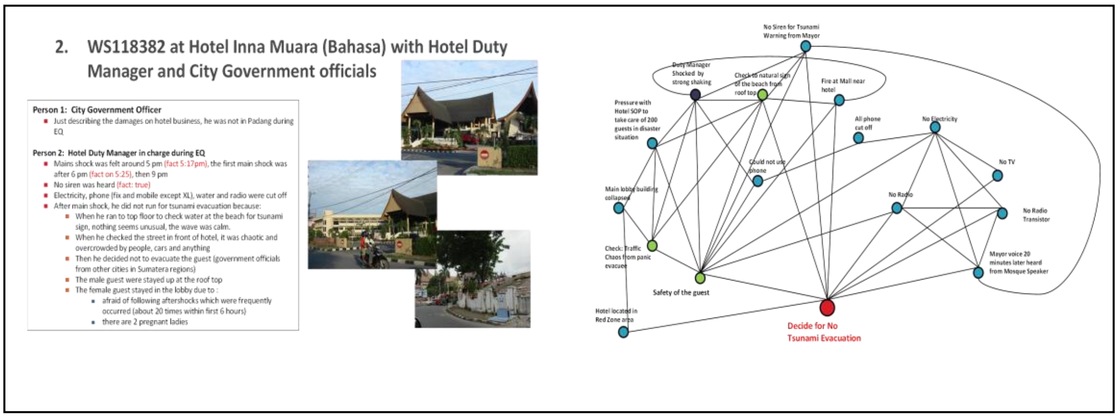


Figure 3.11 The Preliminary Interview and Cognitive Map of Businessman

Second free-style interview was conducted at Hotel Inna Muara (Bahasa) with Hotel Duty Manager and his guest (WS118382, 2009b). Hotel guest was a City Government Officer who just describing the damages on hotel business, he was not in Padang during EQ. Second person is Hotel Duty Manager in charge during EQ. Mains shock was felt around 5 pm (fact 5:17pm), the first main shock was after 6 pm (fact on 5:25), then 9 pm. No siren was heard (fact: true). Electricity, phone (fix and mobile except XL), water and radio were cut off. After main shock, he did not run for tsunami evacuation because. When he ran to top floor to check water at the beach for tsunami sign, nothing seems unusual, the wave was calm. When he checked the street in front of hotel, it was chaotic and overcrowded by people, cars and anything. Then he decided not to evacuate the guest (government officials from other cities in Sumatera regions). The male guests were stayed up at the roof top. The female guest stayed in the lobby due to afraid of following aftershocks which were frequently occurred (about 20 times within first 6 hours). There are 2 pregnant ladies.

The third free-style interview conducted with Fisherman Community in Padang on October 9-15, 2009 (WS118365, 2009c). Reasons of several fisherman reactions not to evacuate during the 2009 event were due to some reasons described as follows. Immediate after strong shaking he and his wife just checked the water at the coast behind their 'tsunami resistant housing' as part of DKP (ocean and fishery department) project. Then they decided to remain at their second floor house, the decision is based on several judgment that no sign of tsunami, i.e. the back drop of water and the closes hill is very far. Moreover, the family has joined tsunami drill once in 2007. If the tsunami occurred they were sure no one will lead them, they have to lead themselves. Before the EQ there were strange phenomena such as sky was dark since morning 10 a.m. the water was bad, so the fishermen could not go to the sea.

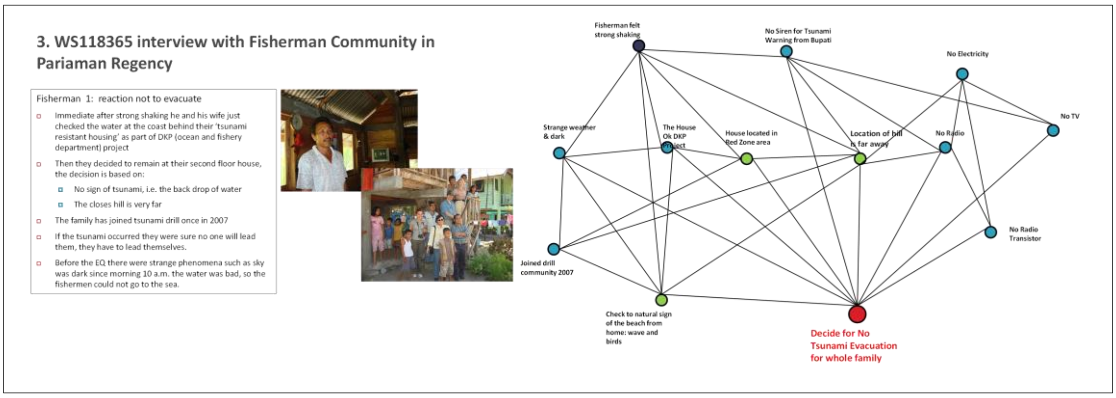


Figure 3.12 The Preliminary Interview and Cognitive Map of General Public (Fisherman)

These three preliminary cognitive maps combined with tacit knowledge gained from previous experiences is used to draft the questionnaires. Such previous experiences included experiences in coordinating two national tsunami drills in Depasar-Bali 2006 and Cilegon-Banten in 2007. There were 2 types of questionnaires as the target for this study, i.e. for general public (people) and government officials. The first target is for developing the People Model (4^{th} Layer Model), while the second target is for developing the Government Model (3rd Layer Model). Example of both questionnaires can be seen at the Appendix A.

Output of this stage was two types of questionnaires for general public and government officials. The first batch questionnaires were semi-open questionnaires which can be seen in the Appendix A of this dissertation.

b. Second Stage of Data Acquisition called as RP1 and RG

Second data acquisition aims for obtaining in-depth and holistic data set from people and government after 2009 event using the two questionnaires developed at the first stage. This stage was conducted during the period of July 21 to August 21, 2010. There were 3 activities involved in this stage of data acquisitions, i.e. pre-test questionnaires based interview, refinement of questionnaires and full questionnaires based interview.

Before implementation of these activities, the targeted interviewees were outlined:

- First target was the government officials represented institutions/agencies related with disaster and/or disaster management and mitigation. They were: Emergency Operation Center, Disaster Management Office – DMO, Planning Department, Fire Brigade, Civil Defense, Social Department, Health Department, public works department, and community empowerment department and GONGO – Government Owned NGO. Number of targeted interview was 30 officials.
- Second target was people at risk, i.e. people who live in tsunami prone cluster or neighborhood, which are divided further based on their gender and social status suh as working people, house wife, students. They are representing 14 targeted clusters. These clusters have identified as the moderate to very high tsunami risk in terms of chance for evacuation in normal condition without any obstacles on the route for evacuation, see Figure 3.9 with number of targeted interviewee was 50 respondents for the pre-test interviewed and 300 respondents for in-depth full data acquisition stage 1. The respondent expected to represented different gender, wide range of ages, education, and socio-economic status shown by the houses and salary.

The pre-test interview conducted aims to test the questionnaire developed and to train the surveyor to be able to fishing out more information which have not identified during the preliminary mapping. Number of respondent targeted for this pre-test was 50 interviewees representing 14 targeted clusters; however it turned out only 48 respondents available to be interviewed. The duration taken for this stage was about 1 hour per respondent at the beginning, later about 40 minutes per respondent.

Improving cognitive map and questionnaire were conducted based on the result of pre-test. The questionnaire was still semi-open question style to recognize more indelible knowledge or information of people’s mind. The final type of questionnaire can be seen in the Appendix A of this dissertation. Improved cognitive is presented and discussed in Chapter 5.

Final activity of this stage was the full in-depth questionnaire-based interview, with target respondent about 300 representing people the 14 clusters and 30 government officials from targeted institutions. From the people respondent, it was expected each cluster represented by minimum 20 respondent. The interview for 300 respondents has taken about 2 weeks by 6 surveyors. Result of the final activity of second data acquisition is 487 observable factors with 39 un-observable (latent) variables. These factors were then used to base the detailing of the development of TKBLM of People model. While from the government officials, there were 502 observable factors with 39 un-observable (latent) variables.

c. Third Stage of Data Acquisition called as RP2

During the study at the field, there was major 12m Mentawai tsunami occurred October 25, 2010 in the region. Even though, it has only affected Padang City with minor tsunami and with advisory tsunami warning, this event was windows of opportunity to conduct direct effect on the people from the case study area. This event lead this study to conduct another batch of data acquisition called as third stage data acquisition.

This third data stage of acquisition aims for obtaining in-depth and holistic data set from people from the most prone cluster from the observed area following the 2010 Mentawai tsunami using the same questionnaires used to for the assessment at the second stage. This stage was conducted during the period of November 7 to November 14, 2010.

Before implementation of the activity, the targeted interviewees were general public from 2 out of 14 observed clusters, i.e. cluster no 8, 11, 12, and 13. The rationale is these areas were the most densely central business districts. There were about 61 people interviewed in this stage.

Location and stages of data acquisition for primary data can be summarized by Figure 3.13 below. This shows the location of data acquisition for RP1, RP2 and RG; as well as the location of each people respondent of data acquisition taken after 2009 event - RP1, people respondent of data acquisition taken after 2010 event - RP 2, and government official respondent of data acquisition taken after 2009 event - RG. The 348 data RP1 covered randomly respondent from all 14 clusters, while 61 data RP2 covered randomly respondent from cluster no 8, 12, 13 and 14; with some respondent of RP1 being re-interviewed for RP2. The 30 data RG location are the same location of their own office address, since the interview taken at their office.

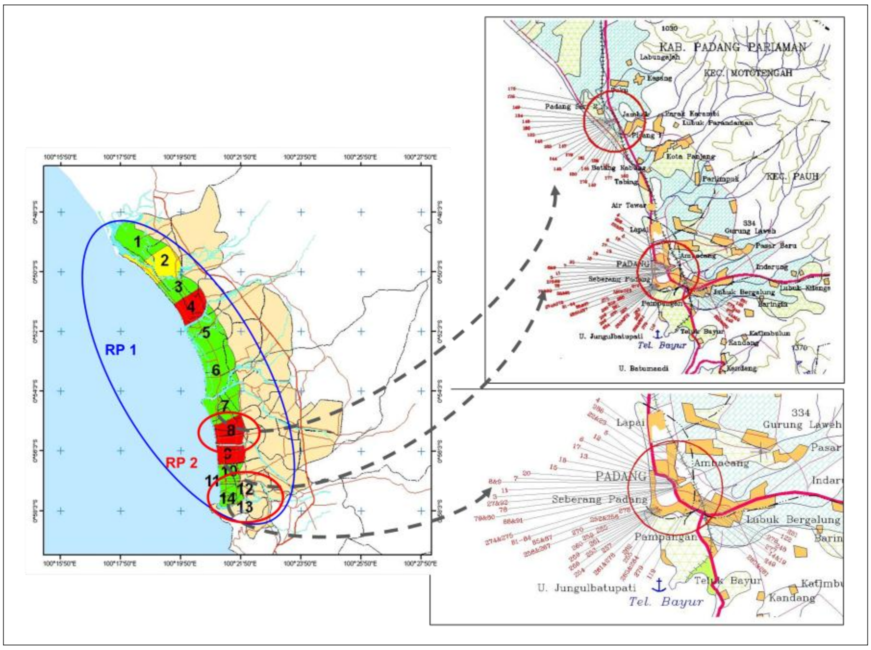


Figure 3.13 Data Acquisition and Example of GPS based Location for Respondents - RP1, RP2 and RG

No	Cluster	RP1	RP2	RG
1	E – Reasoning for Evacuation	184	183	48
2	V – Vulnerability & Capacity	87	86	84
3	H – Hazard Perception & Disaster Experience	29	29	30
4	T – Tsunami Knowledge	9	9	25
5	CM – Countermeasures of DRR	118	118	223
6	TEWS – Tsunami Early Warning System	60	60	92
	T O T A L	487	485	502

Table 3.3 Number of variables acquired for each type of data set.

From the three types of data acquired, there are 487 variables and factors for RP1 and 485 for RP2, 2 variables different each in reasoning for evacuation and vulnerability. Meanwhile there are 502 variables and factors acquired for the RG. The composition of RG and RP is different especially in component reasoning for evacuation, knowledge on tsunami, countermeasures of disaster risk reduction and appreciation to tsunami early warning system. These numbers of variables obtained from each data cluster can be summarized in Table 3.3. Paralel with the survey in the same location in Padang city, during this stage, a semi freestyle interviewed was also conducted at the people of Mentawai Island. Based on the recorded interview, a cognitive map is drawn to have a better picture as comparison how the direct victim of major tsunami responded the phenomena and warning. Figure 3.14 present the logic model.

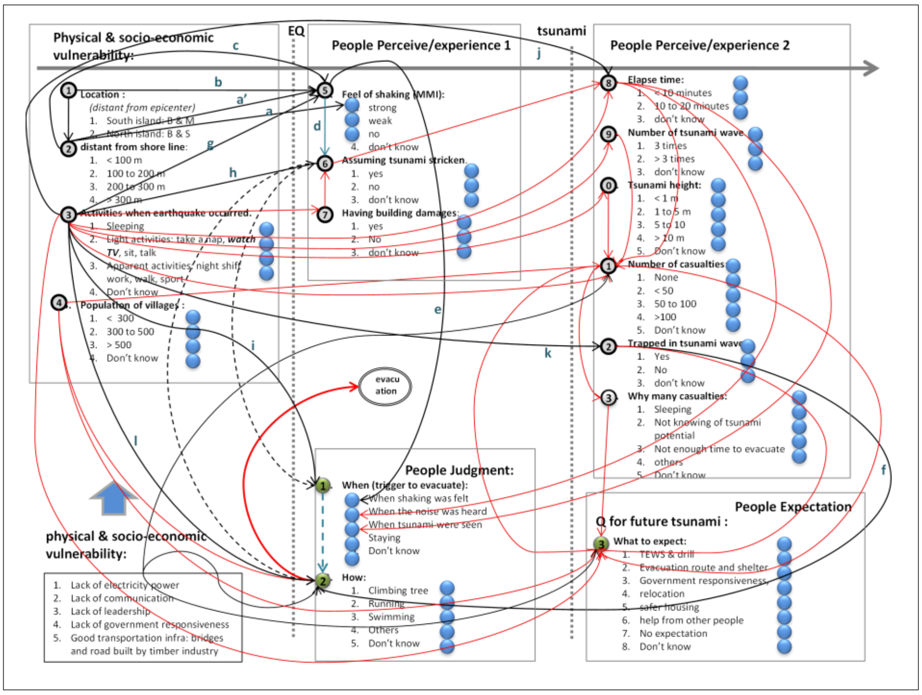
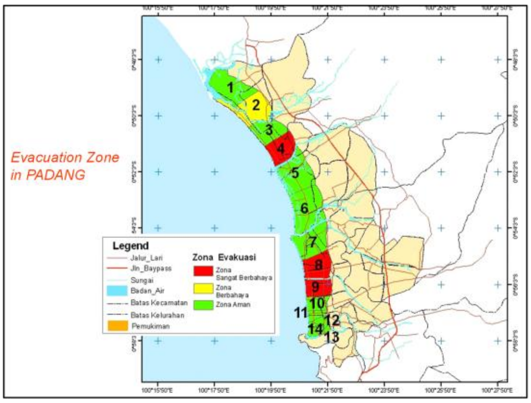


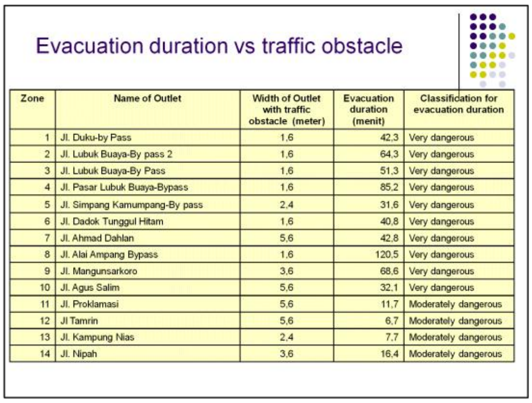
Figure 3.14Cognitive Map of Mentawai People after Tsunami (Fisherman)

3.3.2 Secondary Data Acquisition:

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, previous works to coordinate the two national tsunami drill in Denpasar Bali 2006 and in Cilegon Banten 2007 during the development stage of Ina-TEWS as well as some related works on disaster management and mitigation. These previous works and data obtained at the field were influenced the depth of tacit knowledge in structuring problem of the phenomena of effective early warning system.

Important secondary data or 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.





Evacuation duration vs traffic obstacle

Zone	Name of Outlet	Width of Outlet with traffic obstacle (meter)	Evacuation duration (menit)	Classification for evacuation duration
1	Jl. Duku-by Pass	1,6	42,3	Very dangerous
2	Jl. Lubuk Buaya-By pass 2	1,6	64,3	Very dangerous
3	Jl. Lubuk Buaya-By Pass	1,6	51,3	Very dangerous
4	Jl. Pasar Lubuk Buaya-Bypass	1,6	85,2	Very dangerous
5	Jl. Simpang Kamumpang-By pass	2,4	31,6	Very dangerous
6	Jl. Dadok Tunggul Hitam	1,6	40,8	Very dangerous
7	Jl. Ahmad Dahlan	5,6	42,8	Very dangerous
8	Jl. Alai Ampang Bypass	1,6	120,5	Very dangerous
9	Jl. Mangunsarkoro	3,6	68,6	Very dangerous
10	Jl. Agus Salim	5,6	32,1	Very dangerous
11	Jl. Proklamasi	5,6	11,7	Moderately dangerous
12	Jl Tamrin	5,6	6,7	Moderately dangerous
13	Jl. Kampung Nias	2,4	7,7	Moderately dangerous
14	Jl. Nipah	3,6	16,4	Moderately dangerous

Figure 3.15 Evacuation Zone and Estimated Time for Evacuation in Padang city (H. Latie et al 2007)

Figure 3.15 shows result of previous work done for Padang City on the 14 cluster with 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 (H. Latief and 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.

3.5 Profile of respondents

Results of the survey in Padang City show the demographic condition of the samplesRP1, RP 2 and RG, as described in Figure 3.16.

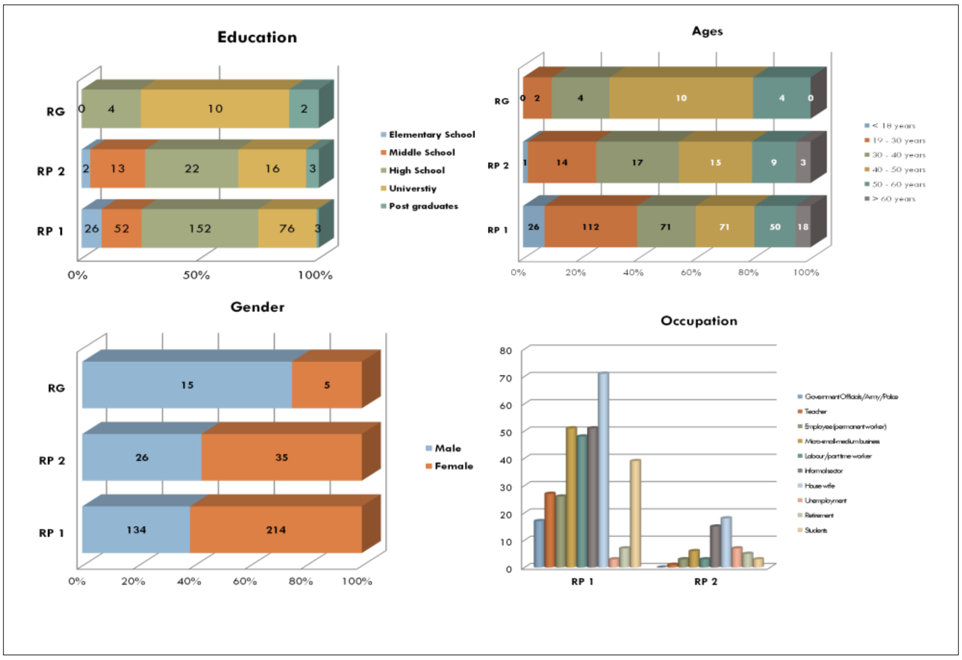


Figure 3.16 Profiles of Respondent RP1, RP2 and RG -Padang City

RP1 sample population was dominated by 62% female between 19-50 years old, with high school as majority education level; majority of sample was housewife, followed by working in the informal sectors, labor/part-time worker, and microbusiness. Meanwhile RP2 sample population was dominated by female between 19-50 years old, with high-school and university as majority education background, majority working in informal sectors and housewife.

While the government officials RG sample population was dominated by male about 75% between 40-50 years old, with university as majority of education background. From the household vulnerability shown by Figure 3.12, the number of children below 15 years old at households is dominant in RP2 compare to RP1 population; while number of elderly above 60 years old at households is dominant at the RP2 compare to RP1 population. The number of total inhabitant at both RP1 and RP2 are almost similar between 5 to 10 people.

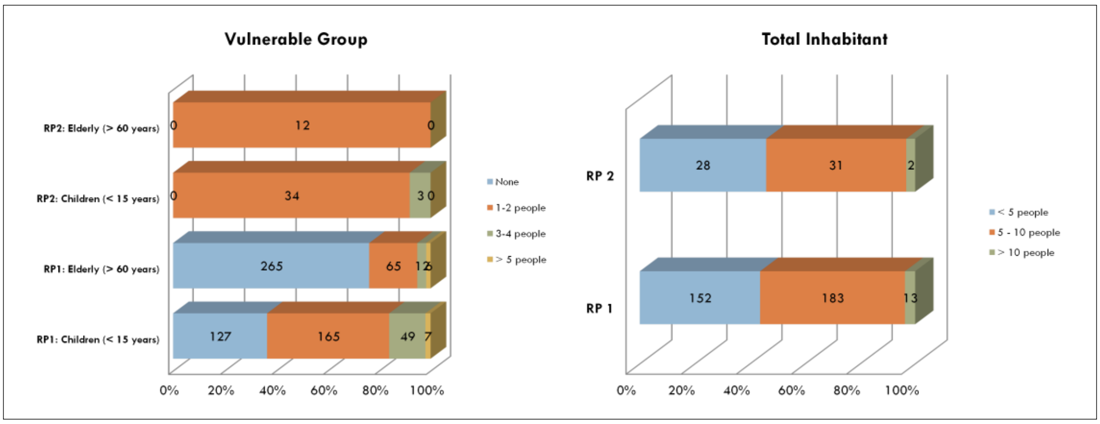


Figure 3.17Profiles of Household Vulnerability of RP1, RP2 and RG - Padang City

In terms of housing vulnerability shown by Figure 3.17, both RP1 and RP2 population house were dominantly concrete structure single house with one story, length of stay around 11-20 years in RP1 population while in RP2 around 6-10 years; and the house mostly owned by themselves/family at both RP1 and RP2.

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.

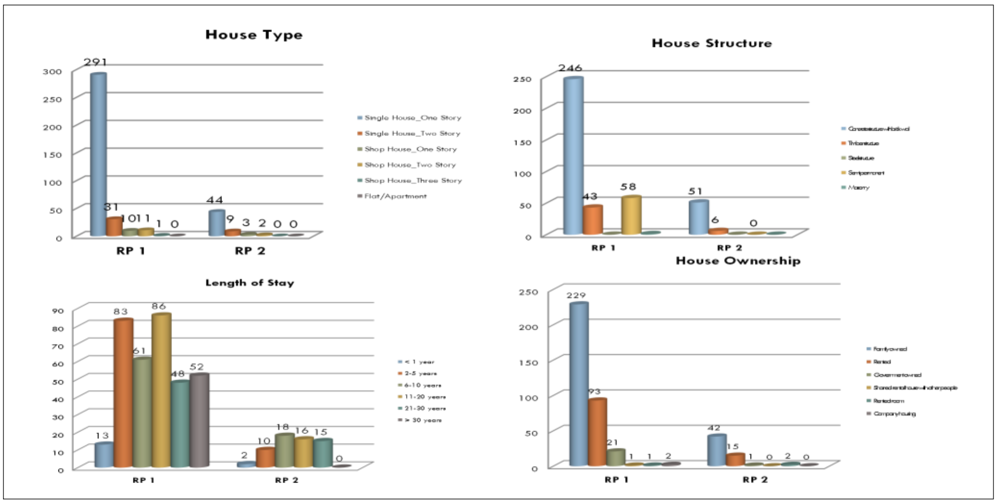
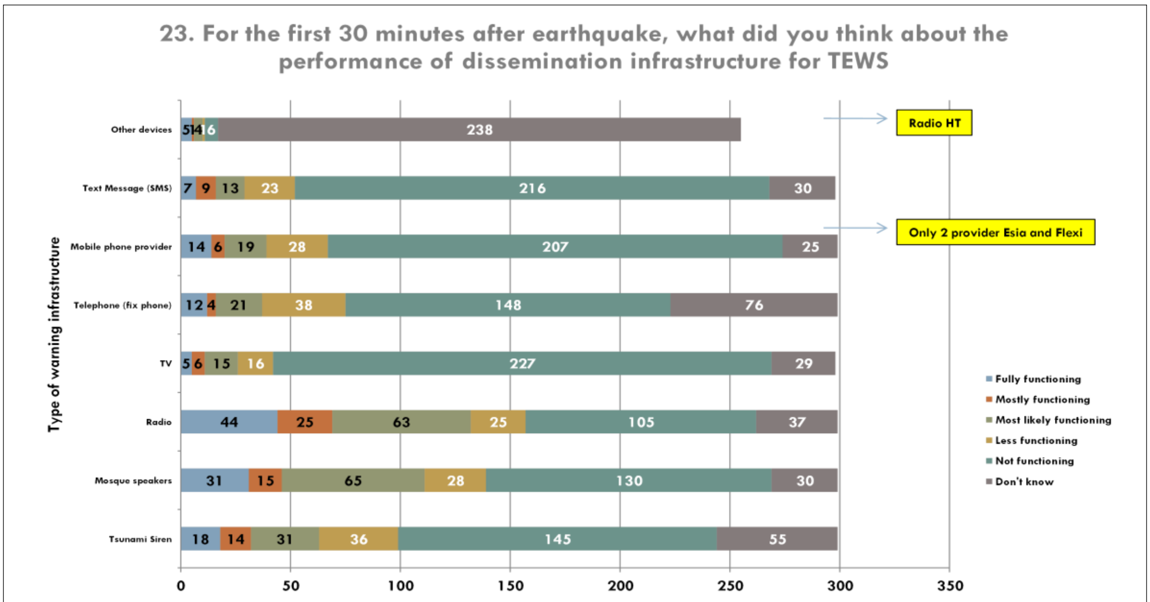


Figure 3.18Profiles of Housing Vulnerability of RP1, RP2 and RG - Padang City



	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

Number of respondents

Figure 3.19 Appreciations 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 3.19. According to Padang people that radio transistor (44) was still effective device for conveying the warning, followed by the mosque speaker (31) and tsunami siren (31). Many telecommunication devices were not functioning due to electricity cut off; they were TV (227), SMS (216), mobile phone (207), and fix phone (148). During the 2009 event, only two from 5 mobile phones provider was still functioning.

3.6 Development of Integrated Layer Model Proposed

As discussed in Chapter 1 that to better recognize, represent and structure the problem and phenomena of effective tsunami early warning system, an integrated logic model of effective early warning system is developed by this study. The model consists of 4 layer model and 1 floating model.

The system architecture of the model developed can be seen in Figure 3.20. It consists of 4 layer models which includes Natural Phenomena model, Structural part of Ina-TEWS model, Government model, and People model; with 1 floating model which is the preparedness index model. The rationale to have this system for describing the recognized problem issues and description of methodology are as follows:

- Each layer model has its variables and factors which has strong correlation among them before it influences the outcome of enhancing the goal of tsunami early warning system, i.e. reduce damages on lives.
- The correlation between layer is two way, i.e. top-down and bottom-up. The top-down correlation is performed if there is any trigger from natural phenomena, down to second layer 'structure model' in the form of 'information' and down to third layer 'government model' and fourth layer 'people model' in the form of damages/destruction. The bottom-up correlation is performed during the development of each layer model as well as in the increasing the preparedness, capacity and responsive ability to tsunami warning; through implementing right policy based on the right and sound problem structuring as explained in section 3.2 and 3.3 of this Chapter 3.
- The floating model has its own correlation among its variables and factors, as well as correlation with any layer.

- The floating model is representing more on the physical and tangible phenomena; as well as the Natural Phenomena model. The Structure model is representing a techno-center phenomenon. Meanwhile government model and people model are each representing the cognitive mapping of the human beings as regulators and/or executors and as the human being who is the subject to be saved in the phenomena of tsunami early warning system.

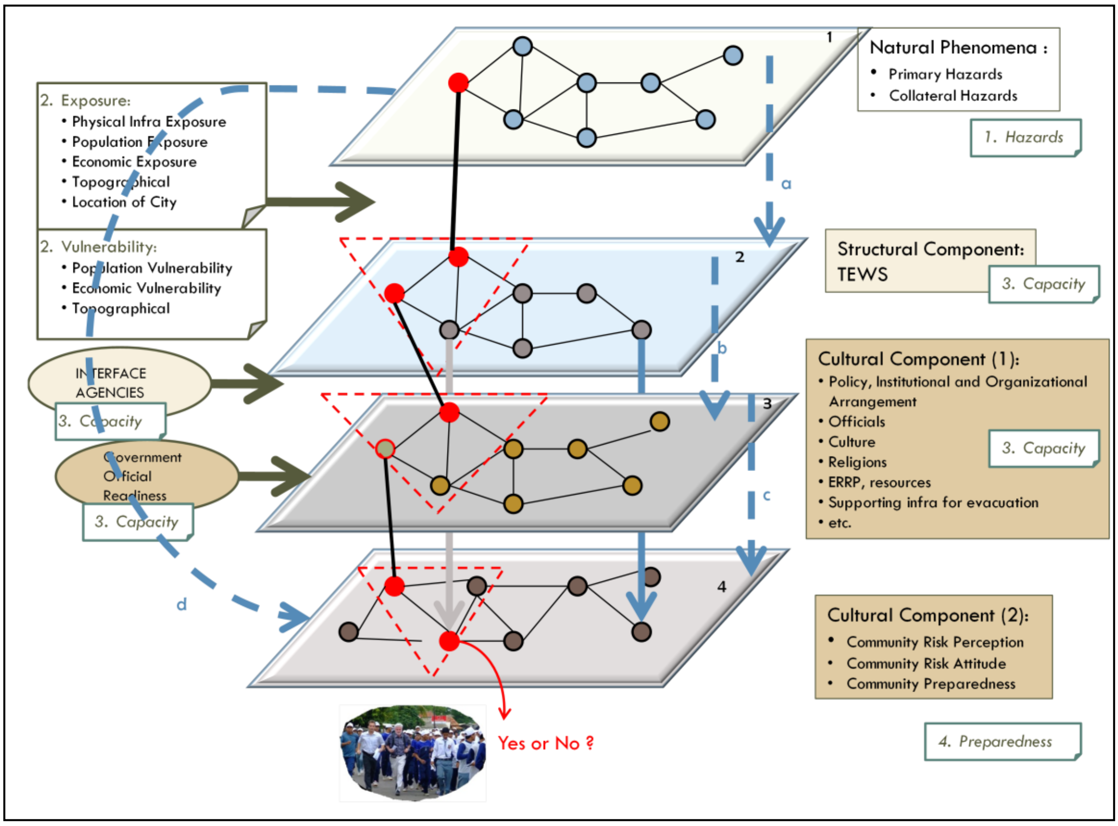


Figure 3.20 Integrated Logic Model of Effective Early Warning System

3.7 Summary

Result of data acquisition and structuring problem issues of the phenomena of tsunami early warning system in Indonesia are used to develop the detailing of logic model holistically. The complexity and the nature of phenomena of TEWS with its associated problem are structured in the form of Layer Models and Floating Model (i.e. four models in layer forms and 1 floating model) called as Integrated Logic Model. The four layer models are: Natural Phenomena Model, Structure Model, Government Model, and People Model. The first two layer model were structured using the PBLM, meanwhile the last two, i.e. people model and government model were developed using the TKBLM approaches using data RP1 and RP2, then TG. The floating model consists of exhaustive relation of physical susceptibility factors and capacity factors which includes the resilient factors of the city. The floating model is presented in this dissertation in the next Chapter 4 together with Layer Model 1 and 2. Meanwhile layer Model 3 and 4 are presented consecutively in Chapter 5 and 6.

Chapter 4
Floating Factor Model and Physically Based Logic Model

4.1 Introduction

This Chapter 4 consists of the description and discussion of the development of the first two major component of Integrated Tsunami Early Warning System. They are the Floating Factor Model and Physically Based Logic Model. The process development of Floating Factor Model as part of Integrated Logic Model of Effective Early Warning System is described and discussed first. It starts from the problem recognition of the tsunami early warning system through identification of functioning and malfunction indicators of the component of Ina-TEWS, i.e. Structure and Culture components. It is then followed by the process development of Preparedness Index. These are followed by presenting the two Physically Based Logic Model, i.e. Natural Phenomena System and Structural System. These two PBLM as discussed in Chapter 1 are the first two layers as part of Integrated Logic Model.

4.2 Problem recognition of the performance Tsunami Early Warning System

As it has been mentioned in Chapter one that the crucial problem issues investigated under this study was the chaotic phenomena shown during September 30, 2009 event. Eventhough the devatstated tsunamigenic earthquake has damaged almost 60 % of public building in the City of Padang, i.e. government office including town hall, banks, hotels, malls, schools, university, houses and central business districts – CBDs; the tsunami only stricken Padang City was only 50 cm. However, the panic and chaotic condition was happened.

Many controversial issues were emerged, some blamed on the tsunami early warning system has created this chaotic condition, some has thought the tsunami early warning was perfectly did the job, but the local government and people were not following its standard operating procedures for evacauation which has been endorsed by local regulation. However, many people just ignored the warning either from the nature such as strong shaking and from the siren wailing. These peole were just tired with so many warning before but the tsunami occurred very low and not as dramatic as the one they saw in TV which affected Aceh and North Sumatera Province during 2004 Sumatera Indian Ocean tsunami. They preferred continued their business, eventhough around 30% of population was rushed for evacuation.

This can be imagined how chaotic the condition was that moment, with insufficient infratdructure of route for evacuation to accommodate almost 200,000 people at the same seconds. As example some people were trapped in traffic jam for 2 hours for driving one segment of 1 km road length. People do not follow the order for evacuation, they just used cars, motorcycles and whatever they have to evacuate. With fire occurred everywhere just within minutes afters the earthquake, and many people were scared and ran for evacuation. Padang city that time was in ferno, however no significant tsunami occurred. Then controversial debates following the event were emerged between the stakholders either at national level, or at the local level and both.

Looking at this situation, the study attempted to initially recognize the real problem issues by investigating the performance of all the factors of both Structure and Culture components, during that event. For the structure component, the knowledge and information were acquired more from national government, in this case was from NTWC – National Tsunami Warning Center of BMKG, National Agency for Disaster Management – BNPB, BPPT, Ristek, Bakosturtanal and some national NGOs. These institutions are basically incharge in the operational of Ina-TEWS as well as during the development and deployment.

Meanwhile for the culture component, information and knowledge were obtained from the city local government and the people. The interviewed and secondary data collecting were obtained. The city stakeholder interviewed were the Mayor, some head of deaprtemtn in the city government, such as head of planning department, head of City Disaster Management Office with its EOC – emergency operation center that incharge to convey the warning received from NTWC, see also Chapter 2 of this dissertation regarding the current status of Ina-TEWS.

The findings are divided into 3, namely indicators related with Structure component, indiators related with interface agencies, indicators related with culture components. All the assessments were based on the time line starting from the earthquake occurrence.

The Structure component consists of a matrix of tsunami detection devices with the activities of tsunami warning at the structure component in time line bases. The component of structural devices consists of seismometer, accelerometer, dart buoy and tide gauge.

The interface agency component consists of institution mandated by the president to help Ina-TEWS in conveying the warning. See also rational of the liability sharing at the chapter 1. The interface agency consists of BNPB, Army, Police, and National Radio (which included RRI, Elshinta, and Trijaya), Newspapers, ORARI/RAPI (citizen-band radio association), INGOs, NGOs and Scientist (University). Meanwhile, the culture components consist of Policy, Institutional and Organizational Arrangement, Capacity of Government Officials, Infrastructure for Tsunami Early Warning System at local level, community preparedness, and City Stakeholder; where each sub component consists of several factors. The international assistance emphasize only on rescue and relief.

The detail problems recognized are presented in Table 4.1, 4.2, 4.3 and 4.4 below:

Table 4.1 Functioning and Malfunctioning indicators of TEWS STRUCTURE Component

Time	**No**	**I. Ina-TEWS Factors – STRUCTURE COMPONENT**				**Review during and after earthquake event**	
		Obser-vation	**Processing**	**Disseminatio n**	**Stakeholders**	**Func tioni ng**	**Situation Description**
	1	Seismic monitoring system: BMKG (10 RC + 1 NC) with 160 Seismic Sensors and 500 Accelerometers	If magnitude < 5.0 RS : 1. To archives for historical records				
5 min			If magnitude 5.0 - 7.5 RS: 1. To disseminate EQ info 2. To archives for historical records	• Information of significant earthquake occurrence • to target recipient • with target time of 5 minute after EQ occurrence	**Target Recipients:** 1. BPBD/Satlak of : • potential city/regency • potential province 2. Interface agencies: • BNPB • Army • Police • Radios • TVs • Scientist • others	Y Y	• Main Shock with Magnitude of 7.6 R.S. Location 0.84 S – 99.65 E, Depth – 71 km, Time 17:16:09 WIB • The magnitude recorded were fluctuated from 7.5 to 8.3 at the first 16 seismic sensors cannot wait for all 160 then decided for the dissemination to the public with magnitude of 7.6 RS. • Received by public individu 9 minute → delay 4 min (tolerable)

	2	Tsunami data base and tsunami scenarios	If the magnitude > 7.5 RS: 1. To make situation assessment and decision based on: • Tsunamigenic criteria: EQ depth <60 km and located in tsunami source zone • Risk and vulnerability modeling, which is based on: Tsunami database, tsunami scenario • Geospatial data repository 2. Classification of warning if estimated tsunami height: • major warning: > 3m • warning: 0.5-3 m • advisory: <0.5 m • cancel or all clear **3.** To disseminate **Warning I and II** 4. To archives for historical records	• **Warning I:** Occurrence of EQ with potential tsunami • to target recipient 1 and 2	**Target Recipients:** 1. BPBD/Satlak of: • potential city/regency • potential province 2. Interface agencies: • BNPB • Army • Police • Radios • TVs • Scientist, others	N	External Matters: No Tsunami Warning • acceptable since there was only very small tsunami occurrence (30 cm) and very local tsunami in Pariaman City coast line • did not worsen the chaotic condition in Padang City Internal Matters: No Tsunami Warning • Fail to comply with SOP (draft) due to: a. COD first have known not to issue the tsunami warning since it was outside the criteria then check the second step by checking the tsunami database. b. Intervention of higher ranking officer to 24/7 COD due to very significant EQ magnitude close to highly populated area in West Sumatera c. Prolong debate with German expert due to differences of model results in estimating the tsunami height (German 15 m and Indonesian 4 m). • Fail to reach target time, the debate taken up to 22 min. Noted if there were tsunami it has reached the shoreline already.
				• **Warning II**: Occurrence of EQ with potential tsunami height at certain cities and/or regencies • to target recipient 1 and 2	**Target Recipients:** 1. BPBD/Satlak of: • potential city/regency • potential province 2. Interface agencies: • BNPB • Army • Police • Radios • TVs • Scientist, etc		
	3	Oceanographic monitoring system: • Dart Buoy (BPPT)	Changing of water column reported: • To BMKG NC → to be used to confirm tsunami occurrence for decision of issuing **Warning II** • To Buoy Data Center (BPPT)	• Warning II: Occurrence of EQ with potential tsunami height at certain cities and/or regencies • to target recipient 1 and 2	**Target Recipients:** 1. BPBD/Satlak of: • potential city/regency • potential province 2. Interface agencies: • BNPB • Army • Police • Radios • TVs • Scientist, etc	Y/N	The tsunami data has been sent to both BMKG NC and BPPT Buoy Data Center

		• Tide Gauge & GPS (Bakosurtanal)	Tsunami wave arrival reported to BMKG NC: 1. to assure for decision of issuing **Warning III** regarding tsunami wave reaching coastline	• **Warning III**: Tsunami with certain height has stricken Certain Cities/Regencies • to target recipient 1 and 2	**Target Recipients:** 1. BPBD/Satlak of: • potential city/regency • potential province 2. Interface agencies: • BNPB • Army • Police • Radios • TVs • Scientist, others	NA	No information related with Tide Gauge detecting data.
			2. to assure for decision of issuing **Warning IV** regarding last wave reaching coastline (tsunami over)	• **Warning IV**: Last Tsunami wave has stricken Cities and/or Regencies • to target recipient 1 and 2	**Target Recipients:** 1. BPBD/Satlak of: • potential city/regency • potential province 2. Interface agencies: • BNPB • Army • Police • Radios • TVs • Scientist, others	NA	No information related with Tide Gauge detecting data.
	4	Earth Observation	To support situational assessment	Tsunami impacts on coastal area		Y	It has been used to support damage assessment

Table 4.2 Functioning and Malfunctioning indicators of TEWS Interface Agencies

T	No	II. Ina-TEWS Factors – INTERFACE AGENCIES				Review during and after earthquake event	
		Factors	**Expected Role in Ina-TEWS**	**Expected Role in first 24 hours**	**Stakeholders**	**Functioning**	**Remark**
	a	BNPB	• To convey the warning to BPBD Province and BPBD cities/regencies through fax, and phone • To convey the warning and damage impacts to public through BNPB website	• To conduct closely monitoring and situational assessment at the affected region • To mobilize Quick Response Team to conduct quick damage and need assessment • To conduct coordination at national level to anticipate if escalation of disaster situation reaching province and/or national level	• BMKG • Operational members of national taskforce: army, police and national departments related to disaster • Media • NGOs • Experts	Y	• closely monitor escalation situation in Padang, Pariaman and other area of West Sumatera Province after receiving **7.6 RS earthquake info** from BMKG • Having report from airport of Padang functioning after 3 hours inspection • coordination meeting with Vice President and national disaster response and management task force at 8 pm • mobilized national first responder to Padang from air force based airport Jakarta by 6 a.m., met and coordinated with Australian army rescue and first responder team • first 24 hours has set up national command post at the Governor Office
	b	Army	• To convey all warnings to province and cities/regencies using army communication devices and technology	Due to capability and field skill personnel, they are expected : • As the very first responder to conduct search and rescue • As the very first responder to conduct quick damage and need assessment	• BMKG • BNPB national task force for response • Satkorlak - Disaster Management Coordinating Unit for Province level	Y	• The first 2 hours national army has mobilized the first responder team and rescue team to Padang to do rescue and quick damage and need assessment using the military aircrafts (Hercules, Choppers) • Regional army has been helping to handle the chaos evacuation situation at the first 2 hours, which is supposed to be handled by Police • Army has rescued some victim from the building ruin starting from the first 2 hours • The first 24 hours, the naval ship has moved from Navy base in Jakarta to Padang

							harbor to be function as floating hospital
	c	Police	• To convey all warnings to province and cities/regencies using police communication devices and technology	Due to capability and field skill personnel, they are expected : • To guard the evacuation process • To maintain the public security in disaster location	• BMKG • BNPB • Satkorlak or BPBD at Province level • Satlak or BPBD at City level	N	• National Police has conveyed information of 7.6 RS earthquake from BMKG to Province and Cities/Regencies using its communication networks • Regional Police did not performed to guard the evacuation process, no personnel were shown at the first 2 hours of chaotic evacuation and traffic jam • No information regarding the theft during the first 2 hours
	d	Media TV : Metro TV, ANTV, Indosiar and Global TV	• To broadcast all warnings to nation wide	• To help broadcasting the information of escalation situation in affected area	• BMKG • BNPB • Satkorlak or BPBD at Province level • Satlak or BPBD at City level • Other sources	Y/N	• broadcast 7.6 RS earthquake information • direct broadcast the situational condition within few hours after earthquake, however some have exaggerated the real situation • documenting and broadcast later the situation of evacuation taken by people and the traffic jam, as well as some chaotic condition such the condition of lifelines and infrastructure
	e	National Radio : RRI, Elshinta, Trijaya	• To broadcast all warnings to nation wide	• To help broadcasting the information of escalation situation in affected area	• BMKG • BNPB • Satkorlak or BPBD at Province level • Satlak or BPBD at City level • Other sources	Y	• broadcast 7.6 RS earthquake information • direct broadcast the situational condition within few hours after earthquake, however some have exaggerated the real situation • documenting and broadcast later the situation of evacuation taken by people and the traffic jam, as well as some chaotic condition such the condition of lifelines and infrastructure
	e	Newspapers	• To disseminate event information and situations condition at available time	NA	• Any sources	Y	• Some journalist has made a lot of documentation on situation of first 2 up to 6 hours.

	f	ORARI/RAPI – Citizen Band Radio Association	• To convey all warnings to any stakeholders of province and cities/regencies using radio UHV or radio satellite communication	Due to capability and field skill personnel, they are expected : • To guard the evacuation process • To maintain the public security in disaster location	• BMKG • BNPB • Satkorlak or BPBD at Province level • Satlak or BPBD at City level	Y	• This communication was really helpful since the electricity shut down, many mobile phone providers not functioning (only 2 from 5 providers were available), fix phone line was functioning but jammed by all people communication.
	g	INGOs, NGOs and Scientist (University)	• To help for response and relief stage • To help for planning for the next stage: rehab and reconstruction	NA	• BMKG • BNPB • Satkorlak, Satlak or BPBD	Y	• UNOCHA working closely with BNPB at Command Post in Governor House to coordinate international assistant during the rescue and relief. It has able to do some screening for the unnecessary international assistant, such as international rescue team without any proper equipment and coming in the wrong time (too late). • Local government officials and university has help identified the safe hotel to be used 3 days after the earthquake, due to many national and international assistant coming to Padang and there were not many hotel available.

