-Institut für Geodäsie und Geoinformation-

Assessing People´s Early Warning Response Capability to Inform Urban Planning Interventions to Reduce Vulnerability to Tsunamis

Case Study of Padang City, Indonesia

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Abstract

In the last decade, more emphasis is given on the human aspect of early warning or the attribute of "people-centered" early warning systems. This study seeks to better understand the specific conditions that shape people´s vulnerability in relation to their tsunami early warning response capability. The study lays emphasis on the bottlenecks within social conditions, issues of perception, and their linkages with urban evacuation spatial and infrastructure requirements. The study is based on an in-depth case study of the coastal city of Padang, Indonesia.

Founded on literature study on vulnerability and early warning concepts, a conceptual study was developed. Here, vulnerability was defined as "the conditions which influence the level of exposure and capability of people to respond to the warning and conduct appropriate evacuation, and in the long term, to change those conditions and enhance their response capability". The study is composed of three main assessment blocks: i) current spatial hotspots and bottlenecks within social conditions assessments; ii) assessment of perception issues related with on-going or planned interventions; and iii) assessment of urban planning´s role and influence on vulnerability and people´s response capability. The first assessment block consists of spatial and temporal distribution of various social groups in the exposed areas (dynamic exposure); their access to safe places; their access to warning; and their evacuation behaviour. The second assessment block examines various cognitive factors connected with objective knowledge as well as socio-psychological factors pertaining to vulnerability reduction. These are intention to evacuate (reactive action) and intention to support improvement of evacuation infrastructure and facilities (proactive action). Moreover, perceptions connected with challenges of possible relocation as well as overall tsunami preparedness are explored. The third assessment block explores the urban planning´s role and interventions linked with various response capability components. In order to assess different thematic areas, an interdisciplinary approach is required, using engineering and social behavioural sciences approaches. Therefore, the combination of qualitative and quantitative data collection and analysis methods is used.

The results show that Padang´s current response capability varies according to its spatial and infrastructure setting as well as people´s socio-economic characteristics. Evacuation facilities and infrastructure were still lacking and their utilization was influenced by social conditions of the people. This implied a significant role for urban planning which needs to take into account various social groups´ specific needs while incorporating the importance of strategic risk communication within various interventions. The assessment needs to be integrated in the overall urban planning process and may provide guidance in finding the balance between long-term exposure reduction in dangerous areas and additional protection measures for mass evacuation.

Zusammenfassung

Im letzten Jahrzehnt wurde der Schwerpunkt im Bereich „Frühwarnsysteme“ zunehmend auf die menschliche Komponente der Frühwarnung im Sinne von "Menschen-zentrierten" Frühwarnsystemen gelegt. Im Rahmen dieser Dissertation werden die Bedingungen analysiert, die die Verwundbarkeit der Menschen gemessen an ihrer Reaktionsfähigkeit auf Tsunami-Frühwarnungen bestimmen. Die Studie berücksichtigt dabei Unterschiede in den sozialen Bedingungen, Fragen der Wahrnehmung, und verknüpft diese mit den städtischen räumlichen und infrastrukturellen Anforderungen der Evakuierung. Die Studie wurde in der Küstenstadt Padang, Indonesien, durchgeführt.

Basierend auf einer Literaturanalyse bestehender Verwundbarkeits- und Frühwarnungskonzepte wurde ein Rahmenkonzept entwickelt. Hierbei wurde die Verwundbarkeit definiert als "die Bedingungen, welche zum einen die Exposition der Menschen und zum anderen deren Fähigkeit beeinflussen, auf die Warnung zu reagieren und an einer Evakuierung teilzunehmen, und auf lange Sicht, diese Bedingungen zu ändern und ihre Reaktionsfähigkeit zu verbessern". Bei der Umsetzung wurden drei Untersuchungsbereiche unterschieden: i) die Einschätzung der aktuellen räumliche Engpässe und unzureichende soziale Bedingungen i) die Analyse der Wahrnehmung in Bezug auf die laufenden oder geplanten Maßnahmen, und iii) die Bewertung der Rolle und des Einflusses der Stadtplanung auf die Verwundbarkeit und Reaktionsfähigkeit der Menschen. Der erste Bereich bestand aus der räumlichen und zeitlichen Verteilung der sozialen Gruppen in den exponierten Gebieten (dynamische Exposition), deren Zugang zu sicheren Orten, deren Zugang zu Warnmeldungen, und deren Evakuierungsverhalten. Der zweite Bereich untersuchte den Einfluss verschiedener kognitiver Faktoren, insbesondere objektiven Wissens sowie sozio-psychologischer Faktoren, auf die Evakuierung (reaktives Handeln) und die Verbesserung der notwendigen Infrastruktur und Einrichtungen (proaktives Handeln). Die Wahrnehmung einer möglichen Umsiedlung und die Tsunamivorsorge wurde ebenfalls ermittelt. Der dritte Bereich untersuchte die Rolle der Stadtplanung in den tatsächlichen Interventionen in Bezug auf die verschiedenen Komponenten. Um die einzelnen Themenbereiche auszuwerten, wurde ein interdisziplinärer Ansatz verfolgt. Dazu wurden Ansätze aus der Technik, den Sozial- und Verhaltenswissenschaften verwendet und qualitative sowie quantitative Datenerhebungs- und Analysemethoden kombiniert.

Die Ergebnisse zeigten, dass die aktuelle Reaktionsfähigkeit der Menschen in Padang von den räumlichen und infrastrukturellen sowie den sozioökonomischen Gegebenheiten abhängig ist. Einrichtungen und Infrastruktur zur Evakuierung fehlen und zudem wird ihre tatsächliche Nutzung von sozialen Bedingungen beeinflusst. Dabei zeigt sich die bedeutende Rolle der Stadtplanung, die die spezifischen Bedürfnisse der verschiedenen sozialen Gruppen in ihrer Planung berücksichtigen und dementsprechend ihre Risikokommunikation strategisch ausrichten sollte. Diese Einschätzung sollte in alle Stadtplanungsprozesse integriert werden. Zusätzlich können dadurch Abwägungen im Hinblick auf eine Balance zwischen langfristiger Reduzierung der Exposition und Bereitstellung zusätzlicher Schutzmaßnahmen für eine Evakuierung ermöglicht werden.

Dedicated to: people of Padang city

"..everybody (should) knows, being prepared is a command from God. That is indeed in God´s hand, when disaster would happen, but we need to be in alert, do our best to save ourselves. Do not do suicide, we have to struggle…"

(Non-structured interview with a community religious leader, Padang, 2009)

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Figures

Tables

Annotation

During the preparation period of this dissertation, the following scientific papers and project report were published containing some parts of the study results:

Setiadi, N. (forthcoming): Understanding challenges at the "Last-Mile" in developing an effective risk communication to reduce people´s vulnerability in context of tsunami early warning and evacuation. In: Kontar, Y., Santiago-Fandino, V., Takahashi, T. (Eds): *Tsunami Events and Lessons Learned – Environmental and Societal Significance*, Advances in Natural and Technological Hazards Research, Vol. 35, ISBN 978-94-007-7268-7, Springer Berlin Heidelberg New York.

N. Goseberg, G. Lämmel, H. Taubenböck, N. Setiadi, J. Birkmann and T. Schlurmann (2013): The Last-Mile Evacuation Project: A Multi-Disciplinary Approach to Evacuation Planning and Risk Reduction in Tsunami-Threatened Coastal Areas. In: F. Wenzel and J. Zschau (Eds.) *Early Warning for Geological Disasters - Scientific Methods and Current Practice*; ISBN: 978-3-642-12232-3, Springer Berlin Heidelberg New York.

Taubenböck, H., Goseberg, N., Lämmel, G., Setiadi, N., Schlurmann, T., Nagel, K., et al. (2012): Risk Reduction at the „Last-Mile": an attempt to turn science into action by the example of Padang, Indonesia. Natural Hazards (online first). DOI 10.1007/s11069-012-0377-0.

Birkmann, J., Chang Seng, D., Setiadi, N. (2012): Enhancing early warning in the light of migration and environmental shocks. *Environmental Science and Policy*. DOI: 10.1016/j.envsci.2012.04.002

Setiadi, N. (2011): Establishment of an effective people-centered tsunami early warning by understanding people´s behavior and needs: Case study of Padang, West Sumatra. In: Anwar, H.Z. & Harjono, H. (Eds.): *Perspektif Terhadap Kebencanaan dan Lingkungan di Indonesia: Studi kasus dan pengurangan dampak risikonya*. LIPI, Bandung, pp.35-52. (ISBN: 978-602-99893-0-4).

Setiadi, N. (2011): Daily mobility – Excursus – Padang, Indonesia. In: Chang Seng, S.D., Birkmann, J.: *Migration and Global Environmental Change: SR4b: Early Warning in the Context of Environmental Shocks: Demographic Change, Dynamic Exposure to Hazards, and the Role of EWS in Migration Flows and Human Displacement*, Foresight Project, Government Office for Science, pp. 35-38.

Setiadi, N., Taubenböck, H., Raupp, S. & Birkmann, J. (2010): *Integrating socio-economic data in spatial analysis: An exposure analysis method for planning urban risk mitigation.* 15th International Conference on Urban Planning and Regional Development in the Information Society (REALCORP), Vienna, Austria. GeoMultimedia 2010.

Setiadi, N.; Birkmann, J. (2010): *Working Package 1000: Socio-Economic Vulnerability Indicators*. Final Report for the "Last-Mile - Evacuation" Project, DFG/BMBF Special Program Geotechnologies. United Nations University, Institute for Environment and Human Security (UNU-EHS). (Final Report of all work packages in German: http://edok01.tib.uni-hannover.de/edoks/e01fb11/659460041.pdf).

Taubenböck, H., Goseberg, N., Setiadi, N., Lämmel, G., Moder, F., Oczipka, M., Klüpfel, H., Wahl, R., Schlurmann, T., Strunz, G., Birkmann, J., Nagel, K., Siegert, F., Lehmann, F., Dech, S., Gress, A., Klein R. (2009): *Last-Mile preparation for a potential disaster – Interdisciplinary approach towards tsunami early warning and an evacuation information system for the coastal city of Padang, Indonesia.* In: Natural Hazards and Earth System Sciences. vol. 9, pp. 1509-1528. http://www.nat-hazards-earth-syst-sci.net/9/1509/2009/nhess-9-1509-2009.html

Birkmann, J., Setiadi, N., & Gebert, N. (2008). Socio-economic Vulnerability Assessment at the Local Level in Context of Tsunami Early Warning and Evacuation Planning in the City of Padang, West Sumatra. In ICTW (Ed.), *International Conference on Tsunami Warning (ICTW), Bali, Indonesia, November 12-14, 2008*.

1 Introduction

1.1 Background

Coastal areas are among the vulnerable locations identified in light of global environmental change. Rapid urbanization in the coastal areas is likely to increase their disaster susceptibility in view of the growing populations in coastal cities that are particularly vulnerable to sea-level rise, tsunamis and other hazards (Klein 2002). During the 20th century, coastal populations grew rapidly around the globe due to economic opportunities and environmental amenities in the coastal zones, thus putting unprecedented pressure on the economic development that led to the development of a variety of important economic activities in coastal zones (Klein, Nicholls and Thomalla 2003; Klein 2002; Turner, Subak and Adger 1996; Post and Lundin 1996). Low Elevation Coastal Zones (LECZ), the continuous areas along coastlines with an elevation of less than 10 metres above sea level, represent 2% of the world´s land area but contains 10% of its total population and 13% of its urban population (McGranahan, Balk and Anderson 2007). Low-lying coastal areas have been identified as areas with the largest number of people concentrations (Small and Cohen 1999). Nicholls and Small (2002) estimated the population in the areas within 100 meters elevation and 100 kilometres distance of the coast in 1990 at 1.2 billion or 23% of the world's population. Thus, these areas are very prone to coastal hazards.

Establishing early warning systems is one of the important measures to reduce vulnerability and risk by providing information that will enhance the disaster preparedness of the people and elements at risk. It was almost a decade ago when the devastating event of major earthquake and tsunami in the Indian Ocean Tsunami in December 2004 occurred. This event drew a strong international attention to and concern of existing tsunami hazard and importance of tsunami early warning system for the region. The Hyogo World Conference on Disaster Reduction took place in 2005 and called for the establishment of an effective and durable tsunami early warning system for the Indian Ocean. From then on, more emphasis has been given to the people at risk and their capability to take actions to reduce their risks to such hazard events. The „people-centered" early warning systems were promoted, in contrast to the traditional early warning systems as mere detection and dissemination technology. In this regard, early warning systems deal not only with planning and the activities of detecting the potential hazard and sending an alert, but also ensure that the warning message reaches the people at risk and triggers appropriate and timely response (UN/ISDR 2006a; UN/ISDR 2006b).

The Indian Ocean tsunami event 2004 has also been one important driver of various milestones of disaster management in Indonesia. Establishment of a tsunami early warning system in Indonesia was initiated not long after this event. In parallel, this event also triggered significant changes in disaster management scheme in Indonesia that highlight disaster risk reduction and its linkage with the overall development planning. In this regard, the newly established tsunami early warning system should be integrated in the overall development planning and the existing institutional setting, and not as a stand-alone system.

Disaster risk reduction especially related with disaster preparedness and early warning is often seen as primarily the responsibility of emergency planners. However, disaster preparedness also deals with some factors which need long-term interventions and involvement of other actors, like urban planning. The linkage between urbanization and disasters has been emphasized in the existing literature (Sánchez-Rodríguez et al. 2005; Kraas 2003; Smith and Petley 2009; Field et al. 2012). Among several factors of urban development that increase disaster susceptibility are livelihood opportunities in hazard-prone locations or subsequent urban growth there, environmental degradation, concentration of people and investments, slow rate of urban replacement, lack of redundancy of functional systems, social-spatial segregation, existence of vulnerable populations, lack of institutional coordination, and limited resources to accommodate various demands including disaster risk reduction (Mitchell 1999; Lavell 1999; Field et al. 2012). The risk is higher especially in rapidly growing small- and medium-sized cities with limited capacity and resources (Cross 2001).

In the specific context of early warning systems, especially for major, sudden-onset hazard events like tsunamis, the early warning response often involves mass evacuation. This is particularly more complex in urban areas, with dense built areas, daily dynamic, and various existing other pressures. Thus, the requirements of early warning and emergency response need to be integrated in long-term planning. For instance, concentration of population and rapid development in tsunami prone areas will increase the exposure of the population and the complexity of early warning and mass evacuation. Sufficient road networks for evacuation routes and accessible constructions for evacuation shelters are also required. Such concerns in the "Last-Mile" need to be anticipated in the long-term involving in some cases high investment as well as multiple stakeholders; two factors requiring to be addressed in the overall long-term urban planning scheme. These are also related with general urban planning questions like: Where and how to provide disaster-resilient city services, infrastructures, and facilities? What are the limits and opportunities for urban development against existing risks? How many protection measures are required considering the existing vulnerable groups?

This dissertation has emanated from the scientific work performed within the scope of a research project called "Last-Mile – Evacuation"[1] in the city of Padang, West Sumatra, Indonesia. This project dealt intensively with the issue of the "Last-Mile" (planning and preparedness efforts at the local and community level) in the context of the tsunami early warning system. The research project aimed to provide a detailed information system for tsunami early warning and evacuation planning, consisting of hazard and vulnerability information, as well as the identification of potential bottlenecks in evacuation for the coastal city of Padang. The research product of this study is embedded in the

[1] This project belonged to the DFG/BMBF special Programme "Geotechnologies" – Early Warning Systems in Earth Management (Sponsorship code: 03G0666A-E). UNU-EHS, for whom the researcher conducted the study, was responsible for the Work Package 1000 "Socio-Economic Vulnerability Assessment" (Project Period: May 2007 – July 2010).

overall objective of the project and supports the development of evacuation strategy and early warning components in the “Last-Mile”. It complemented the project´s other research works on tsunami inundation modelling, evacuation modelling, remote sensing, and geo-database development. The study mainly addresses the conceptual framework and assessment of vulnerability with regard to people´s early warning response capability, and subsequently promoting the role of urban planning in relevant vulnerability reduction interventions.

1.2 State-of-the-Art

Anticipated response is a crucial component of early warning systems which has been promoted in the recent decade (Villagran de León et al. 2006). However, the UN/ISDR´s (2006b) global survey of capacities and gaps of early warning systems still identified warning dissemination and response capability as the weakest elements, while the technical monitoring and warning service have been advancing. This means a lot of work has to be done in assessing and improving these components. Moreover, Villagran de León (2011) stated that little has been addressed in the traditional framework of early warning on the prior knowledge of risks and the preparedness to act. In this regard, Villagran de León (2011; Villagrán de León, Weerawarnakula and Chandrapala 2006) provided a case study of Sri Lanka that emphasized the importance of risk and vulnerability assessment to guide early warning strategies, such as who to warn first, prioritization of evacuation routes, and required community preparedness activities.