Table 4.3 Functioning and Malfunctioning indicators of TEWS Culture Component

No	III. Ina-TEWS Factors – CULTURE COMPONENT					
	Factors	**Reference and Recommended DRR Countermeasures**	**DRR Countermeasure implemented in Padang**	**DRR Outcome in Padang**	**Functioning**	**Remark**
1	**Policy, Institutional and Organizational Arrangement :**					
a	DM related Local Regulation	• Local Regulation for Disaster Management and for Tsunami Early Warning System • Legal Framework ○ MOHA: Permendagri No 33/2006 Pedoman Mitigasi Bencana ○ DM Law: UU 24/2007	• Drafting local regulation for Disaster Management for Padang City • Drafting local regulation for Disaster Management for West Sumatera Province	• local regulation for Disaster Management for Padang City (Perda Kota Padang no. 3 tahun 2008 Penanggulangan Bencana) • local regulation for Disaster Management for West Sumatera Province (Perda Provinsi no 5 tahun 2007)	N	• Need amendment for strengthening to be seismic resistant for all multi story public building designated for vertical evacuation shelter, since many of them were collapsed • Need enforcement **At national level: RAN was endorsed by UN Resolution - Hyogo Framework of Action 2005-2015**
b	Existence of disaster management agency for local level : BPBD or Satlak PB	• Existence of Satlak PB (current format of disaster management coordinating units for local level) • New form of BPBD were based on Legal Framework • MOHA: Permendagri No 33/2006 Pedoman Mitigasi Bencana • NDMO: Perka No 3/2008 tentang BPBD • Govt Reg: ✓ PP21/2008–Penyelenggaraan ✓ PP22/2008 Pendanaan ✓ PP23/2008 Peran serta • DM Law: UU 24/2007	• Establishment BPBD – a new format of disaster management agency for local level	• BPBD of Padang City established at the beginning of 2009	N	• Not fully functioning at the critical stage of response first 24 hours. • This is a very new format of DMO, which follows MOHA decree to implement Government regulation on establishment of new form of DMO (PP
c	Establishment of Crisis center	• SOP for operation and maintenance crisis center: ✓ As a hub of receiving warning from BMKG → report to Mayor ✓ As a hub for calling for coordination to back up Mayor ✓ As Data Center	• Previous form of crisis center, i.e. City Fire Department, has been equipped with the recommended all 3 functions; since Padang city is one of 6 pilot model city for TEWS. • The new form	• The new crisis center under BPBD Padang City is as division function as Data Center and Command Post	N	• Not functioning at the first critical 6 hours, since the 24/7 COD does not have sufficient responsive skills. Until the Mayor mobilized the crisis center to his residence. • This has replaced the old crisis center which previously belong under Fire

				of crisis center only have the 3rd function, since by design of the law, it is function as Information Data Center called Pusdatin.			Department, now independence as sub-ordinate of BPBD
	d	Contingency Plan	Integrate capacity of jurisdictional institution to response tsunami early warning, conduct emergency response and able to manage the evacuee **Minimum requirements:** 1. SOP for Tsunami Early Warning System 2. SOP for Emergency response 3. SOP for camp management 4. SOP for logistic Distribution	• Contingency plan started to be drafted during the preparation of tsunami drill. • In the following years, many INGOs tried to make some version of contingency plan, this have enriched the capacity of officials.	• SOP for Tsunami Early Warning System • SOP for Emergency response • SOP for logistic Distribution	Y/N	• Fire department the only institution which tried their best to comply with the SOP 2 at the first 6 hours for emergency response • Others did not performed
	e	Local Action Plan	• MOHA: Permendagri No 33/2006 Pedoman Mitigasi Bencana • National Action Plan (RAN) • DM Law 24/2007	• Devloped local action plan (RAD) as a follow up of National Action Plan (RAN)	• Local Action Plan (RAD)	NA	
	f	Risk Assessment	• MOHA: Permendagri No 33/2006 Pedoman Mitigasi Bencana • DM Law • As endorsed in 10 task of local government	• Done in 2007 as part of DRRMP Development	• City Disaster Mitigation Plan	NA	
	g	Revised Spatial Plan to accommodate DRR countermeasures & Revised mid and long term development plan to accommodate DRR countermeasures	• MOHA: Permendagri No 33/2006 Pedoman Mitigasi Bencana • DM Law 24/2007 • Spatial Plan Law 26/2007 • As endorsed in 10 task of local government	• Done in 2007 as part of DRRMP Development • Under development of RPJM Padang City	• RPJM Padang City (Midterm Development Planning)	N	• Not affected yet, the traffic congestion during evacuation were due to insufficient capacity of infrastructure. • The additional inland route are planned to be constructed in the next year budget of Public Department of Padang City. There are 9 road widening and lengthening program for main route toward inland.
	i	Integrate DRR countermeasures into education curriculum	• MOHA: Permendagri No 33/2006 Pedoman Mitigasi Bencana • DM Law 24/2007 • Spatial Plan Law 26/2007 • As endorsed in 10 task of local government	• Many DRR education done by many GO, NGO or GONGO, University etc.	• EQ tsunami drill endorsed by Mayor as school activity every 2nd week at school	Y/N	• School children at home can save their life • 40 school children taking private tutorial class (extra class) in the private buildings were

							killed due to the collapsed of buildings and no safety counter measures since it only had 1 small exit doors.
	2	**Capacity of Government Officials**					
	a	Readiness of 24/7 COD in Crisis Center	• Skill personnel for 24/7 COD to operate the communication device for TEWS • Responsive personnel to perform as SOPs of Crisis Center	• Training for increasing knowledge and skill • TTS • Tsunami Drill	• The wrong man and the wrong time and the wrong place due to establishment of new crisis center	N	• Trained and skill personnel were Fire Department personnel • Personnel of new Crisis Center have not been trained. Therefore they were not performed during the earthquake events. • Not functioning at the first critical 6 hours, since the 24/7 COD does not have sufficient responsive skills. Until the Mayor mobilized the crisis center to his residence. • This has replaced the old crisis center which previously belong under Fire Department, now independence as sub-ordinate of BPBD
	b	Readiness of officials of DM related agencies	• Skill and responsive government officials to perform as SOPs of Disaster Management	• Training for increasing skill • TTS • Tsunami Drill	• Trained government officials	Y/N	• Fire department the only institution which tried their best to comply with the SOP 2 at the first 6 hours for emergency response • Others did not performed
	3	**Infrastructure for Tsunami Early Warning System at local level**					
	a	Infra needed for Crisis Center	Minimum standard of multi mode communication devices: • 2 Fax number (in and out) • Fix Phone • Mobile Phone • Radio UHV • Internet • Ranet (Radio Internet) • Back-up power	• Developed the crisis center infrastructure to meet the standard from national guidelines	• New fully equipped crisis center	N	• Not functioning at the first critical 6 hours, since the 24/7 COD does not have sufficient responsive skills.

	b	Facilities for disseminating order for evacuation	• Radio station • Siren (smart and/or dumb) • Back up power • Indigenous devices: mosque speaker, kentongan (bamboo) • SOP for Siren maintenance	• Optimizing the existence of regional radio station in Padang city, i.e. RRI • Deployed some smart sirens by national government • Deployed some dumb sirens by local government own funds • Optimize the function of indigenous devices such as mosque speaker, by distributing back up power to anticipate power cut off condition • SOP of sirens maintenance	• RRI • Smart sirens • dumb sirens • mosque speaker	Y/N	• At the first critical 1 hours, only RRI radio station and mosque speaker using back up power generator were functioning • Other device such as both sirens did not function due to electricity cut off and no back-up power available.
	c	Facilities for Evacuation	• Evacuation Map • Evacuation route • Ristek Guide lines for: ✓ evacuation route ✓ evacuation map ✓ evacuation sign boards	• Developed and deployed during preparation of national tsunami drill	• Evacuation Map • Evacuation route	N	• The evacuation maps though have been displayed in big screen size was effective. • No sign board for evacuation • People were disoriented, ran to the wrong direction due to traffic jam. • Evacuation route capacity was not able to accommodate the not orderly manner number of evacuee. This has been anticipated by many studies presented to the government.
	d	Escape buildings	•		• Law enforcement of using multi story public building ad escape building	N	• Most designated building were collapsed during the earthquake • Need building review regulation and law enforcement
	e	Hospitals	•			N	• Most designated building were collapsed during the earthquake • Need building review regulation and law enforcement

	4	**Community Preparedness**		
	a	**Community capacity**		• Awareness and preparedness of community are very high, since: ✓ many intervention conducted at the after Aceh Tsunami ✓ having direct experience of strong earthquake and potential tsunami in April 2005, 12 September 2007 and 16 August 2009 • Response to current earthquake : ✓ City people trapped in traffic jam for evacuation, then ran to wrong direction ✓ Rural people easily went to higher ground without any obstacle and without waiting for warning from government
		• Disaster experience	Y	
		• Availability of DRR info	Y	
		• Participation on DRR activity/training	Y	
		• Disaster risk perception on:		
		✓ natural hazards	Good	
		✓ environment vulnerability	Moderate	
		✓ vulnerability of escape building and emergency facilities	Bad	
		• Disaster risk attitude toward disaster	Good	
	b	**Community commitment for disaster preparedness**	Good	
	c	**Community emergency response plan**	Done	
		• emergency response plan	Good	
		• evacuation plan	Good	
		• search and rescue	Moderate	
		• first aid	Good	
		• public kitchen	Good	
		• camp management	Good	
		• survival kits/packages	Good	
	d	**Community commitment for regular EQ and tsunami drill**	Good	
	e	**Having local champion or leader for DM**	Good	
	f	**Building partnership with government in DM**	Good	
	g	**Building partnership with private sectors in DM**	Good	
	h	**Building partnership with I/NGOs, CBOs, GONGOs in DM**	Good	
	4	**Vulnerability & Swift Recovery**		
	a	**Population**		to be recognize trhough rimary data acquisition during the logic model developmentn
		• number of children		
		• number of elderly		
		• number of working age		
	b	**Housing:**		
		• density		
		• multi-story		
		• seismic resistant structure		
	b	**Lifelines & utilities swift recovery**		
		• electricity		
		• Water supply		
		• Telecommunication		
	c	**Infrastructure**		
		• Airport		
		• Harbor/Port		
		• Road		
		• Bridge		
	d	**Schools**		

	e	**Culture**		
	5	**City Stakeholder**		
	a	**Private sectors**		to be recognize trhough rimary data acquisition during the logic model development
	b	**Industry**		

Table 4.4 Functioning and Malfunctioning indicators of International Assistestance

	IV	**INTERNATIONAL ASSISTANCE**					
		Factors	**Recommended DRR Countermeasures**	**DRR Countermeasure implemented in Padang**	**DRR Outcome in Padang**	**Functioning**	**Remark**
	1	**Rescue**	• Govt Reg: ✓ PP21/2008– Penyelenggaraan ✓ PP22/2008 Pendanaan ✓ PP23/2008 Peran serta • DM Law: UU 24/2007			Y	• Create burden to local government, if it come with the wrong personnel and wrong time. • SEARAC
	2	**Relief**	• Govt Reg: ✓ PP21/2008– Penyelenggaraan ✓ PP23/2008 Peran serta • DM Law: UU 24/2007			Y	

4.3 Tsunami Preparedness Index – Floating Model

There were several assessment indicators existed to be used to evaluate tsunami prone area in Indonesia. Prior the tsunami 2004, there was no existence of such assessment indicator for tsunami that can used to measure the level of tsunami threat. The assessment was mostly relying on the historical records and geodynamic position of the region in Indonesia. During the period of 2004 - 2009, the measurement of the level tsunami threat was relying on the Global Tsunami Hazard Map, which was based only the expected tsunami height which may occur in the certain tsunami prone region. This measurement tool was not sufficient to identify the level of tsunami risk of the coastal region in Indonesia. By the year 2009, a Global Tsunami Risk Index was developed by Ristek to assess global tsunami risk of cities/regencies of tsunami prone regions. However for having the effective tsunami early warning system, a more detail indicators are needed to measure the level of tsunami preparedness of those tsunami prone cities/regencies is needed prior to the intervention of DRR countermeasures.

To answer the research challenges due to the increase of the number of tsunami risk cities among high populated cities described in Chapter 1 and 2, this study assumes that there is need to restructure the existing tsunami risk index to be able to be used as tsunami preparedness index. The issues related with the needs for assessment indicator for high populated cities from tsunami prone area is decribed also in Figure 4.1.

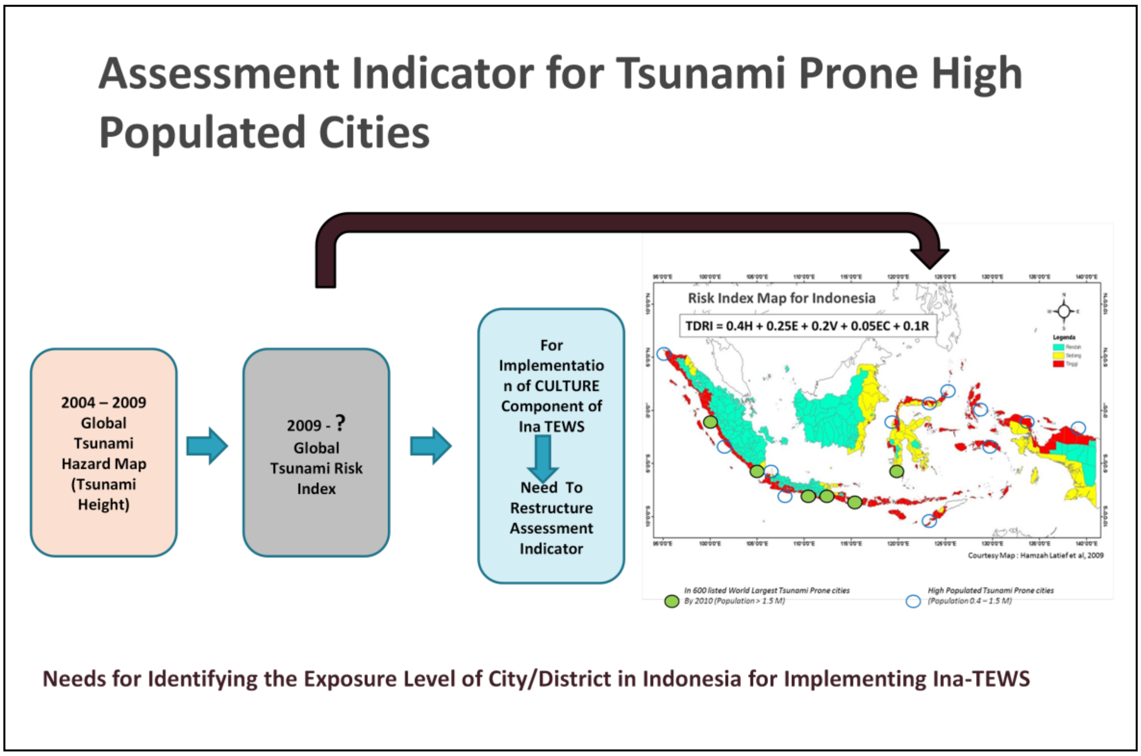


Figure 4.1 Issues Related with the Needs for Assessment Indicators for Populated Cities from Tsunami Prone Area

In this section, the development of Tsunami Preparedness Index is described in sub-section 4.3.2 followinng the brief description of tsunami risk index developed by Ristek (2009) described in sub-section 4.3.1.

4.3.1 Tsunami Risk Index for Cities in Indonesia

Tsunami Risk Index for Indonesian cities developed by Ristek (2010) is basically the attempts to make a tsunami risk zonation for coastal cities from tsunami prone area in Indonesia. Prior to this effort, people only assumes the tsunami risk prone area based on the location of the coastline in subduction area combined with tsunami catalog in Indonesia; except scientific research have done with more indepth with many parameter of tsunami in indentiying the tsunami risk.

Tsunami risk seen from classical principal of disaster risk approach can be viewed as a function of hazard and vulnerability. Several parameters of tsunami hazard can be used to identify the level of hazard its self depending of the purpose of the assessment. The level of hazard may be represented by one or several of these: tsunami height, tsunami inundation, tsunami run-up, tsunami propagation at land, and tsunami arrival time. There is wide range of vulnerability from the preliminary up to advance one.

For the tsunami risk index discussed in previous paragraph, level of hazard is represented by tsunami height which was obtained from precalculated tsunami database developed for Ina-TEWS as shown in by Figure 4.2 (H. Latief and Harris, 2009).

In this figure, the level of hazard categorized into 4: Low, Moderate, High dan Very High, by adapting Tsunami Intensity Scale into the tsunami height resulted from the precalculated tsunami data-base. Low is for the area having expected tsunami height less than 1 m, Moderate for expected tsunami height of 1-2 m, High for expected tsunami height of 4-8m, and Very High for expected tsunami height greated than 8 m (Latief, Haris dan Natawidjaja, 2009).

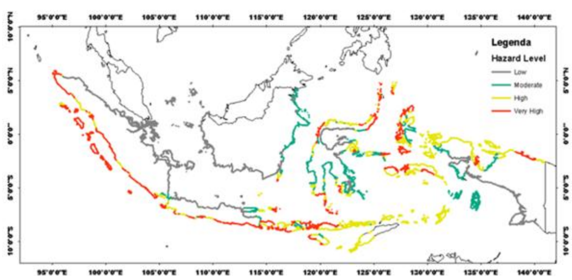


Figure 4.2 Tsunami Hazard Level of Indonesian Coastline

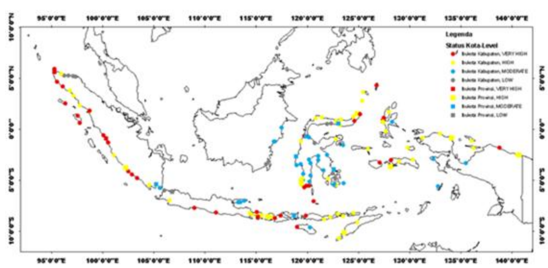


Figure 4.3 Tsunami Risk Levels of Indonesian Coastline Cities

Based on this level of tsunami hazard, it is further identified the level of tsunami risk using the formula of Tsunami Risk Index: TDRI = 0.4H + 0.25E + 0.2V + 0.05EC + 0.1R

H is Hazard, a function of Tsunami and its Collateral Hazard, where tsunami hazard consisting of Tsunami Height and Tsunami Travel Time indicators and collateral hazards including population density, Floating Materials, Ratio doctor to population, and Number of School Building.

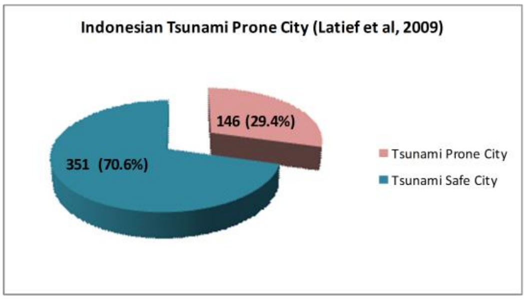
E is Exposure which is a function of Physical Infrastructure exposure consisting of Total Population, Ratio GRDP (service and industry sector) to total, and number of households and Total Road Length (Km) of City/Regency indicators; Total Road Length (Km) of City/Regency; Population exposure consisting of total population; Economy exposure consisting of PDRB per capita of city / regency; and Topography which is less than 20 m

V is Vulnerability which is a function of Physical Infrastructure vulnerability, Population vulnerability and Economic vulnerability. The Physical Infrastructure vulnerability consists of Tsunami indicator, City wealth indicator, Population density, and District/city development rate. The Population vulnerability includes % Population of vulnerable group of children and elderly, Education, People Access for communication, Age Life Expectancy, and Number of Disable; while Economic vulnerability consist of % Poverty Population and Dependency Ratio.

EC is for External context which is location of the district. R is Capacity for Response and Recovery which is a function of Planning, TEWS, Resources, Mobility & Access, and Service Facility which includes Number of health facility, Ratio doctor to population and Number of School Building.

All of these indicators described are based on the census indicators which used in census statistic conducted in every 5 years. The numbers represented in this index is very generic and global.

Result of risk classification shows that about 146 coastal cities are prone to tsunami risk, ranging from moderate to very high risk. Here level of tsunami risk only counting on the tsunami height, see also Figure 4.3. Almost 30% of the Indonesian cities are prone to tsunami, see Figure 4.4, where about 24% with very high risk level, 40% with high risk level, 25% with moderate risk level and 12% with low risk level.



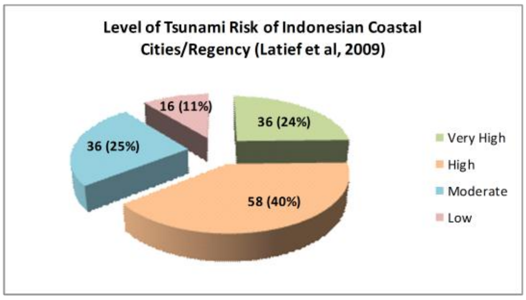


Figure 4.4 29.4% of Indonesian cities – prone to tsunami risk

Figure 4.5 Level of tsunami risk of Indonesian coastal cities/regencies

4.3.2 Tsunami Preparedness Index for City

Looking at Figure 4.3 where the city of Padang is categorized as very high risk; however the index is not sufficient to be used to assess the level of risk prior to the implementation of disaster reduction countermeasures especially to tsunami.

Based on the assessment of function and malfunction indicator developed by this study and described in Section 4.2, there is need to assess more *in-depth but still generic* compare to the level of that riskdicussed in Suc-section 4.3.1 above. The generic preparedness index is very useful prior to the implementation of tsunami disaster risk reduction countermeasure to increase the readiness of the city to response the warning and to evacuate, as to the goal of effective tsunami warning system where the accurate warning which is timely disseminated leaving with sufficient lead time for peole (including the government officials) to response by taking right judgment using the right belief or perception toward the risk and warning.

In overall there is parameter to be included as primary information. In this study Tsunami Risk Index is seen from the preparedness level of the city, thus defined as Tsunami Preparedness Index which consists of basic preparedness parameter should have by the city.

There is significant difference between index and indicators. Index is a composite representation of variable factors (indicators) that show level of disaster risk toward tsunami from one city at a specified time. It is used to measure the conditions and changes over time of a city and to benchmark a city over the other for a specific range of time. Meanwhile Indicators is variable factors that will significantly contribute to the risk of city toward tsunami.

For the needs for having Preapredness index, the restructuring assessment indicators can be described by expanding the tsunami risk index with 6 other paremetes. They are Policy, Institutional and Organizational Arrangement, Community Preparedness, Capacity of Government Officials, Vulnerability & Swift Recovery, City Stakeholder and Existence of International Assistant. Detail of these indicators can be seen in Figure 4.6.

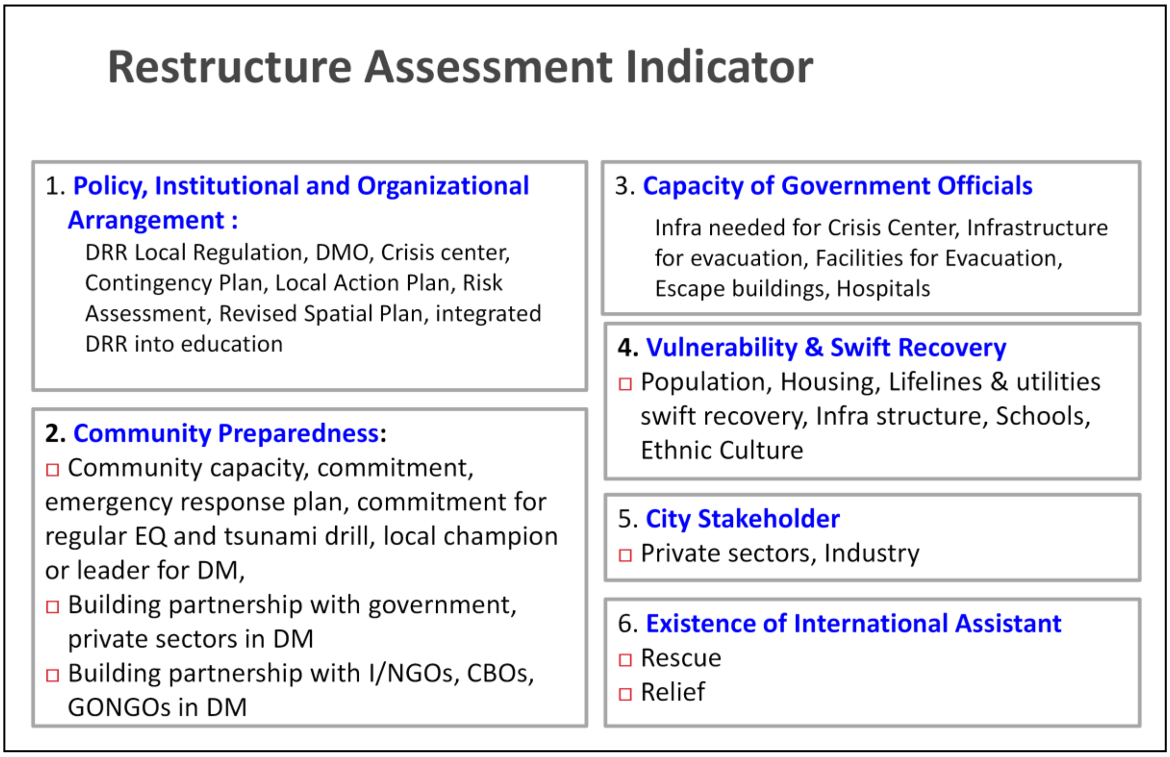


Figure 4.6 Restructure Assessment Indicators for Preparedness Index

All of these indicators for assessing the preparedness level of a city/regency could be obtained prior to the implementation of the DRR countermeasures as well as in the interval time for the monitoring and evaluation the effectiveness of tsunami warning system especially at the culture component.

For initial stage of floating factors (model), the Tsunami Preparedness was developed based on basic vulnerability and capacity information discussed in the section 4.3 above, however for the future works to elaborate the preparedness index from global to more specific is necessary as shown in below:

Now:

Formulation of TPI → global Index

- TPI = 0.4H + 0.25E + 0.2V + 0.05EC + 0.1R
- Using weighting factors

Future-Restructure:

- TPI= αSystem 1(H) + βE + γV+ δSystem 2(Ina-TEWS) + $\varepsilon C_{1\&2}$ + ζSystem 3(Local Govt.) + ηSystem 4(Community Preparedness)

Figure 4.7 Formulations for Preparedness Index

This Preparedness Index graphically can be represented as the floating model shown in Figure 4.8. The relationship among the variables represented by nodes is developed based on the physically based logic model. It means the information gathered from the physical condition not from the people cognitive information.

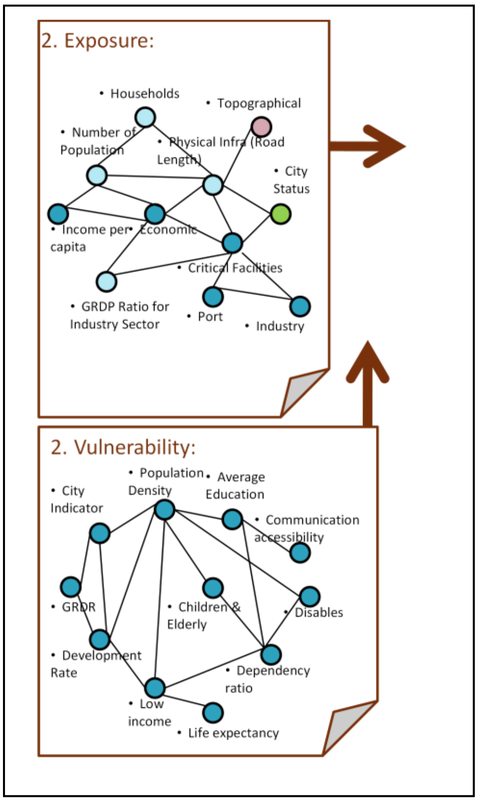


Figure 4.8 Preparedness Index as the Floating Model

4.4 System 1: Natural Phenomena – PBLM

The first floating model of integrated logic model developed by this study is natural phenomena model, which is constructed based on the problem structuring on the series of tsunami events occurred in Indonesia with different magnitude and impacts on the human being and built environment. The development of this model is also gain from the tacit knowledge improved during the development of tsunami disaster scenario for the preparation of implementing DRR countermeasures for national tsunami drill in Bali 2006 and Cilegon Banten 2007, as the best examples of the two different cities. The first Denpasar Bali is a tourist business city, while the second Cilegon Banten is a heavily industrial city.

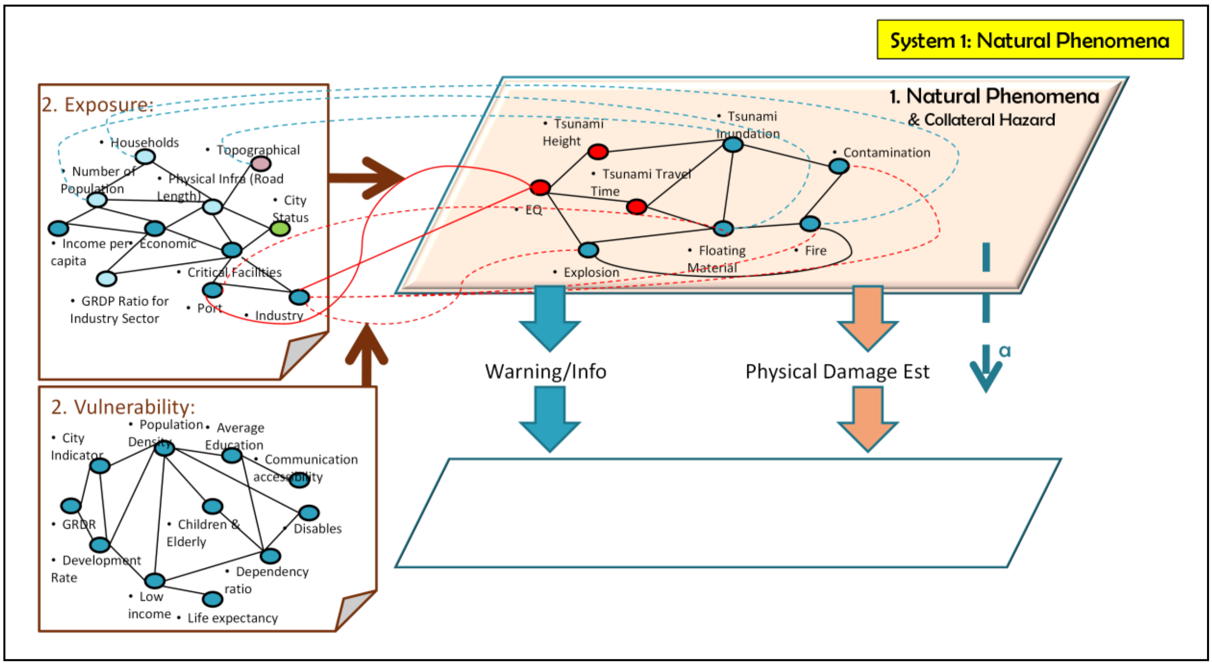


Figure 4.9 Physically based logic model of layer 1 – Natural Phenomena

However, under this study the model of natural phenomena is developed based on the physically based logic model, meaning the correlation among the variable was developed based on the secondary information of the city and tacit knowledge gain during the above activities described in above paragraph.

Graphical representation of this model shown by Figure 4.9 consists of relationship among the primary hazard of the tsunami and its collateral hazard which affected the variables of built environment. The primary hazard of tsunami consists of tsunamigenic earthquake as the main trigger and followed by tsunami variables which include: tsunami height, tsunami travel time, tsunami inundation. Among these tsunami variables only 3 variables shown in red nodes, which means as the most influential variables as primary hazards, which affect other collateral hazard variables and physical variables. While the physical variables consists of floating materials, contamination, fire, explosion, which are expected to be occurred in the industrial area of the city of Padang or Cilegon. Lesson learned from Tohoku tsunami where affected with these phenomena in the Ibaraki prefecture, Sendai City, Rikuzentakata and some other fishing port towns.

The correlation of these variables (nodes) provides two informations to the next layer models, i.e. TEWS Structure Component – layer model and 2 as well as the next layer model 3 (Government Model) and/or layer model 4 (People Model). The first information is the natural warning information in the form of shaking, chanign water column and other characteristic which can be detected by tsunami early warning system devices. The second information is the physical damage that can be estimated throught the intensity felt. The physical damage information due to earthquake can be used by the next layer model as the input for the expected damage of tsunami might occurs.

Figure 4.9 also shows the relationship between the floating models to this Model of Natural Phenomena.

4.5 System 2: Structure Component of Ina TEWS – PBLM

In this second layer model called as the Model of TEWS Structure Component, the development is based on the physically based logic model approach. All the relation among the variables of structure component were structured based on the flow or mechanism of the structure component, which basically can be divided into monitoring and detecting the seismic, the changing of warter column, the evaluating for the potential tsunami based on the information directly observed, or information from the data base, or information obtained from the natural phenomena such report on intensity etc. See also Figure 4.10.

Ouput of this layer model is tsunami warning, as explained in Chapter 2 for progress performace of Structure Component able to disseminate the tsunami warning within less than 5 minutes. The information basically consists of information ralted with estimated tsunami heigh, tshunami travel time, tsunami affected area and tsunami cancellation. However, the most important is that the output of this warning information should be understood and responded by the the third layer government model and fourth layer people model.

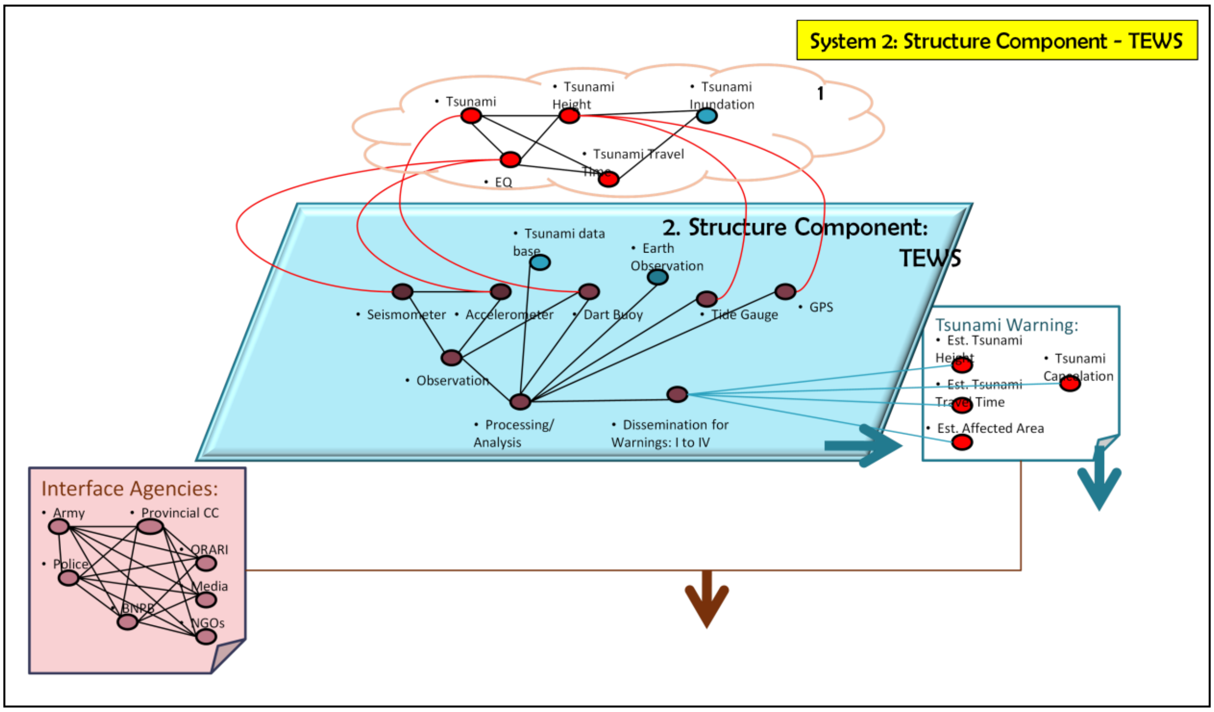


Figure 4.10 Physically based logic model of layer 2 – Structure Component

4.6 Summary

About 30% of coastal cities in Indonesia are exposed to tsunami risk, from low to very high, where Padang City the case study city is exposed to very high tsunami risk interm of expected tsunami height and tsunami arrival time.

From the List if functioning and malfunction indicators, it is found by this study that most of the malfunction indicators were at the Culture component of Ina-TEWS. The structure component was perfectly functioning. These trigger the need for developing the Tsunami Preparedness Index by this study.

For initial stage of floating factors (model), the Tsunami Preparedness was developed based on basic vulnerability and capacity information discussed above, however for the future works to elaborate the preparedness index from global to more specific is necessary as the function of hazard, exposure, vulnerability, layer model 2, layer model 3 and layer model 4.

The first two layer model developed using physically based logic model is very fruitful to describe the relation among the tangible and intangible of physical and technological phenomena. These combined with floating factor model are very important as the input for the layer model 3 and model 4 to find how is relation among those coginitive factors structured using the combination of tacit knowledge and heuristic knowledge.

Chapter 5
People Model

5.1 Introduction

This Chapter 5 presents and discusses detail process development of Logic Model and Numerical Logic Model for people. It starts from problem recognition on people, problem structuring which includes a multi stage of in-depth knowledge acquisition and its cognitive mapping, developing logic model in the format of logic model tree, and developing numerical analysis.

People's behavior in large-scale environments can be explained completely through cognitive map, which is the basis for deciding upon and implementing any strategy of spatial behavior and as basic component of human adaptation. This leads to cognitive map as requisite both for human survival and for everyday environmental behavior (R.M. Kitchin, 1994). Ability to plan and execute movement in a familiar environment requires possession of a cognitive representation of that environment. Cadwallader (1976) suggests that the cognitive maps affect at least three types of decisions: the decision to stay or go, the decision of where to go, the decision of which route to take, and the decision of how to get there.

This shows that knowledge acquisition takes significant role in the development of logic model for people, prior to cognitive mapping and constructing the logic model then its numerical modeling. It is recognized under this study that Padang City historically stricken by 4 tsunamis which were generated by earthquake with magnitude up to 9.0 in 1797, 1833, 1861, and 1864 thousand people were lost according to Tsunami catalog Indonesia (Hamzah, 2005). In addition to that Padang was the first national show case city during the development of Ina-TEWS meaning intensive DRR countermeasures have been implemented. Not only that, international community interest due to ‘expected another mega tsunami’ in Padang has boosted the DRR countermeasures implementation. During 2005, 2007 and 2009 event no impact were seen on the people behavior. This issue has triggered the study to recognize and structure the problem further, since all natural and make-up ‘experiences’ were expected to influence the prior belief or perception of people to tsunami threat and its impact as well as their appreciation to the countermeasures intervention such as tsunami warning.

In overall, the process development for People Logic Model described in Figure 5.1 consists of 8 stages, which are described and discussed in the next section of this Chapter 5.