The emphasis on the “people-centred”-ness of early warning systems has given a new perspective in contrast to the traditional early warning framework that focused primarily on the monitoring of hazard and hazard characteristics. Therefore, this new perspective also incorporates the people at risk and their capacity in the design of early warning systems. This view conforms well with the concept of vulnerability that sees disaster impacts not merely as a result of the magnitude and intensity of the hazard (which would be the focus of the traditional view of early warning), but also, and even more importantly, as a consequence of the intrinsic characteristics of the people exposed to the hazard (issues related to warning dissemination to and response capability of the people).

The concept of vulnerability has been developed and defined in various scientific discourses (Adger 2006; Cutter 1996; Birkmann 2006), as well as its operationalization into measurable indicators to assess change and evaluate political strategies (Birkmann 2006). However, the linkage of vulnerability measurements with on-going disaster risk management and specific disaster risk reduction measures is still lacking (Gebert in preparation). The vulnerability assessment in this study shall contribute to bridge this gap and assess in more in-depth specific factors that are relevant in the context of tsunami early warning and evacuation.

Vulnerability assessments to tsunamis have been conducted, e.g. by Birkmann et al. (2007) in Sri Lanka, which revealed differentiated impacts and the coping capacity of social groups and indicated variation of vulnerability. The assessment and indicators used show overall baseline susceptibility and coping capacity of the people to tsunamis, but are not directly linked with any disaster measures. Another study conducted by Fernando (2010) on the tsunami in Sri Lanka dealt with relocation within the disaster recovery phase which considers the coping capacity of various vulnerable groups. Such

analysis of vulnerability linked to the specific disaster risk reduction measures may guide the planning and practical implementation of such measures.

In the phase of disaster preparedness, a detailed vulnerability assessment related to people´s response capacity is also important to develop an effective early warning system and its supporting interventions. This does not mean assessing solely the potential losses of lives using evacuation modelling and simplified demographic variables (Sugimoto et al. 2003). Rather, many studies have shown that various factors related with people´s perceptions, evacuation behaviour and organization, determine the success of early warning dissemination and evacuation conduct (Sorensen 2000; Santos and Aguirre 2004; Riad and Norris 1998; Roy Lachman, Maurice Tatsuoka and William J. Bonk 1960; Baker 1991; Lindell, Lu and Prater 2005; Tierney, Lindell and Perry 2001). Those factors also need to be considered in assessing people´s response capability and potential loss of lives.

Moreover, the specific needs of early warning identified by the vulnerability assessment should not only inform the short- and medium-term emergency planning but also the long-term urban planning. Both emergency and urban planning interventions have to be linked and assessed. Chang Seng (2010; 2012) has emphasized the importance of communication process between various actors also in the time when there are no hazard events as well as the influence of various political, social, economic, and technological systems on the effectiveness of early warning systems.

Presently, integration of risk assessment and management in the urban planning mostly deals rather with the identification of hazard and hazard-prone areas to guide land-use planning (Greiving 2002; Greiving and Fleischhauer 2006), bringing very little on the vulnerability and coping capacity of the people to the surface. In this regard, it is important to link vulnerability assessment with relevant urban planning interventions and by doing so, identify areas where urban planning can play a role in reducing vulnerability and enhancing people´s response capability in a continuous and sustainable manner.

1.3 Research Objectives and Questions

There are two main issues to be addressed in the study, namely assessing vulnerable conditions which are relevant to disaster risk reduction measures of early warning, and strengthening the synergy of emergency and urban planning interventions in developing a sustainable early warning system. It focuses on response capability component of early warning systems and argues that the conditions that generate vulnerability and lack of capacity to respond to early warning are influenced by the interventions of both emergency and urban planning.

The main objective of this study is to develop an assessment framework and methodologies to understand and measure the early warning response capability of the people, which is also useful to guide urban planning in integrating the early warning needs in their long-term planning. The study describes various approaches including engineering, modelling, remote-sensing, social science approaches which were partly developed by and worked out jointly with the colleagues within the “Last-Mile – Evacuation” Project. The study lays emphasis on the bottlenecks within social conditions,

issues of behaviour and perception, and their linkages with the urban spatial and infrastructure requirements of evacuation.

The main overarching question of this study is: What are and how can we assess the conditions causing people´s vulnerability which are relevant to tsunami early warning at the local level and subsequently use this information basis to strengthen the synergy of emergency and urban planning interventions?

In order to answer the main research question and meet the research objectives, the following sub-research questions are posed:

1. What are the conditions/factors that shape the vulnerability of the people related with their early warning response capability?
2. Are there any subjective factors or issues of perception that influence the response capability of the people as well as the on-going efforts to reduce vulnerability?
3. How can we assess those conditions/factors to identify existing bottlenecks and needs?
4. Is there any linkage between spatial and social bottlenecks within early warning and evacuation stages?
5. What is the role of urban planning in altering the response capability and vulnerability of the people?
6. How should urban planning take into account existing bottlenecks in their long- and medium-term planning?

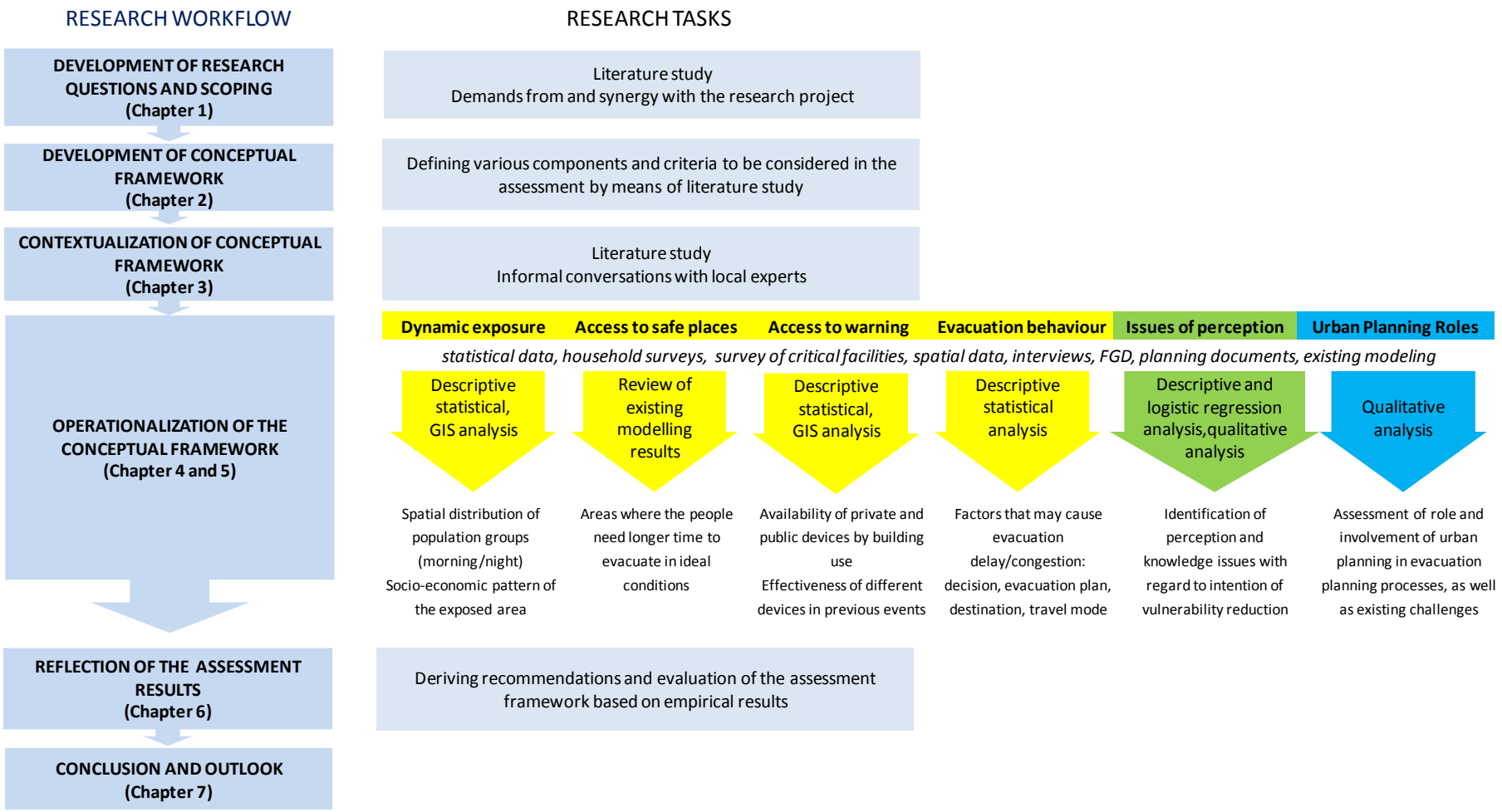
The main audience concerned with the outcomes of this research is the community of urban and emergency planners as well as a range of actors involved in early warning systems. The research is specific for tsunami hazard application in the urban context in Padang city, Indonesia. However, Padang city is representative of many medium-sized urban areas in developing countries, where extreme hazards exist that have not yet been experienced by the generations presently living in the area. It also represents a similar problematic situation as in other developing countries, where a good knowledge basis for disaster risk reduction is lacking and there is no coordination among the various actors in planning, managing limited resources, and resolving conflicts of interest. Furthermore, it describes the initial process to concretize the integration of tsunami early warning in the overall planning scheme. The results of the research should in the first place derive recommendations for application in Padang, but also draw lessons in a wider sense for other urban areas within similar contexts.

1.4 Research Structure

The research consists of three main parts: i) development and contextualization of the conceptual framework; ii) operationalization of the conceptual framework in the case study area; iii) reflection on the results. The first part is described in Chapter 2, where existing concepts related with vulnerability such as early warning and integration of vulnerability assessment in urban planning are

reviewed as a basis of the conceptual framework; and Chapter 3, where prior knowledge of the study area is collected and incorporated in the conceptual framework. The second part deals with the operationalization of the conceptual framework and presented in Chapters 4 and 5, where qualitative and quantitative data are collected and analysed using mixed approaches. It covers the assessment of the current response capability of the people (dynamic exposure, access to safe places, access to warning, and evacuation behaviour); people´s intention to reduce vulnerability (human cognition and issues of perception); and the role and influence of urban planning. The third part (Chapter 6) derives recommendations on criteria to be incorporated in urban planning interventions based on the empirical results and evaluates the assessment framework and methods. Figure 1-1 gives an overview of the research workflow and tasks involved.

Figure 1-1 Research workflow and tasks



Source: own figure

2 Nexus between Vulnerability, Early Warning, and Urban Planning

As illustrated in the introduction, the study links the concept of vulnerability and early warning, and links these concepts with the field of urban planning. This chapter provides a summary of relevant conceptual discussions in these fields and identifies the existing gaps (Sub-chapters 2.1, 2.2, 2.3) that will be addressed to and are necessary to define the conceptual framework (Sub-chapter 1.1).

2.1 Conceptual Discussions of Vulnerability

To begin with, the following discussion on vulnerability and its components follows the basic understanding that disaster risk is a composition of hazard and vulnerability of the exposed elements. It argues that the disaster risk or potential impact of hazard events is not solely determined by the characteristics of the hazards, but more by its interaction with the exposed elements which is characterized by vulnerability. Conceptually, disaster risk should include both the likelihood of the occurrence of the hazard events and the severity of potential impacts of the hazard events. As defined by UNISDR (UNISDR Glossary, 2009), the potential impacts may include categories such as losses of lives, health, livelihoods, assets and services, which could occur to a particular community over some specified future time period. In this study, the term disaster risk is used in a quantitative and qualitative manner that is not including any probability measurement. The term of tsunami risk and vulnerability reduction would be used interchangeably, but the emphasis is given to the component of vulnerability and vulnerability reduction, and not the hazard.

2.1.1 Development of Vulnerability Concepts in Hazard and Disaster Risk Research

The concept of vulnerability has been developed and evolved as a response to the paradigm that disasters are “natural” and that disaster risk is solely determined by the “natural” characteristics of the hazards. Vulnerability research was shaped by various epistemological orientations and theoretical traditions, such as physical science, political economy, human ecology, and geography/spatial analysis (Adger 2006; Cutter 1996; Birkmann 2006). An extensive review on vulnerability in the recent IPCC Special Report on Extreme Events (Field et al. 2012) describes the notion of vulnerability as a social construction of disaster risk by “transforming physical events into hazards of different intensities or magnitudes through social processes that increase the exposure and vulnerability of population groups, their livelihoods, production, support infrastructure, and services”. The concept of vulnerability has gained more weight in the disaster discourses starting with many bodies of research and literature on the concept in the 70s and a wide range of literature in the field has been growing especially after 90s (Field et al. 2012; M. A. Janssen et al. 2006; Janssen 2007). To date, vulnerability is applied as a core concept in disaster risk, study of livelihoods and poverty, food security, and climate change (Miller et al. 2010).

In its conceptual development, the term vulnerability provided the basis to understand the interface between social and environmental systems in the context of disasters that firstly focussed on the

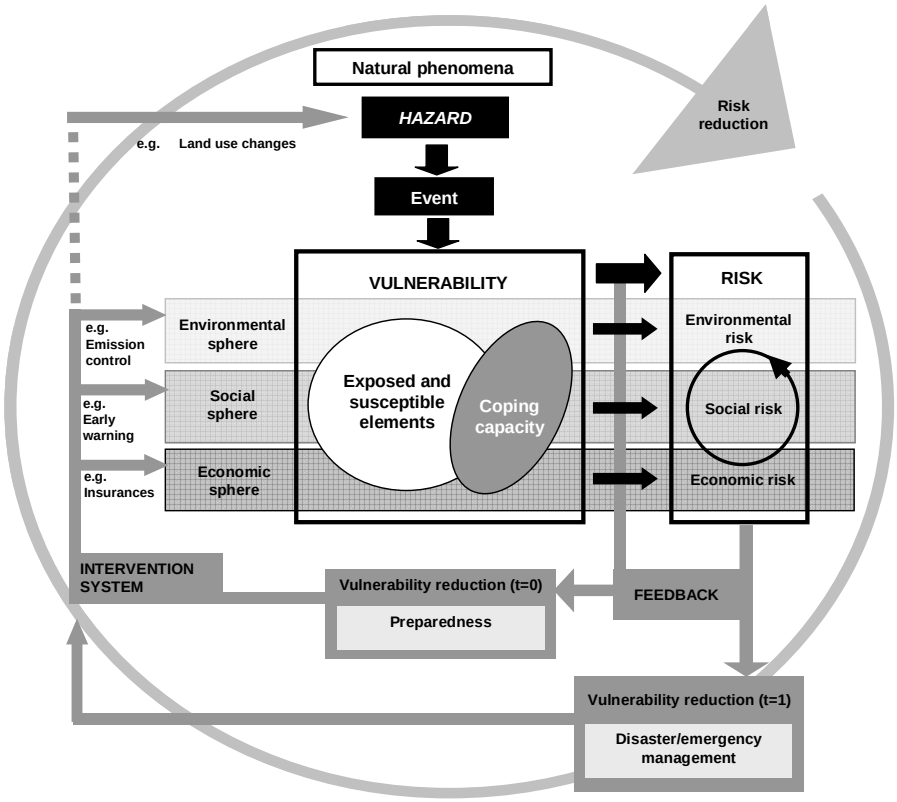
distribution of hazard and human occupancy in the hazardous places (Cutter 1996; White 1974; White and Haas 1975; Burton, Kates and White 1993). This concept also bridged disaster and development, wherein disaster impacts were considered more as a product of social concerns and pressures to be addressed as on-going day-to-day planning (O'Keefe, Westgate and Wisner 1976; Hewitt 1983; Lewis 1999).

Bohle (2001) defines an analytical framework called the double structure of vulnerability that views the external and internal sides of vulnerability. The external side deals with exposure and structural dimensions of vulnerability and risk, which can be explained using human ecology perspectives, entitlement theory, and political economy approaches (Watts and Bohle 1993). On the other hand, the internal side focuses on coping and action to overcome or mitigate the negative effects of economic and ecological change, and combines the conceptual and theoretical discussions in action theory approaches, models of access to assets, and crisis and conflict theory.