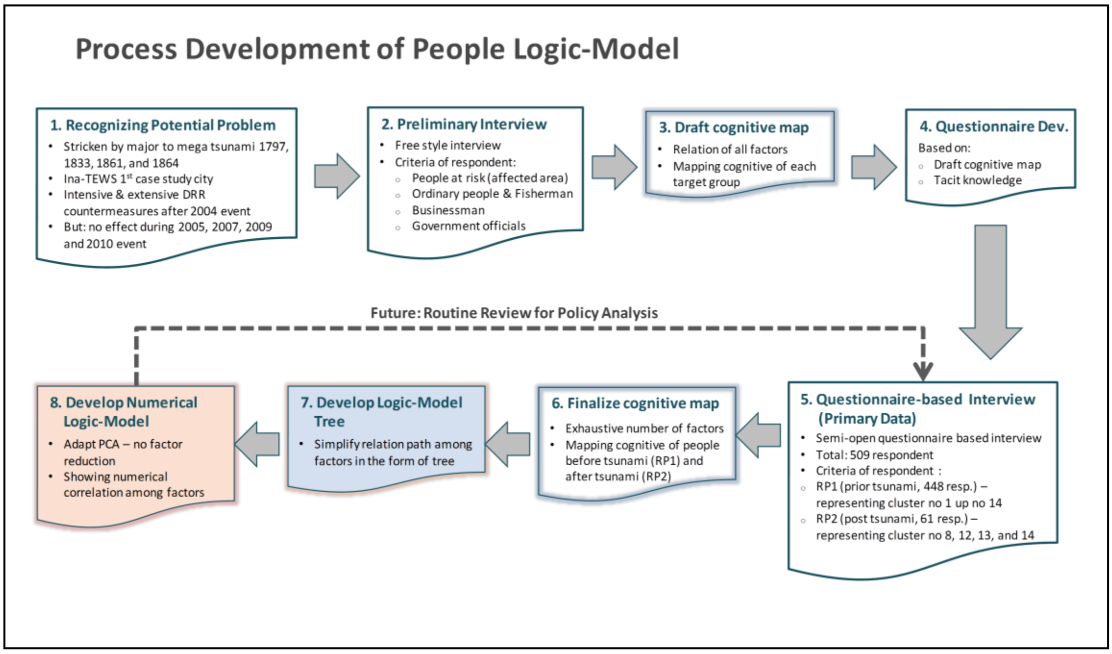


Figure 5.1 Process Development of People Logic-Model

In this scheme, the problem structuring of Logic Model defined in Chapter 3 covers the stage no 1 to 6. This multi stage of knowledge recognition and cognitive mapping are expected to be better method in acquiring and mapping holistic cognitive of people toward tsunami threat and its impact; as well as their behavior in responding whether deciding to stay or go, where to go for saving their lives, which route to take, and how to get to there. Since the problem recognition has been discussed in this introduction and in the Chapter 1, therefore the discussion in this chapter is started from problem structuring (stage 2 to 6) then followed by development of logic-model tree (stage 7), and development of numerical model (stage 8).

For the development of People Logic Model as integrated part of effective tsunami warning system logic model, it requires a sound problem structuring using knowledge acquisition and cognitive mapping. A holistic data set should be acquired through exhaustive identification process for acquiring the human being perception and response to tsunami threat, its impact, and tsunami warning before taking any decision.

This study views that these human behavior are influenced by prior belief gained through many factors or variables, such as knowledge, skills or experiences. Many of these factors or variables are intangible, unseen or indelible inside the people's mind as well as people's understanding concerning their exposure, meaning hazard threat, disaster impact on himself and his environment, his vulnerability, capacity and coping ability to tsunami disaster; and their trust to the existence of tsunami warning including willingness to evacuate. To obtain holistic and exhaustive information from the people, therefore a multilevel questionnaires based interview is used in knowledge acquisition, described in Section 5.2 and 5.3 of this chapter.

5.2 Preliminary knowledge acquisition and cognitive mapping

The preliminary interview was conducted on several target groups among the victim of the 2009 event and people living at tsunami high risk zone. A free style interview is used for recognizing any factors that hinder or support the people's mind or thoughts regarding the shaking and hearing the siren wailing, and their heuristic judgment. Number of recorded respondent is 15 representing the urban community, fishermen, government officials, and government officials in charged with emergency response (i.e. crisis center, fire brigade), as well as other agencies and the mayor/regent and vice governor. The survey conducted from October 7 to 16, 2009 under collaboration between ITB with EERI and UPitt.

There were 3 category of people interviewed, i.e. general public included fisherman, waitress of the hotel, taxi driver, office boy, students, and faculty members local university; and businessman - hotel owner; and government officials. The last target is used to develop the government logic model described and discussed in Chapter 6.

For example from ordinary people interview conducted with Fisherman Community in Padang on October 9-15, 2009 (WS118365, 2009c), see also Figure 5.2. The reasons of these fisherman reactions not to evacuate during the 2009 event were due to some his rationale and judgment described as follows. Immediate after strong shaking the fisherman and his wife just checked the sea water level behind their ‘tsunami resistant housing’ built by DKP ocean and fishery department project. They decided to remain at their second floor house based on two judgments, i.e. no sign of tsunami such as withdrawn water and very far to the closest hill. In addition the family joined 2007 tsunami drill, thus they were sure no one will lead them if tsunami were occurred, they have to lead themselves. Before the earthquake, strange phenomena such as sky was dark since morning and sea water rough were noticed by them, which made him did not go to the sea.

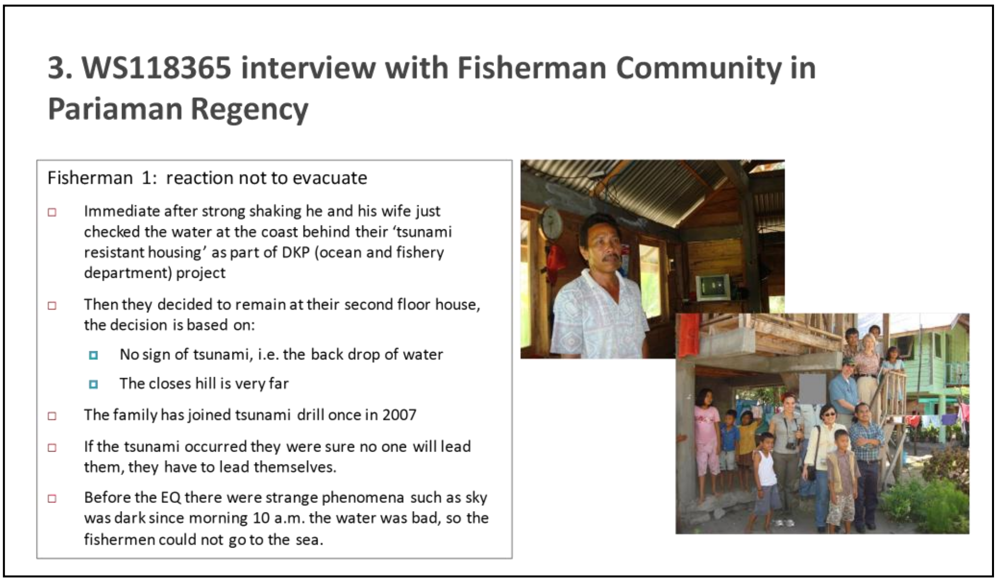


Figure 5.2 The Preliminary Interview with Fisherman

The simple cognitive behavior and the heuristic decision making of single human being, in this case is the fisherman are mapped and can be seen in Figure 5.3. In this mind structure, the decision for evacuating the whole family is directly relied upon three primary factors, i.e. checking the natural sign at the beach, the location of the house is in the tsunami risk zone, and very far from the hill. Each of these factors are directly influenced by several factors, i.e. no radio and no TV for monitoring the warning of potential tsunami due to electricity cut off, not hearing any siren wailed by the mayor, very strong shaking was felt, and strange atmosphere prior to the event.

For the DRR capacity of the family, they have not joined any tsunami drill though they heard the activity conducted in the neighborhood. They have strong house, since it was the pilot project of tsunami safer house from Ministry of Ocean and Fishery.

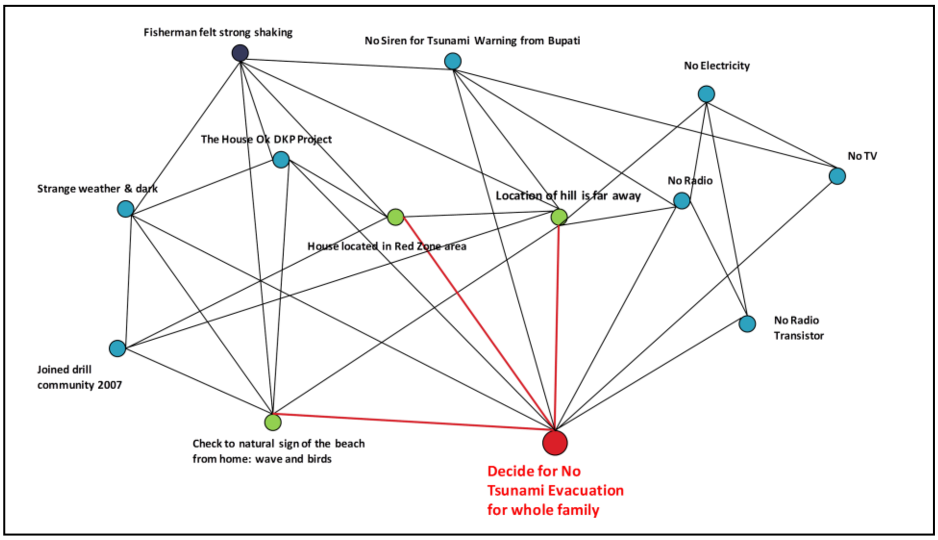


Figure 5.3 Cognitive Maps of People (Fisherman)

Other example of people mind is second target group interviewed was conducted at Hotel Inna Muara in Bahasa Indonesia with Hotel Duty Manager and his guest (WS118382, 2009b), see also Figure 5.4. Hotel guest was a City Government Officer who just describing the damages on hotel business, he was not in Padang during EQ. Second person is Hotel Duty Manager in charge during EQ.

The chronological factors obtained from the freestyle interview were the mains shock was felt around 5 pm (fact 5:17pm), the first main shock was after 6 pm (fact on 5:25), then 9 pm. No siren was heard (fact: true). Electricity, phone (fix and mobile except XL), water and radio were cut off. After main shock, he did not run for tsunami evacuation because. When he ran to top floor to check water at the beach for tsunami sign, nothing seems unusual, the wave was calm. When he checked the street in front of hotel, it was chaotic and overcrowded by people, cars and anything. Then he decided not to evacuate the guest (government officials from other cities in Sumatera regions). The male guests were stayed up at the roof top. The female guest including 2 pregnant ladies stayed in the lobby due to afraid of following aftershocks which were frequently occurred (about 20 times within first 6 hours).

The cognitive mapping of the businessman and the hotel guest is presented in Figure 5.5. This figure shows significant different between fisherman and hotel manager in their disaster risk perception and their heuristic judgment for evacuation. The hotel manager showed pragmatic attitude compare to fisherman showing simple mindset.

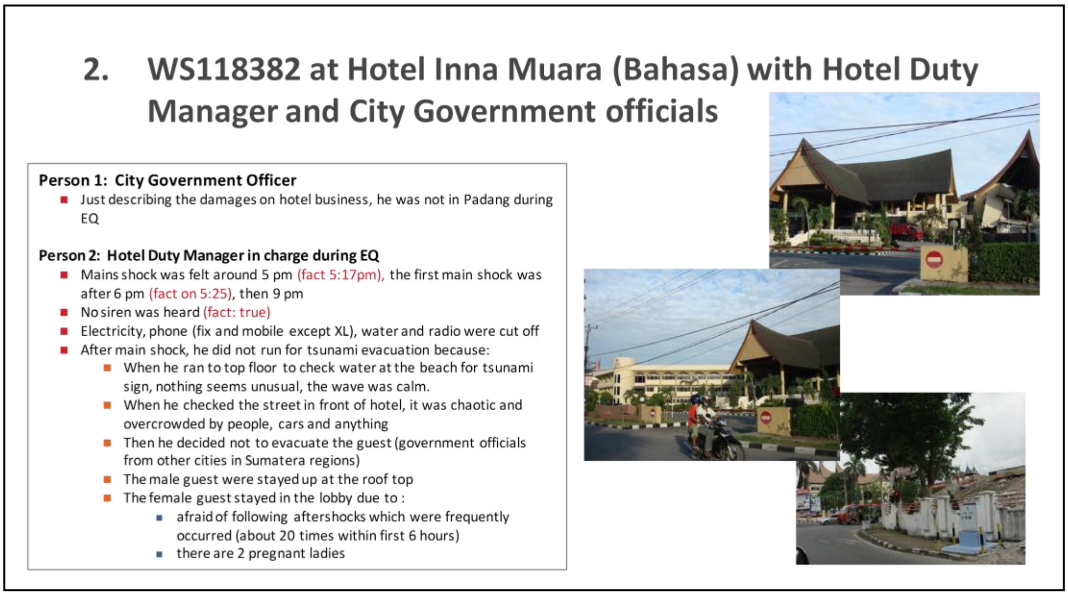


Figure 5.4 The Preliminary Interview with Businessman

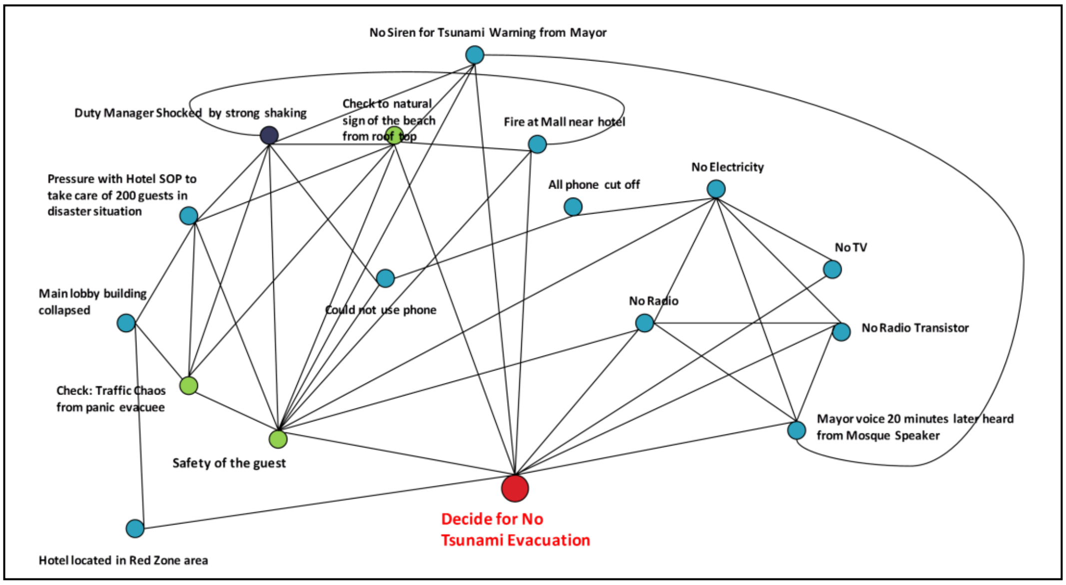


Figure 5.5 Cognitive Map of Businessman

5.3 Primary knowledge acquisition

As discussed in the Chapter 3, there are two target groups of people used to develop the People Logic-Model. They are respondent interviewed prior to 2010 Mentawai tsunami event called in this study as RP1 (Respondent 1), which was about 448 people. While other target group of respondent interviewed after 2010 Mentawai tsunami event called by this study as RP2 (Respondent 2), which was about 61.

First drafted questionnaire for people is developed based on: preliminary cognitive map, preliminary interview survey conducted 7 days after the September 30, 2009 earthquake in Padang City and Pariaman Regency, and tacit knowledge. The tacit knowledge obtained were from the in-depth survey conducted under collaboration of CDM ITB with AUSAID (4,000 data) and the prior knowledge obtain based on the secondary data during activities conducted from 2005 to 2009 during and after coordinating national tsunami drill in 2006 in Denpasar Bali and 2007 in Cilegon Banten as well as observation during 2005 and 2007 event on this national show case city.

The final questionnaire for people is developed based on the further refined and reviewed the draft based on the followed up interview survey on focus target group, i.e. community and government officials involved in the emergency response. This survey conducted on June 2010. The number of respondent was 9.

The pre-test interview survey was conducted by 6 student surveyors from Economic Department of UNAND on the zone red zone area (zone 8 and 9) the first day. About 50 respondents were interviewed. Result of the survey was evaluated and used to refine the final questionnaire. With total numbers of targeted samples about 300 respondents, there were about 10 students from Economic Department and Civil Engineering Department of UNAND.

The focus of 300 target group representing cluster/zone no 1 to 14 of tsunami risk zone with criteria of respondents as stakeholders of community representatives. They were adult man/women, formal/informal worker, residence/worker/trader, DRR countermeasure trained/untrained, and students of school located in zone 1 to 14. Population of students was limited to max 20% from total respondents, since there was previous survey conducted prior this study was focused on the school community. It has been mentioned to every interviewee by the surveyors that any personal data collected through this survey are confidential, strictly used for the study analysis only and will never be disclosed.

This semi-open questionnaire based interview consists of 3 part of assessment. First is the vulnerability and capacity of respondent. Second is hazard perception, disaster experiences and DRR countermeasures. Third is appreciation to tsunami early warning system and its associated factors. The questionnaires can be seen in the appendix of this dissertation.

The first part questionnaires consists of the socio economic vulnerability and capacity of the respondent, such as the age, education, job, income, number of households, the house conditions, and some other information gathered during the interview through the semi-open questionnaires.

The second part of questionnaires includes the perception of people toward the hazard threat, the tsunami threat, its impact, their understanding of disaster risk reduction countermeasures and their heuristic judgment to protect him-self and the family, including to fishing out all hindrance and supporting factors to their judgment.

The third part of questionnaires covers the heuristic judgment of the people when they felt the strong shaking from the earthquake and when hearing the tsunami siren wailing, all hindrance and supporting factors that influenced their judgments, and their knowledge and appreciation toward tsunami early warning system, its infrastructures, and the government in charge.

As described in Chapter 3, the number of factors and parameters of both respondent shown in Figure 5.6 describes the variables and factors that influenced the heuristic judgment as in reasoning for evacuation (Ei) is the biggest number, i.e. 184 variables, and having most complicated relation among variables in its own cluster as well as with other clusters in the cognitive mapping. This is followed by variables and factors of DRR Countermeasures (CMi), i.e. 118, with its all hindrance and supporting factors. The socio economic susceptibility factors (Vi) takes the third biggest, i.e. 87; then followed by appreciation to tsunami early warning system, i.e. 60, where it includes the appreciation to indigenous knowledge or devices to support the early warning system to be effective in reaching the all the people at risk including the last mile. The smallest number of variables and factors acquired from the respondents are from variables and factors that influence people understanding toward the hazard threat, especially tsunami including its impact. There is 1 variables difference between RP1 and RP2 in cluster Ei and Vi. The relation of all of these variables and factors are analyzed and mapped in the cognitive map, which is discussed in the next section.

No	Cluster	RP1	RP2
1	Ei – Reasoning for Evacuation	184	183
2	Vi – Vulnerability & Capacity	87	86
3	Hi – Hazard Perception & Disaster Experience	29	29
4	Ti – Tsunami Knowledge	9	9
5	CMi – Countermeasures of DRR	118	118
6	TEWS – Tsunami Early Warning System	60	60
	T O T A L	487	485

Table 5.1 Number of variables acquired for RP1 and RP2

5.4 Cognitive Mapping of People Mind and Behavior

The 487 of holistic and exhaustive data set obtained from primary data acquisition discussed in Section 5.3 which is an integration of RP1 and RP2 are analyzed and structured based on its cognitive relationship.

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 5.7. 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.

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.

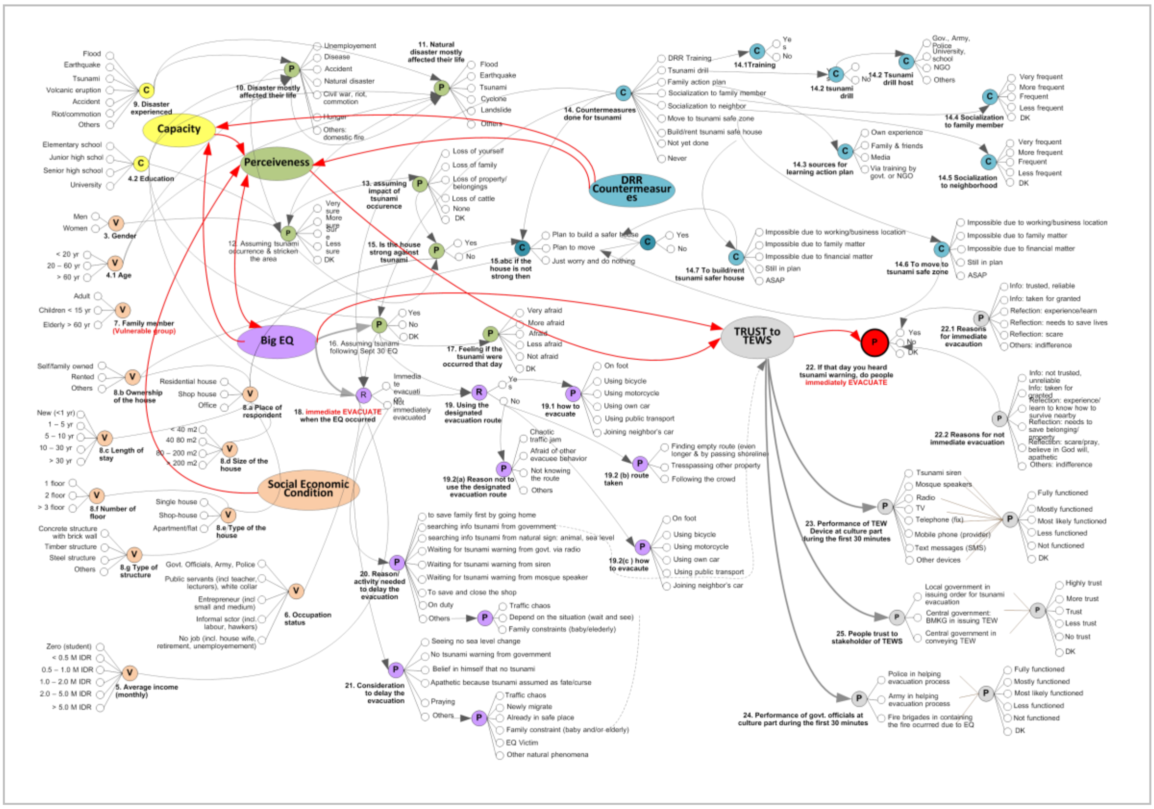


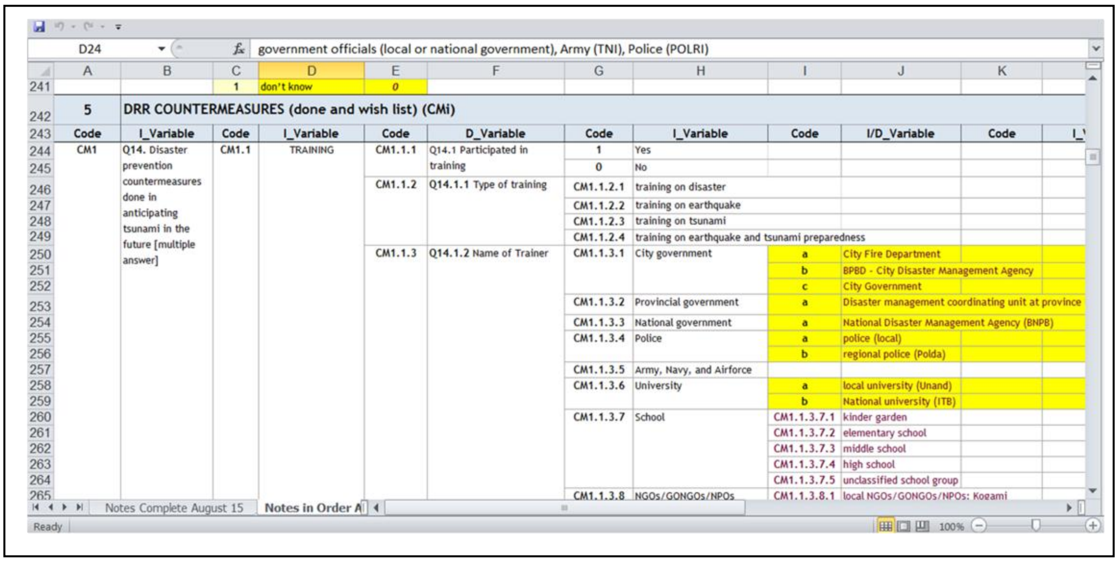
Figure 5.6 Structuring the problem and the people's mind in tsunami disaster situation

5.5 Development of logic model of people's mind toward tsunami early warning

Based on the previous diagram shown in Figure 5.7, then the logic model is constructed by simplifying the relationship among those variables (both observable and unobservable/latent variable), in the form of data structure. Example of some part of data structure is shown by Figure 5.8, while the complete data structure for people can be seen in the Appendix. 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 the nodes of children-parents order like a family tree, in this study called as logic model tree as shown in Figure 5.8 and

Figure 5.9. Figure 5.8 shows a complete Logic Model Tree of People's Mind toward Tsunami Early Warning, while Figure 5.9 is the core model of the Logic Model showing relationship among latent variables.



D24 — government officials (local or national government), Army (TNI), Police (POLRI)

	A	B	C	D	E	F	G	H	I	J	K
241			1	don't know	0						
242	5	DRR COUNTERMEASURES (done and wish list) (CMi)									
243	Code	I_Variable	Code	I_Variable	Code	D_Variable	Code	I_Variable	Code	I/D_Variable	Code
244	CM1	Q14. Disaster prevention countermeasures done in anticipating tsunami in the future [multiple answer]	CM1.1	TRAINING	CM1.1.1	Q14.1 Participated in training	1	Yes			
245							0	No			
246					CM1.1.2	Q14.1.1 Type of training	CM1.1.2.1	training on disaster			
247							CM1.1.2.2	training on earthquake			
248							CM1.1.2.3	training on tsunami			
249							CM1.1.2.4	training on earthquake and tsunami preparedness			
250					CM1.1.3	Q14.1.2 Name of Trainer	CM1.1.3.1	City government	a	City Fire Department	
251									b	BPBD - City Disaster Management Agency	
252									c	City Government	
253							CM1.1.3.2	Provincial government	a	Disaster management coordinating unit at province	
254							CM1.1.3.3	National government	a	National Disaster Management Agency (BNPB)	
255							CM1.1.3.4	Police	a	police (local)	
256									b	regional police (Polda)	
257							CM1.1.3.5	Army, Navy, and Airforce			
258							CM1.1.3.6	University	a	local university (Unand)	
259									b	National university (ITB)	
260							CM1.1.3.7	School	CM1.1.3.7.1	kinder garden	
261									CM1.1.3.7.2	elementary school	
262									CM1.1.3.7.3	middle school	
263									CM1.1.3.7.4	high school	
264									CM1.1.3.7.5	unclassified school group	
265							CM1.1.3.8	NGOs/GONGOs/NPOs	CM1.1.3.8.1	local NGOs/GONGOs/NPOs: Kogami	

Notes Complete August 15 | Notes in Order A

Figure 5.7 Data Structure of People

In Figure 5.8, the logic model is represented many different nodes characterized by some identity of the node's shape, color and with and without 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 nodes at the leaves of logic model's tree; here leaves are called as children nodes which belong to one parent's node. The parents' nodes belong to a grandparent's node and so on. Since the characteristic of variables in one cluster family is different with other cluster family, then the number of family branches is different from one to another cluster, see Figure 5.8.

Moreover, the color of nodes shows the substantial relationship among nodes in one family cluster which are needed to represent their role in the scenario analysis of this numerical model. The grey nodes are recognized as *external factors* to 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.

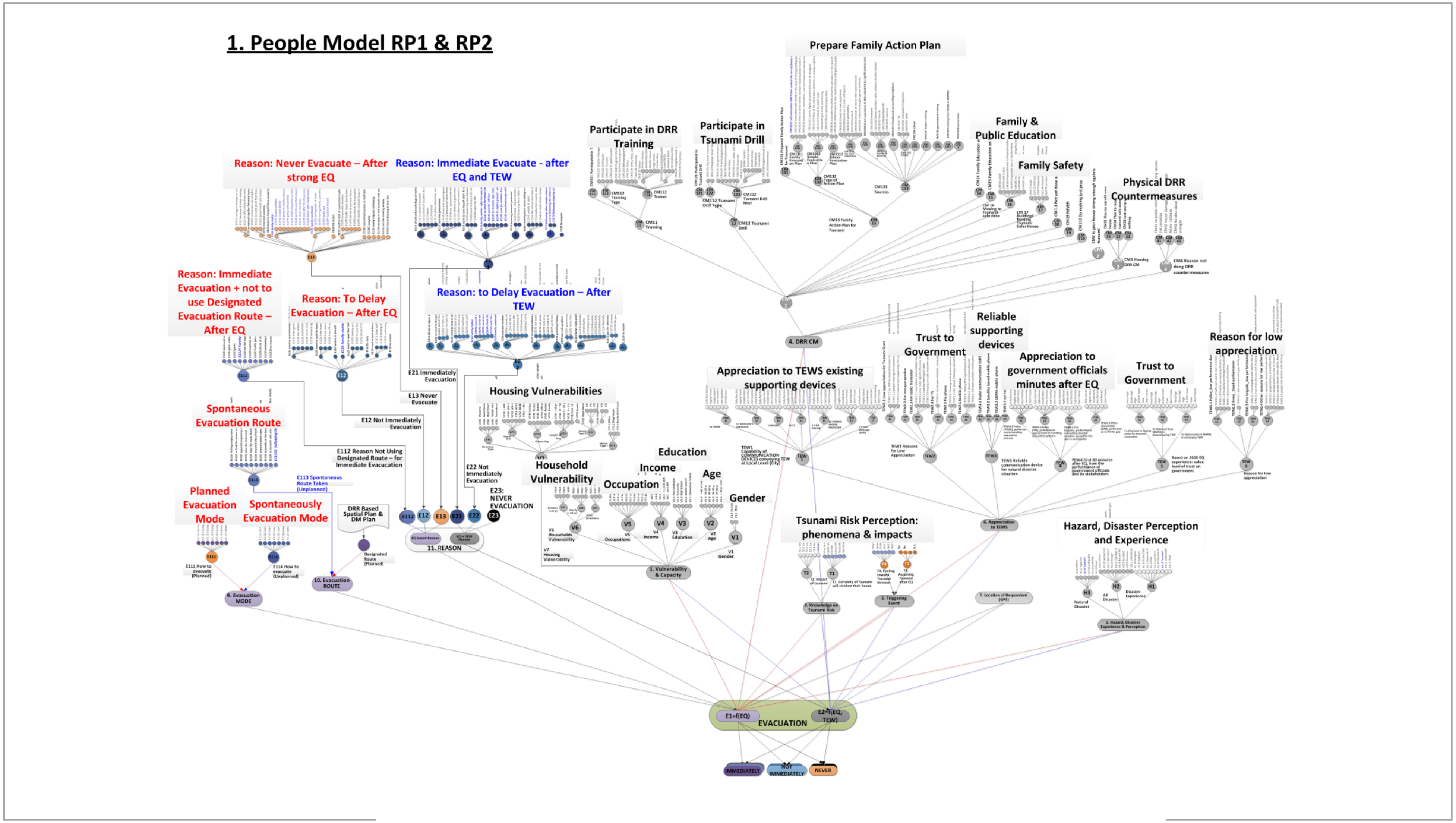


Figure 5.8 Logic Model Tree of People's Mind toward Tsunami Early Warning

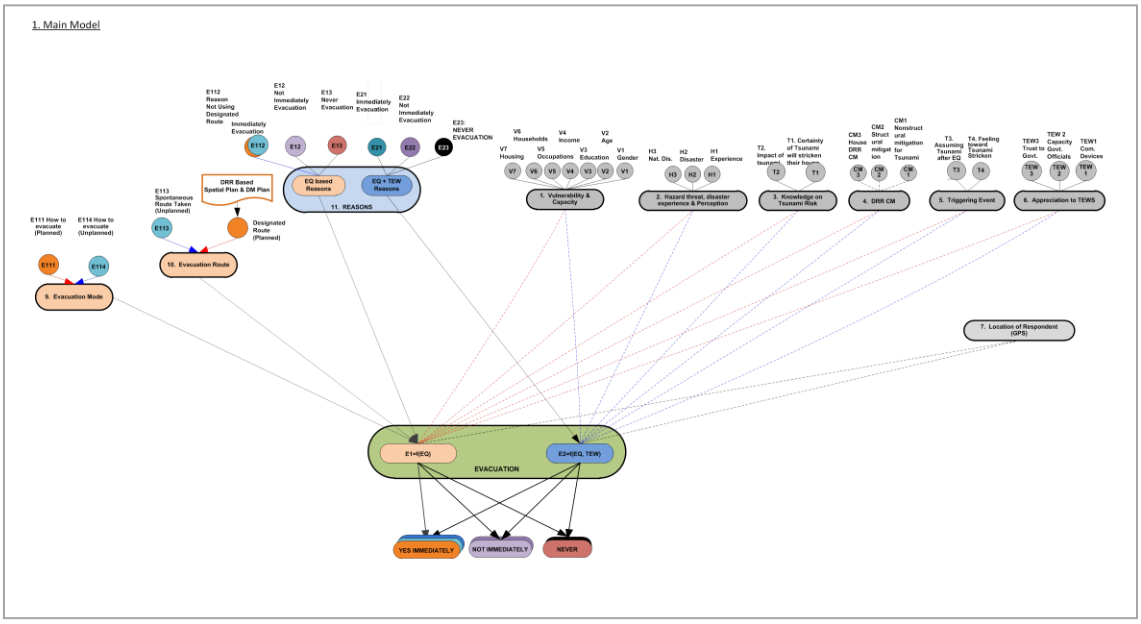


Figure 5.9 Core relationship diagram (Latent Variable) of Logic model of People's Mind toward Tsunami Warning

These grey nodes always considered in the numerical analysis of *every scenario of numerical logic model* that will be described and discussed in the section 5.4. To compare, the color nodes characterized as internal factors which indelible in people mind 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, or from makeup experience such as through DRR countermeasures training. This shows there is correlation between grey nodes to color nodes. 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 layer of 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 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 487 observable variables was hierarchically and/or horizontally and vertically structured in the forms logic model tree with two constellation relationship. The variables having similar characteristic were clustered into one family node, they are treated as children nodes with its siblings under one parent node.

5.6 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 5.10. 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.

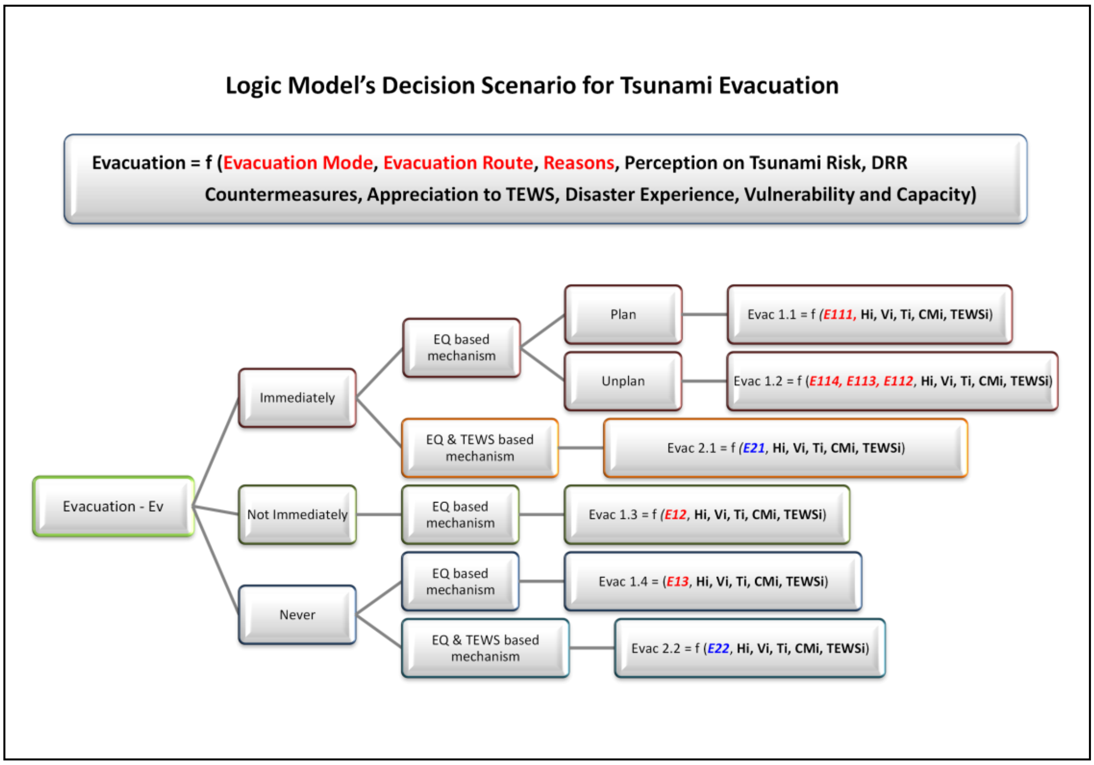


Figure 5.10 Sixth Scenario of Numerical Analysis of the Numerical Logic Model

Each scenario represents each nature of relationship among all assisting, hindrance, indelible and latent factors which influence in decision making process of the people. The formula derived from the 6 scenario based numerical analysis can be presented as follows (Figure 5.11).

Due to the characteristics of scenario of the logic model, each scenario is unique. All the grey nodes have contribution to each scenario; therefore all grey nodes are represented by the top node of each cluster, i.e. Vi, Hi, Ti, CMi, and TEWS.

Meanwhile the color node have unique contribution to the scenario, hence the color nodes is represented by either by top node and/or mid layer node. The color nodes is representing the cognitive and heuristics judgment, which related with reason why, how and where to go for evacuation either triggered by natural phenomena and/or combination of both natural phenomena and tsunami warning. This division just to help visually easy to understand the structure of the logic model tree.

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

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

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)

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

Figure 5.11 Formula of Sixth Scenario used to develop Numerical Logic Model Tree

Numerical modeling is required for this logic model to know the degree of correlation among the variables in every node of branches, up to sub-cluster, cluster and the scenario of judgment (decision). Looking at the appropriateness of statistical methods to the nature of this model, then the numerical model is better developed by integrating the principal component analysis (PCA) into the logic model. However, in this study principal component analysis is used to find out the correlation among the variables member of each node of branches, then up-scaling to the next level until reaching the stem of the tree. Then the decision scenario conducted at the bottom of the tree with 6 scenario of decision making.

Principal component analysis (PCA) is a mathematical procedure that uses an *orthogonal transformation* to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called principal components. It is further described as the simplest of the true *eigenvector-based multivariate analyses*. Currently, it is mostly used as a tool in exploratory data analysis and for making predictive models.

While orthogonal matrix is a square matrix with real entries whose columns and rows are orthogonal unit vectors. Methodology for numerical modeling of the Logic Model for People's Mind is adapted from PCA method where Main Component obtained through the analysis can be assumed as "latent variable" (variable which were not observed) with linear combination of some observed variables (x_1, …… x_k).

As discussed in Chapter 3 that for the People Logic Model that the stage of analysis do not include the final stage of reducing variable, see also Chapter 1 and Chapter 3 of this dissertation. Meanwhile basic principle of PCA is to structure the main component, which is a linear combination of some observed variables. The numerical analysis was used the PCA facilitated by SPSS 19 program.

Summary of the final result of numerical modeling for all 6 decision scenarios of both RP1 and RP2 are presented in the following formula shown in Table 5.2.

In this summary it shows there is significant different cognitive and behavior of people to make judgment to respond the warning from natural phenomena and combination of both natural and tsunami warning system. The differences are shown between data assessed prior and post of Mentawai tsunami (RP1 and RP2 consecutively) at the parents' node. These differences were basically as the result of correlation contribution of children, grandchildren and great grandchildren nodes from each family cluster of each data set.

Table 5.2 Summary of the final result of numerical modeling for all 6 decision scenarios of both RP1 and RP2

No	Variables	RP1		RP2	
		Coeff	%	Coeff	%
	$Evac_{1.1} = f(E_{1.1.1}, H_i, V_i, T_i, CM_i, TEWS_i)$				
1	E1.1.1 How did you evacuate when immediate evacuate after strong shaking?	1.04	17.94	1.58	22.45
2	H Hazard and Disaster Perception and Experiences	0.98	16.98	-1.72	24.45
3	V Social Vulnerability and Capacity	1.23	21.28	1.37	19.50
4	T Knowledge on Tsunami Risk and Triggering Event	-1.19	20.65	-0.53	7.51
5	CM Disaster Risk Reduction Countermeasures	0.29	5.10	-0.75	10.66
6	TEWS Appreciation to Tsunami Early Warning System	1.04	18.05	1.09	15.43
	$Evac_{1.2} = f(E_{1.1.2}, E_{1.1.3}, E_{1.1.4}, H_i, V_i, T_i, CM_i, TEWS_i)$				
1	E1.1.2 What was the reasons not to follow the route when immediate evacuate after strong shaking?	0.58	7.86	1.45	19.69
2	E1.1.3 What alternative route did you take when immediate evacuate after strong shaking?	0.82	11.23	1.77	24.12
3	E1.1.4 How did you evacuated when immediate evacuate after strong shaking?	-0.46	6.30	0.02	0.26
4	H Hazard and Disaster Perception and Experiences	1.50	20.44	1.55	21.11
5	V Social Vulnerability and Capacity	1.16	15.75	-1.65	22.47
6	T Knowledge on Tsunami Risk and Triggering Event	-1.23	16.78	-0.21	2.90
7	CM Disaster Risk Reduction Countermeasures	1.07	14.57	0.70	9.45
8	TEWS Appreciation to Tsunami Early Warning System	0.52	7.08	1.45	19.69

Table. 5.2. Continued.

NO	VARIABLES	RP1		RP2	
		Coeff.	%	Coeff.	%
	$Evac_{1.3} = f(E_{1.2}, H_i, V_i, T_i, CM_i, TEWS_i)$				
1	E1.2 What was your reasons not to evacuate immediately after strong shaking?	1.52	22.49	1.50	21.84
2	H Hazard and Disaster Perception and Experiences	1.31	19.37	-0.67	9.81
3	V Social Vulnerability and Capacity	0.76	11.23	-0.21	3.03
4	T Knowledge on Tsunami Risk and Triggering Event	-1.41	20.84	1.17	17.00
5	CM Disaster Risk Reduction Countermeasures	0.67	9.93	1.59	23.13
6	TEWS Appreciation to Tsunami Early Warning System	1.09	16.13	-1.73	25.18
	$Evac_{1.4} = f(E_{1.4}, H_i, V_i, T_i, CM_i, TEWS_i)$				
1	E1.3 What were your reasons for never evacuated after strong shaking?	0.84	16.11	1.01	14.12
2	H Hazard and Disaster Perception and Experiences	-1.12	21.43	-1.16	16.20
3	V Social Vulnerability and Capacity	0.21	3.94	1.97	27.49
4	T Knowledge on Tsunami Risk and Triggering Event	1.04	19.95	-1.84	25.69
5	CM Disaster Risk Reduction Countermeasures	1.14	21.91	-0.32	4.40
6	TEWS Appreciation to Tsunami Early Warning System	0.87	16.65	0.87	12.10

Table. 5.2. Continued.