Blaikie et al. (1994; updated in Wisner et al. 2004) promoted the necessity to address the root causes of vulnerability. They introduced a widely known Pressure and Release Model (PAR) as an analytical framework to understand vulnerability going through processes of root causes, dynamic pressures, and unsafe conditions, which are linked to people´s access to resources and power. These processes interact with existing hazard events and may cause disasters. This model further emphasizes the strong linkage between long-term developments that may seem "distant" with the resulting unsafe conditions. This requires understanding the broader socio-economic processes linked to various political and economic levels and often uses class-based analysis. In contrast, Cannon suggests that there is another form of social construction of disasters, which could be considered "innocent", which rather involves preference to live in dangerous locations due to the benefits related to livelihood activities (Cannon 2008). In this case, Cannon (2008) emphasizes taking into account the cultural and psychological factors influencing the risky behaviour, so that risk reduction in this sense may involve persuading people to act against what they think is in their own interest and to deny their cultural or psychological interests.

In the recent decade, holistic approaches have been developed that show the multi-dimensionality of vulnerability (Birkmann 2006). One of the holistic approaches of vulnerability assessment is the BBC-Meta-Framework (Figure 2-1) which was developed by Birkmann (2006), based on the works of Bogardi & Birkmann (2004), Cardona (1999), and Cardona (2001). It explores the linkage of the socio-economic spheres (who is vulnerable, e.g. social groups and institutions) and the physical-natural spheres (what is vulnerable, e.g. built environment, critical infrastructures). It also promotes the role of interventions to reduce vulnerability through preparedness before and emergency management during natural disaster events. This also implies that interventions in place influence the vulnerability in the future and have to be taken into consideration in assessing vulnerability.

Figure 2-1 BBC-framework of vulnerability



Source: Birkmann 2006, p. 34, based on Bogardi & Birkmann, 2004; Cardona, 1999; Cardona, 2001

This framework implies various components of vulnerability: exposure, susceptibility, and coping capacity, and link hazard-dependent and independent factors in environmental, social, and economic spheres which contribute to various disaster risks. The components of susceptibility and coping capacity are visualized in the BBC-Framework as overlapping components since they are not always separable. Susceptibility commonly refers to the likelihood of suffering harm and damages and this to some extent also incorporates the available capacity to decrease potential harm and damages (coping capacity).

2.1.2 Strengthening the Use of Vulnerability Assessment in the Development of Specific Disaster Risk Reduction Measures

The development of the vulnerability concept did not originally rest on a well-developed theory and was not yet associated with widely accepted indicators or measurements (Watts and Bohle 1993). As to the mode of development of the concept, vulnerability assessment is conducted in different ways depending on its scientific and practical domains, as well as its context (some extensive reviews can be found e.g. in Birkmann 2006; Cutter 1996; Cutter et al. 2009). It is also still debatable whether vulnerability is quantifiable. Some efforts were done to develop vulnerability indicators that can be used for setting

baselines through mapping distributions and assessing changes, or for evaluating political strategies or specific disaster management measures and monitoring their implementation (Birkmann 2006). It is recognized that vulnerability indicators have limitations in terms of its development and use; thus, they are suggested as descriptive rather than predictive tools, to guide policy development on vulnerability reduction (Cutter et al. 2009).

Many vulnerability assessments develop indicators representing the overall vulnerability, i.e. exposure, susceptibility, and coping capacity of community or systems at various levels (cf. Birkmann et al. 2011; Cutter, Boruff and Shirley 2003, 2008; Fekete 2009; Schneiderbauer and Ehrlich 2006). The existence and effectiveness of disaster risk management and various measures are often included as part of coping capacities either at administrative or community level (Schneiderbauer and Ehrlich 2006; Arakida 2006; Bollin and Hidajat 2006). Cardona (2006) developed a separate Risk Management Index (RMI) to measure risk management performance at country level. While such assessments are important and useful, they only provide general indication of the existing gaps but little practical guidance for developing effective specific disaster risk reduction measures.

Buckle 1998 argued that vulnerability in the context of emergency management has to be linked with the goal of effective delivery of services to the most appropriate target group and meeting needs and that thereby vulnerability needs to be categorized on the basis of the corresponding issues in the particular focus of emergency. Buckle proposed several meta-categories for vulnerability such as management capacity, access to services, cultural attitudes, etc., which should be linked with the dimensions of loss (lives, properties, social, psychological, etc.).

Moreover, Gebert (in preparation) argued that vulnerability consists of lack of various capacities which are linked with specific activity fields of disaster risk reduction and adaptation. He further suggests to link vulnerability assessment with actual disaster management goals and its specific measures, i.e. anticipation, prevention, and preparedness, providing a practical tool for disaster management actors. Generic factors and comprehensive profiles to describe vulnerability are not easily translated into useful information needed by the practitioners and therefore disaster risk reduction measure-specific vulnerability assessment may be a useful tool in this case.

2.1.3 Consideration of Cognitive Factors in Assessing Vulnerability and Disaster Risk Reduction Measures

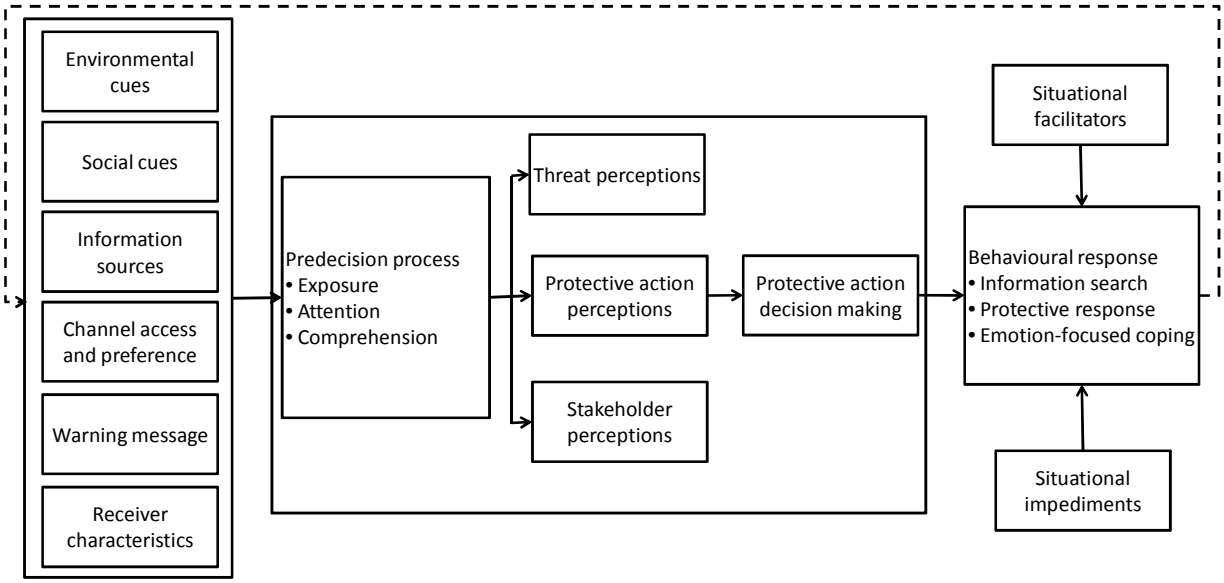
Social scientific works on disaster have long been studying people´s behaviour in case of emergencies and individual and collective perceptions (Quarantelli 1987; Drabek 1986; Lindell and Perry 1992; Tierney, Lindell and Perry 2001). However, such studies were not yet linked with the study of risk (Cardona 2004). Some of the studies to explain people´s behaviour have been developed borrowing the theories of the field of psychology. One of the theories is “Reasoned Action” (Fishbein and Ajzen 1975), which had a significant impact in the development of models to predict behaviour (Lindell and Perry 2004). The theory states that a behavioural intention (that leads to behaviour) is influenced by people´s attitudes

towards the particular action and social norms. This was extended by Ajzen (1991) as theory of "Planned Behaviour" in which the behaviour was linked to the actual control of the behaviour, i.e. the intention to engage in behaviour can be realized only if the behaviour is under volitional control. On the other hand, this also influences the perceived behavioural control which plays an important role in building intention. The theory postulates three determinants of intention: attitude towards the behaviour, subjective norm, and perceived behavioural control.

In the field of public health, the relationship between people´s risk perception and behaviour in reducing or placing themselves in health risks has also been long investigated. One of the widely used theories is "Protection Motivation" theory which was introduced and further extended by Rogers (1983) to explain the cognitive processes that mediate change in behaviour. It describes that the intention of an adaptive (risk-reducing) or maladaptive (risk-increasing) behaviour or willingness to conduct a protective action is a product of four critical cognitive factors: perceived impact, perceived vulnerability, individual efficacy, and perceived efficacy of the particular action. The theory has been applied for persuasive communication of risk (Neuwirth, Dunwoody and Griffin 2000). This theory has also been used in the context of natural hazards, e.g. Martin et al. (2007) used the theory in combination with other models to explain the intention of households to protect themselves against wild-land fires, while using differentiation for people at different stages of decision-making.

Originally, in the context of seismic hazards Lindell and Perry (1992; Lindell and Perry 2000) developed a protective action decision model that hypothesizes protective action intention as a function of attitude towards a behaviour (evaluation of alternative actions) motivated by perception of a hazard, and normative influences to engage in the action. This model was consistent with the theory of reasoned action and originally developed in a study of response to evacuation warnings. It identifies critical pre-decision processes: reception, attention, and comprehension of warnings or exposure or interpretation of environmental or social messages. The information from various sources needs to be heeded and comprehended by the people determined by their expectation, competing attention demands, and the intrusiveness of the information (Lindell and Perry 2004). Subsequently, the information is processed under the influence of various perceptions existing prior to the receipt of information or the event itself. Lindell and Perry (2012) have updated the model to account for three core perceptions – threat, protective action, and stakeholder (Figure 2-2). The threat perception includes expected personal impacts, associations people have from different sources of information about the hazard or prior belief about the hazard, and experience of hazard events considering the ability of people to estimate their exposure. Perception of protective action is related with attitude towards the action and perceived attributes of the action. Perception of social stakeholders encompasses interrelationships among stakeholders, power to ensure compliance, and how the people perceive responsibilities of taking actions. The decision stages consist of risk identification, risk assessment, as well as protection action search, assessment and implementation.

Figure 2-2 Information flow and protective action decision model



Source: Lindell and Perry 2012, redrawn

Furthermore, understanding how the people prioritize the risks they face in everyday life and continuous risk communication is crucial, especially when dealing with low-frequency extreme hazards (Bogardi et al. 2009). Households might be capable of doing very little about extreme infrequent hazards such as strong earthquakes and tsunamis, and rather put emphasis on everyday risks than preparing for low frequency events (ibid.).

Slovic (1987) pointed out the importance of understanding how people think and respond in effectively communicating risk and promoting risk reduction. The perception of natural resources and their associated risks is one determinant factor of how people and various social groups respond to natural hazards. Renn (2008) has also incorporated the evaluation of social concerns in the overall risk appraisal to identify existing behavioural patterns that may, on the one hand, generate secondary consequences due to heightened response to risk or, on the other hand, impede the needed protective actions due to attenuated response to risk (cf. Kasperson et al. 1988). In the context of climate change adaptation, assessment of cognitive factors with regard to climate change risk perception and perceived adaptive capacity in adaptation assessment has also been incorporated (Grothmann and Patt 2005). In the vulnerability assessment to extreme hazards such as tsunamis, the role of cognitive factors and perceptions needs to be recognized or seen as part of vulnerability. The important aspect of cognitive factors which influence motivation and behaviour of the people with regard to reducing their vulnerability is considered crucial. This means that people may perceive the risks that they face differently, and consequently accept the on-going or future interventions according to different levels of acceptance. This may impede vulnerability reduction interventions if not supported by an effective risk

communication or consideration of such issues in developing the interventions. The motivation to reduce risk can relate to acknowledgement of the existing hazard and own vulnerability and the actual constraints faced towards conducting risk-reducing actions. Socio-psychological and subjective perceptual factors which may also influence the decision relating to vulnerability reducing actions are often not addressed in vulnerability assessment and should be incorporated in this study.

2.2 Vulnerability Reduction through "People-Centred" Tsunami Early Warning Systems and Evacuation

2.2.1 "People-centred" Early Warning System and the Issue of the "Last-Mile"

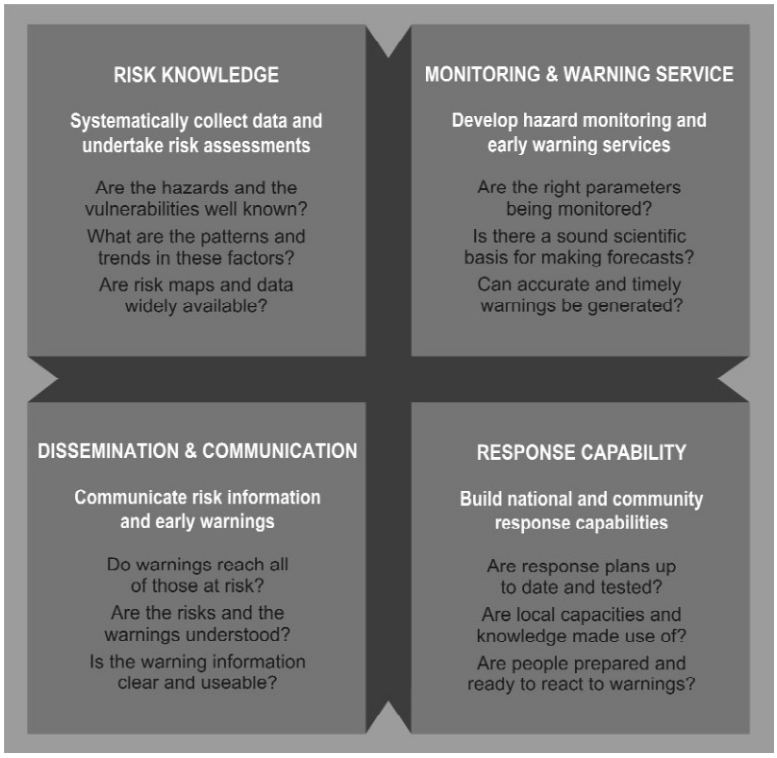
In light of disaster risk reduction, early warning systems are an important means to inform public and other authorities on impending risks, which is directly linked on the one hand with risk identification and impact assessment and on the other hand with disaster preparedness and emergency management. UN/ISDR (2007) defines early warning 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''. This definition encompasses a complete warning chain that not only functions as an interface that delivers information on the natural hazard event, but also integrates risk reducing actions that at risk perform as a response to the warning. It added the phase of anticipated response to warning in addition to monitoring, forecasting catastrophic events, and alert notification, which composed the traditional framework of early warning systems (Villagran de León et al. 2006). This means that early warning should ensure clear messages that reach those at risk, and practiced and knowledgeable responses by risk managers and the public, i.e. it must be embedded in an understandable manner and relevant to the communities they serve ((UN/ISDR 2006a; UN/ISDR 2006b). In the discussion on early warning in the last decade, the adjectival expression "people-centred" has been an essential attribute of early warning. It puts emphasis on the human aspect of early warning and involves systematic approaches in identifying the (vulnerable) people, determining their needs, and involving them in planning activities and enhancing their capacities (Basher 2006).

The UN/ISDR states that a complete and effective early warning should contain the following four elements:

1. Risk knowledge: systematic data collection and analysis that take into account the dynamics and variability of hazards and vulnerabilities; this should support prioritization of early warning systems, response preparation, and disaster prevention activities;
2. Monitoring and warning service: sound scientific basis for predicting and forecasting, reliably operated twenty-four hours a day;
3. Dissemination and communication: clear, useful information that enables proper responses with appropriate regional, national and community-level communication channels ;

4. Response capability: communities´ respect for the warning service and knowledge of how to react to warnings.

Figure 2-3 UN/ISDR elements of early warning systems



Source: UN/ISDR 2006b

The UN/ISDR (2006a) has developed a check-list for the development of early warning systems with regard to the four elements of early warning systems, cross cutting issues of governance and institutional arrangements. With regard to the "Last-Mile", the check-list addresses various aspects to ensure that the warning message is recognized and understood considering the specific needs of those at risk, incorporating the understanding of how people access and interpret early warning, public perception of natural hazard risks, and the enhancement of the preparedness plan and community response capacity. The linkage of the early warning system with the overall development is recognized and UN/ISDR put the issue of governance and participation of local communities in the development of early warning systems in this checklist under cross-cutting issues.

Moreover, Chang Seng (2010) added the importance of communication between the four elements at all times among various actors across scales in the framework, especially since in many cases different actors are dealing with different elements in an isolated manner. Additionally, the communication process within an early warning system during the time when there is no actual event is needed. Chang Seng (2012) also suggested that the early warning model of UN/ISDR (Figure 2-3) seems to suggest active

communication only between the monitoring, warning and response processes and "still lacks the differentiation of the communication process between actors during the time when there are no threatening hazard events or during impeding disaster events". Therefore, it is necessary to differentiate between the two communication processes and to show that communication is a central element across all the components of an early warning system." Strong involvement of actors which are not traditionally identified as dealing with the subject is also required, as well as linkages to sustainable development and community development agendas (UN/ISDR 2007). Here, the early warning system should also be accompanied by "efforts to reduce the fundamental sources of vulnerability" (ibid.).

The promotion of the active role and involvement of various actors is particularly crucial at the local level, where the new demands of disaster preparedness need to be reconciled with other priorities; their value sets, willingness, and priorities determine the extent of implementation of early warning systems and disaster risk management policies (Thomalla and Larsen 2010). The term *"Last-Mile*" has also been used to put emphasis on the linkage between national level (the traditional top-down focal point of early warning systems) and the local level, where the risk knowledge and potential response of the people are dealt with (cf.Birkmann, Chang Seng and Setiadi 2012; Shah 2006).

The first entry point of involvement of and active communication with the local actors is the promotion of programmes and activities such as awareness-raising, education, and the development of an emergency and response plan. However this has to be followed-up with strong commitment at the higher planning and political levels. For instance, planning and budget allocation for sufficient infrastructures and facilities for people´s evacuation as a response to early warning for sudden-onset hazards in densely populated (urban) areas need a strong institutional basis. Even if an alert were issued on time reaching the people at risk and triggering an evacuation, lives would not be saved if infrastructures were not sufficient (e.g. evacuation roads and shelters) to enable people to implement the action they are supposed to conduct. In fact, the development of the endangered areas often does not consider whether or not the existing early-warning system and capacity of emergency management can cope with the increasing exposure and lack of response capability in the areas. Since actors which traditionally associated themselves with early warning-systems are mostly the emergency planners, the temporal planning cycle in an early-warning system tends to be rather short-term oriented (only concerning emergency response and relief). As a consequence, the early warning systems developed are rather stand-alone systems not integrated in an institutionalized manner within the whole development planning scheme. Therefore, the basic argument of this study is that the early warning system should continuously communicate with the other fields and be integrated in the overall development.

2.2.2 Enhancing People´s Early Warning Response Capability: Focusing on the "*Last-Mile"*

The UN-ISDR´s (2006b) global survey of capacities and gaps for early warning systems found that warning dissemination and response capability were the still weak despite of the advancement of the technical

monitoring and warning service. Overall, it identified several failures that impede response to warnings, namely lack of planning and coordination at the national and local levels, lack of awareness for early warning response, lack of evacuation drills, limited understanding of vulnerabilities and the public´s concerns, but also inadequate plans for evacuation and emergency shelters for population.

In recent years, early warning systems have been improving also in terms of more consideration of risk assessment up to promoting response capability, i.e. people´s reactions to early warning have gained more weight when considering the development of early warning systems (S. Dannenmann, personal communication 30.03.2012). Villagran de Leon (2011; Villagrán de León, Weerawarnakula and Chandrapala 2006) also discussed the example of Sri Lanka and utilized information from vulnerability and risk assessment for strategies such as who to warn first, prioritization of evacuation routes, and required community preparedness activities. More studies are needed to get a better understanding of the specific needs of the people at risk and their response capability when improving early warning systems.

Access of the people at risk to the early warning information requires the availability and effectiveness of various dissemination media. Various studies have shown that the target people are not passive and uniform information receivers, i.e. their individual characteristics, their needs for information and behaviour in searching information need to be considered (Zemp 2010). Study from Zemp (2010) on flood events showed e.g. that the utilization of various media in different disaster phases differed. Dissemination of early warning can be through formal and informal media. TV and radio have been mentioned in literature as the most effective, also dissemination media which are supported by informal notification, e.g. through mouth to mouth propaganda (King 2008; Sorensen 2000, 1991).

Effectively disseminating the warning information and evacuation instruction does not necessarily mean that all people would evacuate or be able to conduct timely evacuation. Evacuation behaviour is a complex theme which involves not only physical (evacuation route and places) and institutional aspects (e.g. SOP, emergency plan), but also socio-psychological and socio-organizational aspects (Santos and Aguirre 2004). Bhatti (2001) suggests that the early-warning chain consists of five phases: receiving the warning, understanding the content of the warning, personalizing the warning and its sources, verifying through other sources, and reacting to the warning. Mileti and O´Brien (1992) and Sorensen (2000) share similar phases and also suggest that these phases are influenced by individual characteristics (age, gender, education, etc.) as well as characteristics of the warning information (sources, repetition, etc.). Gregg et al. (2007) describe these response phases as “how the people perceive the risk and shape their behaviour in every warning received”. Moreover, in studies on evacuation, e.g. in case of hurricanes, by Riad and Norris (1998), it was found that different communities interpreted the warning and the danger in different manners, and the decision to evacuate derives from both individual factors and social interactions. Other studies (e.g. Roy Lachman, Maurice Tatsuoka and William J. Bonk 1960; Baker 1991;

Lindell, Lu and Prater 2005; Tierney, Lindell and Perry 2001) provide evidence of cases where warning and evacuation instructions were not always followed by evacuation and influenced by various factors.

In the process of understanding the warning, knowledge generated from previous experience with the hazard events, formal and informal education, as well as own knowledge, may play a role (Rajib Shaw, Koichi Shiwaku Hirohide Kobayashi and Masami Kobayashi 2004). However, knowledge is also often not directly translated into action and not the only determining factor; e.g. in a study conducted by the Indonesian Institute for Science (Hidayati et al. 2006) that measured household preparedness level to tsunamis, it is shown that although there were many households with a good level of knowledge about tsunamis, only a few had prepared a concrete emergency and preparedness plan.

There is also another convergent factor that relates to knowledge and experience. Reflecting on the case of the recent tsunami event in Japan where a large proportion of the people, especially the elderly, did not evacuate due to "cognitive bias" (Parashar et al. 2011; Muhari et al.), that they associated the event with their past experiences with tsunamis of lower magnitude and had underestimated the event ("false sense of security"). This shows that risk perception, shaped prior to the event, is crucial. Therefore, specific information such as warning level, height of the potential tsunami wave and existing protection structures, also needs to be included in the early warning message. The design of the warning message can significantly affect the public's response (Sorensen 2000) and reduce vulnerability thus less potential for losses of life.

An effective early-warning should enable the translation of a warning message to appropriate action in a specific social context, but it should also ensure the provision of necessary infrastructure and facilities taking into account the specific needs of the people at risk. Different population groups may have different evacuation capability, depending on existing facilities (vehicles, transport arrangements for emergency) or their physical capability (pedestrian evacuation) to conduct evacuation. Some studies have found that demographic factors such as age and gender determined the difference in fatality rate (Rofi, Doocy and Robinson 2006; Oxfam 2005; Birkmann et al. 2007; Guha-Sapir et al. 2006). Some evacuation modelling differentiates running velocities of different population groups or household characteristics (Sugimoto et al. 2003; Klüpfel 2003).

Moreover, evacuation behaviour also affects the overall duration of evacuation. Zelinsky and Kosinski (1991) provided comprehensive compilation data and analysis of urban evacuation. Here they explored various case studies to describe the important aspects that have to be considered with regard to evacuation. Firstly, it relates to early warning and emergency planning, namely adequacy of warning and the degree to which the governmental agencies had anticipated disasters and made contingency plans. Secondly, it addresses the participation of evacuees and their characteristics (number and proportion compared to people at risk, categorization by age, gender, etc.). Thirdly, people´s behaviour related to evacuation procedures and facilities such as distance travelled by evacuees, distance-decay effect in

evacuation journeys, mode of transport, types of destinations, timing and duration of evacuation return, convergent behaviour, and security issues like the danger of looting.

Furthermore, one has to understand the existing norms and values and prior beliefs of the community associated with the particular risk. Are they aware of the risk? How do they perceive it? What kind of information do they receive prior to issuance of the early warning? How do they relate it with their life values, concerns, and priorities? Such issues are strongly linked with human cognition as discussed previously in Sub-chapter 2.1.3.

2.3 Strengthening the Linkage of Urban and Emergency Planning in Vulnerability Reduction

Disaster risk reduction is defined as the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events (UN/ISDR 2009). With the early recognition of the crucial link between disasters planning and development planning in contrast to the traditional approach focusing on emergency response (Lewis, O'Keefe and Westgate 1977), urban and spatial planning is playing a growing role in disaster risk reduction.

Urban areas consist of physical and spatial elements that can be categorized in main functional areas: settlement, working and shopping, public use, open space, transportation and supply (Albers and Wékel 2011), which offer people space for their basic and leisure activities. Spatial use and functions in the urban areas influence urban growth and the social setting of urban areas which in turn shape the exposure and vulnerability of the population to natural hazards. Due to the dynamics in urban activity patterns, spatial-temporal variation of population is a crucial component regarding vulnerability. The population of the city will be concentrated in the areas where more city services and infrastructures are provided. The exposure increases with the intensity of the population in the dangerous areas and the dynamics in terms of temporal scale, which ranges from long- and medium-term of planning periods (due to urban development and migration towards the urban areas from the hinterland) up to daily basics (due to daily mobility to and from the dangerous areas). (See also Birkmann, Chang Seng and Setiadi 2012; Geurs and van Ritsema Eck 2001). Moreover, the spatial physical organization of urban areas determines the allocation of built areas in contrast to buffer zones, green areas, open areas for evacuation, etc., which shape the disaster risk.

Urban planning formulates the elements of a city, the structures and functions within urban areas, and develops approaches to plan and regulate its development. It involves description and systematization of objectives, fields of actions, how to assess them and link them with planning practices, which relates to theories of planning as well as decision-making and political planning process (Fürst and Scholles 2008). Urban areas contain multiple demands that need to be negotiated and sorted in priorities considering the limited available resources. This also applies for the allocation of land use, where the use of limited

space is highly contested. Albers and Wekels (2011) divided urban planning in two categories: the organization of the urban functional structures and the urban physical morphology. One of the tasks is visioning city development, which can follow the city growth and extension of the built environment as well as network and supply systems while maintaining the balance and functions (ibid.). Visioning of the city form involves formulation and assessment of objectives and various, sometimes conflicting, options. In building the urban areas, sustainability is often used as a general principle, which contains social, economic, and ecological dimensions. Furthermore, Greiving (2002) suggested - in recognition of the strong linkage between disaster and development - to add one more dimension, namely disaster resilience, which is in close interaction with the other original three dimensions. This is an important acknowledgement of taking into account disaster risk reduction as one important objective of development.

The scope of urban planning in this study focuses on the urban spatial planning, which formulates the allocation of spatial use (land use plan) and spatial structure adjusted to the context of spatial planning in Indonesia (this will be discussed specifically in Chapter 3, but described generally in this section). Focusing on the spatial aspect of urban planning, Greiving (2002) describes the task of implementing the given social and political objectives spatially, providing a platform to assess benefits versus risks and consequences spatially, and find ways to influence them. “Objective” risk analysis is an initial part of the whole process, which is followed by decision-making process to assess and develop possible mitigation options. In this regard, Greiving mentions the further task of spatial planning to communicate the existing (and perceived) risks. Additionally, Fürst & Scholles (2008) mentioned a strong function of planning to mediate network between various actors who oftentimes work and decide in isolation of each other as well as to support the social learning process in particular fields of action. Within the decision process on the use of land, consensus on the acceptable risk has to be reached among the various stakeholders.

The Hyogo Framework for Action (UN/ISDR 2005) stated explicitly that spatial or land use planning is one of the key activities addressing the underlying risk factors. It mentioned several related key activities such as incorporation of disaster risk assessment in the management of disaster-prone settlements or major infrastructure projects, land use policy and planning, as well as building codes and standards. Jha et al. (2013), promoted risk-based land use to identify safest areas to prioritize immediate investments in urban development and infrastructure projects, and to influence the location, type, design, quality, and timing of development. Basic information and methods are needed to assess risk spatially and spatial planning should play a role in regulating (prohibiting or specializing) land use in dangerous areas to minimize the intensity of natural events as well as its impacts (Fleischhauer 2004). Kötter (2005) suggested various strategies of disaster risk reduction in the context of urban planning, such as introducing models of sustainable urban growth, zoning regulation, definition of standards, integrating risk assessment in the planning process, and good governance and land policy. Kötter (2003) also mentioned other themes of contribution of spatial planning and land management, such as the provision

of systematic information about natural and environmental risks for monitoring systems (early warning), and the support in infrastructure and databases for emergency planning and risk management. Greiving and Fleischhauer (2006) also suggested that local land use planning plays a decisive role in integrating emergency response related interests within settlement and infrastructure activities, e.g. accessibility of residential areas by the emergency units and allocation of emergency facilities.

In disaster management, the different phases of a disaster are normally used to categorize various interventions and measures. The disaster cycle generally consists of phases or points of interventions: prior to disasters, namely prevention (avoidance of adverse impacts of disasters), mitigation (lessening impacts), and preparedness (capacities to anticipate, response, and recover, including an early warning system), and after a disaster, notably response (emergency services) and recovery (restoring facilities and livelihoods). The following Table 2-1 summarizes the various roles of urban spatial planning identified in literature study according to these disaster management phases. In spite of the dominant role of urban planning and disaster prevention/mitigation and recovery phases, the role of urban planning in supporting disaster preparedness and response is also indicated.

Table 2-1 Mainstreaming disaster risk reduction in urban planning – Role of urban planning in disaster risk management

Mainstreaming of DRR in the urban planning process - Role of urban planning in DRR	Prevention/ Mitigation	Preparedness	Response	Recovery
Formulation of goals and criteria in urban development planning				
Consideration of natural hazards in planning.	x	(x)	(x)	x
Consideration of the social characters of the current and future populations and vulnerability reduction.	x	(x)	(x)	x
Consideration of disaster resilience in general principles of urban development.	x	(x)	(x)	x
Mainstreaming disaster risk considerations into planning procedures for major infrastructure projects: design criteria, social, economic, and environmental impact assessment.	x	(x)	(x)	x
Provision of information for planning – data collection and analysis				
Analysis of the interrelations between the spatial influences and the environmental disasters to improve or renew the models of spatial development.	x	(x)	(x)	x
Provision of a systematic framework for assessment and mapping of hazard and	x	(x)	(x)	x

disaster risk.				
Multi-objective assessment, risks and benefit assessment in spatial planning.	x	(x)	(x)	x
Support through a database for emergency planning and risk management.	x	x	x	x
Disaster risk reduction tools/measures				
Land use zoning,	x			x
Regulating (prohibiting or specializing) land use in dangerous areas to minimize the intensity of natural events as well as its impacts.	x			x
Revision or development of new building codes, standards for disaster-resistant structures.	x			x
Integration of emergency response related interests within settlement and infrastructure activities, e.g. reachability of residential areas by the emergency unit and allocation of emergency facilities.		x	x	
Support in infrastructure (evacuation routes and spaces).		x	x	
Monitoring				
Develop and promote the use of guidelines and monitoring tools for DRR in the context of land-use policy and planning.	x	(x)	(x)	x
Mediator role				
Risk communication	x	(x)	(x)	x
Provide the platform for consensus on land use allocation among various stakeholders and enhancing exchange / social learning processes.	x	(x)	(x)	x

Source: own figure based on literature review

The importance of integrating emergency and urban planning has long been recognized. Britton & Lindsay (1995) urged that not only emergency managers have to deal with coping with the risks after an urban development plan has been made, but also urban planners have to consider the aspects of emergency management in their planning. Urban planners have to take into consideration the existing natural hazards, the social characters of the current and future populations, as well as ameliorate the conditions that make them vulnerable (ibid.). The effectiveness of linking both domains has also been recognized as part of institutional dimensions of vulnerability (Birkmann 2008).

UN/ISDR (2009) defines emergency management as the organization and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps[2]. Alexander (2009) described the process of sustainable emergency planning and mentioned that there has been only little connection made between urban planning and emergency planning, although linking both would be significantly advantageous, e.g. control of growth in dangerous areas, maintenance of lifelines and preparation of areas for shelters. Alexander went further saying that emergency planning should integrate the actions of different services, functions, jurisdictions and levels, and be compatible with the legislation of other areas. Although it only focuses on disaster response through resource allocation and coordination of various actors in emergency situations rather than on a more proactive feedback to disaster risk reduction and other pre-disaster phases, it gives the first clue of the importance of linking emergency planning with other fields.

In spite of the recognition of the important linkage between urban and emergency planning, the practice has been challenging. Berke and Smith (2009) described various political and economic reasons for the failure of integrating disaster mitigation in the local planning, or the *land use management paradox* (Burby 2006), including lack of recognition that hazard mitigation planning falls under the responsibility of the local land use planners and not local emergency management officials, and lack of incentives for mitigation measures. One other challenge is also lack of coordination or instruments to provide a platform between emergency and urban planners, as in fact both domains often work in isolation of each other. There is also a significant difference in the time horizon of planning; the emergency planning mostly focuses on short-term planning and urban planning on the long-term.