No	Variables	RP1		RP2	
		Coeff.	%	Coeff.	%
	$Evac_{2.1} = f(E_{2.1}, H_i, V_i, T_i, CM_i, TEWS_i)$				
1	E2.1 What is your consideration when immediate evacuate after receiving/hearing tsunami warning?	1.20	22.49	0.94	14.61
2	H Hazard and Disaster Perception and Experiences	1.48	27.78	-0.44	6.82
3	V Social Vulnerability and Capacity	0.33	6.18	0.04	0.63
4	T Knowledge on Tsunami Risk and Triggering Event	-1.18	22.15	1.04	16.20
5	CM Disaster Risk Reduction Countermeasures	0.55	10.25	2.03	31.46
6	TEWS Appreciation to Tsunami Early Warning System	0.59	11.16	-1.95	30.29
	$Evac_{2.2} = f(E_{2.2}, H_i, V_i, T_i, CM_i, TEWS_i)$				
1	E2.2 What is your consideration for never evacuate after receiving/hearing tsunami warning?	-0.17	3.15	1.19	16.95
2	H Hazard and Disaster Perception and Experiences	-0.94	17.51	-1.29	18.27
3	V Social Vulnerability and Capacity	0.59	11.08	1.64	23.25
4	T Knowledge on Tsunami Risk and Triggering Event	1.28	23.94	-1.35	19.21
5	CM Disaster Risk Reduction Countermeasures	1.32	24.71	-0.59	8.36
6	TEWS Appreciation to Tsunami Early Warning System	1.06	19.63	0.98	13.96

This summary shows how the cognitive and behavior of people obtained at the time of prior and post 2010 tsunami event have influenced the decision to respond the natural warning and tsunami warning system. From the immediate response for evacuation plan or spontaneously, up to the never evacuation at all.

To be argued, example taken for the scenario of Evac 1.1, the people cognitive and behavior toward the natural warning, i.e. strong shaking of tsunamigenic earthquake, was different between RP1 and RP2. For the RP1, the strong correlation shown by coefficient above 1.0 was contributed by Vi – Social Vulnerability and Capacity, Ti – knowledge on Tsunami Risk and Triggering Event, TEWS – Appreciation to Tsunami Early Warning System, E1.1.1 – How did you evacuate when immediate evacuate after strong shaking. In this RP1, CM – Disaster Risk Reduction Countermeasures and H – Hazard and Disaster Perception and Experiences showed the small correlation in the scenario Evac 1.1.

To contrast, the H – Hazard and Disaster Perception and Experiences showed the highest correlation in the same scenario. In total in RP2, the strong correlation was contributed by H – Hazard and Disaster Perception and Experiences, E1.1.1 – How did you evacuate when immediate evacuate after strong shaking, Vi – Social Vulnerability and Capacity, and TEWS – Appreciation to Tsunami Early Warning System.

Further discussion for Evac 1.1 , it can be seen how each of this parent nodes (cluster node) influenced by its children node, and how the children node correlation with its siblings node.

1. Vulnerability and Capacity

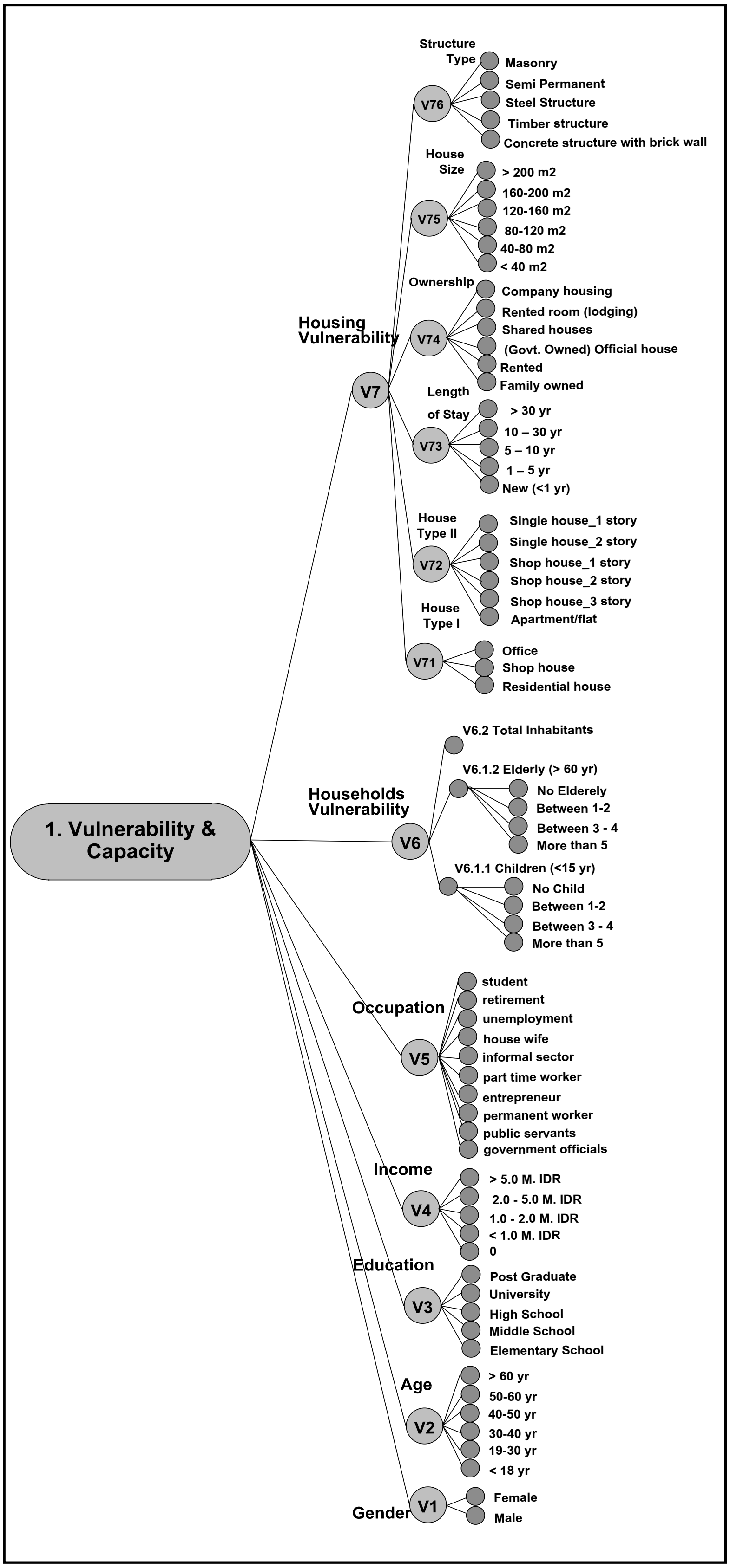


Figure 5.12 Logic Model Tree of Social Vulnerability and Capacity

V = $0.463324(V1) + 0.0070420\ (V2) + 0.649657(V3) + 1.236039(V4) + 0.958223(V5) + 1.22002(V6) + 1.200953(V7)$

$V1$ = $2.00\ (V1.1) - 2.00\ (V1.2)$

$V2$ = $0.901704(V2.1) - 1.634164\ (V2.2) + 0.92376(V2.3) - 1.068256(V2.4) + 0.916095(V2.5) + 1.331971(V2.6)$

$V3$ = $1.424882(V3.1) + 1.131861(V3.2) - 1.60302(V3.3) - 0.077411(V3.4) + 1.004934(V3.5)$

$V4$ = $1.342913(V4.1) + 0.034564(V4.2) - 1.942214(V4.3) + 0.138549(V4.4) + 1.039616(V4.5)$

$V5$ = $1.071168\ (V5.1) - 0.014728(V5.2) + 1.37328(V5.3) - 1.58036\ (V5.4) + 0.615288(V5.5) + 0.2128(V5.6) - 1.329546\ (V5.7) + 1.111368(V5.8) + 0.882428(V5.9) + 0.735284(V5.10)$

$V6$ = $2.00\ (V6.1) - 2.00\ (V6.2)$

$V6.2$ = $- 1.90236(V6.2.1) + 1.24869(V6.2.2) + 0.979374(V6.2.3) + 1.693922(V6.2.4)$

$V6.3$ = $1.660464(V6.3.1) - 2.082392(V6.3.2) + 1.070928(V6.3.3)$

$V7$ = $1.223043(V7.1) + 0.723564(V7.2) + 1.039242(V7.3) + 1.066752\ (V7.4) + 0.508734(V7.5) - 0.282255(V7.6)$

$V7.1$ = $- 1.891495\ (V7.1.1) + 0.826799(V7.1.2) + 1.937267(V7.1.3)$

$V7.2$ = $- 1.84932(V7.2.1) + 0.726707(V7.2.2) + 1.930133(V7.2.3) + 0.59621(V7.2.4) + 1.20878(V7.2.5)$

$V7.3$ = $1.042862(V7.3.1) + 0.080222(V7.3.7.3) - 0.275571(V7.3.3) - 1.899914(V7.3.4) + 1.657857(V7.3.5) + 0.443281(V7.3.6)$

$V7.4$ = $- 1.986783(V7.4.1) + 1.245282(V7.4.2) + 1.309481(V7.4.3) + 0.00\ (V7.4.4) + 1.284862(V7.4.5) + 0.689501(V7.4.6)$

$V7.5$ = $- 0.41206\ (V7.5.1) + 0.060169(V7.5.2) - 1.91783(V7.5.3) + 1.062822\ (V7.5.4) + 1.186536(V7.5.5) + 1.136558(V7.5.6)$

$V7.6$ = $- 1.811724\ (V7.6.1) + 1.95027(V7.6.2) + 0.548791(V7.6.3) + 1.001992(V7.6.4)$

2. Disaster Experience and Perception

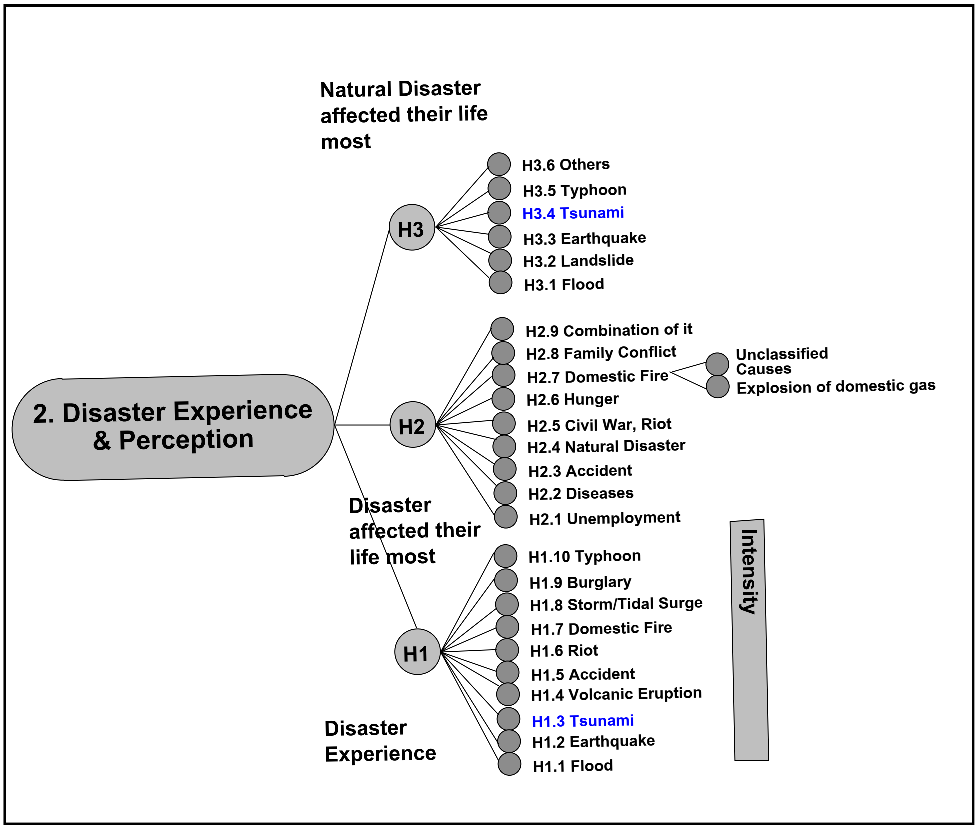


Figure 5.13 Logic Model Tree of Hazard and Disaster Experience and Perception

$$H = 1.147818(H1) + 1.309193(H2) - 1.947506(H3)$$

$$H1 = 3.570876(H1.1) + 2.440566(H1.2) + 4.354604(H1.3) + 4.374807(H1.4) + 3.927448(H1.5) + 4.092085(H1.6) + 2.399272(H1.7) + 1.833258(H1.8) + 2.35212(H1.9) + 2.40292(H1.10)$$

$$H2 = 1.046952(H2.1) + 1.80692(H2.2) + 1.061872(H2.3) - 3.077239(H2.4) + 1.013(H2.5) + 1.02(H2.6) + 1.007(H2.7) + 1.003(H2.8) + 1.029(H2.9)$$

$$H3 = 1.147818(H3.1) + 1.309193(H3.2) - 1.947506(H3.3) + 1.002596(H3.4) + 1.581553(H3.5) + 0.910374(H3.6) - 0.322846(H3.7)$$

From the disaster perception experience and perception aspect (Hi), Figure 5.13 shows the logic model tree and numerical analysis result at those levels.

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.

From the aspect of impact of the countermeasures, i.e. tsunami drill, to the model can be described in Figure 5.14 and 5.15. Result analysis shows in Figure 5.15 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.

3. Tsunami Knowledge

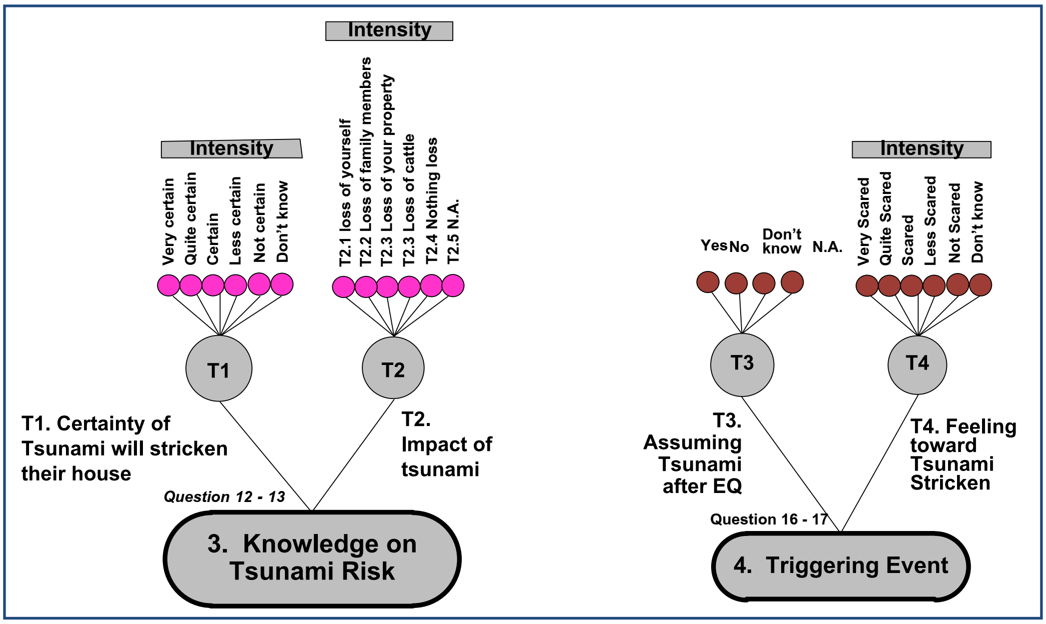


Figure 5.14 Logic Model Tree of People Knowledge on Tsunami Risk and Triggering Event

$$T = 1.30592(T1) + 1.49632(T2) + 1.99808(T3) + 1.81888(T4)$$

$$T2 = 2.15232(T2.1) + 2.113408(T2.2) + 1.911552(T2.3) + 1.281664(T2.4)$$

4. Countermeasures

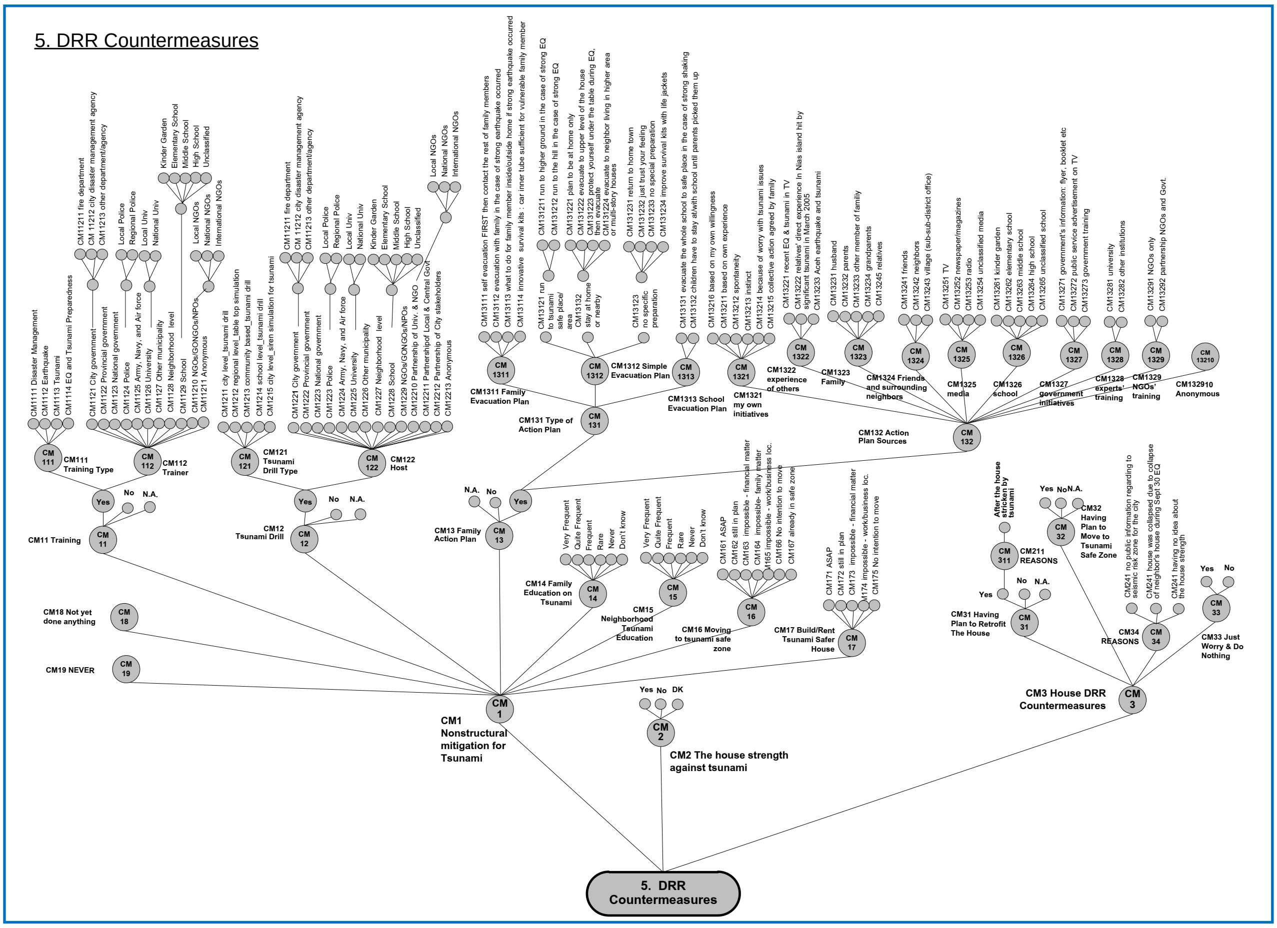


Figure 5.15 Logic Model Tree of Disaster Risk Reduction Countermeasures

$$CM = 0.71514(E1) - 1.095256(E2) + 1.351902(E3) + 1.04143(E4)$$

$$CM1 = 0.465915(CM1.1) - 0.057365\,(CME1.2) + 0.728397(CM1.3) + 2.082983(CM1.4) + 2.108085(CM1.5) + 1.047337(CM1.6) + 1.311341(CM1.7) - 1.675371(CM1.8) + 0.853992(CM1.9) + 1.031063(CM1.10)$$

$$CM1.1.2 = 0.75268(E1.1.2.1) - 0.91636(E1.1.2.2) + 0.70928(E1.1.2.3)$$

$$CM1.1.2 = -0.728686(E1.1.2.1) - 0.79618(E1.1.2.2) + 0.697822(E1.1.2.3) + 1.219936(E1.1.2.4)$$

$$CM1.1.3 = -1.2531(CM1.1.3.1) + 1.526211(CME1.1.3.2) + 0.573193(CM1.1.3.3) - 0.312542(CM1.1.3.4 + 1.160935(CM1.1.3.5) + 0.991858(CM1.1.3.6) + 0.790268(CM1.1.3.7) + 1.64627(CM1.1.3.8) + 1.120238(CM1.1.3.9) - 0.123036(CM1.1.3.10)$$

$$CM1.1.3.7 = 1.496779(E1.1.3.7.1) + 0.056471(E1.1.3.7.2) - 0.448038(E1.1.3.7.3) - 0.787336(E1.1.3.7.4)$$

$$CM1.1.3.8 = 0.300308(E1.1.3.8.1) - 1.015402(E1.1.3.8.2) + 0.882516(E1.1.3.8.3)$$

$$CM1.2 = 1.51666(E1.2.1) + 0.82363(E1.2.2) + 0.823926(E1.2.3) + 1.00(E1.2.4)$$

$$CM1.2.2 = 0.726852(E1.2.2.1) - 0.726852(E1.2.2.2)$$

$$CM1.2.3 = 1.54938(CM1.2.3.1) + 1.32906(CME1.2.3.2) + 1.447612(CM1.2.3.3) + 1.136564(CM1.2.3.4) - 0.532061(CM1.2.3.5) + 1.16334(CM1.2.3.6) + 1.136729(CM1.2.3.7) + 1.178795(CM1.2.3.8) + 1.184922(CM1.2.3.9) - 0.247858(CM1.2.3.10)$$

$$CM1.2.3.7 = 1.460671(E1.2.3.7.1) - 0.444026(E1.2.3.7.2) + 0.175828(E1.2.3.7.3) - 0.787336(E1.2.3.7.4)$$

$$CM1.3 = 1.214(E1.3.1) + 0.964(E1.3.2) + 0.822(E1.1.3.8.3)$$

$$CM1.3.2 = 1.227301(E1.3.2.1) - 0.305425(E1.3.2.2) + 0.00(E1.3.2.3) + 0.788655(E1.3.2.4)$$

$$CM1.3.2.1 = 1.04364(E1.3.2.1.1) - 1.313828(E1.3.2.1.2) + 0.475629(E1.3.2.1.3) + 0.118952(E1.3.2.1.4)$$

$$CM1.3.2.1 = 0.852327(E1.3.2.1.1) - 0.951559(E1.3.2.1.2) - 0.20461(E1.3.2.1.3) + 1.215638(E1.3.2.1.4) + 0.826084(E1.3.2.1.5)$$

$$CM1.3.2.3 = 0.726852(E1.3.2.3.1) - 0.726852(E1.3.2.3.2)$$

$$CM1.3.3 = 1.215655(CM1.3.3.1) - 0.057365(CME1.3.3.2) + 1.239947(CM1.3.3.3) + 0.093820(CM1.3.3.4) + 0.574528(CM1.3.3.5) + 1.31833(CM1.3.3.6) + 1.183265(CM1.3.3.7) - 0.145673(CM1.3.3.8) - 0.157363(CM1.3.3.9) - 0.274797(CM1.3.3.10)$$

$$CM1.3.3.1 = - 0.990879(E1.3.3.1.1) - 0.49221(E1.3.3.1.2) + 0.137744(E1.3.3.1.3) + 0.686962(E1.3.3.1.4) + 1.557992(E1.3.3.1.5) + 0.801995(E1.3.3.1.6)$$

$$CM1.3.3.3 = - 0.183963(E1.3.3.3.1) + 0.876603(E1.3.3.3.2) - 1.181622(E1.3.3.3.3) - 0.0327539(E1.3.3.3.4) + 1.387494(E1.3.3.3.5)$$

$$CM1.3.3.5 = 1.139538(E1.3.3.5.1) + 1.129192(E1.3.3.5.2) + 0.808466(E1.3.3.5.3)$$

$$CM1.6 = 0.69246(CM1.6.1) + 1.343529(CME1.6.2) - .487899(CM1.6.3) + 0.17527(CM1.6.4) - 1.449845(CM1.6.5) + 1.414629(CM1.6.6) - 0.005618(CM1.6.7)$$

$$CM1.7 = 0.893091(E1.7.1) + 0.093564(E1.7.2) - 1.036985(E1.7.3) + 1.510183(E1.7.4) + 0.089935(E1.7.5)$$

$$CM3 = 1.435004(E3.1) + 1.54456(E3.2) + 1.160216(E3.3)$$

$$CM4 = - 0.271944(E4.1) + 1.148304(E4.2) - 0.79395(E4.3)$$

5. TEWS

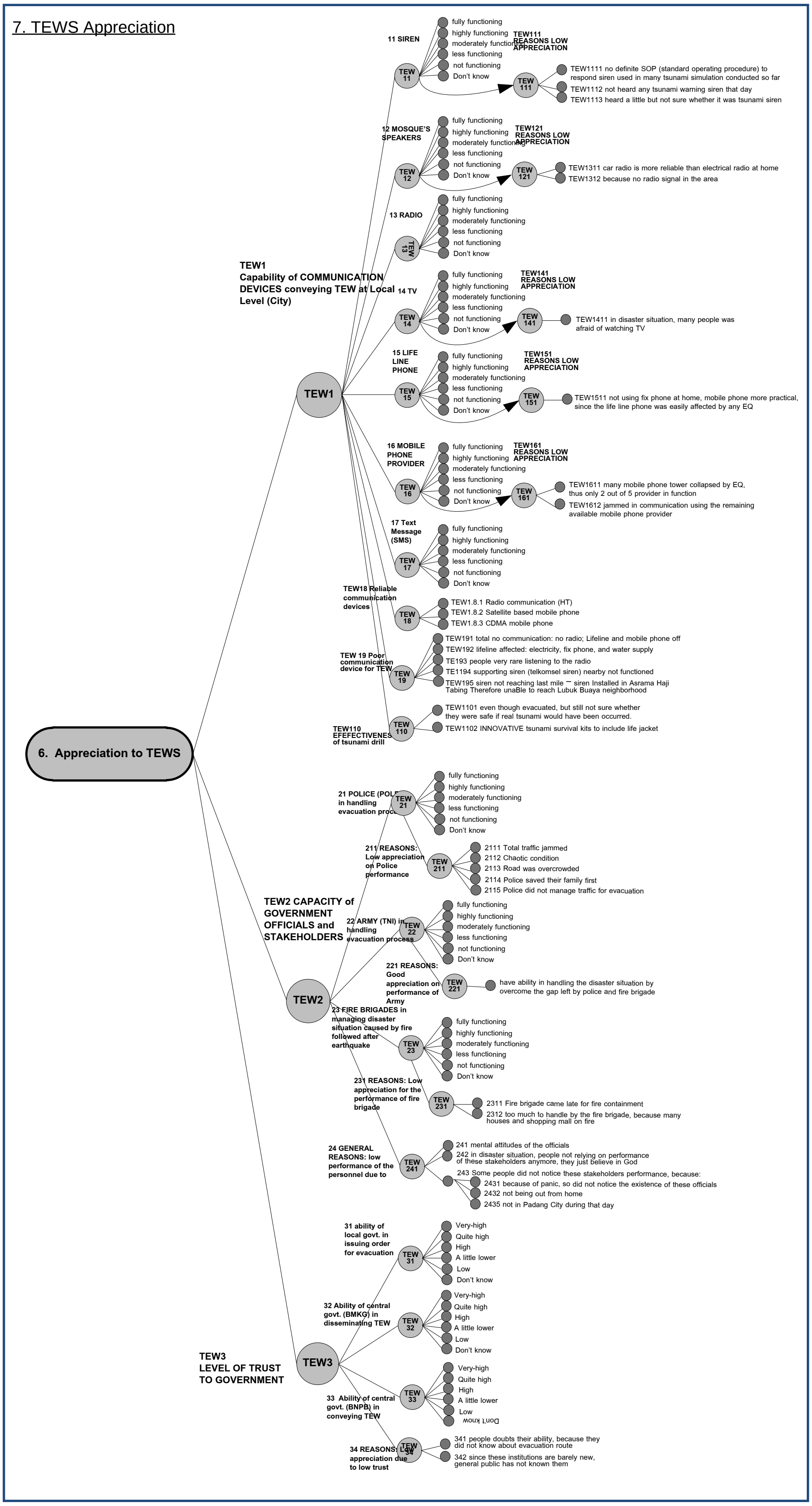


Figure 5.16 Logic Model Tree of People Appreciation to TEWS

$$TEW = 1.1222(TEW1) + 1.24744(TEW2) + 1.376876(TEW3) + 0.932108(TEW4) + 1.12342(TEW5) + 0.589052(TEW6)$$

$$TEW1 = 1.896882(TEW1.1) + 2.144994(TEW1.2) + 1.846254(TEW1.3) + 1.931382(TEW1.4) + 1.38648(TEW1.5) + 1.18254(TEW1.6) + 1.190544(TEW1.7)$$

$$TEW2 = 0.9999(TEW2.1) - 1.681276(TEW2.2) + 1.825096(TEW2.3) + 1.848119(TEW2.4)$$

$$TEW2.1 = 0.781337(TEW2.1.1) - 0.44132(TEW2.1.2) - 1.210621(TEW2.1.3) + 0.869601(TEW2.1.4)$$

$$TEW2.3 = - 0.250932(TEW2.3.1) + 1.169316(TEW2.3.2) - 0.774383(TEW2.3.3)$$

$$TEW2.6 = 1.29577(TEW2.6.1) + 0.00(TEW2.6.2) + 1.29577(TEW2.6.3)$$

$$TEW3 = - 0.801146(TEW3.1) - 0.762156(TEW3.2) + 0.658092(TEW3.3) + 1.178649(TEW3.4)$$

$$TEW4 = 2.198268(TEW4.1) + 2.174058(TEW4.2) + 2.128059(TEW4.3) + 0.326835(TEW4.4)$$

$$TEW5 = 1.684683(TEW5.1) + 1.725823(TEW5.2) + 1.699082(TEW5.3)$$

$$TEW6 = - 0.808416 (TEW6.1) + 0.651689(TEW6.2) - 0.768559(TEW6.3) + 1.172246(\mathrm{TEW}6.4)$$

$$TEW6.1 = - 0.808416(TEW6.1.1) + 0.651689(TEW6.1.2) - 0.768559(TEW6.1.3) + 1.172246(TEW6.1.4)$$

$$TEW6.3 = 0.711836(TEW6.3.1) - 0.711836(TEW6.3.2)$$

$$TEW6.4 = - 0.288864(TEW6.4.1) + 1.116339(TEW6.4.2) + 1.399488(TEW6.4.3) - 0.820454(TEW6.4.4) + 1.397912(TEW6.4.5)$$

5.7 Result and Discussion

For the discussion of the result of numerical model of People Model, in this section one scenario for logic model's decision for evacuation is selected, i.e. scenario of Evacuation 1.2. This scenario represent the decision is taken based on the immediate response, based on the natural warning only since not hearing the siren wailed, and the evacuation was conducted spontaneously due to several reasoning that can be explored from the logic model. Figure 5.17 shows the path of the scenario analysis, which is "*immediately*" from the urgency for evacuation aspect, *"natural warning"* selected over TEWS mechanism and with the circumstances of *"un-plan"*.

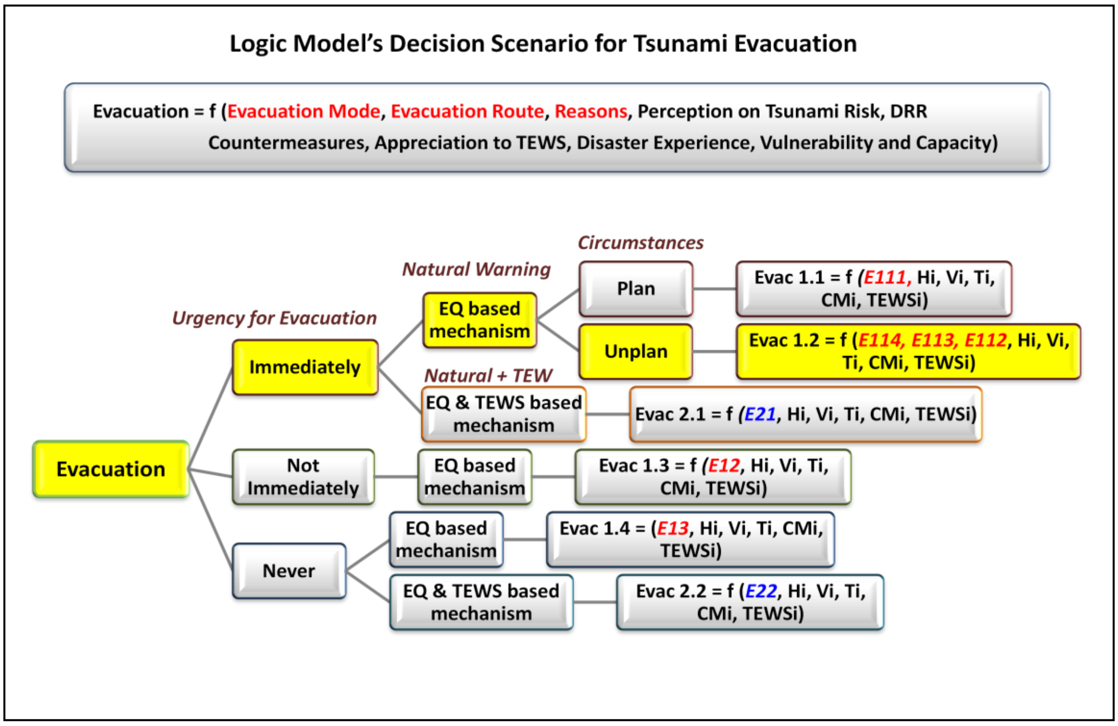


Figure 5.17 The Scenario Analysis for Evac1.2

This scenario Evacuation 1.2 is a function of E114, E113, E112, Hi, Vi, Ti, CMi, and TEWSi, which graphically shown in the logic model in Figure 5.17. The function involved three different conditional variables from reasoning (Ei), vulnerabilities (Vi), countermeasures (CMi), knowledge on tsunami phenomena and impacts (Ti), appreciation to tsunami warning (TEWS), and hazard perception (Hi). Numerical analysis was conducted using the bottom up approach.

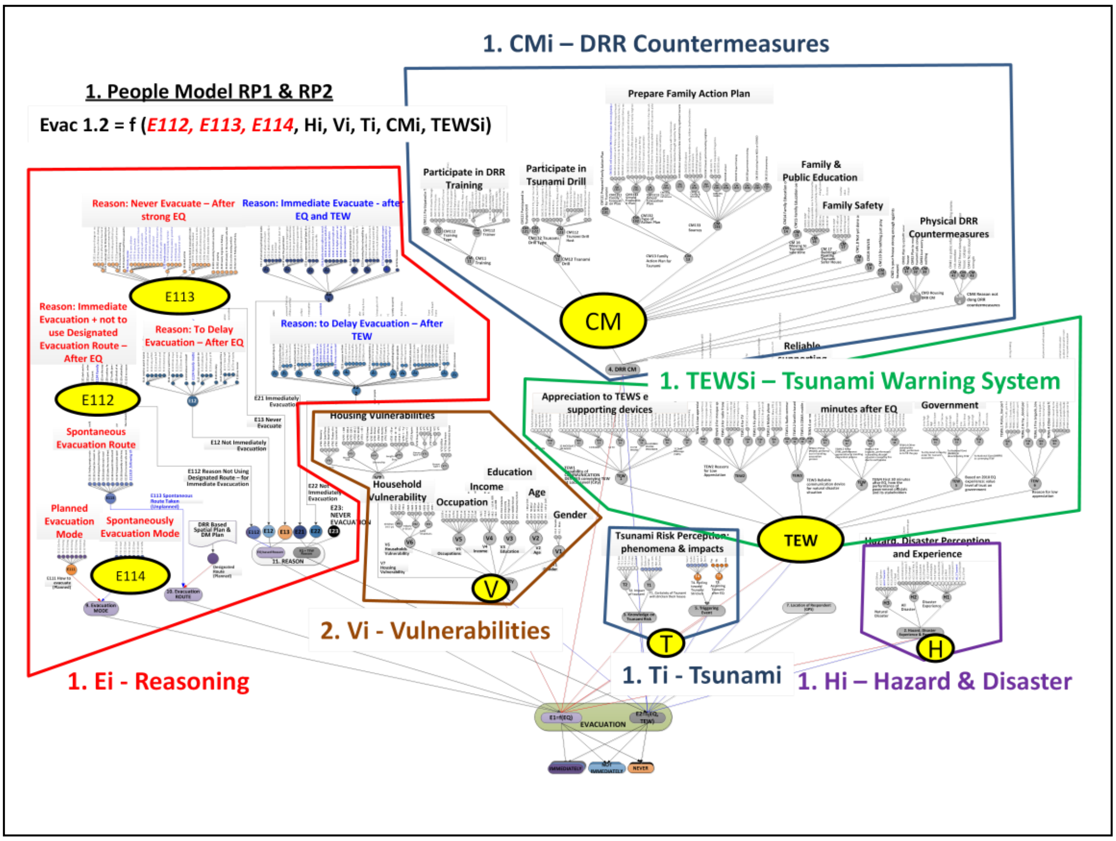
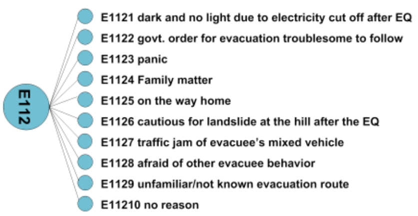


Figure 5.18 Logic model for Analysis for Evac1.2

E1.1.2 What was the reasons not to follow the designated evacuation route?



PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
E1.1.2.1 Dark and no light due to no electricity	2.92%	
E1.1.2.2 Troublesome government order for evacuation	**12.03%**	
E1.1.2.3 Panic	11.93%	
E1.1.2.4 FAMILY MATTER_Family agreement to wait for parents before evacuate	8.95%	
E1.1.2.5 On the way home	**16.12%**	
E1.1.2.6 Cautious for landslide following EQ	7.43%	
E1.1.2.7 traffic jammed by evacuee	**12.26%**	50.00%
E1.1.2.8 afraid of evacuee behavior	**14.54%**	
E1.1.2.9 unfamiliar route for evacuation	10.12%	50.00%
E1.1.2.10 no reason	3.70%	

$$E1.1.2=0.284944(E1.1.2.1)+1.172599(E1.1.2.2)+1.162726(E1.1.2.3)+0.872157(E1.1.2.4)+1.57079(E1.1.2.5)-0.724074(E1.1.2.6)+1.195278(E1.1.2.7)+1.41669(E1.1.2.8)-0.986338(E1.1.2.9)-0.360927(E1.1.2.10)$$

$$\mathbf{E1.1.2 = -0.857298(E1.1.2.7) + 0.857298(E1.1.2.9)}$$

Figure 5.19 Logic model for Analysis for Evac1.1.2

Result analysis of E112 can be seen in Figure 5.19. From the model of prior tsunami, the most dominant reasoning for not to follow the designated route for the evacuation are due to several factors, i.e. E1125 because on the way home when the strong shaking occurred, E1128 because of afraid of evacuee behavior who is panic and uncontrolled, E1127 because the road was jammed by the evacuee, E1122 because the government order is troublesome to follow, E1123 because of panic and never think clearly for taking what route, and E1129 because of unfamiliar route for evacuation.

For the model of post tsunami there is increased contribution for E1127 traffic jammed by evacuee and unfamiliar route for evacuation. Other factors have never been considered as reason. Figure 5.20 shows stages results of Principal Component Analysis for E112. For the prior tsunami people model, it shows that at the primary component that factors E1123 and E1128 are the most dominant, where the two factors exhibiting the human factors of fear. Meanwhile at the second component, the factors of E1124 Family matter and traffic jammed by evacuee were the most dominant. These two factors show circumstances of external factors. For the post people model, the first component shows that E1127 traffic jammed by evacuee and E1129 unfamiliar route for evacuation were the most dominant found.