Greiving and Fleischhauer (2006) discussed how the elements of risk assessment and management can be incorporated in the decision process about spatial plans. The planning and decision process consists of three main parts, namely problem definition, data collection and analysis (scientific basis), i.e. considerations of the information basis to decide on specific plans or programmes (political decisions), and feasibility and possible hindrances in implementation (implementation process). Within this framework, considerations of natural hazards, vulnerability, and risk become explicit in the planning goal formulations, are assessed based on scientific requirements, bargained with various competing goals and constraints in the overall spatial planning process, as well as continuously monitored in the implementation. On the other hand, emergency planning – here represented by the component of disaster control – should deal with the remaining risk resulting from the decision process of the spatial planning (such as correction of land use or maintenance of status quo). Also here, the linkage and feedback of disaster control within the risk assessment process seems to be weak. This may imply that emergency planning is a rather passive agent and that there is lack of communication between

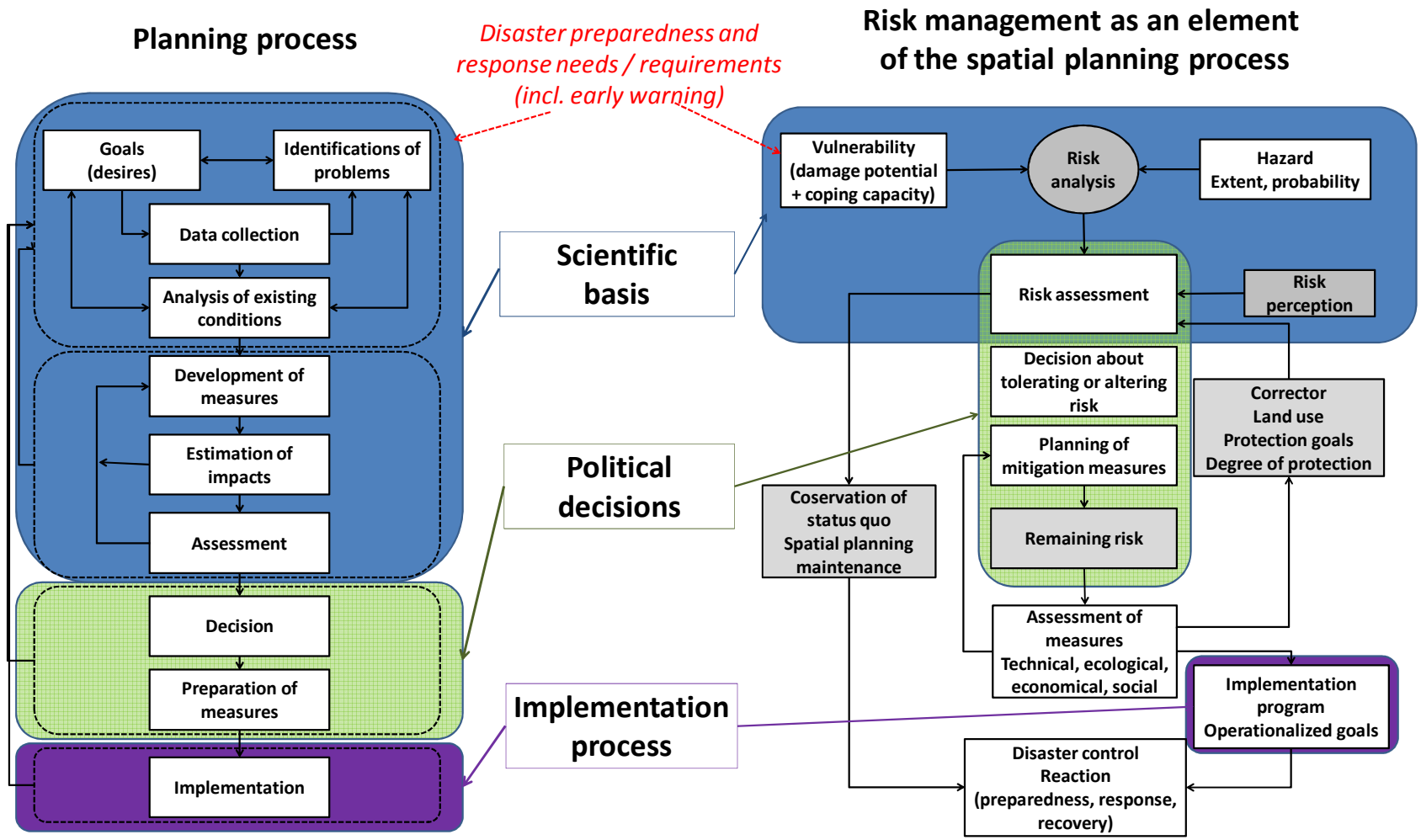
[2] The expression “disaster management” is sometimes used instead of emergency management.

emergency and spatial planning in the planning goal formulation and the risk assessment stages. Both inputs related with emergency and spatial planning and possible measures to mitigate risk have to be linked and assessed. Figure 2-4 visualizes Greiving and Fleischhauer´s framework but also points out the need to include the concerns related with disaster preparedness and response in risk assessment and development of measures that are relevant for both emergency and urban spatial planning.

Moreover, so far, risk assessment and management in spatial planning have mostly dealt with the identification of hazards and hazard-prone areas to guide future land-use planning so that vulnerability-related information was considered less important compared to hazards (Greiving 2002; Greiving and Fleischhauer 2006). Greiving and Fleischhauer (2006) acknowledged the importance of integrating vulnerability information in the overall disaster risk management that includes all structural and non-structural measures including preparedness and response elements, but viewed land use planning as a rather passive instrument. Bahlburg (2003) also mentioned similar limitations of spatial planning, in which it has most influence on new land use but only little – if any – on the land use already in existence, requiring that landowners be willing to comply with the assigned land use (or change of particular land use) establishing an institutional set-up for compensation.

Vulnerability assessment informs urban planning about the current conditions (and to some extent also hints at potential future conditions) that will exacerbate the potential impact of hazard events; therefore, its use in urban planning needs to be promoted. Vulnerability information is especially important in determining and prioritizing areas to restrict development or revise land use allocation, where the potential impact of already “low” or “medium” hazard events may be high due to the low capacity of the people and facilities currently located there. Also, as already pointed out in the previous discussion (Table 2-1), urban spatial planning plays a decisive role in supporting disaster preparedness and response, such as providing sufficient infrastructure and ensuring integration of emergency response related interests in settlement and infrastructure planning. Such needs and concerns need to be addressed from the beginning of the planning and decision process and require more interaction between both domains. Instead of merely compensating the existing risks, emergency planners should be more involved in the overall planning process and provide feedback to the existing plans that may have the potential to increase risks and/or exceed the threshold of the existing emergency response capacity.

Figure 2-4 Risk assessment and management as planning process



Source: Greiving and Fleischhauer 2006, p. 116; redrawn with own annotation

2.4 Assessment Framework on Early Warning Response Capability for Urban Planning Interventions

The following main points have been identified in the previous conceptual discussions (Sub-chapters 2.1, 2.2, 2.3) which are relevant for this study:

- Potential use of vulnerability assessment for early warning interventions: the study argues that vulnerability assessment should also identify specific factors causing the lack of people´s response capability linked to early warning interventions to derive practical recommendations at the local level.
- Need for further incorporation of human cognitive factors in vulnerability assessment: the study argues that issues of perception related with specific hazard and risk reduction measures are crucial and are part of the decisive intrinsic factors that influence the effectiveness of vulnerability reduction in the long-term.
- Limited linkage of the vulnerability concept with assessment with urban planning: the study argues that vulnerability assessment is an important element that should be integrated in urban planning, especially considering its continuous planning cycle.
- Potential use of vulnerability assessment as a tool to enhance synergy between emergency and urban planning, In this respect, the study argues that vulnerability assessment which is linked to disaster preparedness, such as early warning, may indicate specific needs required to be incorporated in the long-term urban planning, thereby enhancing its synergy with emergency planning.

In the attempt of addressing those points in the conceptual framework, this section describes how the concept of vulnerability is applied in the context of tsunami early warning systems at the local level and linked with the urban planning scheme. Initially, the term vulnerability in this study was defined based on the UN/ISDR (2004) internationally accepted definition of vulnerability:

"The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards; for positive factors, which increase the ability of people to cope with hazards."

This means that people or the community are put at the centre, but the vulnerability assessment considers various factors (not only human conditions) that influence their susceptibility and coping capacity. Vulnerability in the context of this study does not encompass the overall vulnerability to tsunamis. Rather, it is formulated in the context of disaster preparedness to meet the objective of an effective people-centred early warning at the local level and limited to thematic areas which are directly relevant to the interventions and specific goals of tsunami early warning. The potential impact or risk of

concern is loss of lives (not including livelihoods), which should be reduced by early warning and timely evacuation to safe areas.

Despite the controversy, whether exposure may be treated as an independent component showing relationship between the system and the hazard component (Gallopin 2003; 2006), the study views exposure as part of vulnerability which represents an inventory of elements in an area in which hazard events may occur (Field et al. 2012; UN/ISDR 2009, e.g. the existence of various social groups in the endangered area. This is important to show on the one hand that exposure analysis includes the differentiation of exposed people by their susceptibility and response capacity (who, where, and why) and, on the other hand, to address the issue that development and intensification of elements (e.g. urbanization) in the hazardous areas would increase the overall vulnerability of the people if there are no sufficient mechanisms in place to counteract those aggravating effects. In this context, this study proposes a modified definition of vulnerability as:

"The conditions which influence the level of exposure and capability of people to respond to the warning and conduct appropriate evacuation, and in the long term, to change those conditions and enhance their response capability."

The BBC-Framework (Sub-chapter 2.1.1) is helpful as a basis for the development of the conceptual framework in this study because it provides guidance in visualizing the process of reducing vulnerability and altering its components as a feedback loop system linked to various interventions. Extending the basic ideas of the BBC-Framework[3], the vulnerability in the context of the tsunami early warning as defined above was incorporated to the model, (Figure 1).

The first block visualizes the current response capability of the people which is influenced by dynamic exposure and factors playing a role in the stages of early warning delivery at the local level up to people at risk taking action, namely access to warning, evacuation behaviour, and access to safe places. The component of dynamic exposure is visualized in a box that covers also the other components since it also determines the quantity and social constellation of the other components.

Dynamic exposure

The exposure of population to potential major tsunamis is strongly determined by the spatial distribution of the same. In the context of urban areas, the exposure of the people or population groups is dynamically determined by the spatial setting of the urban areas (the locations of various city functions where people are concentrated) and their daily activity patterns. The level of exposure will be higher the

[3]Initial vulnerability framework was developed jointly with the project partners in the first phase of the "Last-Mile – Evacuation" research project in Birkmann et al. (2008) and its further development received inputs from Gebert (2011)

more intensive the activities of the people in the potentially affected areas of the city are. Besides the settlement density, it is also important to consider the spatial distribution of city services and facilities. Especially in urban settings, the spatial and temporal dynamics are often high. This is also linked with the mobility of the people to and from dangerous areas to conduct activities and results in dynamic exposure. The daily activity pattern of various population groups and household members may differ according to their role in the household and community as well as their available resources. Hägerstrand (1970; Pred 1981) suggested that every individual has a certain available time and resources that would limit their mobility. According to this concept, the mobility of the people is a combination of the availability of individual resources, locations as well as the accessibility of the locations, which is strongly linked with the urban land use (Hägerstrand 1970; Oßenbrügge and Haferburg 2005).

Access to safe places

Availability of evacuation routes and places which are accessible to the people exposed considering the short time frame of a tsunami arrival is very important. In the context of densely built cities, especially the street network and open areas passable by the people play a big role. In case of long horizontal evacuation distance, additional facilities like vertical evacuation shelters may be needed.

Access to the warning

More directly related to the early warning dissemination is the availability of media that can be used to deliver early warning and relevant information. Also, how these media are utilized in case of emergency determines the effectiveness of warning dissemination.

Evacuation behaviour

This component encompasses the understanding of and response to the early warning translated in the people's evacuation behaviour: whether they sense the urgency and decide to conduct evacuation and how are they going to do it. Such factors can be observed in past events and are related to the people's prior knowledge about evacuation and their perceptions (related with the next component).

Issues of perceptions related with vulnerability reduction

The separate component below people´s response capability addresses the issues of perception and links the above components with various interventions to reduce vulnerability. This implies that vulnerability reduction actions will be filtered out by the people depending on their subjective judgements. The attitude and motivation of the people to conduct protective or vulnerability reducing actions is influenced by various cognitive factors and may differ depending on socio-economic characteristics.

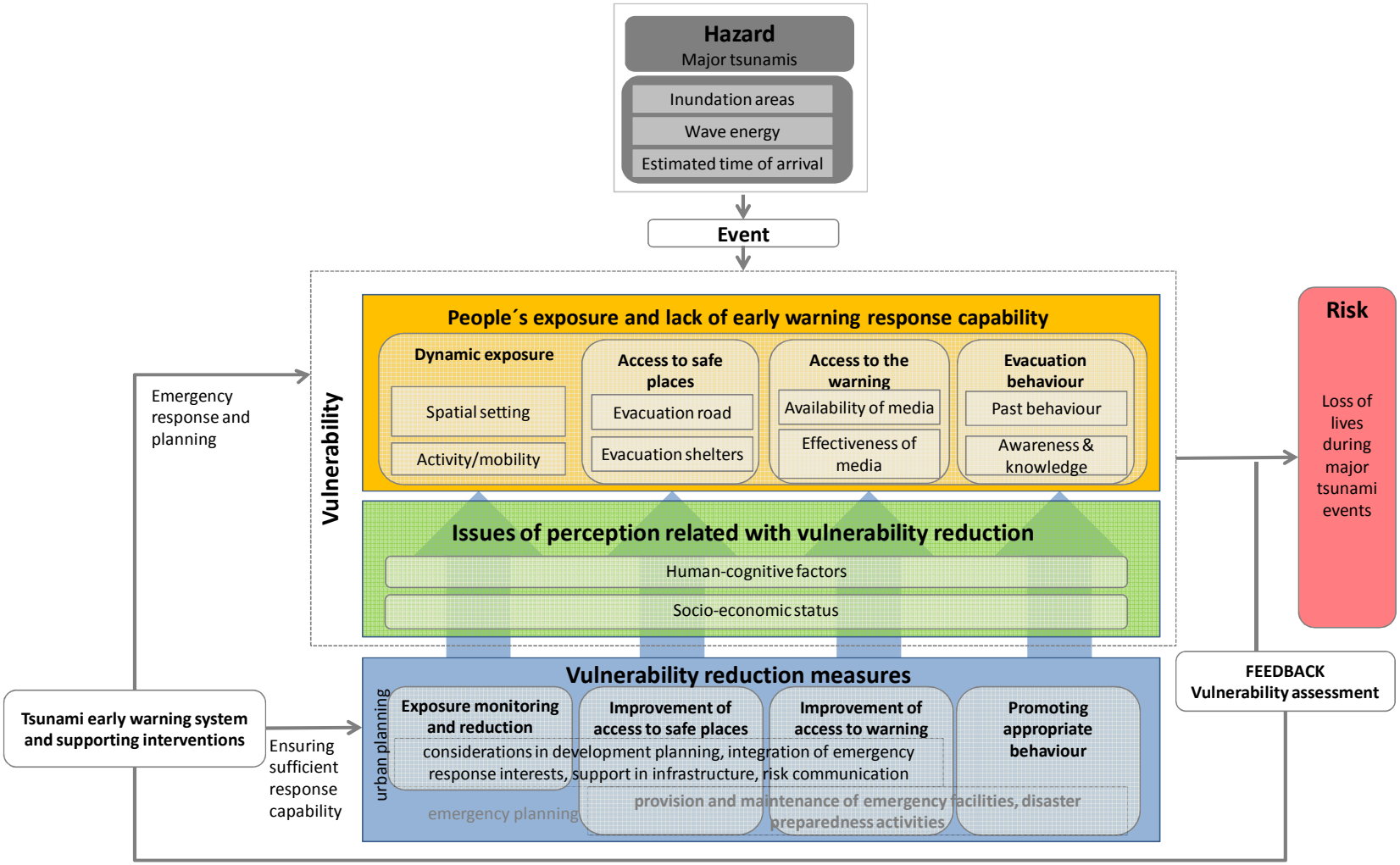
Vulnerability reduction measures

This block represents various interventions that are necessary within urban planning, which should be planned and implemented in strong cooperation with emergency planning. The role of urban planning is crucial in various thematic components of the people's vulnerability. As identified in the Table 2-1, the

role of urban planning are firstly in the considerations of hazard and risk in the overall formulation of goal and planning, integration of emergency related response interests, and support in infrastructure. In this scope, linkage of urban spatial and land-use planning in controlling growth and use in the exposed areas considering the evacuation capability of the people as well as providing space and infrastructure for evacuation routes and facilities were examined. The link between urban planning with promoting appropriate evacuation behaviour, as well as emergency planning with exposure reduction, is initially assumed to be indirect but will be explored further in the case study.

Overall, this feedback loop system shows continuous changes of the components that should be dealt with in various interventions. It emphasizes the necessity of continuous vulnerability assessment and reduction.

Figure 2-5 Conceptual framework of vulnerability in the context of tsunami early warning and evacuation



Source: own figure, initial ideas from BBC-Framework, Birkmann et al. (2008) and Gebert (2011)

3 Context of the Tsunami Early Warning and Risk Reduction in the City of Padang, Indonesia

After the Indian Ocean Tsunami event in December 2004, the attention of the international scientific and humanitarian community was drawn to the other endangered areas where major earthquakes and tsunamis may occur in the future. The city of Padang, West Sumatra, Indonesia (Figure 3-1), was one point of concern, due to its huge seismic potential in the near future and the dense development of its low-lying coastal areas. This chapter provides an overview of the context of Indonesia but particularly the city of Padang encompassing the existing earthquake and tsunami hazards, the spatial development of the city, as well as the institutional setting of the tsunami early warning system and urban planning in the area. This prior knowledge is useful to embed the conceptual framework developed in Chapter 2 and further on interpret the assessment results within the local context.

Figure 3-1 The city of Padang, West Sumatra, Indonesia

Source: Google Maps, 2013

3.1 Existing Earthquake and Tsunami Hazard in Padang

The seismic hazard in Indonesia is generally high. Indonesia is located between the Pacific ring of fire and the Alpide belt and is considered as one of the most seismically active areas in the world (United States Geological Survey (USGS)). The existence of seismic and tsunami risks in many regions in Indonesia has long been recognized, although not much considered in planning. Hamzah et al. (2000) compiled and analysed the historical earthquake and tsunami data in Indonesia and suggested that the tsunami occurrences correlate with the seismo-tectonic characteristics of the region. Furthermore, they found

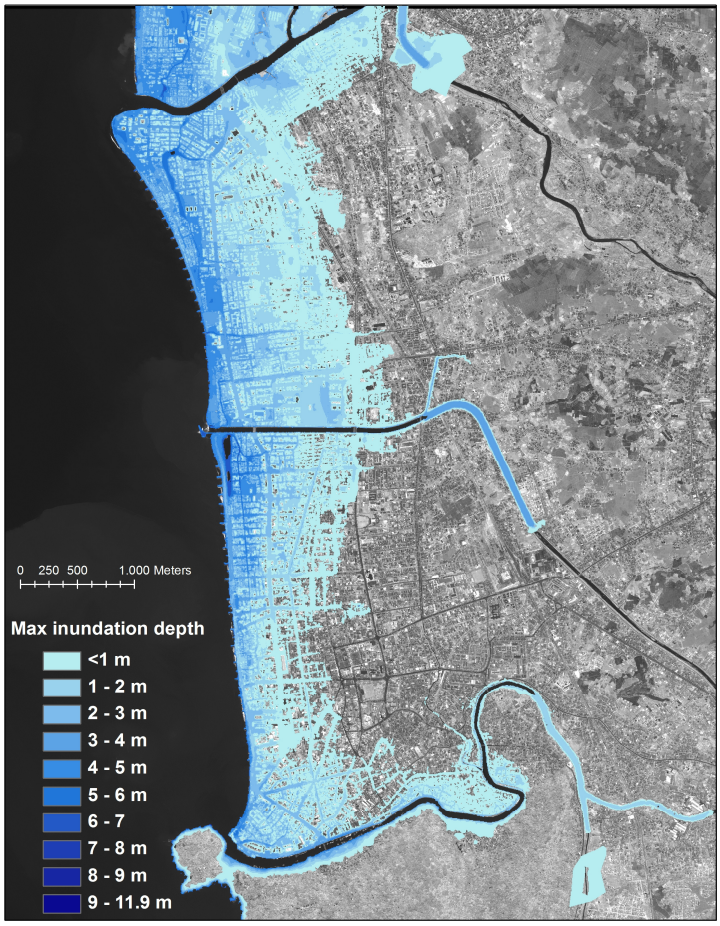
the average interval of tsunami occurrences in various zones in Indonesia ranging from 10 to 15 years up to 15 to 20 years (ibid.).

The city of Padang is located above the Sumatran subduction zone, which is the contact platform between the Indian-Australian and the Eurasian plate. The contact accumulates compressed energy over decades to be released through great earthquakes which may trigger major tsunamis. The historical earthquake-triggered tsunami events on the Mentawai area close to the city of Padang occurred in 1797 and in 1833 (Borrero et al. 2006), and similar events are likely to occur anytime within a period of decades (Sieh 2006). Consequently, the city of Padang is counted as one of the most tsunami threatened areas in the near future (Borrero et al. 2006; McCloskey et al. 2008; McCloskey et al. 2010).

Since the Indian Ocean Tsunami event in 2004, there were several strong earthquakes (with no major tsunami occurrence) happening in the region that affected the city of Padang and intensified the concern about potential future tsunamis. Those events were the Nias earthquake in March 2005 with the moment magnitude (M(w)) of 8.6, the Bengkulu earthquake in September 12, 2007 with M(w) of 8.4, 7.9, and 7.0 (Ambikapathy et al. 2010), and the Padang earthquake in September 30, 2009 with M(w) of 7.6 (McCloskey et al. 2010).

The fact that about 43% of the population or 340.446 inhabitants of the city dwell in coastal areas up to 5 meter above sea level which are highly exposed to potential tsunamis (Hidayati et al. 2006), would magnify the disastrous impact of potential tsunamis. Based on the studies on tsunami scenarios in Padang (McCloskey et al. 2008; Taubenböck et al. 2009a), a tsunami wave arrival is estimated at an average of 30 minutes, ranging from 23 – 65 minutes (personal communication with AWI, cited in Taubenböck et al. 2009a), after the strong earthquake occurrence. The modelled maximum tsunami inundation covered some of the low-lying part of the city and showed considerable inundation depths in some areas (Figure 3-2). In this case, very little time is available for delivering an early warning and for the people to evacuate themselves to the safe areas, so that an evacuation for all the exposed inhabitants would be very problematic. Therefore, an effective tsunami early warning and evacuation system is crucial.

Figure 3-2 Modelled highest tsunami inundation depth in Padang



Source: Franzius Institute Hannover/Last-Mile, 2010

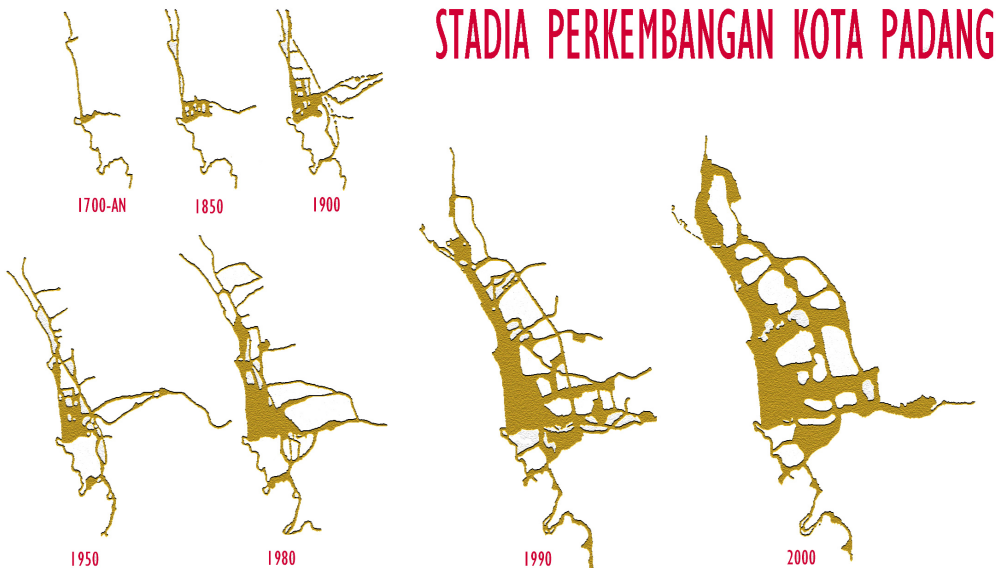
3.2 Spatial Development and Consideration of Tsunami Hazards in Spatial Planning in Padang

Padang is one of the oldest cities in the western coast of Sumatra and is the capital city of the province of West Sumatra. It is a medium-sized coastal city with a dynamic urban system and on its way to becoming a metropolitan city. The city of Padang initially only covered an area of 33 km^2 and was composed of three sub-districts (*Kecamatan* Padang Barat, Padang Selatan and Padang Timur). After issuance of the Law Nr. 5 in the year 1979 (UU 5/1979) and Government Regulation Nr. 17 year 1980 (PP 17/1980), the area of the city was extended to 694.96 km^2, composed of 11 sub-districts and 193 villages (*Kelurahan*). Since 2004, the number of villages in the city of Padang has become 104. The city has 833,562 inhabitants and an annual population growth rate of 1.57% (BPS Padang in Figures 2010). The western part of the city is a low-lying coast with elevation between 0-15 meters above the sea level directly facing the Indian Ocean. It has about 68 km long coastline (without counting the small islands), with the

water authority covering 19 small islands. Of the 694.96 km^2 total administrative area, only less than 10% is constructed while the rest is used for agricultural, forestry and other non-physical activities. Nevertheless, the main employment sectors of the inhabitants remain trade and services.

The development of the city of Padang was shaped by political and economic activities originating from the area of the *Muaro* river delta during the colonial time as well as its geographical conditions that limit development in some areas like the hills of Padang. There are two previous studies that provide rich information and a systematic overview of the chronological development of the city of Padang from the 17th century up to the year 2003: *Patches of Padang* from Colombijn (1994) and *Morphology of Padang* from Zaidulfar (2002). The description in this sub-chapter mostly refers to these studies.

Figure 3-3 Development stages of the city of Padang



Source: Zaidulfar, 2002

The Figure 3-3 from Zaidulfar (2002) shows how the city has developed from the point close to the river mouth (*Muaro*) towards the east and the north (Figure 3-3). Prior to the 17th century, Padang city was referred to as a port town between cities in the western coast of Sumatra. Although the significance of Padang for the trading activities was not as high as the cities at the eastern coast of Sumatra along the Malacca Strait, it was located at a strategic meeting point with the coast between rivers which enabled the development of settlements and trading activities. Ports in West Sumatra were also among the entry points for gold from the mountains and pepper from the coastal strip. Colombijn (1994) also described Padang´s importance was also increased when the Dutch made Padang their headquarters on Sumatra´s west coast in 1666. Between 1667 and 1800, the city of Padang was a trading centre for the hinterland. The trading activities were concentrated around the fortress of the Dutch trading union *VOC*, the indigenous market (*Pasar Gadang*), and the indigenous settlement around the mosque (*Mesjid*

Gantiang). Around the 1800s, the colonial era by the Dutch Government began and intensified agricultural activities in the northern areas that extended the city activities there. Moreover, the land management was changed as in 1874 the West Sumatran government stated that it would dispose of all waste land that was without custom landownership (*Minangkabau* claims) and would let out land on long lease for a fixed rent The slowly growing European estates in the hinterland of Padang constituted an additional stimulus to the growth of the town. Until before the Second World War, the city was developing rapidly and it became a regional city centre. Coal mining activities in West Sumatra started in 1892 were supported by the construction of the network of railways from Padang to the hinterland as well as the construction of a new larger harbour in *Teluk Bayur* in the south. Additionally, a cement industry was also built in the east of Padang.

Zaidulfar (2002) indicated that the development of the city in the colonial time reached its highest point in 1938, as it was planned to become the capital of the island of Sumatra. This development was then stagnant and even decreasing during the independence wars and civil unrest due to communist uprisings during the period from 1942 to 1970. In this period, the road transportation network increased and replaced the railways. The planned city development started from 1970 onwards with the initial main functions of trade, administration and port, and extended the functions of government service centres in charge of education, health, regional transportation and industry, which triggered the 's development, at first more towards the east compared to the north. After the extension of the city from 33 km^2 to 694.96 km^2 (of which only about 180 km^2 are potential constructed areas due to steep hills and natural preservation areas) in 1981, the city developed with the further concentric circulation from the old city centre and sub-centres in the extended city area. However, the development in the extended city area was sporadic due to insufficient infrastructure, land prices, and the possibility of land clearing.

In the Spatial Plan (RTRW) 2004-2013, which was later revised and replaced by Spatial Plan (RTRW) 2010-2030, the development was oriented following the previous plans, emphasizing the functions of the city as a centre of trade and service, industries, tourism, regional transportation, and education, as well as supporting development towards the city sub-centres to decrease pressures in the city centre.

Looking at the historical development of the city, the population concentration in the coastal areas or coastal zone was linked to the activities along the coast which can be traced back historically. The main high exposure of the people to the coastal hazards is rather due to the economic activities which have been taking place mostly surrounding the old city centre. The existing literature did not specifically mention considerations about earthquake or tsunami hazards in the urban development planning. It seems that such concerns only emerged after the Indian Ocean Tsunami event in 2004. The last Spatial Plan 2004-2013 was revised and replaced by the Spatial Plan for 2010-2030, which takes into consideration overall disaster mitigation and particularly earthquake and tsunami hazards.

3.3 Institutional Setting of Tsunami Early Warning System in Padang

The devastating event of the Indian Ocean tsunami in 2004 has been a wake-up call for the international world to realize the importance of an effective tsunami early warning system in the region. An international effort to establish an Indian Ocean Tsunami Early Warning System has been initiated since then as a joint effort of various countries and international communities. Germany has been one of the countries with highest contributions in terms of technological contributions and scientific efforts in the establishment of the tsunami early warning system in Indonesia. An early warning system has been developed to detect and assess potential tsunami occurrences and to issue a warning within five minutes[4], thus contributing to reduce the number of potential victims through the timely evacuation of people in the endangered coastal areas. The system was handed over officially to the Indonesian government by the end of March 2011 (Helmholtz Association of German Research Centres 2008; Bundesministerium für Bildung und Forschung (BMBF) 2011).

The Tsunami Early Warning Centre is based in the National Agency of Meteorological, Climatological, and Geophysics (*BMKG*) in the capital city of Jakarta. During the time of this study, the official Standard Operational Procedure (SOP) for tsunami early warning issuance and evacuation instructions was still being developed. Basically, *BMKG* issues tsunami warnings from the national warning centre directly to the people by means of public media and through local decision-makers at the local level, according to the local arrangements and available outdoor and indoor media (Alexander Kesper 2007). *BMKG* does not have the mandate to provide evacuation instructions to the community at risk, but rather provides just the information about earthquake characteristics and potential tsunami occurrences. The dissemination of the warning to the people in the risk areas as well as the provision of guidance (to evacuate or not) fall within the authority and responsibility of the local governments. After receiving a warning from the *BMKG* National Warning Centre, local government (e.g. City Mayor) together with the local disaster management body (*BPBD*), have to decide on the message to be distributed to local agencies and population. Local government has an important role in ensuring that the warning messages and evacuation orders will reach all the people in risk areas and trigger appropriate actions.

In parallel to the development of the Tsunami Early Warning System in Indonesia, the overall disaster management has been changed particularly due to the Disaster Management Law (UU) No. 24/2007 passed in 2007. The development of this new law encompasses the integration of disaster management into the overall development activities, e.g. Article 40 of the Law states that “Every development activity involving high disaster risks is equipped with disaster risk analysis as part of disaster management efforts in accordance with the power vested”. This law, however, does not specify the (tsunami) early warning

[4] For more information please refer to GITEWS website: http://www.gitews.org/index.php?id=6

system in detail and how it should be integrated into the overall planning, but merely provides a description of early warning to disasters in general.

As a derivation of the Law, a President Regulation on the establishment of the National Disaster Management Body (*BNPB*) (PP 8/2008) was passed. *BNPB*, in contrast to the former disaster management coordinating body (*BAKORNAS*), has also an implementing function before, during, and after disaster. According to another President Regulation on Disaster Management (PP 21/2008), the national disaster management body is responsible for the formulation of the disaster risk analysis criteria to be used as basis for environmental impact assessment, spatial planning, and disaster mitigation. At the provincial and subsequently at the district level, the local disaster management body (*BPBD*) replacing the former local disaster management coordinating body should also be established under Local Regulations (*PERDA*).