COMPONENT	RP 1							RP 2
	1	2	3	4	5	6	7	1
E1.1.2.1 Dark and no light due to no electricity			.227	.302	.473	-.721		
E1.1.2.2 Troublesome government order for evacuation			.227	.302	.391	.656	-.410	
E1.1.2.3 Panic	.866	-.182						
E1.1.2.4 FAMILY MATTER_Family agreement to wait for parents then evacuate		.741						
E1.1.2.5 On the way home			.227	.302		.191	.843	
E1.1.2.6 Cautious for landslide following EQ			.227	.302	-.787	-.126	-.34	
E1.1.2.7 traffic jammed by evacuee	.201	.744						-.754
E1.1.2.8 afraid of evacuee behavior	.891							
E1.1.2.9 unfamiliar route for evacuation		-.160	-.787					.754
E1.1.2.10 no reason all			.432	.432				

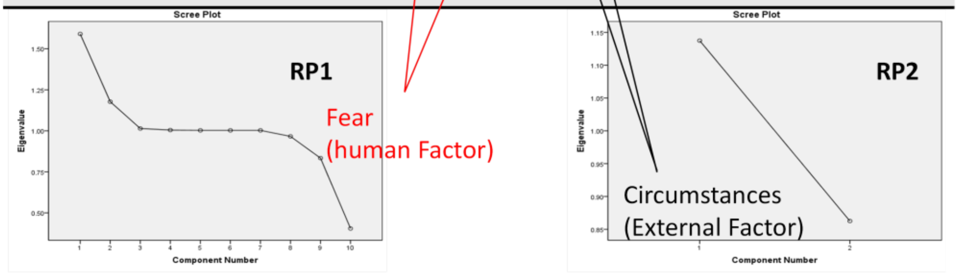
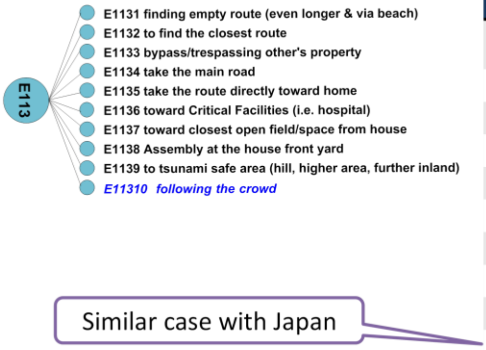


Figure 5.20 Principal Component Analysis for E112

E1.1.3 What evacuation route taken? (Q19.2.2)



PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
E1.1.3.1 Finding empty route even though passing by beach	16.39%	39.01%
E1.1.3.2 Finding closest route	0.76%	
E1.1.3.3 Bypass/trespassing other's property	0.08%	56.33%
E1.1.3.4 Taking main road	21.28%	
E1.1.3.5 Taking route directly to home	22.36%	
E1.1.3.6 To Critical Facilities (i.e. hospital)	2.39%	
E1.1.3.7 To closest open field from the house	9.22%	
E1.1.3.8 Assembly at house front yard	0.12%	
E1.1.3.9 To tsunami safe area - Hill, Higher ground	4.65%	
E1.1.3.10 Following the crowd	22.74%	4.66%

$$\text{E1.1.3} = -1.231975(E1.1.3.1) + 0.05739(E1.1.3.2) + -0.005788(E1.1.3.3) + 1.59979(E1.1.3.4) + 1.680948(E1.1.3.5) + 0.179542(E1.1.3.6) + 0.693166(E1.1.3.7) + 0.0093659(E1.1.3.8) + 0.349148(E1.1.3.9) + 1.709513(E1.1.3.10)$$

$$\mathbf{E1.1.3} = -0.853275(E1.1.3.1) + 1.232193(E1.1.3.3) + 0.101966(E1.1.3.10)$$

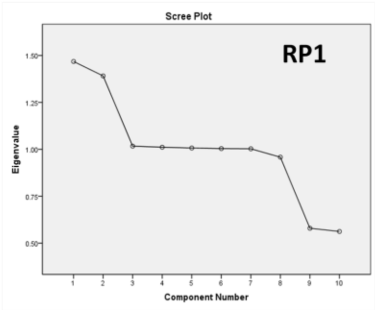
Figure 5.21 Logic model for Analysis for Evac1.1.3

Meanwhile for the E113 regarding what evacuation route taken for this scenario, Figure 5.21 shows that E11310 Following the crowd is the most significant followed by E1135 Taking the route directly home, 1134 Taking the main road, E1131 finding empty route even passing the beach, and E1137 to the closest open field from house. The main factor E 11310 following the crowd is similar with the case of Japan during the 2011 Tohoku tsunami.

As shown in Figure 5.22, the PCA for E113, it show in the first component that E11310 following the crowd is the most significant showing the passive behavior. This is followed by E1133 by pass/trespassing other’s property and E1132 finding closest route and E1135 taking the rout directly home, which are active behavior but guided or limited by the physical factors in second component.

COMPONENT	RP 1							RP 2	
	1	2	3	4	5	6	7	1	2
E1.1.3.1 Finding empty route even though passing by beach		-0.126	-0.781	-0.153	-0.107			-.672	-.393
E1.1.3.2 Finding closest route	-0.556	0.628							
E1.1.3.3 Bypass/trespassing other's property	-0.581	0.609							.902
E1.1.3.4 Taking main road			0.129		0.151	0.604	0.708		
E1.1.3.5 Taking route directly to home	0.534	0.486	-0.235	0.455					
E1.1.3.6 To Critical Facilities (i.e. hospital)			0.129		0.151	0.604	-0.708		
E1.1.3.7 To closest open field from the house			0.231	0.172	0.741	-0.460			
E1.1.3.8 Assembly at house front yard			0.385	0.458	-0.619	-0.221			
E1.1.3.9 To tsunami safe area - Hill, Higher ground	0.336	0.258	0.343	-0.727	-0.116				
E1.1.3.10 Following the crowd	0.650	0.543						.796	-.259

Physical Factor



Passive behavior

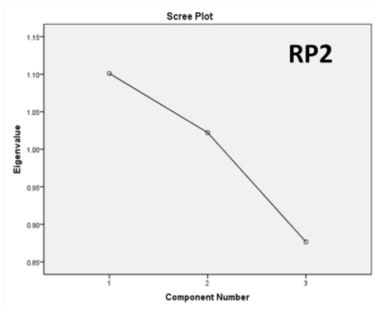


Figure 5.22 Principal Component Analysis for E113

Figure 5.23 show the comparison analysis result from numerical analysis. For the scenario Evacuation 1.2 for the three model developed, i.e. people model prior to tsunami RP1, people model post tsunami RP2 and the government model RG, there is significant differences of perception of the people which influenced by its circumstances and capacity they have, leading to the influence of their mind to their heuristic behavior in terms of decision to evacuate.

To compare for the RP1 model the most significant contribution above 20% for the decision making is Disaster Perception (Hi), while in RP2 there is 2 other factors such as E113 alternative route taken for immediate evacuation and Vi social vulnerability beside the beside Disaster Perception (Hi). In RG the most significant is the knowledge on tsunami (Ti) beside Disaster Perception (Hi).

Comparison of Mind of RP1, RP2 and RG on Scenario Evacuation 1.2

No	Variables	RP1		RP2		RG	
	$Evac_{1.2} = f\ (E_{1.1.2}, E_{1.1.3}, E_{1.1.4}, H_i, V_i, T_i, CM_i, TEWS_i)$						
1	E1.1.2 What was the reasons not to follow the route when immediate evacuate after strong shaking?	0.57724	7.86%	1.447738	19.69%	0.603038	6.42%
2	E1.1.3 What alternative route did you take when immediate evacuate after strong shaking?	0.824712	11.23%	1.773732	24.12%	0.633795	6.74%
3	E1.1.4 How did you evacuated when immediate evacuate after strong shaking?	-0.46242	6.30%	0.019332	0.26%	-1.96159	0.00%
4	H Hazard and Disaster Perception and Experiences	1.501194	20.44%	1.552004	21.11%	0.895627	20.87%
5	V Social Vulnerability and Capacity	1.156557	15.75%	-1.65246	22.47%	2.563676	9.53%
6	T Knowledge on Tsunami Risk and Triggering Event	-1.23216	16.78%	-0.2132	2.90%	1.565015	27.27%
7	CM Disaster Risk Reduction Countermeasures	1.070411	14.57%	0.69524	9.45%	1.177439	16.65%
8	TEWS Appreciation to Tsunami Early Warning System	0.520371	7.08%	1.447738	19.69%	0.603038	12.53%

Figure 5.23 Comparison of Mind of RP1, RP2 and RG on Scenario Evac 1.2

5.8 Summary

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 city, i.e. Padang 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.

Chapter 6
Government Model

6.1 Introduction

This Chapter 6 presents and discusses process development of Government Logic Model and its Numerical Modeling. Almost at the similar methodology to People Logic Model discussed in Chapter 5, this Chapter 6 starts from problem recognition, problem structuring which includes a multi stage of in-depth knowledge acquisition and its cognitive mapping, developing logic model in the format of logic model tree, and developing numerical analysis.

As the first national show case city for tsunami preparedness, Padang government official is expected to be more responsive to tsunami early warning. Under leadership of the two term mayor, since 2004 till now, alot of DRR countermeasures have been implemented as well as endorsement of local regulation for tsunami evacuation shelters, tsunami education at school and many others; especially after Padang city has been stricken by several tsunamigenic earthquakes in 2005, 2007, 2009 and 2010. Even though only minor tsunami occurred, less than 50 cm in the city but the devastated shaking have damaged many city infrastructure and strategic building designated for vertical evacuation especially in 2007 and 2009 events.

However, aside from the damage and fire due to the devastated event, during 2005, 2007 and 2009 event no impact of any DRR countermeasure were seen on the people and the government official behavior. No official handling the situation during evacuation, no officer on duty in EOC of DMO Province and City level doing their task to convey the tsunami warning received. They left the duty as shown on some recorded information, such CCTV and media. Only the mayor as before was taking all responsibility. This issue has triggered the study to recognize and structure the problem further, since all natural, make-up ‘experiences’ and many countermeasures implemented by the government together with national and international community were expected to influence the prior belief or perception of people to tsunami threat and its impact as well as their appreciation to the countermeasures intervention such as tsunami warning.

In overall, the process development for Governmen Logic Model described in Figure 6.1 consists of 8 stages, which are described and discussed in the next section of this Chapter 6.

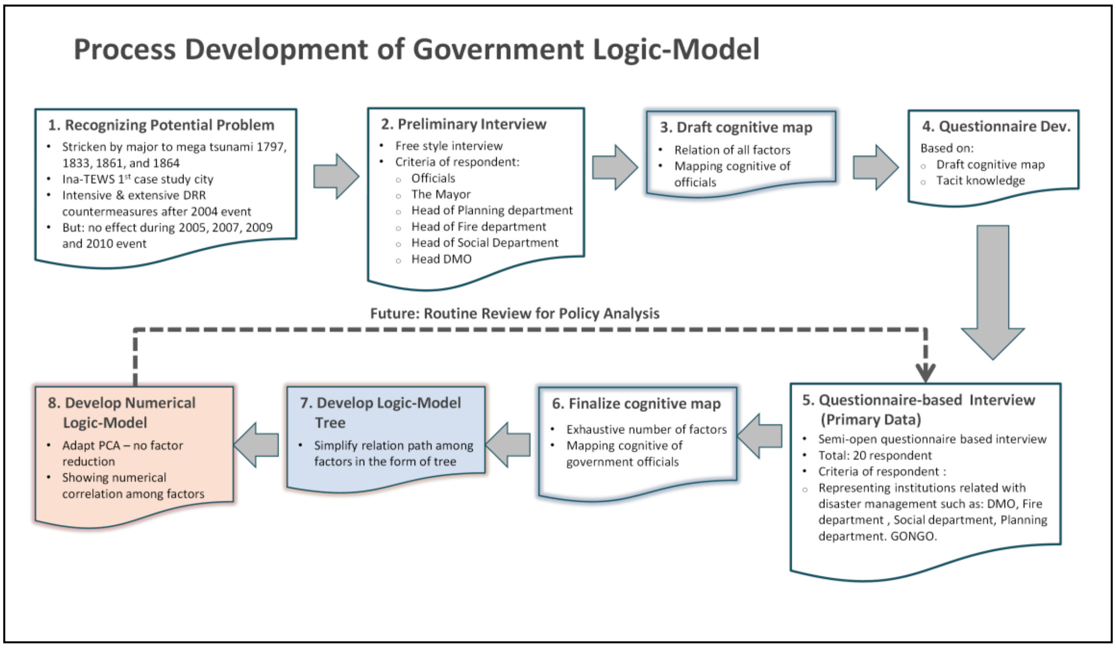


Figure 6.1 Process Development of Government Logic-Model

6.2 Preliminary knowledge acquisition and cognitive mapping

The preliminary interview was conducted on several target groups among the victim of the 2009 event and people living at tsunami high risk zone. A free style interview is used for recognizing any factors that hinder or support the people's mind or thoughts regarding the shaking and hearing the siren wailing, and their heuristic judgment. Number of recorded respondent is 15 representing the urban community, fishermen, government officials, and government officials in charged with emergency response (i.e. crisis center, fire brigade), as well as other agencies and the mayor/regent and vice governor. The survey conducted from October 7 to 16, 2009 under collaboration between ITB with EERI and UPitt.

First interview was conducted with government official who did not evacuate, i.e. Mr. Ardiansyah Ridwan from Economic Department of City Assistant II. The interview was in dual languages English and Bahasa and recorded (WS118370, 2009a), see also Figure 6.2. The EQ event occurred when he was on the way home about 500 m from home and about 3 minutes to reach home in normal condition. People were panic on the street due to strong shaking, then he decided to go immediately home in Juniarso Street which is in the red zone (very high risk). He checked the neighbor house (shop houses Pharmacies at the first floor and lodging for student at the second house) collapsed. His 2 stories home was remained firmed. He ran to the top floor checking the natural sign for tsunami, i.e. flock of the birds flying from the coastline to the mainland. Nothing can be seen. He calmed the family not to evacuate with the decision since there was no sign for tsunami, no point for evacuation since the panic flock of the crowd of evacuee rushing with cars and many others vehicles. He is afraid the family could be killed. The two story house was still remaining strong. In front and the back side of his house there were two middle schools with 3 stories were remain, i.e. SMP Muhammadiyah and SMP Swasta. The logic model tree and mapping of cognitive behavior of government official is presented in Figure 6.3 and Figure 6.4.

Figure 6.2 The Preliminary Interview with Government Officials

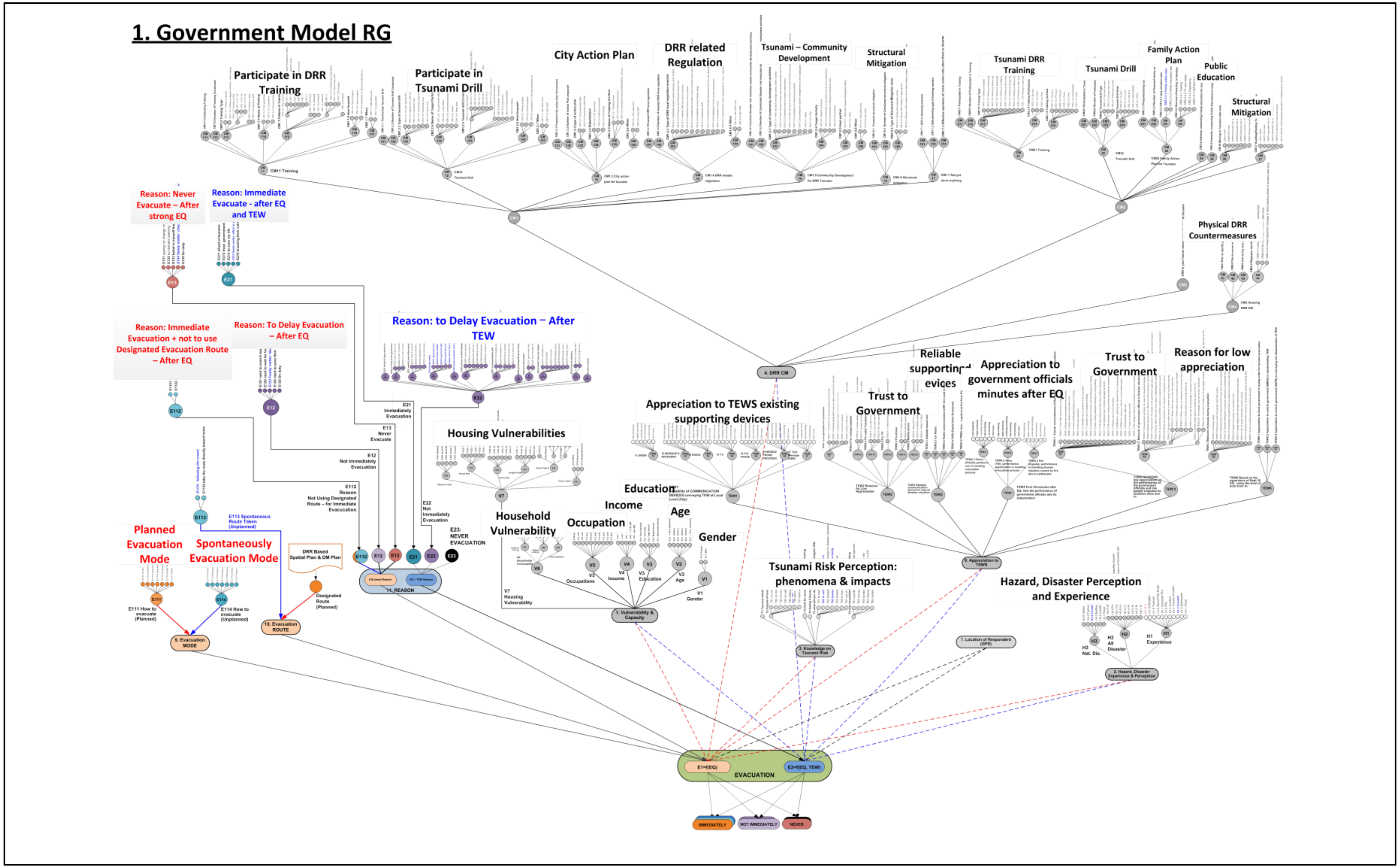


Figure 6.3 Logic Model Tree of Government's Mind toward Tsunami Early Warning System

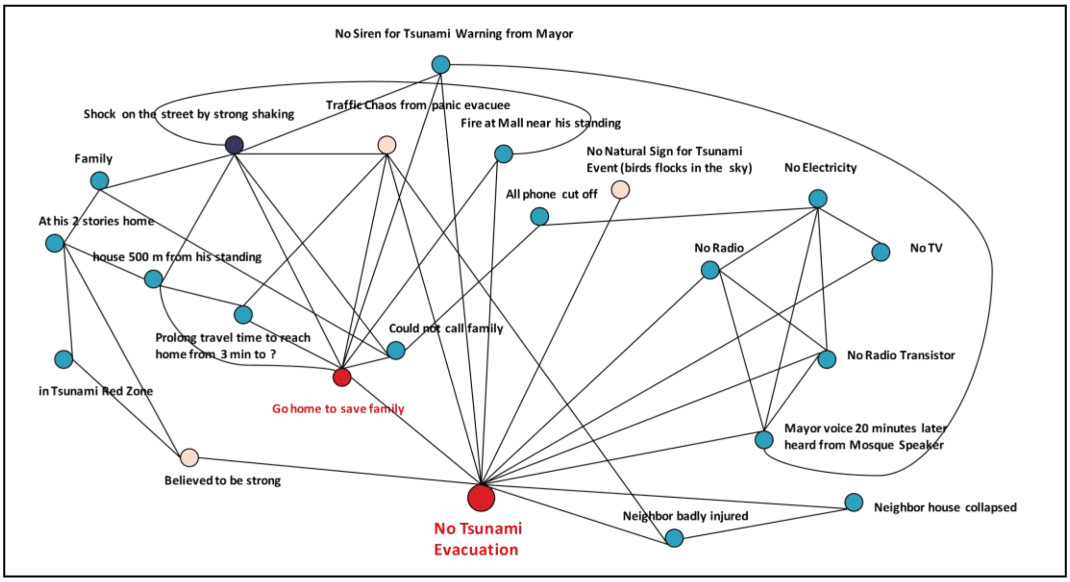


Figure 6.4 The Preliminary Cognitive Map of Government Officials

6.3 Primary knowledge acquisition

As discussed in the Chapter 3, for the government official due to limited number of officials compare to people, the questionnaire based interview was limited to 20 respondent who were exclusively selected from the department or agencies related closely with the tsunami and disaster matter, including planning department, fire brigade, DMO, and social department.

First drafted questionnaire for government is developed based on: preliminary cognitive map, preliminary interview survey conducted 7 days after the September 30, 2009 earthquake in Padang City and Pariaman Regency, and tacit knowledge. The tacit knowledge obtained were from the in-depth survey conducted under collaboration of CDM ITB with AUSAID (4,000 data) and the prior knowledge obtain based on the secondary data during activities conducted from 2005 to 2009 during and after coordinating national tsunami drill in 2006 in Denpasar Bali and 2007 in Cilegon Banten as well as observation during 2005 and 2007 event on this national show case city.

The final questionnaire for government is developed based on the further refined and reviewed the draft based on the followed up interview survey on focus target group, i.e. community and government officials involved in the emergency response. This survey conducted on June 2010. The number of respondent was 9. No pretest for final questionnaire developed was conducted for the government.

This semi-open questionnaire based interview consists of 4 part of assessment; the questionnaire format is different from the people. The questionnaires was designed for semi open questionnaire, aiming to absorbed his cognitive and behavior as officials and as human being to judge and respond toward natural warning and tsunami warning system; beside it needs to assess what has been done by his office in term of DRR countermeasures and many other government DRR initiatives structurally or nonstructural. Detailed of the questionnaire can be seen in Apendix.

As described in Chapter 3, the number of factors and parameters of government respondent shown in Figure 6.6 describes the variables and factors that influenced the heuristic judgment as in DRR Countermeasures (CMi) is the biggest number, i.e. 223 variables, and having most complicated relation among variables in its own cluster as well as with other clusters in the cognitive mapping. This is followed by variables and factors of appreciation to TEWS, i.e. 92, with its all hindrance and supporting factors. The socio economic susceptibility factors (Vi) takes the third biggest, i.e. 84, which not much different with people; then followed by Hazard perception and disaster expereince, i.e. 30,. The smallest number of variables and factors acquired from the respondents are from variables and factors that influence people understanding toward the hazard threat, especially tsunami including its impact.

No	Cluster	RG
1	Ei – Reasoning for Evacuation	48
2	Vi – Vulnerability & Capacity	84
3	Hi – Hazard Perception & Disaster Experience	30
4	Ti – Tsunami Knowledge	25
5	CMi – Countermeasures of DRR	223
6	TEWS – Tsunami Early Warning System	92
	T O T A L	502

Table 6.1 Number of variables acquired for RG

The relation of all of these variables and factors are analyzed and mapped in the cognitive map, which is discussed in the next section.

6.4 Cognitive Mapping of People Mind and Behavior

The 502 of holistic and exhaustive data set RG obtained from primary data acquisition discussed in Section 6.3 are analyzed and structured based on its cognitive relationship. The direct relationship of these variables was structured following the logical thinking flow as human being as well as the official that have duty in disaster situation which were recognized from the sample was structured as shown in Figure 6.7. Not only the way in responding natural phenomena (strong shaking) and tsunami warning before their decision to evacuate, to delay evacuation or never to evacuate, the information gathered on their thinking about their duty also what done in countermeasures were presented in this diagram.

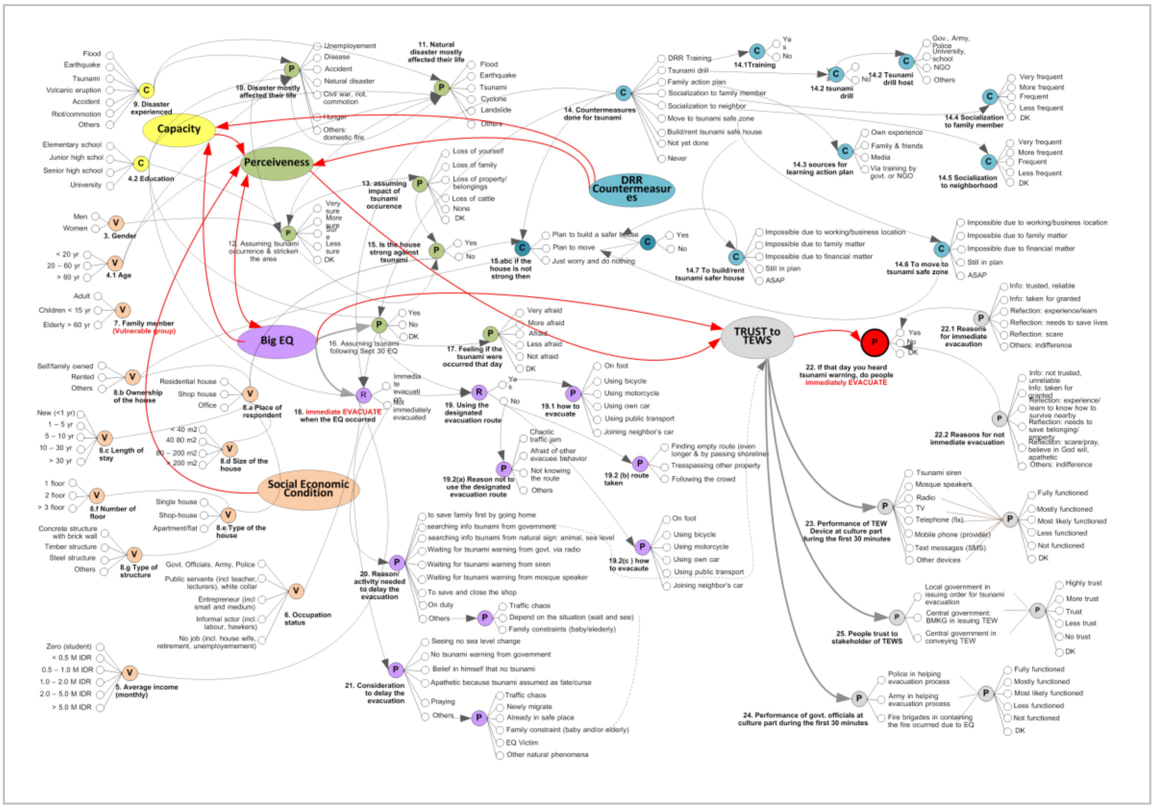
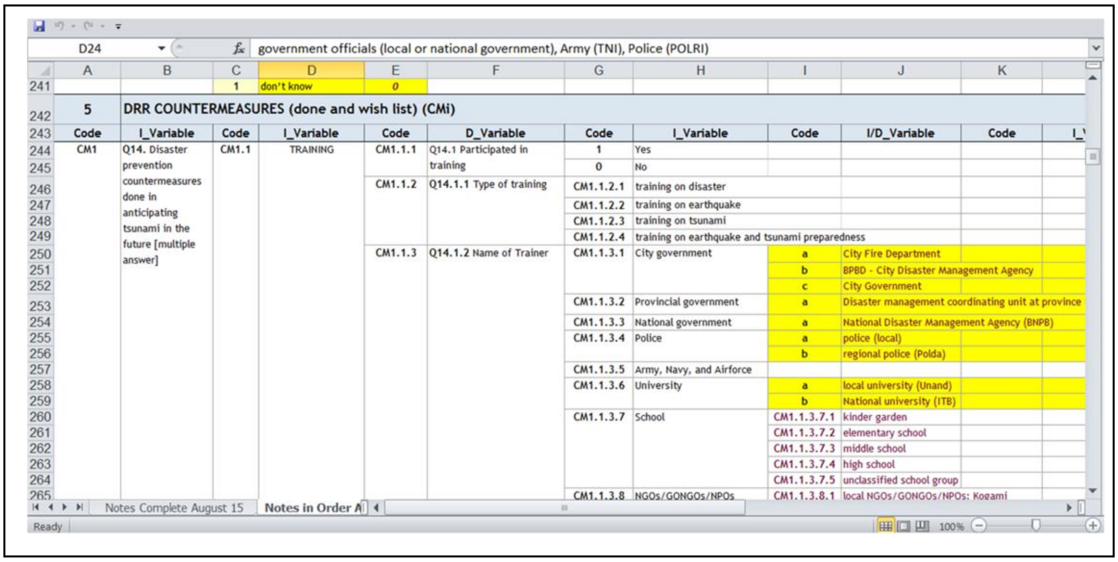


Figure 6.5 Structuring the problem and the people's mind in tsunami disaster situation

6.5 Development of logic model of people's mind toward tsunami early warning

Based on the previous diagram shown in Figure 6.7, then the logic model is constructed by simplifying the relationship among those variables (both observable and unobservable/latent variable), in the form of data structure. Example of some part of data structure is shown by Figure 5.8, while the complete data structure for people can be seen in the Appendix. Through the logic model, these two type variables can be easily recognized and the relationship between and among those variables are best presented.



D24 government officials (local or national government), Army (TNI), Police (POLRI)

	A	B	C	D	E	F	G	H	I	J	K
241			1	don't know	0						
242	5	DRR COUNTERMEASURES (done and wish list) (CMi)									
243	Code	I_Variable	Code	I_Variable	Code	D_Variable	Code	I_Variable	Code	I/D_Variable	Code
244	CM1	Q14. Disaster prevention countermeasures done in anticipating tsunami in the future [multiple answer]	CM1.1	TRAINING	CM1.1.1	Q14.1 Participated in training	1	Yes			
245							0	No			
246					CM1.1.2	Q14.1.1 Type of training	CM1.1.2.1	training on disaster			
247							CM1.1.2.2	training on earthquake			
248							CM1.1.2.3	training on tsunami			
249							CM1.1.2.4	training on earthquake and tsunami preparedness			
250					CM1.1.3	Q14.1.2 Name of Trainer	CM1.1.3.1	City government	a	City Fire Department	
251									b	BPBD - City Disaster Management Agency	
252									c	City Government	
253							CM1.1.3.2	Provincial government	a	Disaster management coordinating unit at province	
254							CM1.1.3.3	National government	a	National Disaster Management Agency (BNPB)	
255							CM1.1.3.4	Police	a	police (local)	
256									b	regional police (Polda)	
257							CM1.1.3.5	Army, Navy, and Airforce			
258							CM1.1.3.6	University	a	local university (Unand)	
259									b	National university (ITB)	
260							CM1.1.3.7	School	CM1.1.3.7.1	kinder garden	
261									CM1.1.3.7.2	elementary school	
262									CM1.1.3.7.3	middle school	
263									CM1.1.3.7.4	high school	
264									CM1.1.3.7.5	unclassified school group	
265							CM1.1.3.8	NGOs/GONGOs/NPOs	CM1.1.3.8.1	local NGOs/GONGOs/NPOs: Kogami	

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Figure 6.6 Data Structure of Government

The 502 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 502 observable factors were structured further in simplified format as the nodes of children-parents order similar pattern as the people model. Figure 6.7 shows the core model of the Logic Model showing relationship among latent variables.

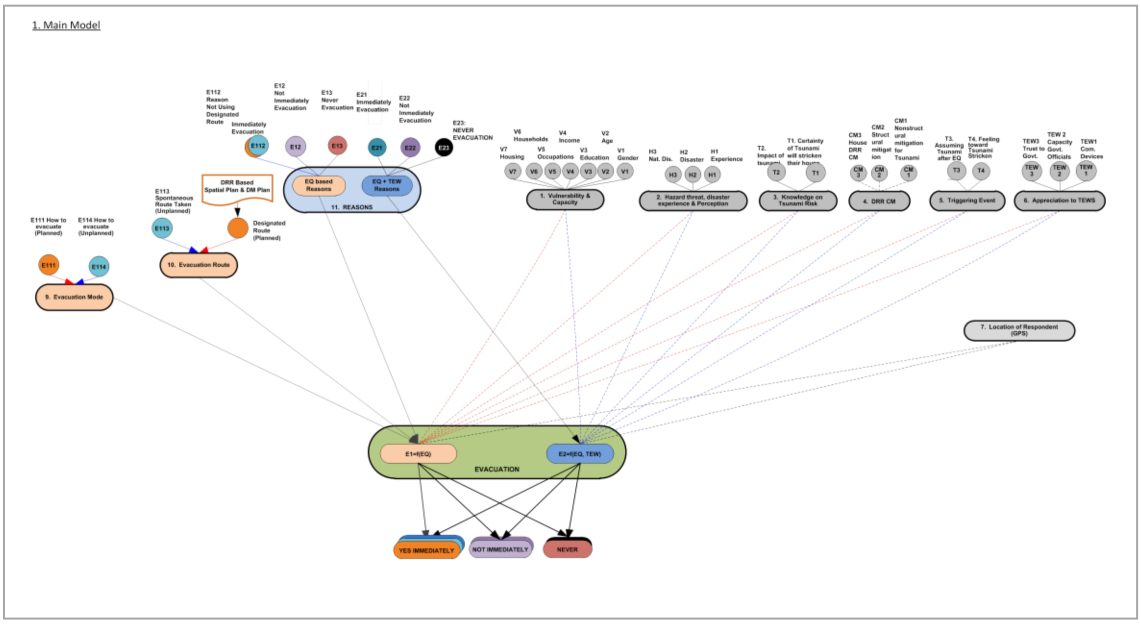

Figure 6.7 Core relationship diagram (Latent Variable) of Logic model of People's Mind toward Tsunami Warning

Moreover, the color of nodes shows the substantial relationship among nodes in one family cluster which are needed to represent their role in the scenario analysis of this numerical model. The grey nodes are recognized as *external factors* to 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 nodes always considered in the numerical analysis of *every scenario of numerical logic model* that will be described and discussed in the section 6.4. To compare, the color nodes characterized as internal factors which indelible in people mind 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, or from makeup experience such as through DRR countermeasures training. This shows there is correlation between grey nodes to color nodes. 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 layer of 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 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 487 observable variables was hierarchically and/or horizontally and vertically structured in the forms logic model tree with two constellation relationship. The variables having similar characteristic were clustered into one family node, they are treated as children nodes with its siblings under one parent node.

6.6 Development of Numerical logic model

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 6.8. The six 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.

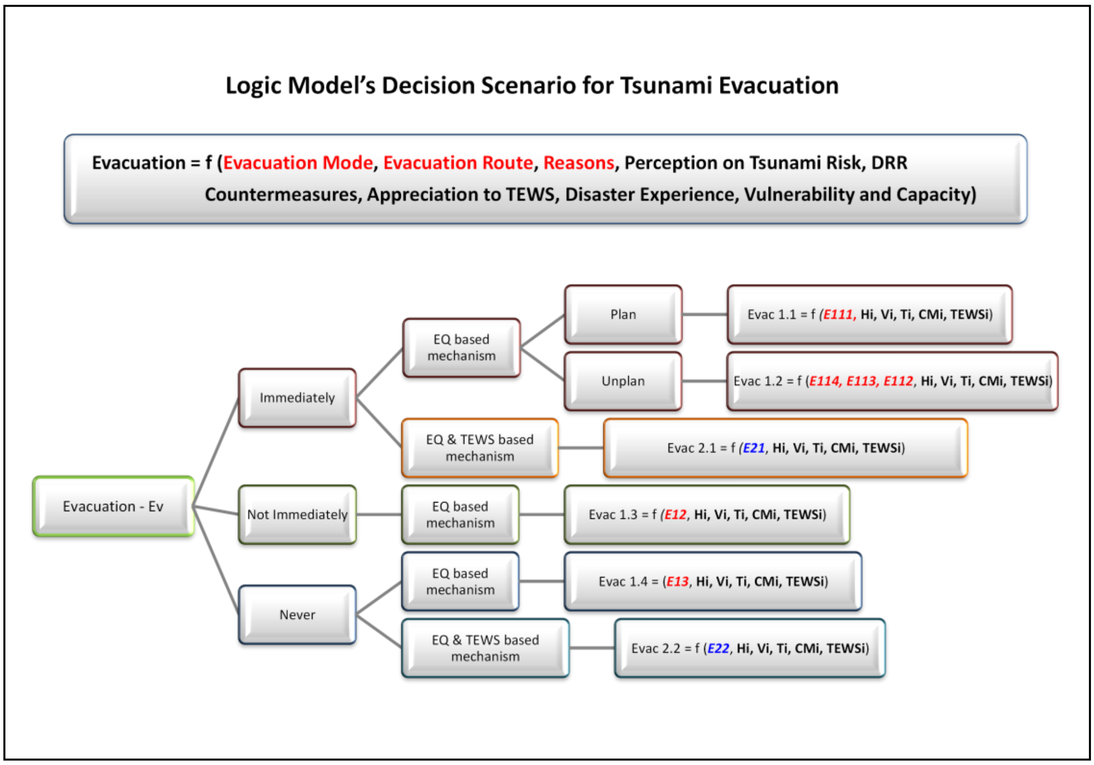

Figure 6.8 Sixth Scenario of Numerical Analysis of the Numerical Logic Model

Each scenario represents each nature of relationship among all assisting, hindrance, indelible and latent factors which influence in decision making process of the people. The formula derived from the 6 scenario based numerical analysis can be presented as follows (Figure 6.9).

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

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

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)

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

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

Figure 6.9 Formula of Sixth Scenario used to develop Numerical Logic Model Tree

Due to the characteristics of scenario of the logic model, each scenario is unique. All the grey nodes have contribution to each scenario; therefore all grey nodes are represented by the top node of each cluster, i.e. Vi, Hi, Ti, CMi, and TEWS. Meanwhile the color node have unique contribution to the scenario, hence the color nodes is represented by either by top node and/or mid layer node. The color nodes is representing the cognitive and heuristics judgment, which related with reason why, how and where to go for evacuation either triggered by natural phenomena and/or combination of both natural phenomena and tsunami warning. This division just to help visually easy to understand the structure of the logic model tree.

Numerical modeling is required for this logic model to know the degree of correlation among the variables in every node of branches, up to sub-cluster, cluster and the scenario of judgment (decision). Looking at the appropriateness of statistical methods to the nature of this model, then the numerical model is better developed by integrating the principal component analysis (PCA) into the logic model. However, in this study principal component analysis is used to find out the correlation among the variables member of each node of branches, then up-scaling to the next level until reaching the stem of the tree. Then the decision scenario conducted at the bottom of the tree with 6 scenario of decision making.

Principal component analysis (PCA) is a mathematical procedure that uses an *orthogonal transformation* to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called principal components. It is further described as the simplest of the true *eigenvector-based multivariate analyses*. Currently, it is mostly used as a tool in exploratory data analysis and for making predictive models.

While orthogonal matrix is a square matrix with real entries whose columns and rows are orthogonal unit vectors. Methodology for numerical modeling of the Logic Model for People's Mind is adapted from PCA method where Main Component obtained through the analysis can be assumed as "latent variable" (variable which were not observed) with linear combination of some observed variables (x_1, …… x_k).

As discussed in Chapter 3 that for the Government Logic Model that the stage of analysis do not include the final stage of reducing variable, see also Chapter 1 and Chapter 3 of this dissertation. Meanwhile basic principle of PCA is to structure the main component, which is a linear combination of some observed variables. The numerical analysis was used the PCA facilitated by SPSS 19 program.

Summary of the final result of numerical modeling for all 6 decision scenarios of government data set RG are presented in the following formula shown in Table 6.2.

Table 6.2 Summary of the final result of numerical modeling for all 6 decision scenarios of RG

No	Variables	RG	
		Coeff.	%
	$Evac_{1.1} = f(E_{1.1.1}, H_i, V_i, T_i, CM_i, TEWS_i)$		
1	E1.1.1 How did you evacuate when immediate evacuate after strong shaking?	-1.29	18.08
2	H Hazard and Disaster Perception and Experiences	1.03	14.46
3	V Social Vulnerability and Capacity	2.09	29.26
4	T Knowledge on Tsunami Risk and Triggering Event	1.12	15.66
5	CM Disaster Risk Reduction Countermeasures	1.61	22.53
6	TEWS Appreciation to Tsunami Early Warning System	-1.29	18.08
	$Evac_{1.2} = f(E_{1.1.2}, E_{1.1.3}, E_{1.1.4}, H_i, V_i, T_i, CM_i, TEWS_i)$		
1	E1.1.2 What was the reasons not to follow the route when immediate evacuate after strong shaking?	0.60	6.42
2	E1.1.3 What alternative route did you take when immediate evacuate after strong shaking?	0.63	6.74
3	E1.1.4 How did you evacuated when immediate evacuate after strong shaking?	-1.96	0.00
4	H Hazard and Disaster Perception and Experiences	0.90	20.87
5	V Social Vulnerability and Capacity	2.56	9.53
6	T Knowledge on Tsunami Risk and Triggering Event	1.57	27.27
7	CM Disaster Risk Reduction Countermeasures	1.18	16.65
8	TEWS Appreciation to Tsunami Early Warning System	0.60	12.53

Table 6.2 Continued

No	Variables	RG	
		Coeff.	%
	$Evac_{1.3} = f(E_{1.2}, H_i, V_i, T_i, CM_i, TEWS_i)$		
1	E1.2 What was your reasons not to evacuate immediately after strong shaking?	2.14	23.94
2	H Hazard and Disaster Perception and Experiences	-1.00	11.22
3	V Social Vulnerability and Capacity	1.59	17.80
4	T Knowledge on Tsunami Risk and Triggering Event	2.21	24.68
5	CM Disaster Risk Reduction Countermeasures	0.93	10.39
6	TEWS Appreciation to Tsunami Early Warning System	1.07	11.98
	$Evac_{1.4} = f(E_{1.4}, H_i, V_i, T_i, CM_i, TEWS_i)$		
1	E1.3 What were your reasons for never evacuated after strong shaking?	2.18	26.38
2	H Hazard and Disaster Perception and Experiences	-0.59	7.07
3	V Social Vulnerability and Capacity	1.21	14.58
4	T Knowledge on Tsunami Risk and Triggering Event	2.21	26.71
5	CM Disaster Risk Reduction Countermeasures	0.30	3.65
6	TEWS Appreciation to Tsunami Early Warning System	1.79	21.62

Table 6.2 Continued

No	Variables	RG	
		Coeff.	%
	$Evac_{2.1} = f(E_{2.1}, H_i, V_i, T_i, CM_i, TEWS_i)$		
1	E2.1 What is your consideration when immediate evacuate after receiving/hearing tsunami warning?	1.32	16.60
2	H Hazard and Disaster Perception and Experiences	-1.56	19.57
3	V Social Vulnerability and Capacity	1.05	13.19
4	T Knowledge on Tsunami Risk and Triggering Event	2.16	27.09
5	CM Disaster Risk Reduction Countermeasures	1.09	13.73
6	TEWS Appreciation to Tsunami Early Warning System	0.78	9.82
	$Evac_{2.2} = f(E_{2.2}, H_i, V_i, T_i, CM_i, TEWS_i)$		
1	E2.2 What is your consideration for never evacuate after receiving/hearing tsunami warning?	-1.61	18.17
2	H Hazard and Disaster Perception and Experiences	-0.79	8.90
3	V Social Vulnerability and Capacity	1.71	19.26
4	T Knowledge on Tsunami Risk and Triggering Event	2.33	26.22
5	CM Disaster Risk Reduction Countermeasures	0.57	6.43
6	TEWS Appreciation to Tsunami Early Warning System	1.86	21.01

$$V = 2.136365(V1) + 1.164818(V2) + 1.171924(V3) - 0.576438(V4) + 0.709552(V6) - 1.448208(V7)$$

$$V1 = 2.00\,(V1.1) - 2.00\,(V1.2)$$
$$V2 = 1.510082\,(V2.2) + 1.486032(V2.3) - 1.609158(V2.4) - 0.491468(V2.5)$$
$$V3 = -0.491468(V3.3) - 1.609158(V3.4) + 1.510082(V3.5) + 1.486032(V3.6)$$
$$V5 = 1.382576\,(V5.1) + 1.382576(V5.2)$$

$$V5.1 = -1.82292(V5.1.1) + 0.209792(V5.1.2) + 0.553116(V5.1.3) + 0.876202(V5.1.4) + 2.079966(V5.1.5)$$
$$V5.2 = 1.177457(V5.2.1) + 1.291053(V5.2.2) - 2.060128(V5.2.3)$$

$$V6 = 0.731445\,(V6.1) - 0.731445(V6.2)$$

$$V6.1 = 1.581431(V6.1.1) + 0.004037(V6.1.2) + 1.371242(V6.1.3) - 1.755155(V6.1.4) + 0.63708(V6.1.5)$$
$$V6.2 = 0.630249(V6.2.2) + 0.507843(V6.2.3) - 1.864134(V6.2.4) + 2.157099(V6.2.5)$$

$$V7 = 2.020278\,(V7.1) - 1.056201(V7.2) + 2.029023(V7.3) + 0.898843\,(V7.4) - 2.133635(V7.5) + 1.786553(V7.6)$$

$$V7.1 = 2.00\,(V7.1.1) - 2.00(V7.1.2)$$
$$V7.2 = -1.993791(V7.2.1) + 0.421219(V7.2.2) - 0.439258(V7.2.3) + 1.660823(V7.2.4) + 1.364726(V7.2.6) + 0.133973(V7.2.7)$$
$$V7.3 = 1.15136(V7.3.1) - 1.78927(V7.3.7.2) + 0.365132(V7.3.3) + 0.103649(V7.3.4) + 1.891982(V7.3.5)$$
$$V7.4 = 2.00(V7.4.1) - 2.00(V7.4.2)$$
$$V7.5 = 1.510082(V7.5.3) + 1.486032\,(V7.5.4) - 0.491468(V7.5.5) - 1.609158(V7.5.6)$$
$$V7.6 = 2.00\,(V7.6.1) - 2.00(V7.6.5)$$

$$H = 1.572(H1) + 0.889(H2) + 0.539(H3)$$

$$H1 = 2.292967(H1.1) + 2.861667(H1.2) + 3.445832(H1.3) + 4.280346(H1.4) + 4.062981(H1.5) + 2.995413(H1.6) + 0.219955(H1.7) + 2.93718(H1.8) + 2.35212(H1.9) + 1.546432(H1.11)$$

$$H2 = 1.919643(H2.2) - 1.929(H2.4) + 0.937884(H2.9)$$

$$H3 = 1.968896(H3.1) - 1.667(H3.3) + 1.496721(H3.4) - 0.317542(H3.5) - 0.334207(H3.7)$$

$$T = -0.788088(T1) - 0.293048(T2) + 1.648816(T3) + 1.885448(T4) +$$

$0.659232(T5) + 1.09616(T6)$

$T2 = 2.522844(T2.1) + 2.769228(T2.2) + 3.08184(T2.3) + 2.29443(T2.4) – 2.447884(T2.5) + 3.400182(T2.6) - 0.574976(T2.7)$

$T5 = - 1.01103(T5.1) - 1.185336(T5.2) + 2.571167(T5.3) + 0.257974(T5.4) – 1.064344(T5.5) + 2.489974(T5.6) + 0.290827(T5.7)$

$T6 = 1.47816(T6.1) + 1.297496(T6.2) + 1.47816(T6.3) + 1.47816(T6.4) - 0.646695(T6.5)$

$CM = 1.446947(E1) + 1.357403(E2) - 1.557717(E3) + 1.585818(E4)$

$CM1 = 1.256706(CM1.1) + 1.33755(CME1.2) - 1.53159(CM1.3) + 0.0073340(CM1.4) + 1.831145(CM1.5) + 1.799814(CM1.6) + 1.405632(CM1.7)$

$CM1.1 = 2.392292(CM1.1.1) + 2.424352(CM1.1.2) - 0.267886(CM1.1.3) + 2.261778(CM1.1.4) + 1.88021(CM1.1.5) - 0.698852(CM1.1.6) + 2.010336(CM1.1.6)$

$CM1.1.3 = 1.435374(CM1.1.3.1) - 0.36861(CM1.1.3.2) + 0.358329(CM1.1.3.3) - 1.520622(CM1.1.3.4) + 1.02492(CM1.1.3.5)$

$CM1.1.3.3 = - 0.946682(CM1.1.3.3.1) - 0.181925(CM1.1.3.3.2) + 1.344925(CM1.1.3.3.3)$

$CM1.1.4 = - 1.470813(CM1.1.4.1) + 1.076103(CM1.1.4.2) + 0.415059(CM1.1.4.3)$

$CM1.1.5 = 0.822817(CM1.1.5.1) + 0.336911(CM1.1.5.2) + 1.724395(CM1.1.5.3) + 0.739453(CM1.1.5.4) + 1.430609(CM1.1.5.5) - 1.805564(CM1.1.5.6)$

$CM1.1.5.1 = 1.351224(CM1.1.5.1.1) - 0.013540(CM1.1.5.1.2) + 2.057961(CM1.1.5.1.3) + 2.630773(CM1.1.5.1.4) + 2.385244(CM1.1.5.1.5) + 2.123645(CM1.1.5.1.6)$

$CM1.1.5.5 = 2.00598(CM1.1.5.5.1) + 2.00598(CM1.1.5.5.2) - 0.763425(CM1.1.5.5.3) + 0.763425(CM1.1.5.5.4)$

$CM1.1.6 = 0.469378(CM1.1.6.1) + 1.172766(CM1.1.6.2) - 1.261442(CM1.1.6.3)$

$CM1.1.7 = 1.0248(CM1.1.7.1) - 1.0248(CM1.1.7.2)$

$CM1.2 = 2.60395(CM1.2.1) + 2.312725(CM1.2.2) + 0.517214(CM1.2.3) + 0.323(CM1.2.4) + 0.514254(CM1.2.5) + 0.45867(CM1.2.6) + 1.255353(CM1.2.7)$

$CM1.2.3 = - 1.05158(CM1.2.3.1) + 0.11516(CME1.2.3.2) + 0.661817(CM1.2.3.3) + 1.801499(CM1.2.3.4) - 0.857098(CM1.2.3.5) + 2.188667(CM1.2.3.6)$

$CM1.2.4 = - 1.815378(CM1.2.4.1) - 0.288528(CME1.2.4.2) + 1.27053(CM1.2.4.3) + 0.740028(CM1.2.4.4) + 0.271668(CM1.2.4.5)$

$CM1.2.5 = 1.828102(CM1.2.5.1) + 2.50863(CME1.2.5.2) + 0.451573(CM1.2.5.3) – 1.597259(CM1.2.5.4) + 2.50863(CM1.2.5.5) + 0.044407(CM1.2.5.6)$

$CM1.2.5.1 = - 0.555486(CM1.2.5.1.1) - 0.639738(CME1.2.5.1.2) + 1.994742(CM1.2.5.1.3) – 0.344055(CM1.2.5.1.4) + 2.060456(CM1.2.5.1.5) + 2.188667(CM1.2.5.1.6)$

$CM1.2.6 = 1.383148(CM1.2.6.1) + 0.273014(CM1.2.6.2) - 1.094214(CM1.2.6.3)$

$CM1.2.7 = 1.130509(CM1.2.7.1) - 1.130509(CM1.2.7.2)$

$CM1.3 = 1.25452(CM1.3.1) + 1.25452(CM1.3.2) + 3.12496(CM1.3.3) + 2.46158 (CM1.3.4) + 2.751796(CM1.3.5) + 3.142486(CM1.3.6)$

$CM1.3.3 = 0.963536(CM1.3.3.1) + 0.963536(CM1.3.3.2)$
$CM1.3.4 = 0.996408(CM1.3.4.1) + 1.02804(CM1.3.4.2) - 0.490296(CM1.3.4.3)$
$CM1.3.5 = 1.032923(CM1.3.5.1) - 0.100206(CM1.3.5.2) + 1.426644(CM1.3.5.3)$
$CM1.3.6 = 1.050714(CM1.3.6.1) - 1.050714(CM1.3.6.2)$

$CM1.4 = - 1.007014(CM1.4.1) + 1.42738(CM1.4.2) + 1.535536(CM1.4.3) +$
$0.216632(CM1.4.4)$

$CM1.4.3 = 0.02212799(CM1.4.3.1) - 0.166448(CM1.4.3.2) - 1.537137(CM1.4.3.3) –$
$0.166448(CM1.4.3.4) - 0.77648(CM1.4.3.5) - 0.010287(CM1.4.3.6) +$
$0.669159 (CM1.4.3.7) + 0.669159(CM1.4.3.8) + 0.118952(CM1.4.3.9) +$
$4.521953(CM1.4.3.10) + 4.521953(CM1.4.3.11)$
$CM1.4.4 = 1.081505(CM1.4.4.1) - 1.081505(CM1.4.4.2)$

$CM1.5 = 0.51608(CM1.5.1) - 1.956325(CM1.5.2) + 0.310663(CM1.5.3) + 1.683102$
$(CM1.5.4) + 2.219173(CM1.5.5)$

$CM1.5.3 = - 0.491038(CM1.5.3.1) + 2.736739 (CME1.5.3.2) +$
$2.901403(CM1.5.3.3) + 2.574504(CM1.5.3.4) - 0.106747(CM1.5.3.5) -$
$1.595785(CM1.5.3.6) + 0.555494(CM1.5.3.7) - 0.698629(CM1.5.3.8)$
$CM1.5.4 = 1.221209(CM1.5.4.1) + 0.457941 (CME1.5.4.2) + 0.626455(CM1.5.4.3)$
$– 1.426759(CM1.5.4.4)$
$CM1.5.5 = 1.697971(CM1.5.5.1) - 1.697971 (CME1.5.5.2)$
$CM1.5.6 = 0.743446(CM1.5.6.1) - 0.743446 (CME1.5.6.2)$

$CM1.6 = 2.04(CM1.6.1) + 0.96 (CME1.6.2) - 3.7E - 17(CM1.6.3)$

$CM1.6.3 = - 0.904056(CM1.6.3.1) - 0.235225(CME1.6.3.2) + 1.291625(CM1.6.3.3)$

$CM1.7 = - 1.204632(CM1.7.1) + 0.322218 (CME1.7.2) + 0.882414(CM1.7.3)$

$CM2 = 2.398356(CM2.1) + 1.739412(CM2.2) + 1.13337(CM2.3) + 0.888984(CM2.4) –$
$0.145656(CM2.5) + 2.194506(CM2.6) + 0.811044(CM2.7)$

$CM2.1 = 2.30204(CM2.1.1) + 2.777593(CM2.1.2) + 2.477722(CM2.1.3) -$
$1.768936(CM2.1.4) + 2.347475(CM2.1.5)$

$CM2.1.3 = 1.832529(CM2.1.3.1) + 0.139432(CM2.1.3.2) + 3.091305(CM2.1.3.3) –$
$1.686015(CM2.1.3.4) + 2.624536(CM2.1.3.5) - 3.0085(CM2.1.3.6) +$
$1.252632 (CM2.1.3.7) + 0.01831499(CM2.1.3.8) - 0.122093(CM2.1.3.9)$
$+ 0.517851(CM2.1.3.10)$
$CM2.1.4 = - 1.023(CM2.1.4.1) - 0.107465 (CM2.1.4.2) + 1.419385(CM2.1.4.3)$
$CM2.1.5 = 1.537232(CM2.1.5.1) + 1.698672(CM2.1.5.2) + 2.671904(CM2.1.5.3) –$
$1.540425(CM2.1.5.4) - 0.013575(CM2.1.5.5) + 2.175704(CM2.1.5.6) +$
$2.671904 (CM2.1.5.7)$

$CM2.2 = 1.959832(CM2.2.1) + 2.256452(CM2.2.2) - 1.123806(CM2.2.3) +$
$1.066973(CM2.2.4)$

$CM2.2.3 = 0.836095(CM2.2.3.1) + 0.80028 (CM2.2.3.2) - 0.737295(CM2.2.3.3)$
$CM2.2.4 = 2.473149(CM2.2.4.1) + 0.403044(CM2.2.4.2) - 1.123806(CM2.2.4.3) +$
$2.687727(CM2.2.4.4) + 2.687727(CM2.2.4.5)$

$CM2.3 = 2.18828(CM2.3.1) + 2.18828(CM2.3.2) + 1.23488(CM2.3.3) +$
$0.77634(CM2.3.4)$

$CM2.3.3 = 1.181312(CM2.3.3.1) - 1.181312(CME2.3.3.2)$

$CM2.3.4 = -1.292907(CM2.3.4.1) + 0.372021(CM2.3.4.2) + 1.322214(CM2.3.4.3) + 1.228275(CM2.3.4.4)$

$CM2.6 = 0.0625530(CM2.6.2) + 0.14776(CM2.6.3) + 1.589403(CM2.6.4) + 0.423893(CM2.6.6) - 1.656224(CM2.6.7)$

$CM2.7 = 1.564692(CM2.7.2) + 0.206381(CM2.7.3) + 0.558024(CM2.7.4) - 0.593958(CM2.7.5) - 1.395486(CM2.7.6)$

$CM4 = 1.300256(CM4.1) + 1.659824(CM4.2) - 0.79395(CM4.3) + 0.00(CM4.4)$

$CM4.4 = 1.2571(CM4.4.1) - 0.888615(CM4.4.2) - 0.26975(CM4.4.3)$

$TEW = 1.637124(TEW1) - 1.318604(TEW2) + 0.321842(TEW3) + 1.974454(TEW4) + 0.769844(TEW5) + 2.363664(TEW6)$

$TEW1 = 2.222448(TEW1.1) + 2.644427(TEW1.2) + 2.690601(TEW1.3) + 2.41238(TEW1.4) + 2.148675(TEW1.5) + 0.741645(TEW1.6) + 1.304868(TEW1.7)$

$TEW2 = -0.10287(TEW2.1) + 0.090086(TEW2.2) + 1.868899(TEW2.3) + 3.146597(TEW2.4) + 3.146597(TEW2.5) + 0.532187(TEW2.6)$

$TEW2.1 = -0.303213(TEW2.1.1) + 2.834327(TEW2.1.2) + 2.834327(TEW2.1.3) - 0.217923(TEW2.1.4) - 0.217923(TEW2.1.5)$

$TEW2.2 = 0.851264(TEW2.2.1) - 0.851264(TEW2.2.2)$

$TEW2.3 = -1.144973(TEW2.3.1) + 1.214457(TEW2.3.2) + 0.232371(TEW2.3.3)$

$TEW2.5 = 2.00(TEW2.5.1) - 2.00(TEW2.5.2)$

$TEW2.6 = 1.240262(TEW2.6.1) - 1.240262(TEW2.6.2)$

$TEW3 = 2.338007(TEW3.1) + 0.623628(TEW3.2) + 0.742312(TEW3.3) + 2.338007(TEW3.4) - 0.42228(TEW3.5)$

$TEW4 = 2.592224(TEW4.1) + 2.644398(TEW4.2) + 2.647144(TEW4.3)$

$TEW5 = 0.842268(TEW5.1) + 1.408116(TEW5.2) + 1.26828(TEW5.3)$

$TEW5.1 = 0.988699(TEW5.1.1) + 0.227355(TEW5.1.3) - 1.433923(TEW5.1.4) + 0.704959(TEW5.1.5) + 1.245612(TEW5.1.6) - 0.337047(TEW5.1.7) - 0.961557(TEW5.1.8) - 0.961557(TEW5.1.9) + 3.427148(TEW5.1.10) + 3.427148(TEW5.1.11) + 0.28307(TEW5.1.12) + 3.568918(TEW5.1.13) + 0.005078(TEW5.1.14) + 0.397947(TEW5.1.15) - 1.624478(TEW5.1.16) - 2.063579(TEW5.1.17)1.556532(TEW5.1.18)$

$TEW5.2 = 3.530988(TEW5.2.1) + 4.51638(TEW5.2.2) + 4.51638(TEW5.2.3) + 4.51638(TEW5.2.4) - 0.306768(TEW5.2.5) + 4.51638(TEW5.2.6) + 1.33854(TEW5.2.7) + 1.33854(TEW5.2.8)$

$TEW5.2.7 = 4.536(TEW5.2.7.1) + 0.464(TEW5.2.7.2) + (2.684E - 16)(TEW5.2.7.3) - (4.76E - 33)(TEW5.2.7.4) - (2.82E - 16)(TEW5.2.7.5)$

$TEW5.2.8 = 1.551272(TEW5.2.8.1) + 1.551272(TEW5.2.8.2)$

$TEW5.3 = 1.651431(TEW5.3.1) + 0.423199(TEW5.3.2) + 3.928482(TEW5.3.3) + 3.928482(TEW5.3.4) - 0.155779(TEW5.3.5) + 2.222856(TEW5.3.6) - 0.155779(TEW5.3.7) + 0.109507(TEW5.3.8) + 2.222856(TEW5.3.9) + 3.928482(TEW5.3.10)$

$TEW6 = 1.469358(TEW6.1) + 1.469358(TEW6.2)$

$Evac\ 1.1 = 1.03525(E1.1.1) + 0.980266(H) + 1.228022(V) - 1.191704(T) + 0.294421(CM) + 1.042065(TEWS)$

$Evac\ 1.2 = 0.57724(E1.1.2) + 0.824712(E1.1.3) - 0.46242(E1.1.4) + 1.501194(H) + 1.156557(V) - 1.23216(T) + 1.070411(CM) + 0.520371(TEWS)$

$Evac\ 1.3 = 1.524423(E1.2) + 1.312855(H) + 0.761002(V) - 1.412381(T) + 0.673033(CM) + 1.093189(TEWS)$

$Evac\ 1.4 = 0.841219(E1.3) - 1.118966(H) + 0.20584(V) + 1.041528(T) + 1.144105(CM) + 0.86943(TEWS)$

$Evac\ 2.1 = 1.198446(E1.1.1) + 1.480426(H) + 0.329104(V) - 1.180598(T) + 0.546179(CM) + 0.594646(TEWS)$

$Evac\ 2.2 = - 0.168594(E2.2) - 0.938497(H) + 0.593755(V) + 1.283106(T) + 1.324307(CM) + 1.052126(TEWS$

6.7 Result and discussion

Result of the numerical analysis for government model 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 city, i.e. Padang 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.

Chapter 7
Research Findings and Future Works

7.1 Research Findings

The complexity of the phenomena of ***effective tsunami early warning system*** is defined by this study as the integration of natural, socio, technical and physical phenomena, aiming to save people as many as possible by alerting the *people at risk* with sufficient lead time to make decision for evacuation. To understand better the phenomena, ***the study has proved to be able*** describe the phenomena in total in the forms of integration of layer models and floating indicators.

The layers models represent the phenomena of natural phenomena system as the first model, the phenomena of detecting, analyzing and disseminating the warning of potential tsunami as the second model, the phenomena of government cognitive representation model as the third model, and the phenomena of people cognitive representation model as the fourth model. The floating indicators consist of the indicators representing preparedness level of the city and the stakeholders including, physical and socio vulnerability and capacity indicators. Total model can be seen also in Figure 7.1.

The study is not only ***able to prove the knowledge representation of tsunami early warning phenomena in total***, but also it is able to prove the methodology of structuring the problem in the form of relation among factors and variables of each phenomena, see Figure 7.2.

The use of new approach of logic model, i.e. PBLM - physically based logic model and TKBLM - tacit knowledge based logic model, is ***very fruitful findings*** which enables the process of problem structuring and acquiring all related variables and factors in total and holistic. These new approach of logic model is able to bridge the limitation in data acquisition. Meanwhile the use of non-reduction factors approach of Principal Component Analysis - PCA is very useful to have a complete and holistic model structure of the logic model.

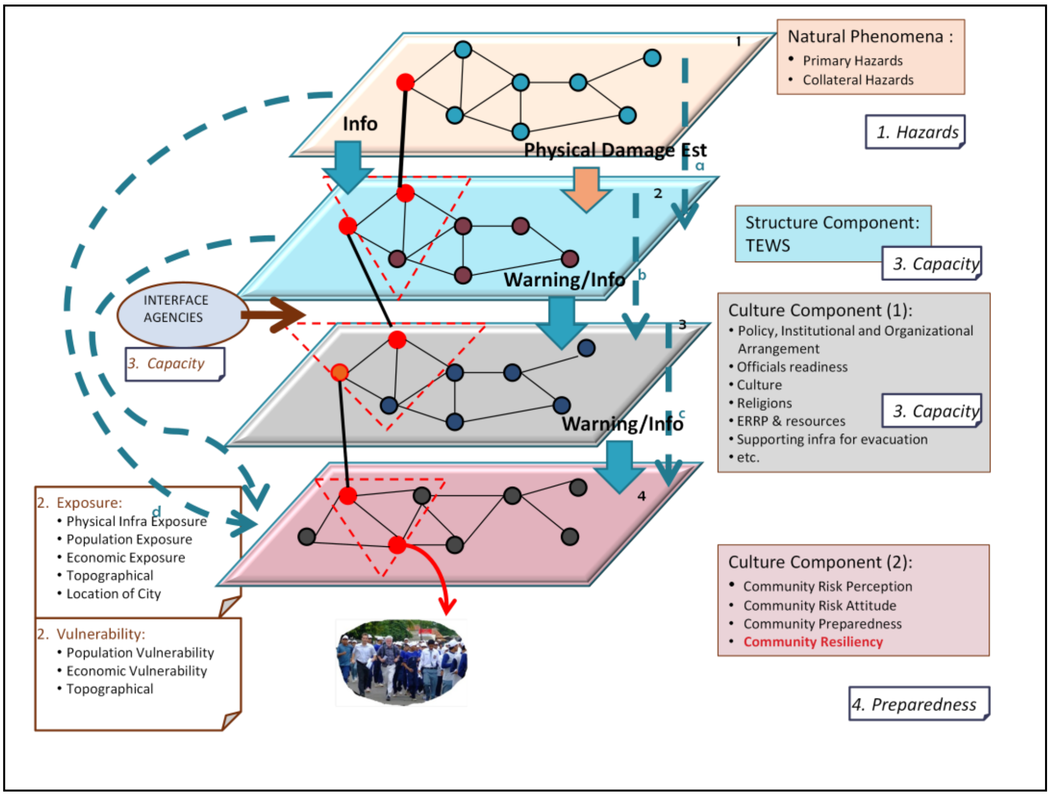

Figure 7.1 Integrated Logic Model of Effective Tsunami Early Warning System

The numerical logic model developed using the Principal Component Analysis - PCA is ***proved the ability of the model to analyze the people mind***, by showing the numerical correlation between variables and factors, also among factors in the integrated model.

Meanwhile the occurrence of Mentawai tsunami in 2010 during the study was valuable windows of opportunity to model people's mind for before and after the tsunami phenomena. Two people model were developed, i.e. prior tsunami model and post tsunami model, to complement with the ability to develop government model.

Detailed result of numerical model developed in this study is very useful to recognize how the people minds are influenced by their social status (job position), prior perception/belief to tsunami early warning system triggered by past experience and past information, and heuristic belief triggered by current external factors. The study also finds that prior belief based risk perception of the people toward disaster experience has limitation, as shown by the correlation among factors/elements between different group and different timeline of data acquisition.

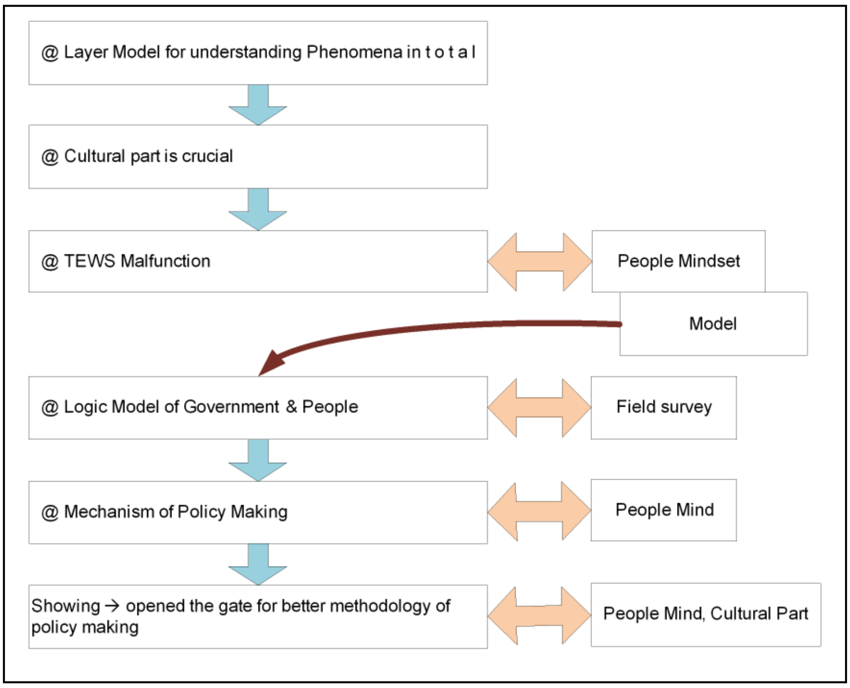

Figure 7.2 Research Methodologies for the Development of Integrated Logic Model of Effective Tsunami Early Warning System

This numerical analysis performed is confirming the correlations among variables/factors in every level of the tree and in each cluster, as well as in the decision scenario. Then keeping all factors (no reduction), is conforming the holistic logic model. There are 487 variables structured for prior tsunami people model and 485 variables for post tsunami people model and 502 variables of government models, see Figure 7.3 for the summary of variables and Figure 7.4 for graphical representation of the people model and Figure 7.5 for government model.

	Cluster	RP1	RP2	RG
1	E – Reasoning for Evacuation	184	183	48
2	V – Vulnerability & Capacity	87	86	84
3	H – Hazard Perception & Disaster Experience	29	29	30
4	T – Tsunami Knowledge	9	9	25
5	CM – Countermeasures of DRR	118	118	223
6	TEWS – Tsunami Early Warning System	60	60	92
	T O T A L	487	485	502

Figure 7.3 Number of variable (acquired through Questionnaire based Interview) for People Prior Tsunami (RP1), People Post Tsunami (RP2) and Government Officials (RG)

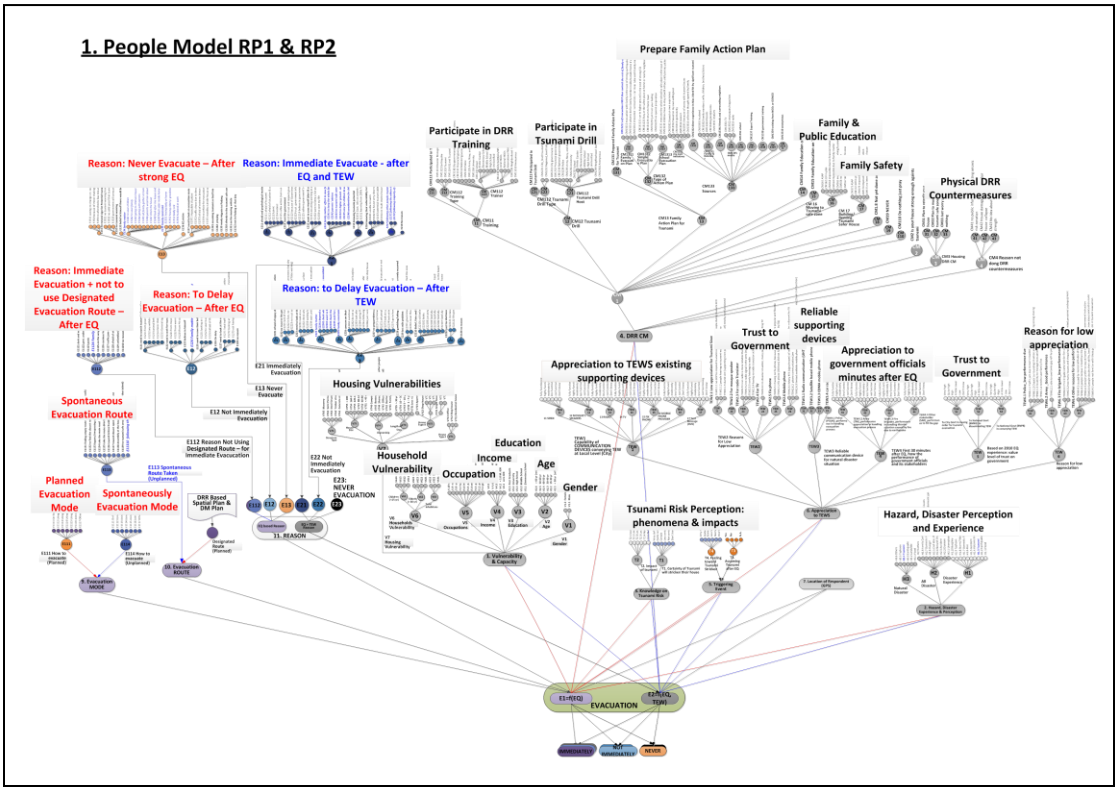

Figure 7.4 People Model

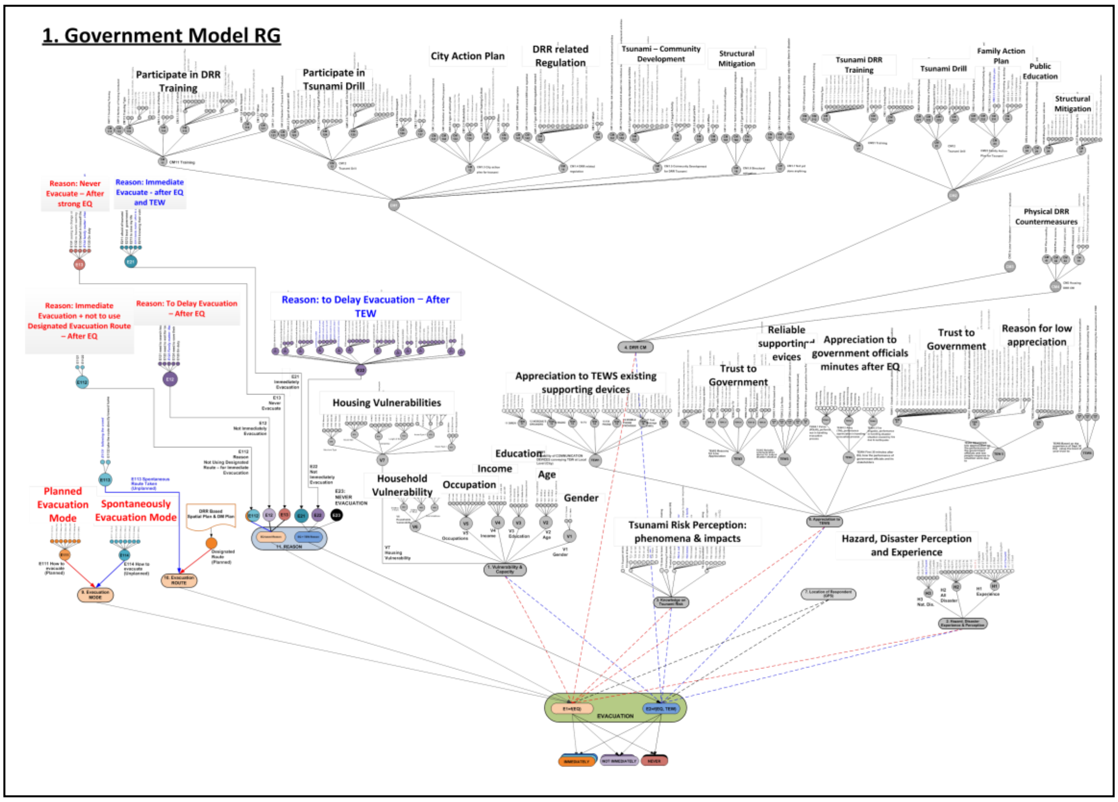

Figure 7.5 Government Model

To conclude that the outcome of the study is proving two original findings, i.e. the integrated logic model developed and the new methodology for the process development of logic model which is a new theory as a gate for better methodology in policy making. It is expected that the model developed by this study will be a useful policy making tool for the city managers from tsunami prone area in Indonesia as well as in other region for achieving effective tsunami early system.

7.2 Future Works

In the future, the more frequent the model used, the more exhaustive the model. Some basic people perception toward disaster threat (tsunami) found in the study, no matter region, nationality or intensity of DRR countermeasures implemented, i.e. responses of people during 2009 Padang City and 2011 Tohoku tsunami cases and the factors related with family important and following the mass evacuation.

For future works, implementation can be two schemes, i.e. for cities level tsunami prone cities in Indonesia or other cities in other region. For tsunami prone *cities* (Indonesia) – this model is useful for policy making tool for the city managers in achieving effective TEW through assessing the level of tsunami risk, assessing the allocation needs for implementing tsunami DRR countermeasures and monitoring and evaluation the effectiveness of tsunami early warning.

For the regional level the model can be up-scaled for regional policy making tool through comparison analysis between cities from tsunami prone area for policy development and policy review at regional and national level.

Other future work is that the research methodology can be applied not only in disaster area but also to other area of works, such as any area related with public management, health management.

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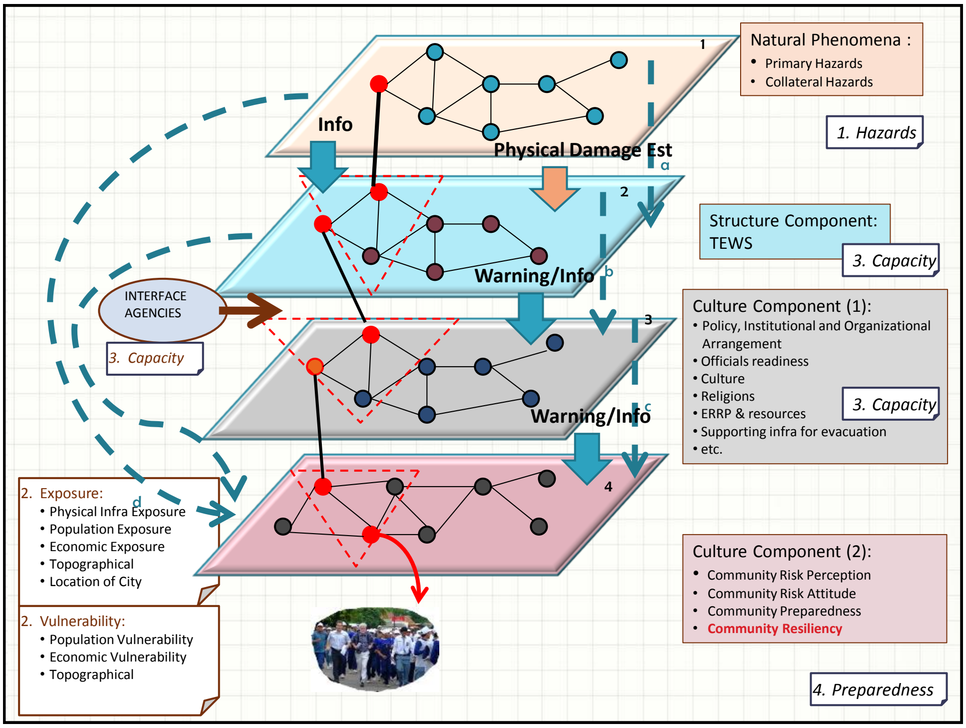
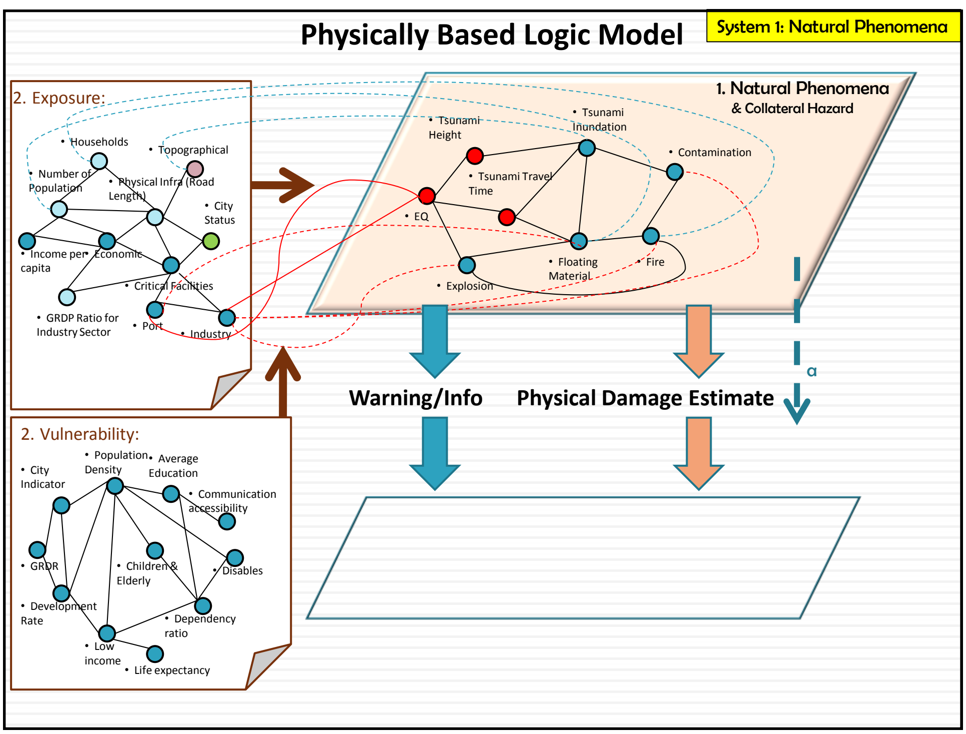
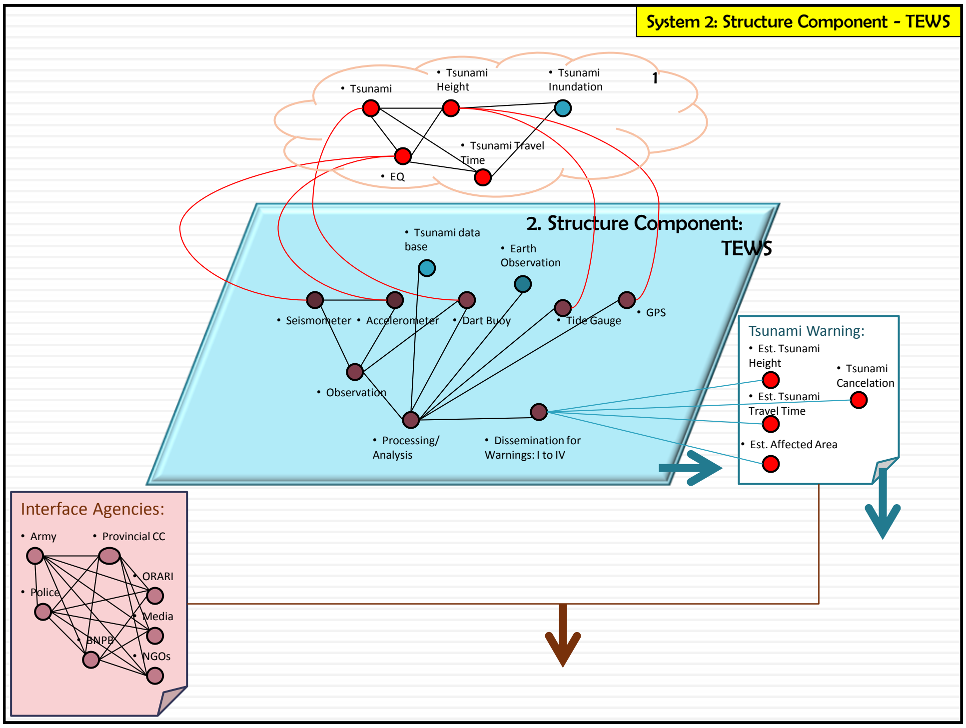
APPENDIX A

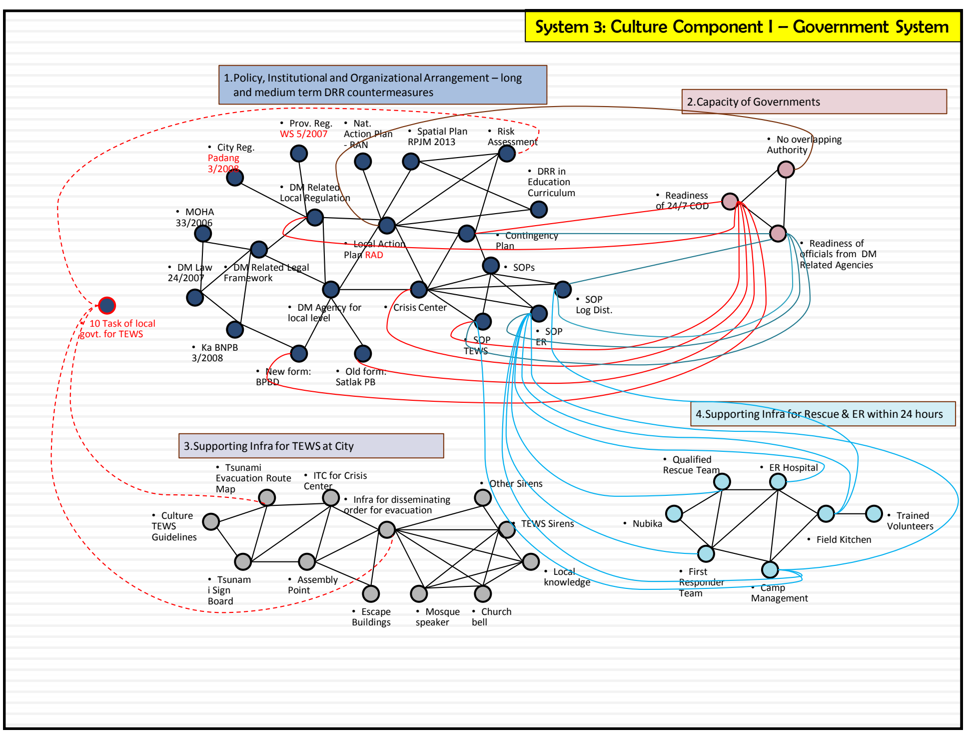
- A1 – System Architecture of Integrated Logic Model of Effective Tsunami Early Warning Tsunami
- A2 – Cognitive Map of People's Mind Toward Tsunami Warning
- A3 – Detailing Logic Model
- A4 – Example of Result of Numerical Logic Model for Scenario Evacuation 1.2