At the local level in the city of Padang, the tsunami preparedness efforts were initiated at the community level to raise awareness about the earthquake and tsunami potential in the city (KOGAMI staff, personal communication in 2007-2010). Several strong earthquakes after the Tsunami 2004 event contributed to the intensification of tsunami preparedness efforts in the area. Development of the tsunami early warning and evacuation planning in the city is relatively advanced compared to other coastal areas in Indonesia and the efforts to improve the effectiveness of the tsunami early warning are still on-going.

Considering its recent establishment in 2009, the local disaster management body still lacks the capacity to deal with the task of operating the newly established early warning system and to be in charge of possible mass evacuations, let alone the responsibilities to be involved in continuous risk assessment and the overall development planning. Also, the coordination between stakeholders and processes in the city, both at planning and community level, still happens in an ad-hoc and sporadic manner. Here, the role of an urban planning agency is essential, especially in being the focal point in the collection of basis data – including hazards, vulnerability, and on-going development activities, and in mediating planning processes that involve various actors.

For instance, the development of an official tsunami hazard map and basis evacuation plan has undergone a few years of processing involving various local, national, and international actors, who worked simultaneously in Padang. During observation at the study period, there were at least eight tsunami hazard maps being generated by local and national agencies, as well as international scientific communities. Two Padang Consensus meetings which involved scientists and decision-makers were conducted to compare the state-of-the-art of scientific findings on tsunami hazards and modelling and reach an agreement on a tsunami hazard map to be used as planning basis for the city. At the moment, the city is using the tsunami hazard map based on the modelling results of the Last-Mile project, which was also used as the reference for this study. Nevertheless, discussion on the uncertainty of the model and advancement on the “most suitable and precise” tsunami hazard map of Padang city is still on-going

(cf. Schlurmann et al. 2010; Muhari et al. 2011b), i.e. the current hazard and evacuation zone map is treated as a living document which will incorporate any new future findings.

Considering the process going on in Padang, it is crucial to examine the gaps and opportunities in linking tsunami early warning and the long-term urban planning and to provide an information basis that may support this synergy at this initial development stage. On the other hand, drawing lessons from this process can be useful for knowledge transfer. This study does not further discuss the tsunami hazard assessment – acknowledging its crucial importance – rather, it emphasizes the conditions at the community and household levels that determine their response to the early warning and capability of conducting evacuation, and addresses the topic of how urban planning may contribute to enhance this capacity.

3.4 Linking Vulnerability Assessment in the Context of Tsunami Early Warning with Urban Planning in Indonesian Context

With regard to the role of urban planning in disaster risk reduction, the new Disaster Management Law (UU 24/2007) clearly indicates that disaster mitigation should also be conducted through spatial planning (UU 24/2007, verse 47). Parallel to this Law, a new Law on Spatial Planning (UU 26 /2007) was also passed. It emphasizes the incorporation of disaster mitigation in the Spatial Plan.

The spatial plan according to the new law is valid for 20 years and to be revised every five years. It consists of spatial structures and spatial patterns. The first deals with settlement and network of infrastructure and facilities that support socio-economic activities of the people with interrelated functions, while the latter concerns the distribution of space allocation for conservation and utilized functions. The Spatial Plan serves as a basis for permits issuance for the location of development, green or non-green open spaces, public infrastructure and facilities. Moreover, the spatial planning process (development of the plan, utilization of space and its control) should be participatory and involve the community. The new law has explicitly incorporated disaster risk reduction as one criteria of spatial planning, which had been included only to a limited extent in the former law on spatial planning (UU 24/1992). In the new law it is clearly stated to allocate conservation land use and incorporate disaster management in disaster prone areas. The derivation of the new law, the Government Regulation on Spatial Planning (PP 15/2010) mentions the identification of disaster prone areas in spatial planning and control of their use through zoning regulations. In the regulations, it is stated that disaster prone areas should be mapped separately based on their typology and used as planning basis. It also specifically mentions the allocation of space for evacuation. Some relevant technical guidelines were developed, particularly the Public Work Ministry´s Regulation on the development of detailed spatial plans and zoning regulations (Permen PU 20/PRT/M/2011) and on infrastructure planning for tsunami prone areas (Permen PU 6/PRT/M/2009). However, so far the criteria of tsunami risk zoning in the guidelines (Permen PU 20/PRT/M/2011) mainly focuses on hazard (the biophysical aspect) and does not give clear guidance on how to incorporate vulnerability in spatial planning.

This study attempts to link vulnerability assessment and required interventions in the context of tsunami early warning (see the conceptual framework in the previous Sub-chapter 1.1) that should be incorporated in the spatial planning. There are three main points where the study contributes to the spatial planning process within the Indonesian context: 1) informing spatial planning on specific criteria to assess vulnerability in the context of early warning and identify prone areas; 2) utilization of these criteria to develop interventions such as land-use allocation for exposure control and evacuation routes (spatial pattern) and provision of additional infrastructure and facilities (structure plan) to be incorporated in the spatial plan; and 3) understanding of the issues of perception to enhance community participation in the spatial planning process in this scope.

4 Methodological Approach

The main goal of the case study and data analysis was to utilize the developed conceptual framework to provide an information basis for the development of effective urban planning interventions within the early warning system and evacuation plans. At a later phase, it was intended to evaluate the conceptual framework and assessment methods based on the findings.

The research activities and information generated consist of three assessment blocks representing the main research questions (Sub-Chapter 1.3) and the conceptual framework (Sub-Chapter 1.1):

1. What are the conditions that influence people´s early warning and response capability at the local level?
2. What are the conditions that enable or influence the effectiveness of vulnerability reduction within the on-going interventions (related with issues of perception)?
3. What is the role and influence of urban planning on the vulnerability and response capability of the people?

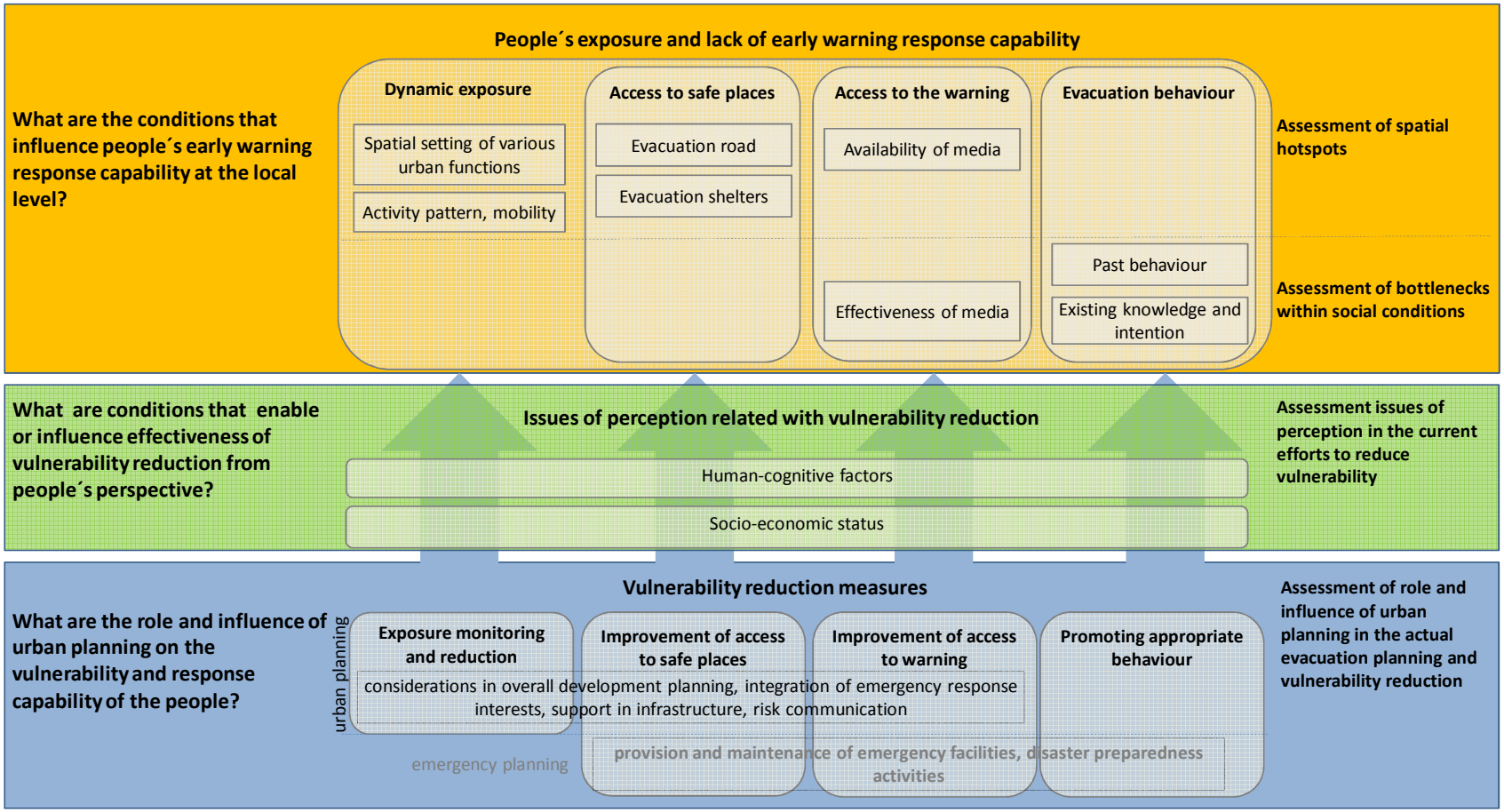
Figure 4-1 visualises the assessment blocks and their components.

The upper assessment block (yellow) assesses conditions influencing the vulnerability and response capability of the people to tsunami early warning. It covers the thematic areas of the whole early warning chain at the local level: dynamic exposure, access to the warning, access to safe places, and evacuation behaviour. Spatial hotspots and bottlenecks within social conditions were assessed to identify the required interventions and specific criteria that urban planning should address in cooperation with emergency planning. It was assumed at the beginning that urban planning interventions related with land use and infrastructure planning are directly linked only with the three components of dynamic exposure, access to the warning, and access to safe places, while the evacuation behaviour is linked with community education, evacuation procedures and drill activities under the main responsibility of emergency planning. Nevertheless, in order to get the overall picture of the vulnerability and response capability of the people, and later on to understand the bottlenecks within social conditions that may have influence on the effectiveness of interventions on spatial and physical aspect, this component was also assessed in this study.

The middle assessment block (green) indicates “filter” conditions that enable the reduction of the current vulnerability and improvement of response capability through urban planning interventions. The study attempted to look at it from the people´s point of view and assessed the possible hindrances caused by challenges related with subjective factors or people’s perception of the interventions to reduce vulnerability. In this matter, risk communication criteria on how to promote the involvement of the people in the urban planning interventions were assessed. It was done with reference to the identified specific interventions in the next (blue) assessment block.

The bottom assessment block (blue) assesses how urban planning plays a role and influences the vulnerability and response capacity of the people with regard to exposure threshold, providing space and infrastructure for warning devices, as well as space and infrastructure for evacuation routes and facilities. This study only focused on the interventions that involve urban planning directly, i.e. spatial and infrastructure requirements of evacuation and corresponding criteria with regard to people´s vulnerability. Interventions related with standard operational procedures from the Local Disaster Management Body, evacuation drills, etc. were not part of this study. The assessment also gives an indication of the cooperation between urban and emergency planning in the current efforts.

Figure 4-1 Linkage between research questions, conceptual framework and the structure of data analysis

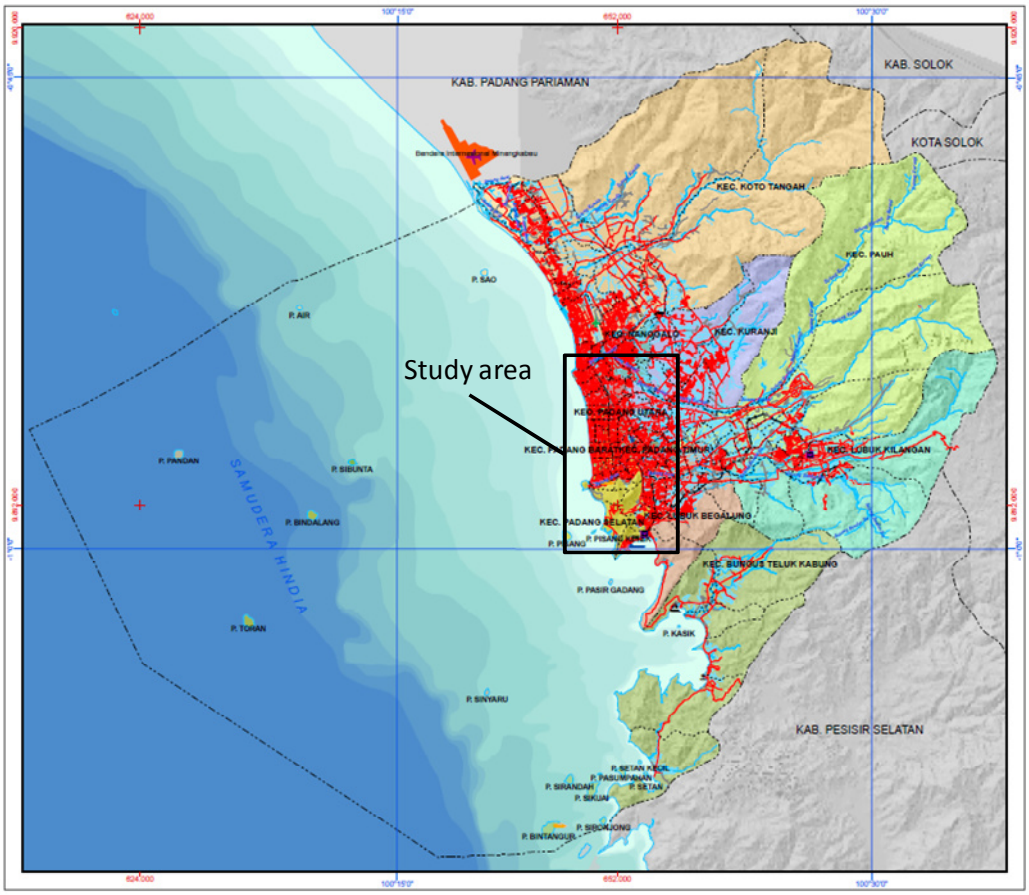


Source: own figure

The study was based on an in-depth case study in one selected area to get a better understanding of the specific context and to reflect it in a wider sense. The study targeted to find ways to apply the assessment framework in a medium-sized city in the context of a developing country. The city of Padang, province of West Sumatra, Indonesia, was selected as a representative case study with regard to the on-going processes in developing early warning and tsunami risk reduction systems at the local level (see sub-chapter 3). The study aimed to learn from experiences in the city of Padang and generate new knowledge for improvement of the conceptual framework and derive practical recommendations. The results of the research were expected to allow in the first place to derive recommendations for application in Padang, but also to draw lessons in a wider sense for other medium-sized cities with similar context. With regard to the methodological issues, the development of a comprehensive knowledge basis for decision making in such a city like Padang is still challenging due to often unavailable highly sophisticated data and the lack of centralized information on risk and vulnerability. Thus, a tailor-made and mixed approach for data collection and analysis was a logical consequence, which fits well in the reality of many medium cities in developing countries. This was another important aspect to be addressed through the case study.

The study was conducted at the local scale, describing situations and deriving recommendations at the city level. The boundary of the spatial scope in this study, especially for the quantitative analysis, follows the boundary determined by the research project “Last-Mile – Evacuation”, since only for this part of the city detailed data on tsunami hazards and remotely sensed building information was made available within the “Last Mile” research project (see Figure 4-2). Nevertheless, the study area provides good coverage of the main part of the city which is mostly densely built, economically active and exposed to tsunami hazards. Thus, the context of and the recommendations that will be derived for tsunami risk reduction and evacuation planning used for this analysis apply not only to the situation in the study area, but to the whole city of Padang.

Figure 4-2 Study area in Padang city, Indonesia



Source: BAPPEDA Kota Padang Map of administrative boundaries of the City of Padang, 2008

The analysis was done to provide a “screen-shot” situation during the study period (especially during the main data collection in 2007-2009, and limited qualitative update in 2010) and to address potential challenges for the on-going and future vulnerability reduction measures.

In order to assess different thematic areas, an interdisciplinary approach was required. The study used approaches from engineering and social behavioural sciences. Therefore, the combination of qualitative and quantitative data collection and analysis methods from these disciplines was used. For each thematic area, an analysis framework or specific approach was developed and a different set of data was used. The next sections describe the analysis frameworks and data sources in more detail.