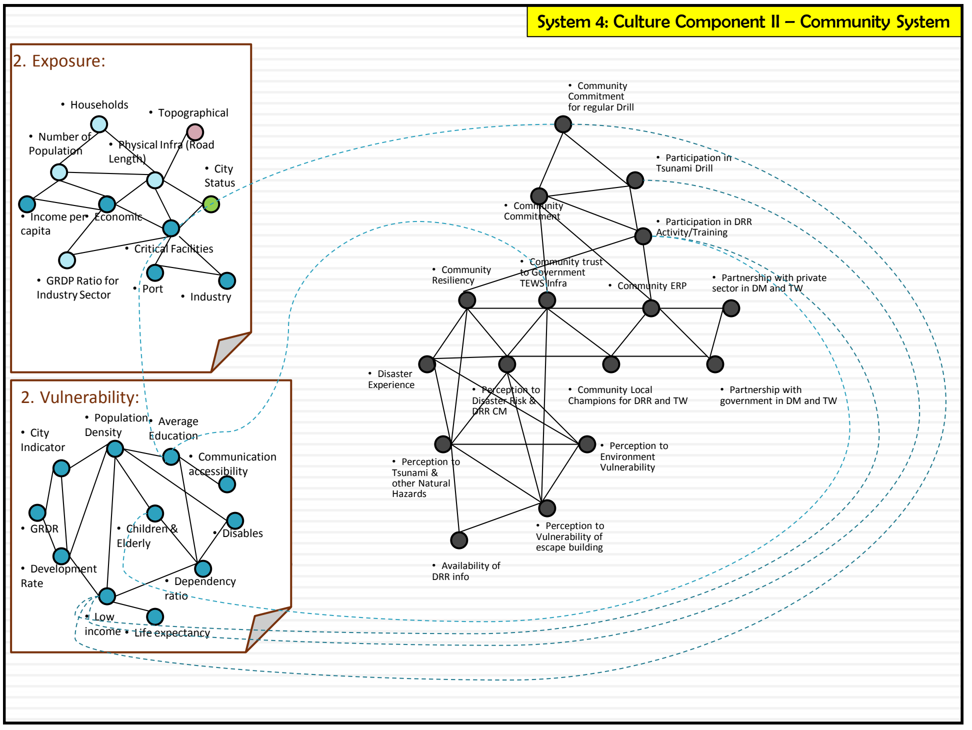
A1 – System Architecture of Integrated Logic Model of Effective Tsunami Early Warning Tsunami


Natural Phenomena :
Primary Hazards
Collateral Hazards
1. Hazards
Info
Physical Damage Est
a
1
2
Structure Component: TEWS
3. Capacity
INTERFACE AGENCIES
3. Capacity
Warning/Info
b
3
Culture Component (1):
Policy, Institutional and Organizational Arrangement
Officials readiness
Culture
Religions
ERRP & resources
Supporting infra for evacuation
etc.
3. Capacity
Warning/Info
c
4
d
2. Exposure:
Physical Infra Exposure
Population Exposure
Economic Exposure
Topographical
Location of City
2. Vulnerability:
Population Vulnerability
Economic Vulnerability
Topographical
Culture Component (2):
Community Risk Perception
Community Risk Attitude
Community Preparedness
Community Resiliency
4. Preparedness


Physically Based Logic Model
System 1: Natural Phenomena
2. Exposure:
Households
Topographical
Number of Population
Physical Infra (Road Length)
City Status
Income per capita
Economic
Critical Facilities
GRDP Ratio for Industry Sector
Port
Industry
1. Natural Phenomena & Collateral Hazard
Tsunami Height
Tsunami Inundation
Contamination
Tsunami Travel Time
EQ
Floating Material
Fire
Explosion
a
Warning/Info
Physical Damage Estimate
2. Vulnerability:
City Indicator
Population Density
Average Education
Communication accessibility
GRDP
Children & Elderly
Disables
Development Rate
Dependency ratio
Low income
Life expectancy


System 2: Structure Component - TEWS
Tsunami
Tsunami Height
Tsunami Inundation
1
Tsunami Travel Time
EQ
2. Structure Component: TEWS
Tsunami data base
Earth Observation
Seismometer
Accelerometer
Dart Buoy
Tide Gauge
GPS
Observation
Processing/ Analysis
Dissemination for Warnings: I to IV
Tsunami Warning:
Est. Tsunami Height
Tsunami Cancelation
Est. Tsunami Travel Time
Est. Affected Area
Interface Agencies:
Army
Provincial CC
ORARI
Police
Media
BNPB
NGOs


System 3: Culture Component I – Government System
1.Policy, Institutional and Organizational Arrangement – long and medium term DRR countermeasures
2.Capacity of Governments
Prov. Reg. WS 5/2007
Nat. Action Plan - RAN
Spatial Plan RPJM 2013
Risk Assessment
City Reg. Padang 3/2008
No overlapping Authority
DRR in Education Curriculum
DM Related Local Regulation
Readiness of 24/7 COD
MOHA 33/2006
Local Action Plan RAD
Contingency Plan
Readiness of officials from DM Related Agencies
DM Law 24/2007
DM Related Legal Framework
SOPs
DM Agency for local level
Crisis Center
SOP Log Dist.
10 Task of local govt. for TEWS
SOP TEWS
SOP ER
Ka BNPB 3/2008
New form: BPBD
Old form: Satlak PB
4.Supporting Infra for Rescue & ER within 24 hours
3.Supporting Infra for TEWS at City
Tsunami Evacuation Route Map
ITC for Crisis Center
Infra for disseminating order for evacuation
Other Sirens
Qualified Rescue Team
ER Hospital
Culture TEWS Guidelines
TEWS Sirens
Nubika
Trained Volunteers
Field Kitchen
Tsunami Sign Board
Assembly Point
Local knowledge
First Responder Team
Camp Management
Escape Buildings
Mosque speaker
Church bell

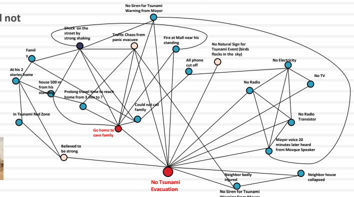

System 4: Culture Component II – Community System
2. Exposure:
Households
Topographical
Number of Population
Physical Infra (Road Length)
City Status
Income per capita
Economic
Critical Facilities
GRDP Ratio for Industry Sector
Port
Industry
2. Vulnerability:
Population Density
Average Education
City Indicator
Communication accessibility
GRDR
Children & Elderly
Disables
Development Rate
Dependency ratio
Low income
Life expectancy
Community Commitment for regular Drill
Participation in Tsunami Drill
Community Commitment
Participation in DRR Activity/Training
Community Resiliency
Community trust to Government TEWS Infra
Community ERP
Partnership with private sector in DM and TW
Disaster Experience
Perception to Disaster Risk & DRR CM
Community Local Champions for DRR and TW
Partnership with government in DM and TW
Perception to Tsunami & other Natural Hazards
Perception to Environment Vulnerability
Perception to Vulnerability of escape building
Availability of DRR info

A2 – Cognitive Map of People's Mind toward Tsunami Warning

Preliminary Problem Structuring

1. WS118370 interview with government official who did not evacuate (English and mix recorded interview)

- Name: Ardiansyah Ridwan , from Economic Department of City Assistant II
- Email/Facebook: Ardiansyah Ridwan
- The EQ event occurred when he was on the way home about 500 m from home and about 3 minutes to reach home in normal condition.
- People were panic on the street due to strong shaking → he decided to go immediately home in duniarso Street which is in the red zone (very high risk).
- He checked the neighbor house (shop houses Pharmacies at the first floor and lodging for student at the second house) collapsed. His 2 stories home was remained firmed.
- He ran to the top floor checking the natural sign for tsunami, i.e. flock of the bird flying from the coastline to the mainland. Nothing can be seen.
- He calmed the family not to evacuate with the decision:
  - No sign for tsunami
  - No point for evacuation since the panic flock of the crowd of evacuee rushing with cars and many others vehicles → he is afraid the family could be killed.
  - The two story house was still remain strong
  - In front and the back side of his house there were two middle schools with 3 stories were remain, i.e. SMP Muhammadiyah and SMP Swasta

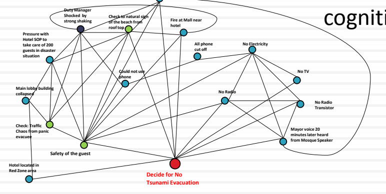


Government officials cognitive map

2. WS118382 at Hotel Inna Muara (Bahasa) with Hotel Duty Manager and City Government officials

Person 1: City Government Officer
- Just describing the damages on hotel business, he was not in Padang during EQ

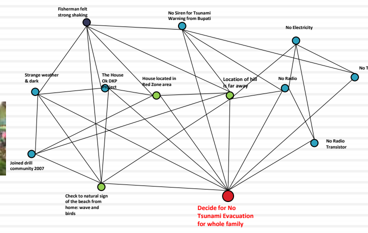
Person 2: Hotel Duty Manager in charge during EQ
- Mains shock was felt around 5 pm (fact 5:17pm), the first main shock was after 6 pm (fact on 5:25), then 9 pm
- No siren was heard (fact: true)
- Electricity, phone (fix and mobile except XL), water and radio were cut off
- After main shock, he did not run for tsunami evacuation because:
  - When he ran to top floor to check water at the beach for tsunami sign, nothing seems unusual, the wave was calm.
  - When he checked the street in front of hotel, it was chaotic and overcrowded by people, cars and anything
  - Then he decided not to evacuate the guest (government officials from other cities in Sumatera regions)
  - The male guest were stayed up at the roof top
  - The female guest stayed in the lobby due to :
    - afraid of following aftershocks which were frequently occurred (about 20 times within first 6 hours)
    - there are 2 pregnant ladies



Businessman's cognitive map

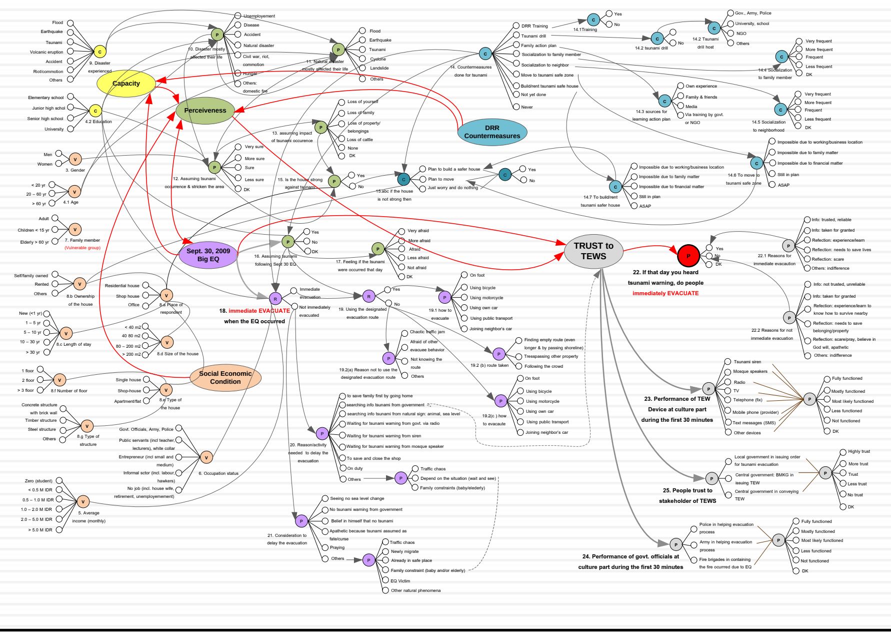
3. WS118365 interview with Fisherman Community in Pariaman Regency

Fisherman 1: reaction not to evacuate
- Immediate after strong shaking he and his wife just checked the water at the coast behind their 'tsunami resistant housing' as part of DKP (ocean and fishery department) project
- Then they decided to remain at their second floor house, the decision is based on:
  - No sign of tsunami, i.e. the back drop of water
  - The closes hill is very far
- The family has joined tsunami drill once in 2007
- If the tsunami occurred they were sure no one will lead them, they have to lead themselves.
- Before the EQ there were strange phenomena such as sky was dark since morning 10 a.m. the water was bad, so the fishermen could not go to the sea.

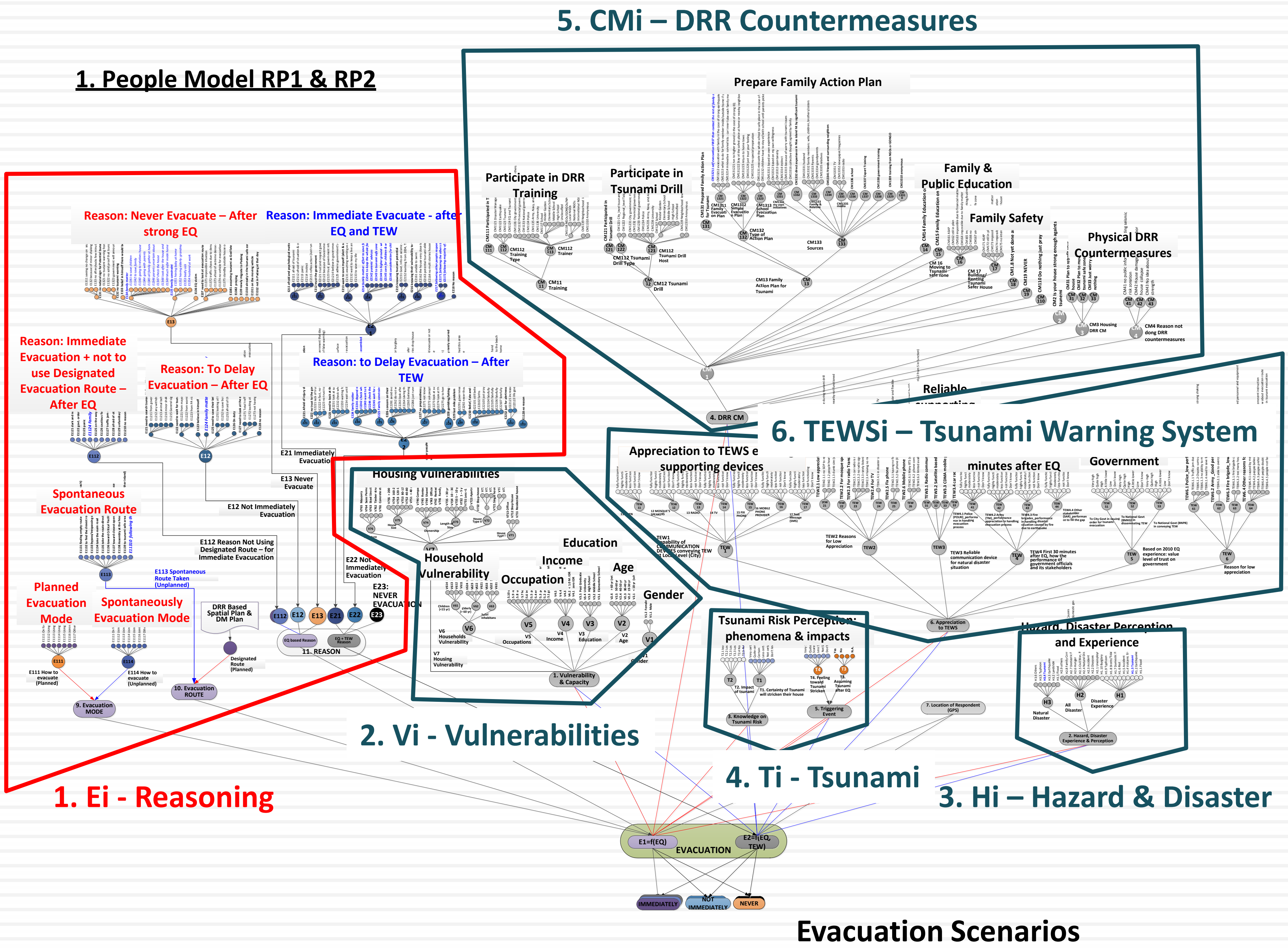


Fisherman's cognitive map

Structuring *People*'s Mind vs. Tsunami Warning & Tsunami Phenomena

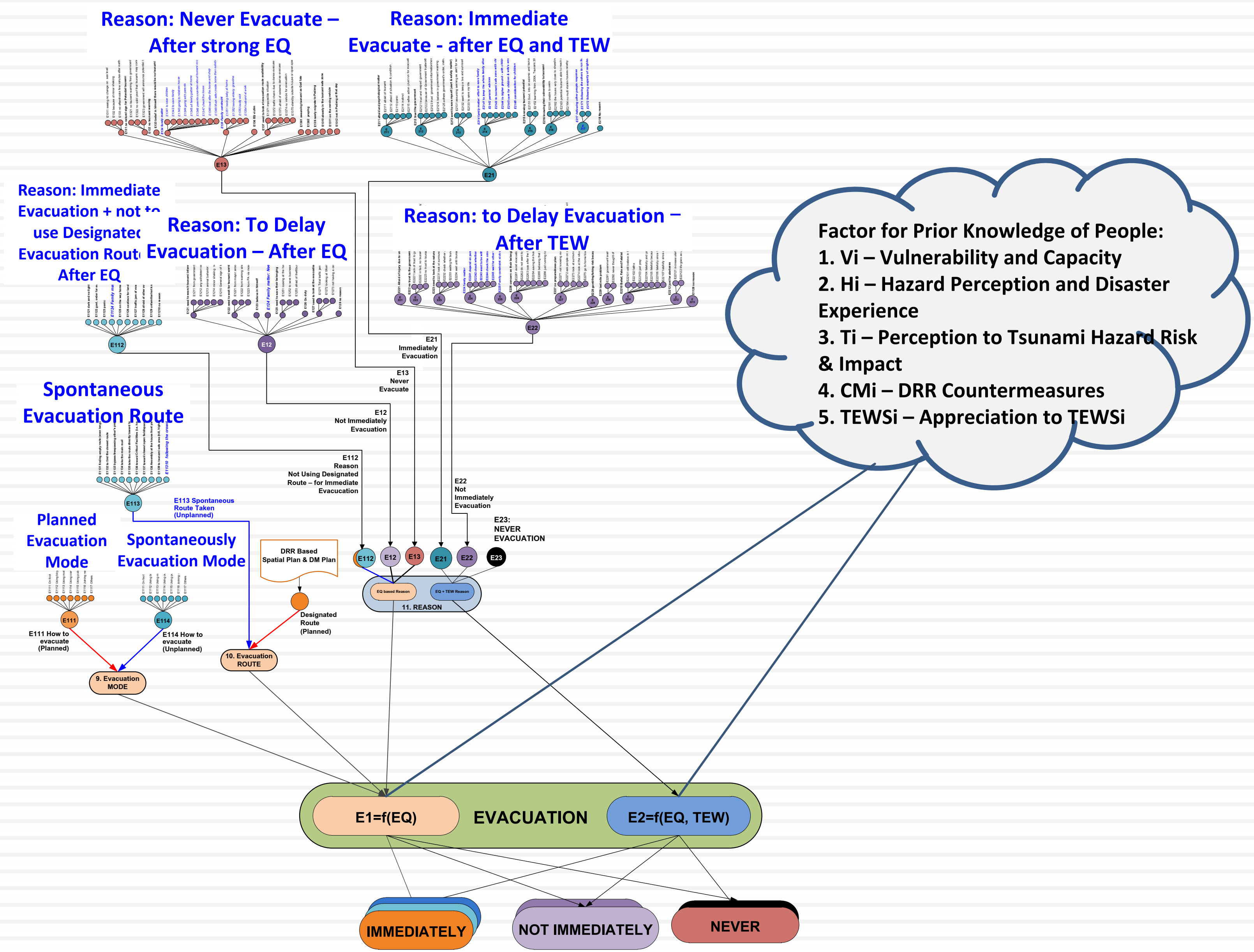


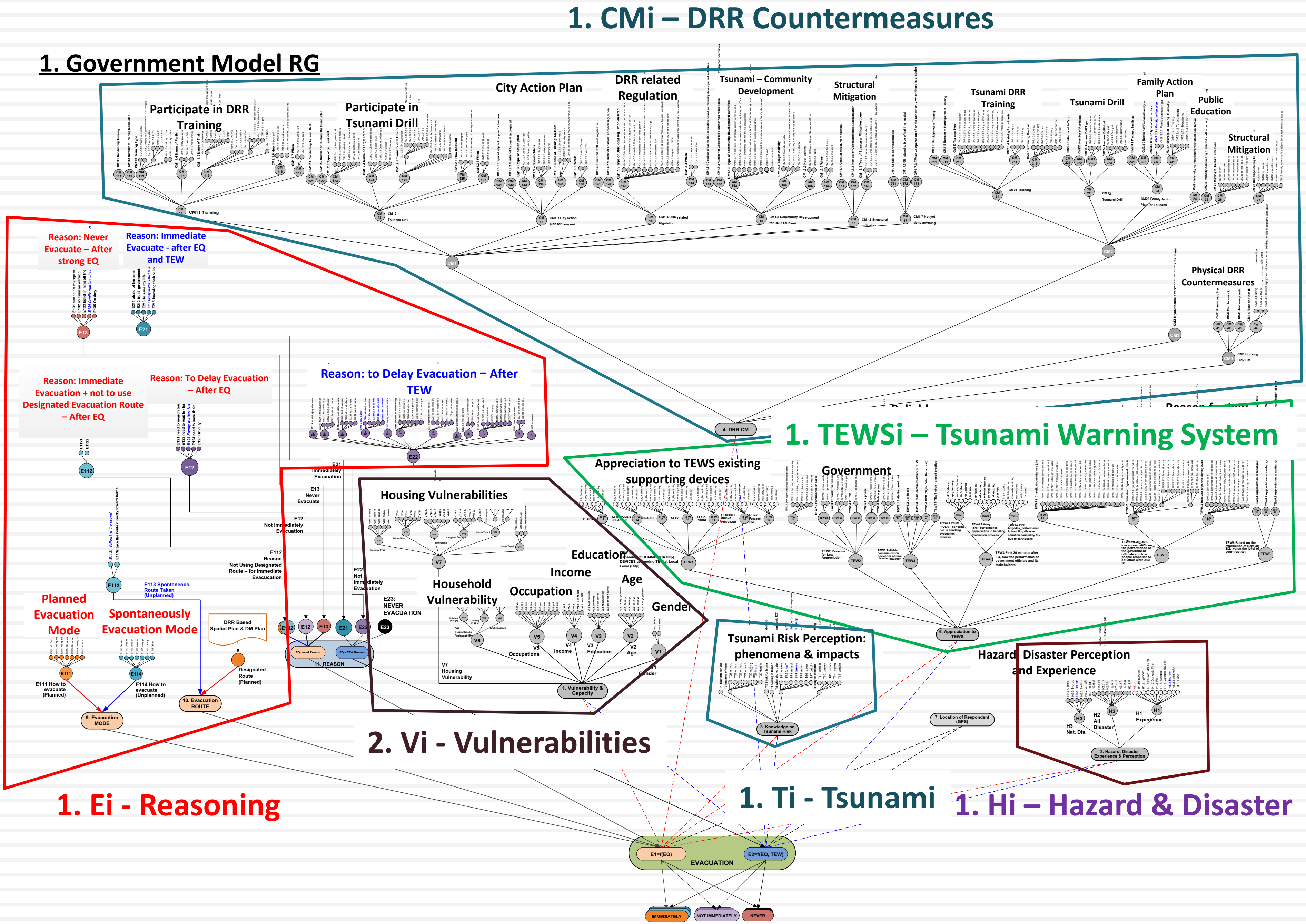
A3 – Detailing Logic Model



5. CMi – DRR Countermeasures
1. People Model RP1 & RP2
Prepare Family Action Plan
Participate in DRR Training
Participate in Tsunami Drill
Family & Public Education
Family Safety
Physical DRR Countermeasures
Reason: Never Evacuate – After strong EQ
Reason: Immediate Evacuate - after EQ and TEW
Reason: Immediate Evacuation + not to use Designated Evacuation Route – After EQ
Reason: To Delay Evacuation – After EQ
Reason: to Delay Evacuation – After TEW
4. DRR CM
6. TEWSi – Tsunami Warning System
Appreciation to TEWS e supporting devices
minutes after EQ
Government
Housing Vulnerabilities
Spontaneous Evacuation Route
E21 Immediately Evacuation
E13 Never Evacuate
E12 Not Immediately Evacuation
E112 Reason Not Using Designated Route – for Immediate Evacuation
E113 Spontaneous Route Taken (Unplanned)
E22 Not Immediately Evacuation
E23: NEVER EVACUATION
Household Vulnerability
Education
Income
Occupation
Age
Gender
Planned Evacuation Mode
Spontaneously Evacuation Mode
DRR Based Spatial Plan & DM Plan
Designated Route (Planned)
E111 How to evacuate (Planned)
E114 How to evacuate (Unplanned)
9. Evacuation MODE
10. Evacuation ROUTE
11. REASON
1. Vulnerability & Capacity
Tsunami Risk Perception: phenomena & impacts
Hazard, Disaster Perception and Experience
6. Appreciation to TEWS
7. Location of Respondent (GPS)
3. Knowledge on Tsunami Risk
5. Triggering Event
2. Hazard, Disaster Experience & Perception
2. Vi - Vulnerabilities
4. Ti - Tsunami
1. Ei - Reasoning
3. Hi – Hazard & Disaster
E1=f(EQ)
E2=f(EQ, TEW)
EVACUATION
IMMEDIATELY
NOT IMMEDIATELY
NEVER
Evacuation Scenarios

Ei - Reasoning



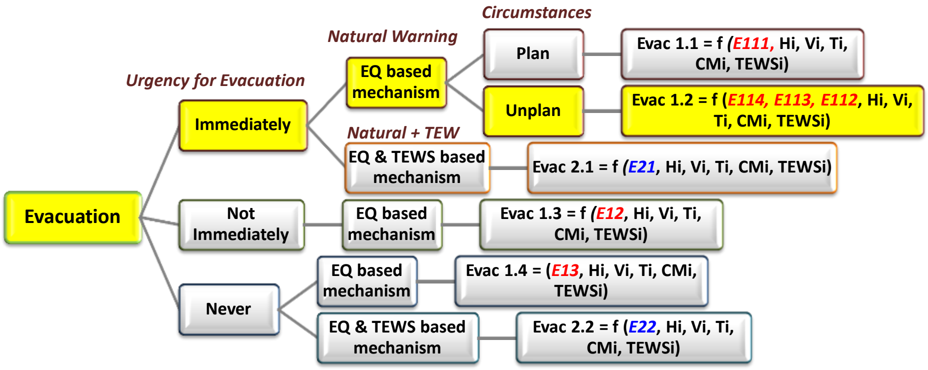


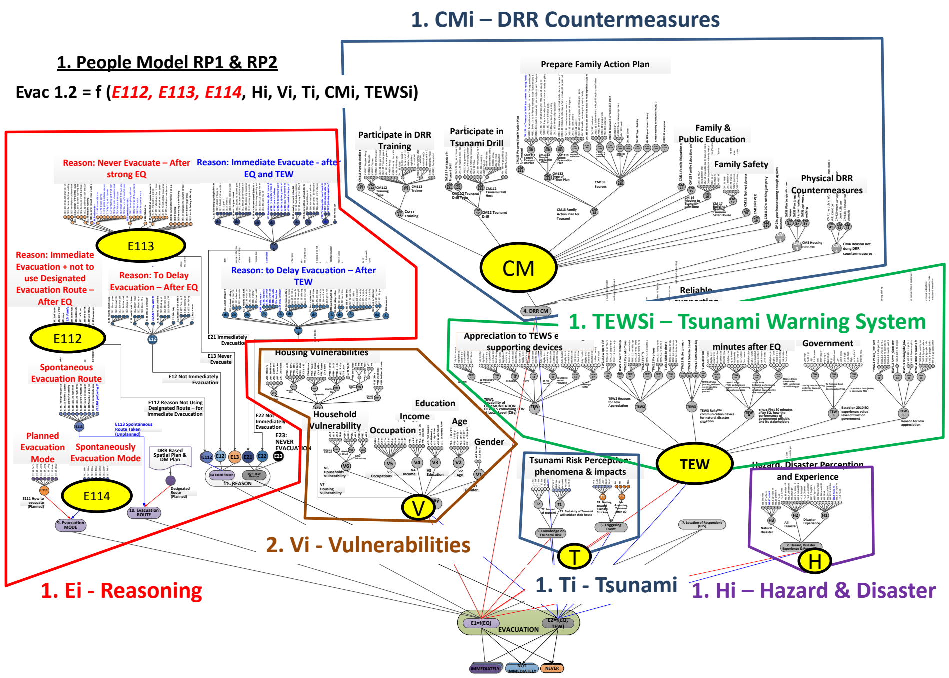
1. CMi – DRR Countermeasures
1. Government Model RG
Participate in DRR Training
Participate in Tsunami Drill
City Action Plan
DRR related Regulation
Tsunami – Community Development
Structural Mitigation
Tsunami DRR Training
Tsunami Drill
Family Action Plan
Public Education
Structural Mitigation
Physical DRR Countermeasures
Reason: Never Evacuate – After strong EQ
Reason: Immediate Evacuate - after EQ and TEW
Reason: Immediate Evacuation + not to use Designated Evacuation Route – After EQ
Reason: To Delay Evacuation – After EQ
Reason: to Delay Evacuation – After TEW
1. TEWSi – Tsunami Warning System
Appreciation to TEWS existing supporting devices
Government
Housing Vulnerabilities
Household Vulnerability
Education
Income
Occupation
Age
Gender
Planned Evacuation Mode
Spontaneously Evacuation Mode
DRR Based Spatial Plan & DM Plan
Tsunami Risk Perception: phenomena & impacts
Hazard, Disaster Perception and Experience
2. Vi - Vulnerabilities
1. Ei - Reasoning
1. Ti - Tsunami
1. Hi – Hazard & Disaster
E1=f(EQ)
E2=f(EQ, TEW)
EVACUATION
IMMEDIATELY
NOT IMMEDIATELY
NEVER

A4 – Example of Result of Numerical Logic Model for Scenario Evacuation 1.2

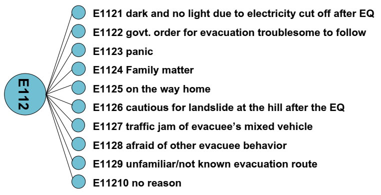
Logic Model's Decision Scenario for Tsunami Evacuation

Evacuation = f (Evacuation Mode, Evacuation Route, Reasons, Perception on Tsunami Risk, DRR Countermeasures, Appreciation to TEWS, Disaster Experience, Vulnerability and Capacity)





E1.1.2 What was the reasons not to follow the designated evacuation route?

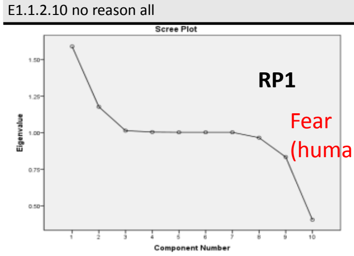


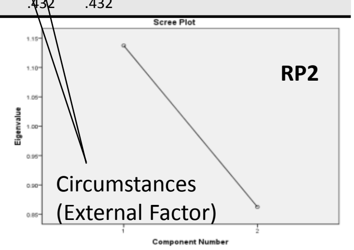
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
E1.1.2.1 Dark and no light due to no electricity	2.92%	
E1.1.2.2 Troublesome government order for evacuation	**12.03%**	
E1.1.2.3 Panic	11.93%	
E1.1.2.4 FAMILY MATTER_Family agreement to wait for parents before evacuate	8.95%	
E1.1.2.5 On the way home	**16.12%**	
E1.1.2.6 Cautious for landslide following EQ	7.43%	
E1.1.2.7 traffic jammed by evacuee	**12.26%**	50.00%
E1.1.2.8 afraid of evacuee behavior	**14.54%**	
E1.1.2.9 unfamiliar route for evacuation	10.12%	50.00%
E1.1.2.10 no reason	3.70%	

$$E1.1.2=0.284944(E1.1.2.1)+1.172599(E1.1.2.2)+1.162726(E1.1.2.3)+0.872157(E1.1.2.4)+1.57079(E1.1.2.5)-0.724074(E1.1.2.6)+1.195278(E1.1.2.7)+1.41669(E1.1.2.8)-0.986338(E1.1.2.9)-0.360927(E1.1.2.10)$$

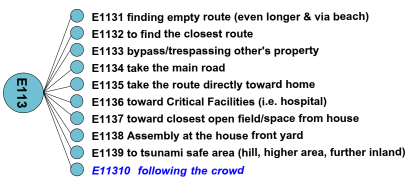
$$E1.1.2 = -0.857298(E1.1.2.7) + 0.857298(E1.1.2.9)$$

COMPONENT	RP 1							RP 2
	1	2	3	4	5	6	7	1
E1.1.2.1 Dark and no light due to no electricity			.227	.302	.473	-.721		
E1.1.2.2 Troublesome government order for evacuation			.227	.302	.391	.656	-.410	
E1.1.2.3 Panic	.866	-.182						
E1.1.2.4 FAMILY MATTER_Family agreement to wait for parents then evacuate		.741						
E1.1.2.5 On the way home			.227	.302		.191	.843	
E1.1.2.6 Cautious for landslide following EQ			.227	.302	-.787	-.126	-.34	
E1.1.2.7 traffic jammed by evacuee	.201	.744						-.754
E1.1.2.8 afraid of evacuee behavior	.891							
E1.1.2.9 unfamiliar route for evacuation		-.160	-.787					.754
E1.1.2.10 no reason all			.432	.432				





E1.1.3 What evacuation route taken? (Q19.2.2)



PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
E1.1.3.1 Finding empty route even though passing by beach	16.39%	39.01%
E1.1.3.2 Finding closest route	0.76%	
E1.1.3.3 Bypass/trespassing other's property	0.08%	56.33%
E1.1.3.4 Taking main road	21.28%	
E1.1.3.5 Taking route directly to home	22.36%	
E1.1.3.6 To Critical Facilities (i.e. hospital)	2.39%	
E1.1.3.7 To closest open field from the house	9.22%	
E1.1.3.8 Assembly at house front yard	0.12%	
E1.1.3.9 To tsunami safe area - Hill, Higher ground	4.65%	
E1.1.3.10 Following the crowd	22.74%	4.66%

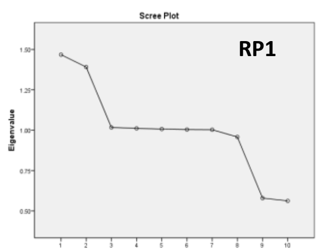
Similar case with Japan

$$E1.1.3 = -1.231975(E1.1.3.1) + 0.05739(E1.1.3.2) + -0.005788(E1.1.3.3) + 1.59979(E1.1.3.4) + 1.680948(E1.1.3.5) + 0.179542(E1.1.3.6) + 0.693166(E1.1.3.7) + 0.0093659(E1.1.3.8) + 0.349148(E1.1.3.9) + 1.709513(E1.1.3.10)$$

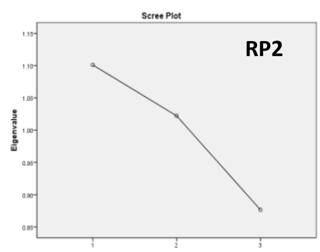
$$\mathbf{E1.1.3 = -0.853275(E1.1.3.1) + 1.232193(E1.1.3.3) + 0.101966(E1.1.3.10)}$$

COMPONENT	RP 1							RP 2	
	1	2	3	4	5	6	7	1	2
E1.1.3.1 Finding empty route even though passing by beach		-0.126	-0.781	-0.153	-0.107			-.672	-.393
E1.1.3.2 Finding closest route	-0.556	0.628							
E1.1.3.3 Bypass/trespassing other's property	-0.581	0.609							.902
E1.1.3.4 Taking main road			0.129		0.151	0.604	0.708		
E1.1.3.5 Taking route directly to home	0.534	0.486	-0.235	0.455					
E1.1.3.6 To Critical Facilities (i.e. hospital)			0.129		0.151	0.604	-0.708		
E1.1.3.7 To closest open field from the house			0.231	0.172	0.741	-0.460			
E1.1.3.8 Assembly at house front yard			0.385	0.458	-0.619	-0.221			
E1.1.3.9 To tsunami safe area - Hill, Higher ground	0.336	0.258	0.343	-0.727	-0.116				
E1.1.3.10 Following the crowd	0.650	0.543						.796	-.259

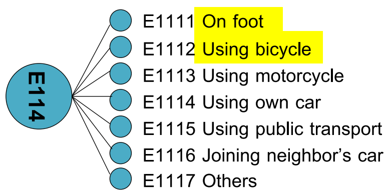
Physical Factor

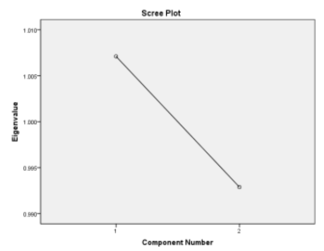


Passive behavior



E1.1.4 How did you evacuate (Unplanned/spontaneously)?

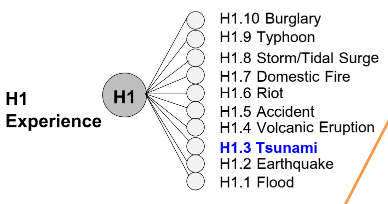




PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
E1.1.4.1 On foot	50.00%	-
E1.1.4.3 By motor cycle	50.00%	-

$$E1.1.4 = 0.71497(E1.1.4.1) - 0.71497(E1.1.4.3)$$

H1. Disaster experienced and awareness (multiple answer)



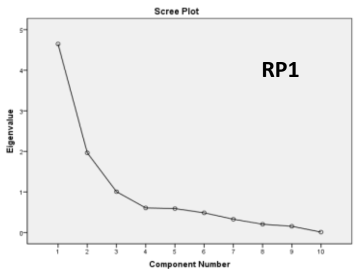
Similar case with Japan

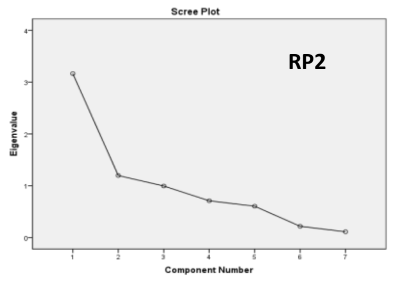
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
H1.1 Flood	11.25%	14.34%
H1.2 Earthquake	7.69%	13.86%
H1.3 Tsunami	13.72%	19.69%
H1.4 Volcanic Eruption	13.78%	19.66%
H1.5 Accident	12.37%	12.23%
H1.6 Riot	12.89%	13.71%
H1.7 Domestic Fire	7.56%	-
H1.8 Storm / Tidal Surge	5.77%	6.50%
H1.9 Typhoon	7.41%	-
H1.10 Burglary	7.57%	-

$$\mathbf{H1} = 3.570876(H1.1) + 2.440566(H1.2) + 4.354604(H1.3) + 4.374807(H1.4) + 3.927448(H1.5) + 4.092085(H1.6) + 2.399272(H1.7) + 1.833258(H1.8) + 2.35212(H1.9) + 2.40292(H1.10)$$

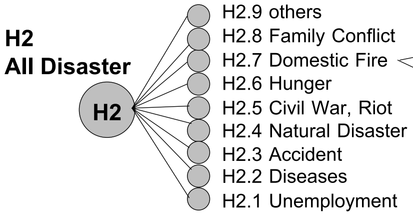
$$\mathbf{H1} = 2.110437(H1.1) + 2.040783(H1.2) + 2.89914(H1.3) + 2.894124(H1.4) + 1.800387(H1.5) + 2.018832(H1.6) - 0.956862(H1.8)$$

COMPONENT MATRIX	RP 1			RP 2	
	1	2	3	1	2
H1.1 Flood	.517	.408	.364	.483	.486
H1.2 Earthquake	.186	.381	.822	.388	.679
H1.3 Tsunami	.829	.364	-.212	.916	
H1.4 Volcanic Eruption	.846	.352	-.247	.821	.247
H1.5 Accident	.703	.336		.750	-.479
H1.6 Riot	.732	.444	-.181	.802	-.434
H1.7 Domestic Fire	.729	-.559	.108		
H1.8 Storm / Tidal Surge	.543	-.447	.186	-.249	-.141
H1.9 Typhoon	.730	-.530			
H1.10 Burglary	.746	-.542			





H2 Q10. Disaster that affected or will affect your life the most (1 answer)

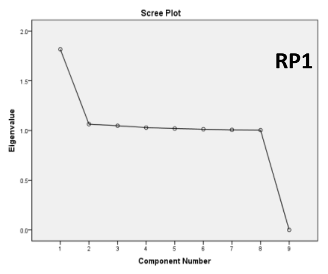


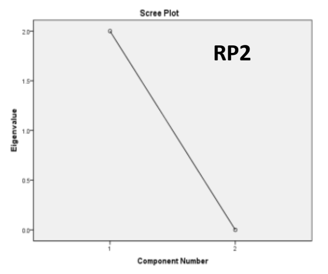
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
H2.1 Unemployment	8.68%	
H2.2 Diseases	14.98%	
H2.3 Accident	8.80%	50.00%
H2.4 Natural disaster	25.51%	
H2.5 Civil war, riot, commotion	8.40%	
H2.6 Hunger	8.45%	
H2.7 domestic fire	8.35%	
H2.8 family conflict due to personal reason	8.31%	50.00%
H2.9 None	8.53%	-

$$\mathbf{H2} = 1.046952(H2.1) + 1.80692(H2.2) + 1.061872(H2.3) - 3.077239(H2.4) + 1.013(H2.5) + 1.02(H2.6) + 1.007(H2.7) + 1.003(H2.8) + 1.029(H2.9)$$

$$\mathbf{H2} = 2.00(H2.3) - 2.00(H2.8)$$

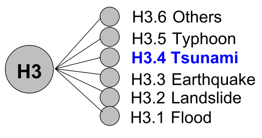
COMPONENT	RP 1								RP 2
	1	2	3	4	5	6	7	8	1
H2.1 Unemployment	.396	.323	.758	-.379	-.107				
H2.2 Diseases	.528	-.819	-.107	-.173					
H2.3 Accident	.427	.513	-.674	-.290					1.000
H2.4 Natural disaster	-1.000								
H2.5 Civil war, riot, commotion	.193			.176	.175	.923	-.196		
H2.6 Hunger	.239			.327	.841	-.322	-.112		
H2.7 domestic fire	.135					.119	.961	-.169	
H2.8 family conflict							.137	.981	-1.000
H2.9 None	.279	.110		.788	-.500	-.162			





H3 Q11.Natural disaster that have affected or will affect your life the most. (1 answer)

H3 Natural Disaster

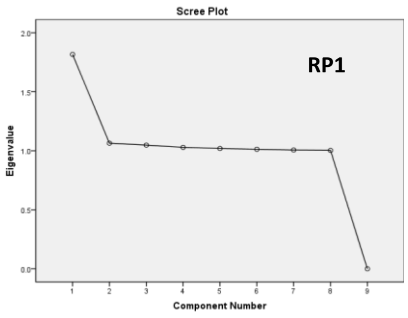


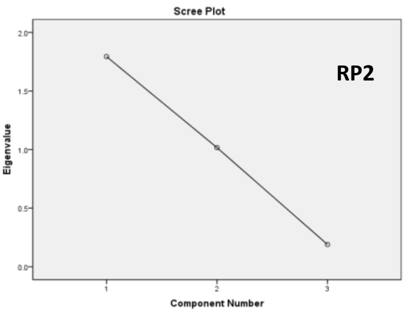
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
H3.1 Flood	13.96%	11.46%
H3.2 Landslide	15.92%	
H3.3 Earthquake	23.69%	41.68%
H3.4 Tsunami	12.19%	46.86%
H3.5 Cyclone	19.24%	
H3.6 Others	11.07%	
H3.7 None	3.93%	

$$\mathbf{H3} = 1.147818(H3.1) + 1.309193(H3.2) - 1.947506(H3.3) + 1.002596(H3.4) + 1.581553(H3.5) + 0.910374(H3.6) - 0.322846(H3.7)$$

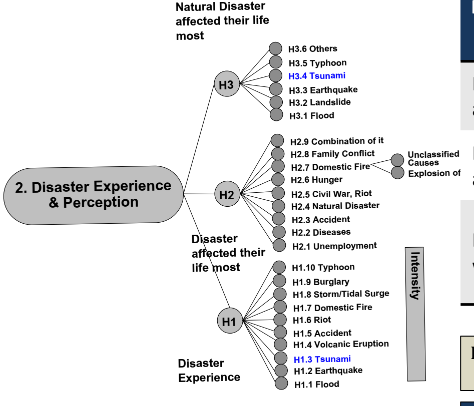
$$\mathbf{H3} = 0.469683(H3.1) - 1.707888(H3.3) + 1.919925(H3.4)$$

COMPONENT MATRIX	RP 1						RP 2	
	1	2	3	4	5	6	1	2
H3.1 Flood	.210	.519	.716	-.390	-.136			.975
H3.2 Landslide		.120			.207	.968		
H3.3 Earthquake	-.991	-.111					-.673	-.673
H3.4 Tsunami	.850	-.522					.975	
H3.5 Cyclone	.197	.463		.849	-.151			
H3.6 Others		.176			.950	-.236		
H3.7 None	.210	.519	-.716	-.390	-.136			





Hi – Hazard Perception and Disaster Experience

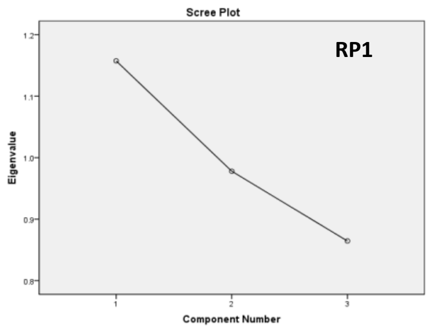


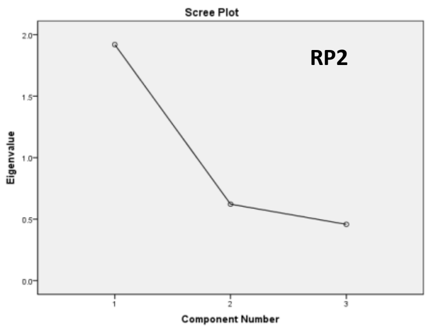
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
H1 Disaster experienced and awareness	21.33%	33.97%
H2 Disaster that affected or will affect your life the most	38.73%	33.28%
H3 Natural disaster affected or will affect your life the most.	39.94%	32.75%

$$\mathbf{H} = 1.147818(H1) + 1.309193(H2) - 1.947506(H3)$$

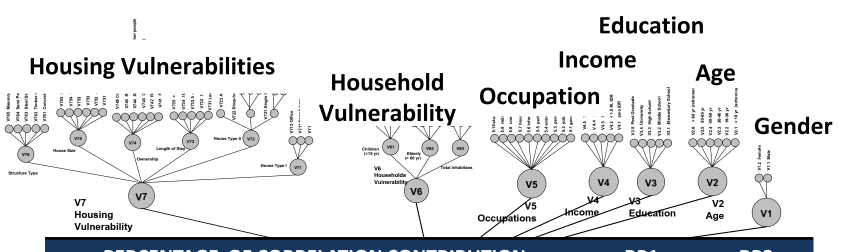
$$\mathbf{H} = -0.445445(H1) - 0.74851(H2) + 0.73661(H3)$$

COMPONENT MATRIX	RP1	RP2
H1 Disaster experienced and awareness	-0.385	.642
H2 Disaster that affected or will affect your life the most	0.699	-.629
H3 Natural disaster that have affected or will affect your life the most.	0.721	.619





Vi – Social and Physical Vulnerability

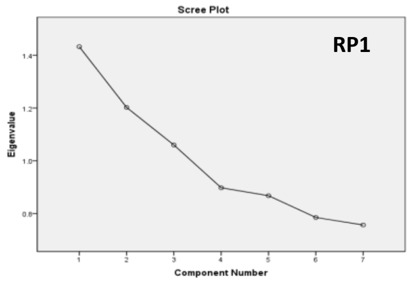


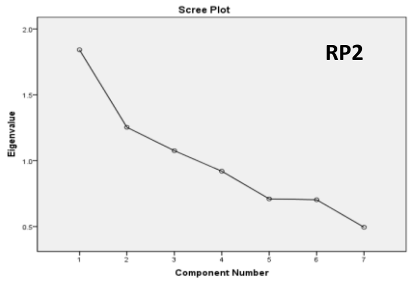
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
V1 Gender	8.08%	15.63%
V2 Ages	0.12%	10.32%
V3 Education	11.33%	4.94%
V4 Average Monthly Income	21.55%	12.69%
V5 Occupation	16.71%	17.50%
V6 households Vulnerability	21.27%	20.34%
V7 House Vulnerability	20.94%	18.58%

$$\mathbf{V} = \mathbf{0.463324}(\boldsymbol{V1}) + \mathbf{0.0070420}\ (\boldsymbol{V2}) + \mathbf{0.649657}(\boldsymbol{V3}) + \mathbf{1.236039}(\boldsymbol{V4}) + \mathbf{0.958223}(\boldsymbol{V5}) + \mathbf{1.22002}(\boldsymbol{V6}) + \mathbf{1.200953}(\boldsymbol{V7})\mathbf{1.200953}(\boldsymbol{V7})$$

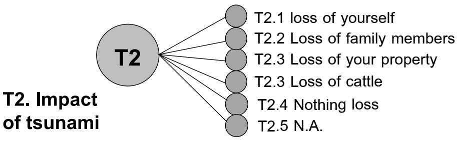
$$\mathbf{V} = \mathbf{1.19712}(\boldsymbol{V1}) + \mathbf{0.790336}\ (\boldsymbol{V2}) + \mathbf{0.378463}(\boldsymbol{V3}) + \mathbf{0.971452}(\boldsymbol{V4}) + \mathbf{1.339952}(\boldsymbol{V5}) + \mathbf{1.557709}(\boldsymbol{V6}) + \mathbf{1.422996}(\boldsymbol{V7})$$

COMPONENT MATRIX	RP 1			RP 2		
	1	2	3	1	2	3
V1 Gender	.454	.331	-.552	.720		-.120
V2 Ages	.508	-.501	-.112	.324	-.396	.641
V3 Education	.575	-.399	.288	.403	-.463	.201
V4 Average Monthly Income	.543		.432	.726		-.340
V5 Occupation	.517	.411	-.261	.648		.136
V6 households Vulnerability		.470	.618	.328	.761	
V7 House Vulnerability	.275	.539	.150		.544	.689





T2 Impact of tsunami [multiple answer]

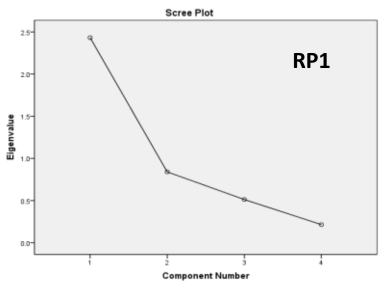


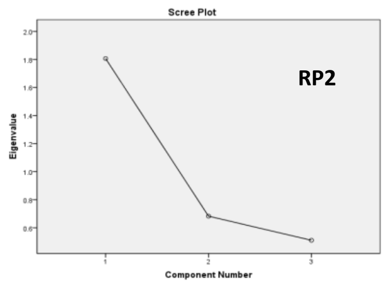
$$T2 = 2.15232(T2.1) + 2.113408(T2.2) + 1.911552(T2.3) + 1.281664(T2.4)$$

$$T2 = 1.441188(T2.1) + 1.464666(T2.2) + 1.29129(T2.3)$$

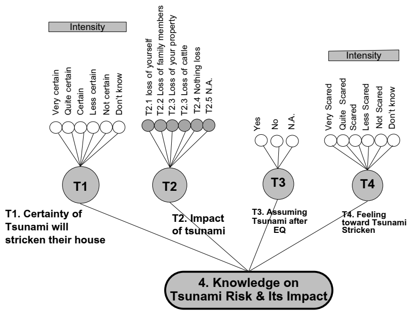
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
T2.1 On yourself	28.86%	34.34%
T2.2 On family members: spouse, children, parents, brothers/sisters	28.33%	34.90%
T2.3 On your property/ belonging	25.63%	30.77%
T2.4 On cattle	17.18%	

COMPONENT MATRIX	RP1	RP2
T2.1 On yourself	.885	.798
T2.2 On family members: spouse, children, parents, brothers/sisters	.869	.811
T2.3 On your property/ belonging	.786	.715
T2.4 On cattle	.527	





T – Tsunami Knowledge and Triggering Event

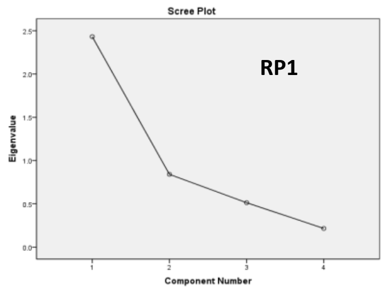


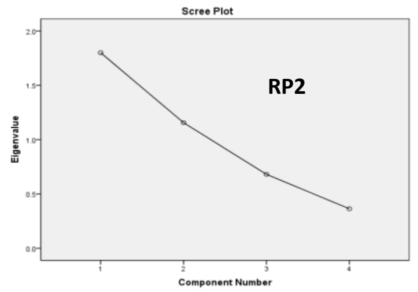
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
T1 Tsunami stricken your house	19.73%	27.24%
T2 Impact of tsunami [multiple answer]	22.61%	30.71%
T3 Did you think for a tsunami occurrence following the shaking?	30.19%	20.26%
T4 What would you feel if the tsunami were occurred?	27.48%	21.79%

T =1.30592(T1)+ 1.49632(T2)+1.99808(T3)+ 1.81888(T4)

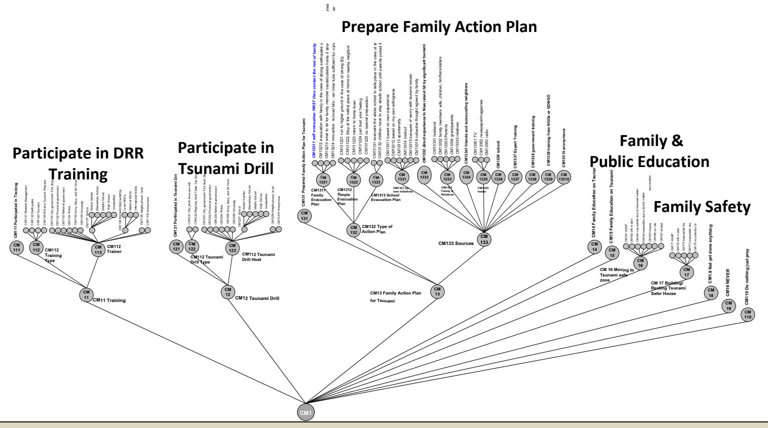
$$T = 1.459268(T1) + 1.64522(T2) + 1.085156(T3) + 1.167132(T4)$$

COMPONENT MATRIX	RP 1	RP 2	
	1	1	2
T1 Tsunami stricken your house	.885	.295	.803
T2 Impact of tsunami [multiple answer]	.869	.564	.545
T3 Did you think for a tsunami occurrence following the shaking?	.786	.827	-.349
T4 What would you feel if the tsunami were occurred?	.527	.843	-.303





CM1 DRR countermeasures in anticipating tsunami



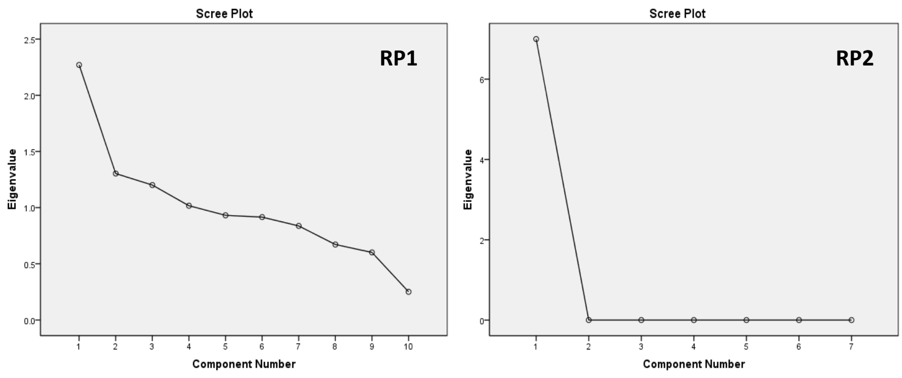
$$\text{CM1} = 0.465915(CM1.1) - 0.057365\,(CME1.2) + 0.728397(CM1.3) + 2.082983(CM1.4) + 2.108085(CM1.5) + 1.047337(CM1.6) + 1.311341(CM1.7) - 1.675371(CM1.8) + 0.853992(CM1.9) + 1.031063(CM1.10)$$

$$\text{CM1} = 7.00(CM1.1) + 7.00\,(CME1.2) + 7.00(CM1.3) + 7.00(CM1.4) + 7.00(CM1.5) + 7.00(CM1.6) + 7.00(CM1.7)$$

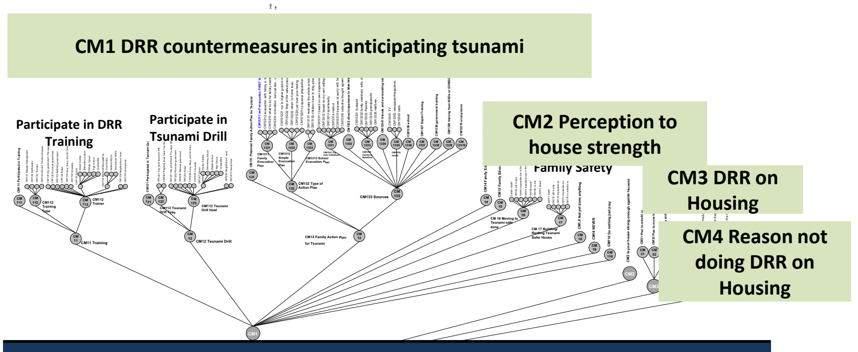
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
CM1.1 TRAINING	3.67%	14.29%
CM1.2 Tsunami Drill	10.86%	14.29%
CM1.3 Family action plan for tsunami	5.74%	14.29%
CM1.4 Family education on tsunami	16.42%	14.29%
CM1.5 Public Education to neighborhood on tsunami	16.62%	14.29%
CM1.6 Moving to tsunami safe zone (in land and higher ground)	8.26%	14.29%
CM1.7 Building/renting TSUNAMI SAFER HOUSE (multi stories houses)	10.34%	14.29%
CM1.8 Not yet done anything	13.21%	
CM1.9 Never	6.73%	
CM1.10 Do nothing just pray	8.13%	

Similar case with Japan

COMPONENT MATRIX	1	2	3	4
CM1.1 TRAINING	.278	-.581	.199	.347
CM1.2 Tsunami Drill	.501	-.361	.192	.472
CM1.3 Family action plan for tsunami	.345	.331	-.182	-.263
CM1.4 Family education on tsunami	.863	.181		-.110
CM1.5 Public Education to neighborhood on tsunami	.811	.205		
CM1.6 Moving to tsunami safe zone (in land and higher ground)		.451		.452
CM1.7 Building/renting TSUNAMI SAFER HOUSE (multi stories houses)		.542		.595
CM1.8 Not yet done anything	-.611		-.368	.151
CM1.9 Never	-.188	.358	.678	
CM1.10 Do nothing just pray		.159	.686	



CMi - Disaster Risk Reduction (DRR) Countermeasures

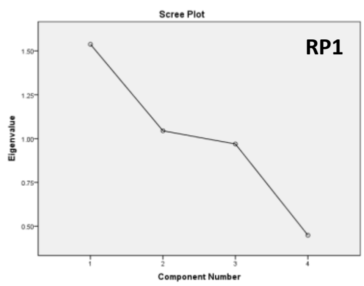


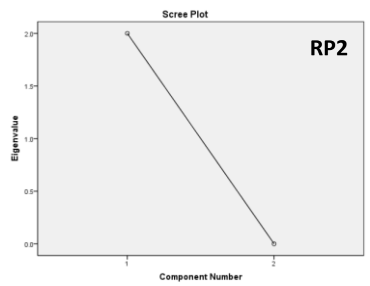
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
CM1 DRR Countermeasures in anticipating Tsunami	17.01%	50.00%
CM2 Perception to house strength	26.05%	50.00%
CM3 DRR Countermeasures on housing	32.16%	0%
CM4 Reasons not doing DRR on housing	24.77%	0%

$$CM = 0.71514(CM1) - 1.095256(CM2) + 1.351902(CM3) + 1.04143(CM4)$$

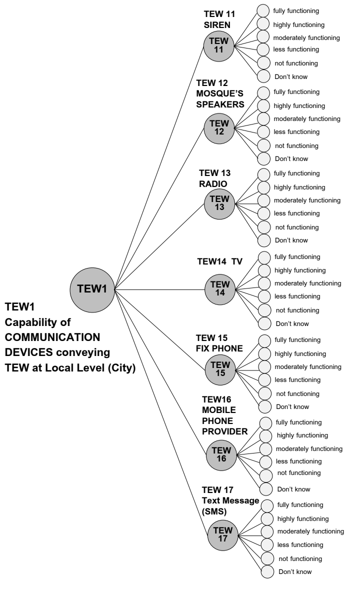
$$CM = 1.0(CM1) + 1.0\,(CM2)$$

COMPONENT MATRIX	RP 1		RP 2
	1	2	1
CM1 DRR Countermeasures in anticipating Tsunami		0.685	1.000
CM2 Perception to house strength	-0.854	0.209	1.000
CM3 DRR Countermeasures on housing	0.879		
CM4 Reasons not doing DRR on housing	0.185	0.725	





TEW1 First 30 minutes after EQ, what did you think about the performance of TEWS supporting Infrastructure

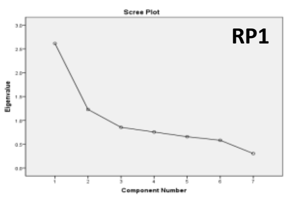


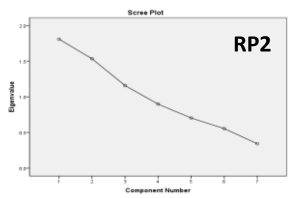
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
TEW1.1 Tsunami Siren as TEWS device	16.38%	20.63%
TEW1.2 mosque speakers	18.52%	8.51%
TEW1.3 Radio as TEWS multi-mode device	15.94%	20.48%
TEW1.4 TV as TEWS multi-mode device	16.68%	11.57%
TEW1.5 fix phone as communication tool	11.97%	19.29%
TEW1.6 Mobile phone	10.21%	19.47%
TEW1.7 Text Message (SMS)	10.28%	0.05%

$$\begin{aligned}\mathbf{TEW1} &= \mathbf{1.896882(\mathit{TEW}1.1) + 2.144994(\mathit{TEW}1.2)} \\ &\quad \mathbf{+ 1.846254(\mathit{TEW}1.3) + 1.931382(\mathit{TEW}1.4)} \\ &\quad \mathbf{+ 1.38648(\mathit{TEW}1.5) + 1.18254(\mathit{TEW}1.6)} \\ &\quad \mathbf{+ 1.190544(\mathit{TEW}1.7)}\end{aligned}$$

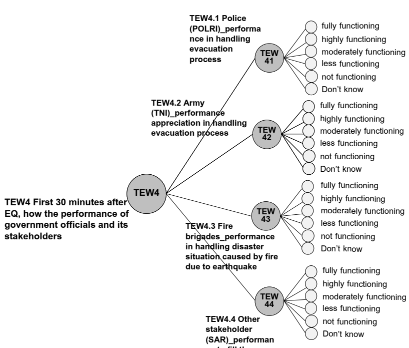
$$\begin{aligned}\mathbf{TEW1} &= \mathbf{1.615204(\mathit{TEW}1.1) + 0.666444(\mathit{TEW}1.2)} \\ &\quad \mathbf{+ 1.60366(\mathit{TEW}1.3) + 0.905848(\mathit{TEW}1.4)} \\ &\quad \mathbf{+ 1.510612(\mathit{TEW}1.5) + 1.524798(\mathit{TEW}1.6)} \\ &\quad \mathbf{- 0.004194(\mathit{TEW}1.7)}\end{aligned}$$

COMPONENT MATRIX	RP 1		RP 2		
	1	2	1	2	3
TEW1.1 capability of Tsunami Siren as TEWS device at local level (city)	.577	.315	.481		.643
TEW1.2 capability of mosque speakers to be TEWS supporting device at local level (city)	.559	.555	.754	-.268	-.248
TEW1.3 capability of Radio as TEWS multi-mode device to reach wider public at local level (city)	.489	.461	.886		
TEW1.4 capability of TV as TEWS multi-mode device to reach wider public at local level (city)	.672	.141	.238	.666	-.472
TEW1.5 capability of fix phone as communication tool to save connected people by conveying the TEW	.530		.235	.789	-.108
TEW1.6 capability of Mobile phone provider and its provider as as communication tool to save connected people by conveying the TEW	.705	-.538		.492	.665
TEW1.7 capability of Text Message (SMS) as as communication tool to save connected people by conveying the TEW	.709	-.540	-.332	.389	





TEW4 First 30 minutes after EQ, what do you think about the performance of ***government officials*** and its ***stakeholders***

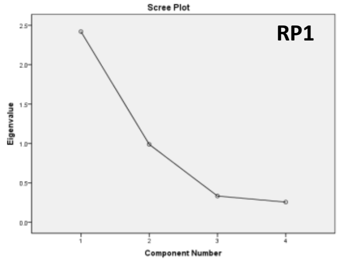


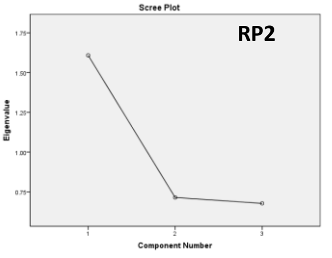
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
TEW4.1 Police	32.20%	33.88%
TEW4.2 Army	31.84%	33.38%
TEW4.3 Fire brigades	31.17%	32.74%
TEW4.4 Others (SAR)	4.79%	

$$TEW4 = 2.198268(TEW4.1) + 2.174058(TEW4.2) + 2.128059(TEW4.3) + 0.326835(TEW4.4)$$

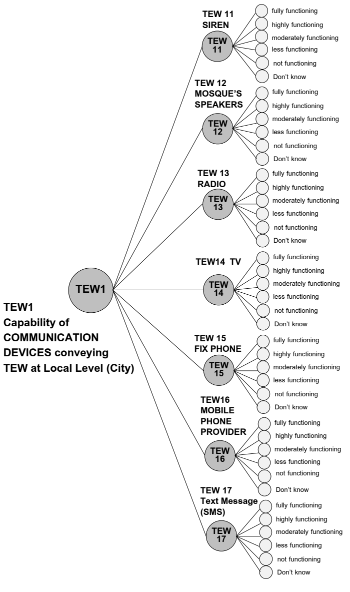
$$TEW4 = 1.196352(TEW4.1) + 1.178664(TEW4.2) + 1.156152(TEW4.3)$$

COMPONENT MATRIX	RP1	RP2
TEW4.1 Police (POLRI) in handling evacuation process	.908	.744
TEW4.2 Army (TNI) in handling evacuation process	.898	.733
TEW4.3 Fire brigades in containing fire followed EQ	.879	.719
TEW4.4 Other stakeholder (SAR) to fill the gap	.135	





TEW5 Based on Sept 30 EQ experience: value the level of trust on government

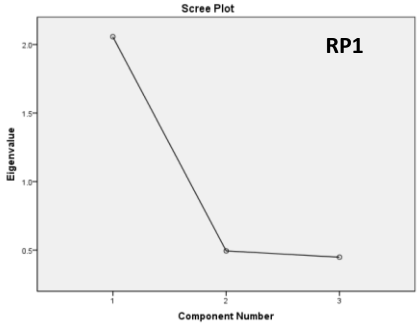


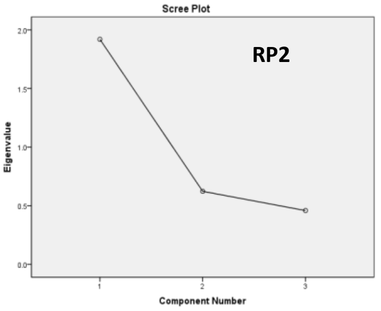
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
TEW5.1 Trust to City Government in isuing order for tsunami evacuation	32.97%	31.21%
TEW5.2 Trust to National Govt (BMKG) in disseminating TEW	33.78%	34.29%
TEW5.3 Trust to National Govt (BNPB) in conveying the dissemination of TEW	33.25%	34.50%

$$\mathrm{TEW5} = 1.684683(TEW5.1) + 1.725823(TEW5.2) + 1.699082(TEW5.3)$$

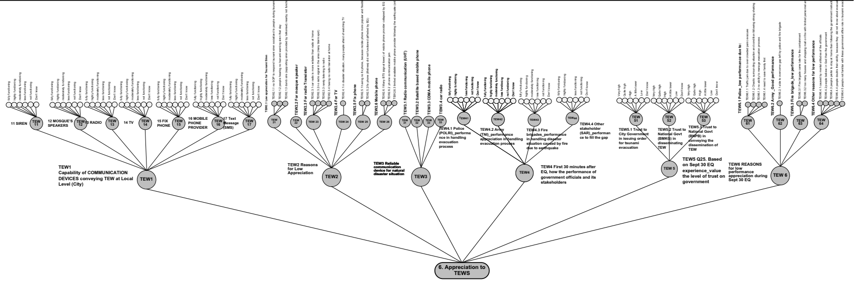
$$\mathrm{TEW5} = 1.43616(TEW5.1) + 1.57824(TEW5.2) + 1.58784(TEW5.3)$$

COMPONENT MATRIX	RP1	RP2
TEW5.1 Trust to City Government	.819	.748
TEW5.2 Trust to National Govt (BMKG)	.839	.822
TEW5.3 Trust to National Govt (BNPB)	.826	.827





TEWi - Appreciation to TEWS

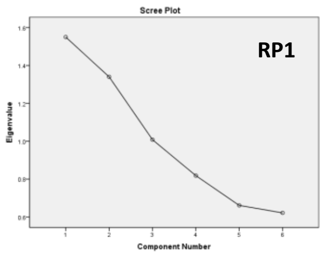


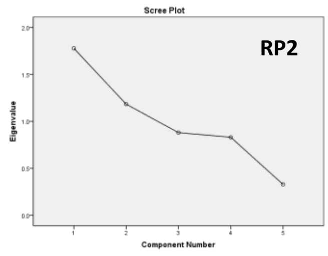
PERCENTAGE OF CORRELATION CONTRIBUTION	RP1	RP2
TEW1 First 30 minutes after EQ - performance of TEWS infrastructure	17.56%	38.70%
TEW2 Reasons for Low Appreciation	19.52%	7.76%
TEW3 Realiable communication device in disaster situation	21.54%	0%
TEW4 First 30 minutes after EQ - performance of government officials	14.58%	37.50%
TEW5 Based on Sept 30 EQ experience - level of trust on government	17.58%	8.68%
TEW6 REASONS for low performance appreciation during Sept 30 EQ	9.22%	7.36%

$$TEW = 1.1222(TEW1) + 1.24744(TEW2) + 1.376876(TEW3) + 0.932108(TEW4) + 1.12342(TEW5) + 0.589052(TEW6)$$

$$\mathbf{TEW = 1.875897(TEW1) + 0.376263(TEW2) + 1.817516(TEW4) + 0.420596(TEW5) + 0.356641(TEW6)}$$

COMPONENT MATRIX	RP 1			RP 2	
	1	2	3	1	2
TEW1 First 30 minutes after EQ, what did you think about the performance of TEWS infrastructure	0.724			.810	.369
TEW2 Reasons for Low Appreciation	0.108	0.806		-.209	.632
TEW3 Realiable communication device for natural disaster situation		0.349	0.902		
TEW4 First 30 minutes after EQ, what do you think about the performance of government officials and its stakeholders	0.768	-0.107	-0.114	.881	.213
TEW5 Based on Sept 30 EQ experience_value the level of trust on government	0.650		0.115	.489	-.379
TEW6 REASONS for low performance appreciation during Sept 30 EQ		0.745	-0.406	-.250	.677





Comparison of Mind of RP1, RP2 and RG on Scenario Evacuation 1.2

No	Variables	RP1		RP2		RG	
	$Evac_{1.2} = f(E_{1.1.2}, E_{1.1.3}, E_{1.1.4}, H_i, V_i, T_i, CM_i, TEWS_i)$						
1	E1.1.2 What was the reasons not to follow the route when immediate evacuate after strong shaking?	0.57724	7.86%	1.447738	19.69%	0.603038	6.42%
2	E1.1.3 What alternative route did you take when immediate evacuate after strong shaking?	0.824712	11.23%	1.773732	24.12%	0.633795	6.74%
3	E1.1.4 How did you evacuated when immediate evacuate after strong shaking?	-0.46242	6.30%	0.019332	0.26%	-1.96159	0.00%
4	H Hazard and Disaster Perception and Experiences	1.501194	20.44%	1.552004	21.11%	0.895627	20.87%
5	V Social Vulnerability and Capacity	1.156557	15.75%	-1.65246	22.47%	2.563676	9.53%
6	T Knowledge on Tsunami Risk and Triggering Event	-1.23216	16.78%	-0.2132	2.90%	1.565015	27.27%
7	CM Disaster Risk Reduction Countermeasures	1.070411	14.57%	0.69524	9.45%	1.177439	16.65%
8	TEWS Appreciation to Tsunami Early Warning System	0.520371	7.08%	1.447738	19.69%	0.603038	12.53%

APPENDIX B

- B1 – Sample Questionnaires For People
- B2 – Sample Questionnaires For Government Officials

B1 – Sample Questionnaires For People

Introduction

Questionnaire Acquiring People's Mind toward Tsunami Warning

Objective of the survey:

The objective of the survey is to collect data on the mindset of government officials performance for not to evacuate for tsunami after a strong earthquakes, in the selected communities of 14 coastal area along Padang City (the red and green tsunami risk zone).

Method:

- First drafted questionnaire is developed based on: tacit knowledge and preliminary interview survey conducted 7 days after the September 30, 2009 earthquake in Padang City and Pariaman Regency. Number of recorded respondent is 15 representing the urban community, fishermen, government officials, and government officials in charged with emergency response (i.e. crisis center, fire brigade), as well as other agencies and the mayor/regent and vice governor. The survey conducted from October 7 to 16, 2009 under collaboration between ITB with EERI and UPitt. The tacit knowledge obtained were from the in-depth survey conducted under collaboration of CDM ITB with AUSAID (4,000 data) and the prior knowledge obtain based on the secondary data during activities conducted from 2005 to 2009 during and after national tsunami drill.
- The drafted questionnaire is developed based on the further refined and reviewed the first draft based on the followed up interview survey on focus target group, i.e. community and government officials involved in the emergency response. This survey conducted on June 2010. The number of respondent was 9.
- The pre-test interview survey was conducted by 6 surveyors (students and graduate from Economic Department of UNAND) on the zone red zone area (zone 8 and 9) the first day. Result of the survey will be evaluated to refine the questionnaire developed.
- Total numbers of samples needed are 300 respondents. The 6 + 4 surveyors (students and graduate from Economic Department and Civil Engineering Department of UNAND.
- The focus of target group, 300 people representing:
    - Zone 1 to 14 (green and red zone of tsunami protection).
    - Stakeholders of community representatives
        - adult man/women,
        - formal/informal worker,
        - residence/worker/trader
        - students of school located in zone 1 to 14 (max 20% from total respondents)
        - trained/untrained

Note:

It should be mentioned to every interviewee by the surveyors that any personal data collected through this survey will be confidential, strictly used for the study analysis only and will never be disclosed.

Questionnaire for Mindset Model for People from Tsunami Prone City

PART I: VULNERABILITY AND CAPACITY OF RESPONDENT

1. Respondent IDs: No Respondent / No Cluster/Name Respondent.

No. of Respondent : ______________________________
No. of Cluster : ______________________________
Name of Respondent : ______________________________
Coordinate of Respondent location (using GPS) : ______________________________
Name of Interviewer/Surveyor : ______________________________

2. Address of Respondent during interview + remark (house/shop/business/office)

Address :
____
____
Remark : house / shop / business / office / others :
____

3. Gender:

(1) Man	2) Woman

4. Age & Level of Education

<u>Age:</u>	<u>Education:</u>
(1) 5 – 12	(1) Elementary School
(2) 13 – 18	(2) Middle School (Junior High School)
(3) 19 – 30	(3) Senior High school
(4) 31 – 40	(4) Undergraduate (university and vocational polytechnic)
(5) 41 – 50	(5) Postgraduate
(6) 51 – 60	
(7) 61 – 70	
(8) > 70	

5. Average monthly income (in IDR)

(1) Zero (for school student)
(2) < 0.5 M IDR
(3) 0.5 M – 1 M IDR
(4) 1.0 M – 1.9 M IDR
(3) 2.0 M – 4.9 M IDR
(4) > 5.0 M IDR

6. Job

____

7. Number of inhabitants (family members) living at the same house with the respondent :

Total number of inhabitants : ______________________________

Number of children < 15 year old: ______________________________

Number of elderly > 60 year old: ______________________________

8. House/ shop-houses / business / work place

(8a) How long have you stayed in the house/ building?

(1) 1 – 2 year
(2) 2 – 5 year
(3) 5 – 10 year
(4) 10 – 20 year
(5) > 20 year

(8b) Ownership of the house / building

(1) own / family own

(2) rent

(3) others : ______________________________

(8c) Area

(1) < 40 m^2
(2) 40 – 80 m^2
(3) 80 – 120 m^2
(4) 120 – 160 m^2
(5) 160 – 200 m^2
(6) > 200 m^2

(8d) Type of house/ building

(1) Single	with number of floors	(a) 1	(b) 2	(c) 3 and more
(2) Shop-house/Townhouse	with number of floors	(a) 1	(b) 2	(c) 3 and more
(3) Flat/apartment	which floor ________	(1 st floor = ground floor)		

(8e) Main structure of house/ building

(1) Concrete structure with brick wall

(2) Timbre structure

(3) Steel structure

(4) Others: ______________________________

PART II: DISASTER PERCEPTION AND DISASTER RISK REDUCTION COUNTERMEASURES

9. Please select what type of disasters you have experienced and rate how ***frequent***? *[**Multiple answers**]*

(1) Flood	5	4	3	2	1	NA
	Very-high	high	moderate	low	never	don't know
(2) Earthquake	5	4	3	2	1	NA
	Very-high	high	moderate	low	never	don't know
(3) Tsunami	5	4	3	2	1	NA
	Very-high	high	moderate	low	never	don't know
(4) Volcanic Eruption	5	4	3	2	1	NA
	Very-high	high	moderate	low	never	don't know
(5) Accident	5	4	3	2	1	NA
	Very-high	high	moderate	low	never	don't know
(6) Commotion / Riot	5	4	3	2	1	NA
	Very-high	high	moderate	low	never	don't know
(7) *Other disaster* : ________						
	5	4	3	2	1	NA
	Very-high	high	moderate	low	never	don't know

10. Which one of the following **disasters**, do you think that will affect (have affected) your life the most? *[**only 1 answer**]*

(1) Unemployment
(2) Outbreak/Disease
(3) Accident
(4) Natural disaster (earthquake, tsunami, dll)
(5) Civil war / riot / commotion
(6) Hunger
(7) *Others* : ________________________

11. Which one of the following **natural disasters**, do you think that will affect (have affected) your life the most? *[**only 1 answer**]*

(1) Flood
(2) Landslide
(3) Earthquake
(4) Tsunami
(5) Cyclone
(6) *Others* : ________________________

12. How sure you think that tsunami will occur and stricken your house in the future?

5	4	3	2	1	NA
Very sure	quite sure	moderately sure	less sure	not sure	don't know

13. Could you describe your opinion on how **possible** that tsunami would have affected your life if it were occurred? ***[multiple answer]***

(1) loss your life 5------------------4-----------------3------------------2-----------------1-----------------NA
Very-high high moderate low never don't know

(2) loss your family 5-----------------4-----------------3------------------2-----------------1-----------------NA
Very-high high moderate low never don't know

(3) loss your property / belonging
5----------------4-----------------3------------------2-----------------1----------------NA
Very-high high moderate low never don't know

14. What have you done to prepare yourself for anticipating tsunami in the future? Please select from the following questions. ***[multiple answer]***

(1) Participated in Disaster Risk Reduction training :
a. What kind of training: ______________________________
b. Who is the organizer: ______________________________

(2) Participated in Tsunami Drill:
a. how big is the drill : city level / neighborhood level / school level
b. Who is the organizer: ______________________________

(3) Prepared family action plan for tsunami (consisting who is doing what if a tsunami occurs)
a. Where/whom did you learn: ……………………………….

(4) Socialized tsunami disaster to family member and how frequent:
5----------------------4--------------------3-------------------2---------------------1--------------------NA
Very-high high moderate low never don't know

(5) Socialized tsunami disaster to the neighbor and how frequent:
5----------------------4--------------------3-------------------2---------------------1--------------------NA
Very-high high moderate low never don't know

(6) Moved the house / business to the higher area (tsunami safe zone):
a. soon in near future
b. still in the plan
c. impossible to do because of financial matter
d. impossible to do because of family matter
e. impossible to do because of working / business location

(7) Constructed / rented a tsunami safe house (multi story house)
a. soon in near future
b. still in the plan
c. impossible to do because of financial matter

(8) Not yet

(9) Never

15. Do you think your house is strong enough against tsunami?

(1) Yes

(2) No → if no, please describe your preference among the following option (15a, 15b or 15C):
(15a) have a plan to reconstruct/retrofit your current house to be strong against tsunami?
(15b) have a plan to move your house to higher area
(15c) do nothing

PART III: TSUNAMI EARLY WARNING SYSTEM

16. During September 30, 2009 earthquake, did you think a tsunami will come after that strong shaking?

(1) yes → see question 17
(2) no
(3) don't know

17. How was your feeling that time if a tsunami would have occurred?

5	4	3	2	1	NA
Very scared	highly scared	moderately scared	less scared	not sacred at all	don't know

18. During September 30, 2009 earthquake when you felt strong shaking, did you ***immediately evacuate*** to save yourself to the tsunami safe area / zone?

(1) yes	→ continue to question ***no 19***
(2) not immediately	→ continue to question ***no 20***
(3) no	→ continue to question ***no 21***

19. For ***immediate evacuation*****,** did you use local government designated routes for evacuation?

(1) **yes** → what kind of transportation did you use during the evacuation through that designated route?

(a) on foot
(b) using your own bicycle
(c) using your own motor cycle
(d) using your own car
(e) using public transport
(f) going with your neighbor's car
(g) others: ______________________________

(2) **no** → 1. Please provide reason why you did not follow that designated route?

(a) road were blocked
(b) afraid of selfish behavior of evacuee
(c) did not know the location of the route
(d) others: ______________________________

→ 2. What alternative routes you have taken during that day?

(a) finding empty road even though longer and moving toward beach area
(b) finding a short cut even though by passing or trespassing some one's property
(c) following the crowd

→ 3. What kind of transportation did you use to evacuate through this alternative routes?

(a) on foot
(b) using your own bicycle
(c) using your own motor cycle
(d) using your own car
(e) using public transport
(f) going with your neighbor's car
(g) others: ______________________________

20. For ***not immediate evacuation***, what did you do that time? [***multiple answer***]

(1) went home to save family member

(2) actively searched information of tsunami possibility following the shaking, *from*:

  (a) government tsunami early warning

  (b) looking natural sign of tsunami by yourself, such as: no se level change, birds flock at the sky etc

  ____________________(please describe)

(3) waited for tsunami early warning *from*:

  (a) mayor/city government announcement (order for evacuation) via radio

  (b) warning siren

  (c) Public announcement from mosque's speaker

(4) closed and saved the shop/business

(5) on duty

(6) Others:____________________

21. For ***no evacuation***, what were your reasons for that? [***multiple answer***]

(1) no change on the sea level at the beach

(2) no tsunami early warning from the government

(3) belief in yourself that tsunami would not occurred

(4) giving up because of fate

(5) just praying

(6) others:____________________

22. If during that time you have heard ***tsunami early warning from government,*** would you immediately evacuate? What were your reasons?

(1) yes → reasons: ____________________

(2) no → reasons: ____________________

(3) don't know

23. Could you describe your opinion on the performance of the supporting devices for tsunami early warning during the ***first 30 minutes after the earthquake***:

(a) performance of tsunami **siren**:

3-----------------------------------2---------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

(b) performance of **mosque speakers**:

3-----------------------------------2---------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

(c) performance of **radio**

3-----------------------------------2---------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

(d) performance of **TV**

3-----------------------------------2---------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

(e) performance of **fix-phone** (Telkom Co.)

3-----------------------------------2--------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

(f) performance of **HP/mobile phone provider**

3-----------------------------------2--------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

(g) performance of **SMS (short message/text)**

3-----------------------------------2--------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

(h) performance of **other devices**, please describe and value its performance:

3-----------------------------------2--------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

24. Could you describe your opinion on the performance of government officials in charge during the ***first 30 minutes after the shaking***:

(a) performance of Police (POLRI) personnel in handling the evacuation process:

3-----------------------------------2--------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

(b) Performance of army (TNI) personnel in handling the evacuation process:

3-----------------------------------2--------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

(c) performance of personnel of fire brigades in handling the fire induced by the shaking:

3-----------------------------------2--------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

(d) performance of other devices, please describe and value its performance:

3-----------------------------------2--------------------------------1---------------------------------N/A

Fully function partly function not function at all don't know

remark:

25. Based on your experience during September 30 earthquake, describe your ***level of trust*** to:

a) Ability of city/local government to convey BMKG tsunami early warning to the public in the form of order for evacuation:

5------------------------4--------------------------3-------------------------2---------------------1----------------N/A

Very high quite high moderately high less high not at all don't know

b) Ability of national/central government (BMKG) to issue tsunami early warning:

5------------------------4--------------------------3-------------------------2---------------------1----------------N/A

Very high quite high moderately high less high not at all don't know

c) Ability of national/central government (BNPB) to issue tsunami early warning:

5------------------------4--------------------------3-------------------------2---------------------1----------------N/A

Very high quite high moderately high less high not at all don't know

Signature of Surveyor ________________________________

Date of interview ________________________________

The surveyor is requested to:

- Take **1 photo (digital) of respondent** (in front of the hose/business/school).
- Tag the **coordinate** using GPS to show location of the respondents.