4.1 Assessment of Spatial Hotspots and Evacuation Bottlenecks within Social Conditions

4.1.1 Dynamic Exposure

Dynamic exposure deals with the question of who, when, and where with regard to the population in the city. It is the first component of vulnerability that determines who is potentially affected and should be reached by tsunami early warning as well evacuated to safe places prior to the occurrence

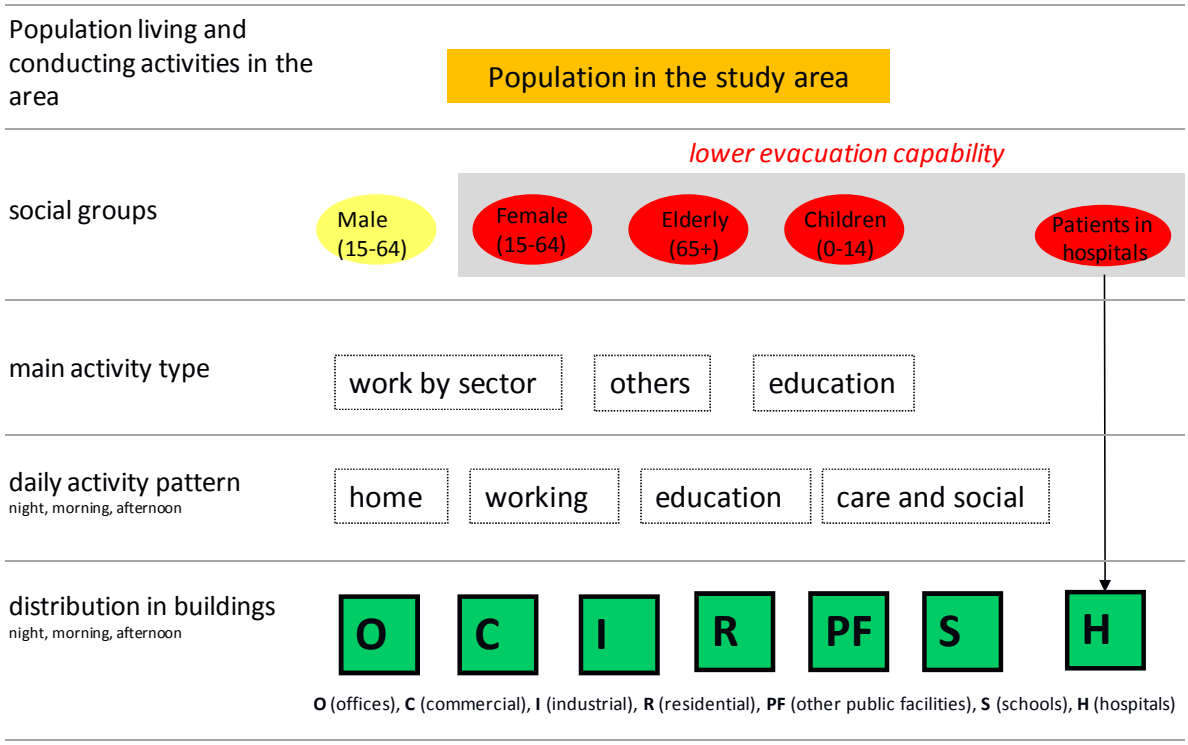
of major tsunamis. This component is linked closely with the other components of access to warning, access to safe places, and evacuation behaviour.

As discussed in the conceptual Sub-chapter 1.1, it is important to take into consideration the spatial and temporal dynamics of the population distribution in the urban context. In order to assess the response capability, not only the quantification of exposed people but also the social configuration of the people is crucial. The dynamic exposure analysis is conducted to firstly get an overview of the concentration of various population groups in different city areas at different times of the day, then to assess who is potentially affected by potential tsunamis and has to be evacuated. Exposure analysis in this study is innovatively conducted for population groups with different evacuation capability as an attempt to advance other existing approaches such as night-and-day population analysis using remote-sensing (Taubenböck et al. 2008) or dynamic population distribution using population census and land-use data (Khomaruddin et al. 2008).

The analysis assumed that the spatial distribution of the population groups depends on the urban land (represented by buildings) use. To identify the mobility patterns, the population groups were classified according to the existing data sets and different degrees of capability to conduct evacuation. In the existing studies on natural hazards, including major tsunami events in the past, women, children, and the elderly have been identified as the most vulnerable groups (Birkmann et al. 2007; Rofi, Doocy and Robinson 2006; Guha-Sapir et al. 2006). With regard to evacuation, these population groups also have lower physical capacity in terms of running velocity, stamina, and capability to swim in case of inundation. Based on this, the daily pattern and exposure of children (age below 15), women (age 15 to 64), and elderly citizens (age 65 and above) were assessed separately as they constitute the group with lower evacuation capability (more vulnerable group) and compared with the male (age 15 to 64) population. Additionally, people in hospitals were also considered as limited in their mobility and included in the first group.

The Figure 4-3 shows the analysis framework for dynamic exposure. It basically describes the components of analysis, starting from the classification of the population groups divided into main activities, which are distributed in various building uses. The weighting scheme was derived for each daytime based on the daily activity patterns of each population group.

Figure 4-3 Analysis framework of dynamic exposure of various population groups



Source: Setiadi et al. 2010, slightly modified

Data on the daily occupancy of buildings for schools and hospitals were collected as part of surveys of critical facilities. However, it was not implementable to carry out detailed surveys on the working areas and therefore, the occupancy of these working areas was estimated according to the number of working population in various sectors. The data collection method of Activity Diary was utilized. It has been a common method to get the micro-scale temporal and spatial use of the city by the population and is normally used for transportation planning (Anderson 1971; Chapin 1974; Arentze et al. 2000). It contains documentation of the daily routine by type of activities, time of conduct, locations of the activities, and mode of travel. The Activity Diary was collected as part of the UNU-EHS Household Survey in 2008 in Padang. Additionally, a qualitative study through informal conversation with several local people and participatory rapid appraisal was conducted to obtain a picture of the daily activity of the fishermen community in Padang. For the Activity Diary in the context of the city of Padang, the activities were divided into working activities, education activities (going to school / campus), daily care (household tasks, shopping, religious activities), and social activities (meeting with friends and family, entertainment). Three daytime categories were selected for the analysis to show the temporal dynamics: morning time (9-12 am) as the main working and school time; afternoon time (3-6 pm), when a proportion of pupils and workers are at home / conducting other activities; and the night time with the assumption that most people are at home and that only very few are in public buildings. The daily activity patterns of the population groups were then compared according to their main activity (working, education, others) and occupational sectors for the working population. Table 4-1 lists the data used to analyse the daily activity patterns of various population groups.

Table 4-1 Variables and data sources for analysis of dynamic exposure

Variables	Data source	Remarks
Proportion of population groups by age and gender	BPS Padang Dalam Angka 2006	-
Proportion of population groups by main activity types	BPS Population Census 2000	Such detailed data could only be obtained from Population Census. In the study period, the latest census was in 2000. The variable was assumed to be constant throughout the years and compatible with other more updated statistic data.
Proportion of working population by working sectors by gender	BPS Padang Dalam Angka 2006	Only differentiation between male and female working population was available. Working elderly followed the pattern of the total population.
Proportion of total population in Padang that perform their daily activities in the study area by building use	BPS PODES 2006	The city population conduct activities inside the study areas in non-settlement buildings are proportional to the number of corresponding facilities inside compared to outside of the study areas, as far as the data is available.
Location of daily activities conducted by day time and population groups (daily activity and mobility pattern)	UNU-EHS Household survey 2008	Correction was made due to difference of the proportion of the working sectors by population groups of the survey sample compared to the total population
Occupation rate of schools and universities by daytime	UNU-EHS survey on critical facilities 2008	Average value is used for all schools and universities
Occupation rate of hospitals by daytime	UNU-EHS survey on critical facilities 2008	Average value is used for all hospitals
Occupation rate of public facilities during the night	Estimated values given from results of other project partners	The public facilities have a minimal occupation during the night. The estimation was based on discussion with the local experts conducted by DLR/Last-Mile 2008

Source: own figure

The data of the daily activities were linked with building use data of DLR/Last-Mile 2008, the UNU-EHS Survey of Critical Facilities 2008, GPS measurements/Google Earth identification and

participatory mapping. Distribution of people in the settlement areas was done according to the given semantic classification of the buildings as suburb, slum, low class, middle class, and high class, based on urban physical morphology such as building density, size, height, and uses (Taubenböck et al. 2009a; Taubenböck et al. 2009b). People conducting daily care and social activities were distributed in the settlement and commercial buildings based on their daily activity patterns, and people conducting education-related activities were distributed in school or university buildings based on their educational level. As mentioned previously, people in hospitals were treated separately and distributed among the hospital buildings. For the working population, it was assumed that their working places correspond to the building uses representing their occupational sectors. The occupational sectors and building uses were summarized using the new classification as shown in Table 4-2.

Table 4-2 Classification of the occupation sectors and building uses for distribution of the working population

Occupation sector based on statistics (BPS, 2006)	Building use classification based on existing building data (DLR / Last-Mile, 2008)	New classification for the analysis
Primary sectors: agricultural, fishery, forestry	Outdoor	-
Industry	Industrial buildings	Industrial buildings
Electricity, gas, and water supply	Office buildings	Office buildings
Construction	Outdoor	-
Trade, hotels and restaurants	Commercial, shopping centres, hotels	Commercial buildings
Communication and transportation	1/3 in office buildings 2/3 outdoors	Office buildings -
Finance	Office buildings, banks	Office buildings
Services	Office buildings, schools, universities	Office buildings
-	Ports	Commercial buildings
-	Mixed use buildings	25% office buildings 25% commercial buildings 50% settlements

Source: own figure

The basis for the potentially tsunami inundated areas is the tsunami hazard modelling results of the Franzius Institute Hannover of the Last-Mile Project[5].

[5] For further information on tsunami hazard modeling methods and calculation, please refer to Goseberg and Schlurmann (2008), Goseberg et al. (2008)

The analysis was conducted using SPSS, Microsoft Excel (for processing local statistics data) and ArcMap version 9.3.1 (for analysis of distribution at building level) and lastly, the derived population distribution was summarized in grids using ArcMap for the map visualization and overlay with the hazard information to produce exposure maps.

4.1.2 Access to Safe Places

Availability of evacuation infrastructure is crucial to ensure that mass evacuation can be conducted prior to arrival of the first tsunami wave. In the scope of this study, the accessibility to safe places using the existing street network for evacuation routes of the potentially affected people was presented. Empirical results of evacuation modelling were already provided by the TU Berlin/Last-Mile which was dealing intensively with the topic of traffic modelling. In this matter, a multi-agent based modelling was developed using MATSim (Lämmel 2011), wherein the results of dynamic exposure of this study were incorporated as an input parameter. The existing modelling results of TU Berlin/Last-Mile will be presented and discussed in this study to assess the needs of urban spatial planning interventions and link with results from other thematic areas.

In this study, the scenario with the assumption that no buildings inside the exposed areas could be used for vertical evacuation was presented, since the structural seismic resistance and capacity for future earthquakes and tsunamis has not been validated yet. A building vulnerability assessment was conducted by DLR/Last-Mile to identify potential buildings[6] (Taubenböck 2011). The assessment was based on remote sensing analysis, combined with a building survey on the buildings' structural stability according to the expert rating of in-situ civil engineering on various parameters (e.g. building height, material or construction type) using an additive approach (Taubenböck et al. 2012; Mück et al. 2013). These will be presented complementarily to the evacuation modelling results to give a rough picture of the potential vertical evacuation shelters using the existing buildings.

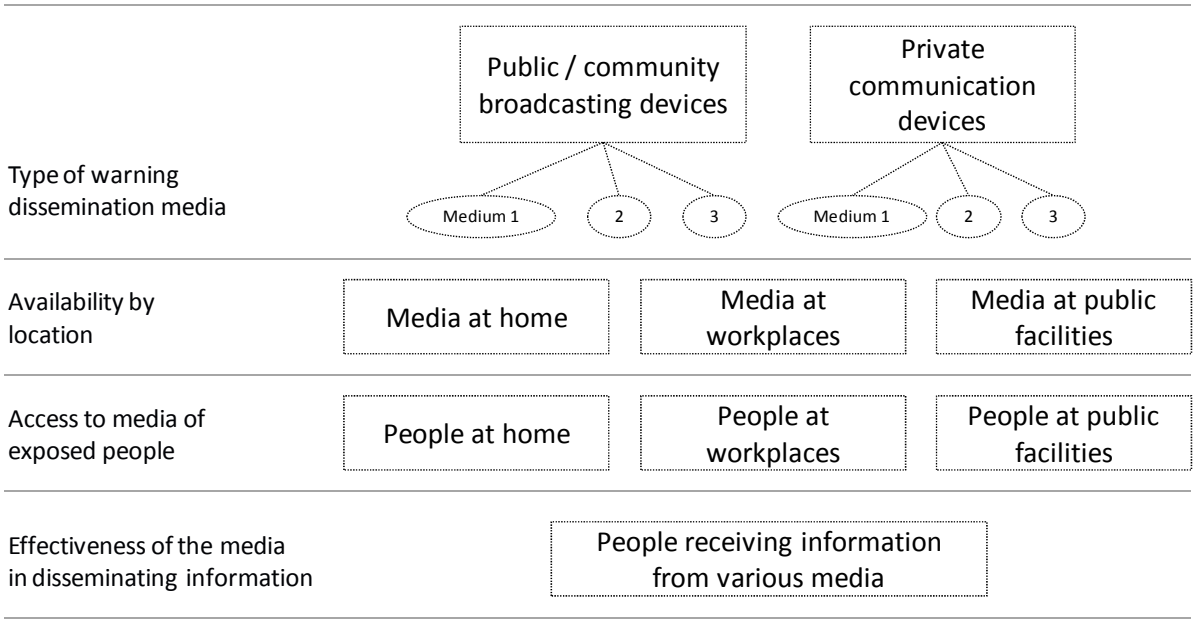
4.1.3 Access to Warning

Access to warning in this study considered the availability of private and public dissemination devices in various locations in the city. Firstly, the type of warning dissemination devices was identified. For the case of Padang, some devices were utilized to disseminate information of earthquake events, potential tsunami warnings, as well as instructions to evacuate from the national early warning centre and local authorities, were identified based on past experiences of strong earthquakes in Padang, especially the ones in September 2007 and September 2009. In the study, the availability of various devices was examined through identification of the location of these devices and their spatial coverage. Availability of private devices at home and in workplaces or public facilities was examined using the UNU-EHS Household Survey 2008 and Survey on Critical Facilities 2008 (for hospitals and schools). This was finally linked with the dynamic exposure of the population. Figure 4-4 displays the analysis framework.

[6] Some scenarios were also simulated by TU-Berlin/Last-Mile but is not presented in this study

Additionally, the utilization and effectiveness of these devices was assessed. According to the opinion of the local actors, the effectiveness of various devices is influenced by many factors. The robustness of devices after a strong earthquake and their utilization by the people to get information about potential tsunamis are the most important criteria. In the study period, there were no available data with regard to technical specifications of the devices and there have been very limited experiences with strong earthquakes anyway. Thus, a rough assessment of the effectiveness could only be done using data from the household surveys on two recent experiences with strong earthquakes in 2007 and 2009, derived from data of the UNU-EHS Household Survey 2008 and the GTZ Household Survey 2009, and qualitative assessment based on informal conversations with the local actors.

Figure 4-4 Analysis framework of access to warning devices



Source: own figure

4.1.4 Evacuation Behaviour

In the context of local tsunamis as in the city of Padang, the estimated tsunami arrival time and early warning lead time respectively is very short. As described in Sub-chapter 3.1, the predicted tsunami arrival time was about 30 minutes after the occurrence of a major earthquake. Within this time frame, the tsunami warning has to be disseminated to all exposed people and evacuation to the safe places has to be conducted immediately. Thus, a quick decision to evacuate and the time-efficient conduct of evacuation are crucial. This requires a clear and precise understanding by the population at risk of the potential tsunamis as well as of what to do next. For the households, different reactions to a potential tsunami event based on previous experiences of strong earthquakes and early warning as well as their intention to comply with the early warning and evacuation instructions in future events were identified by the UNU-EHS Household Survey 2008. Descriptive analysis of the past earthquake events, especially in 2007, was done to get a picture of the variations in taking evacuation decisions. Potential bottlenecks related with family evacuation arrangements, modes of

transport, and types of destinations were also identified using the same household survey. Additional qualitative information was obtained from a focus group discussion with actors involved in disaster management in February 2008, interviews with six purposively selected households with different intended evacuation behaviours in November 2008, as well as informal conversations with various informants at the community level during field visits in 2008 and 2009.

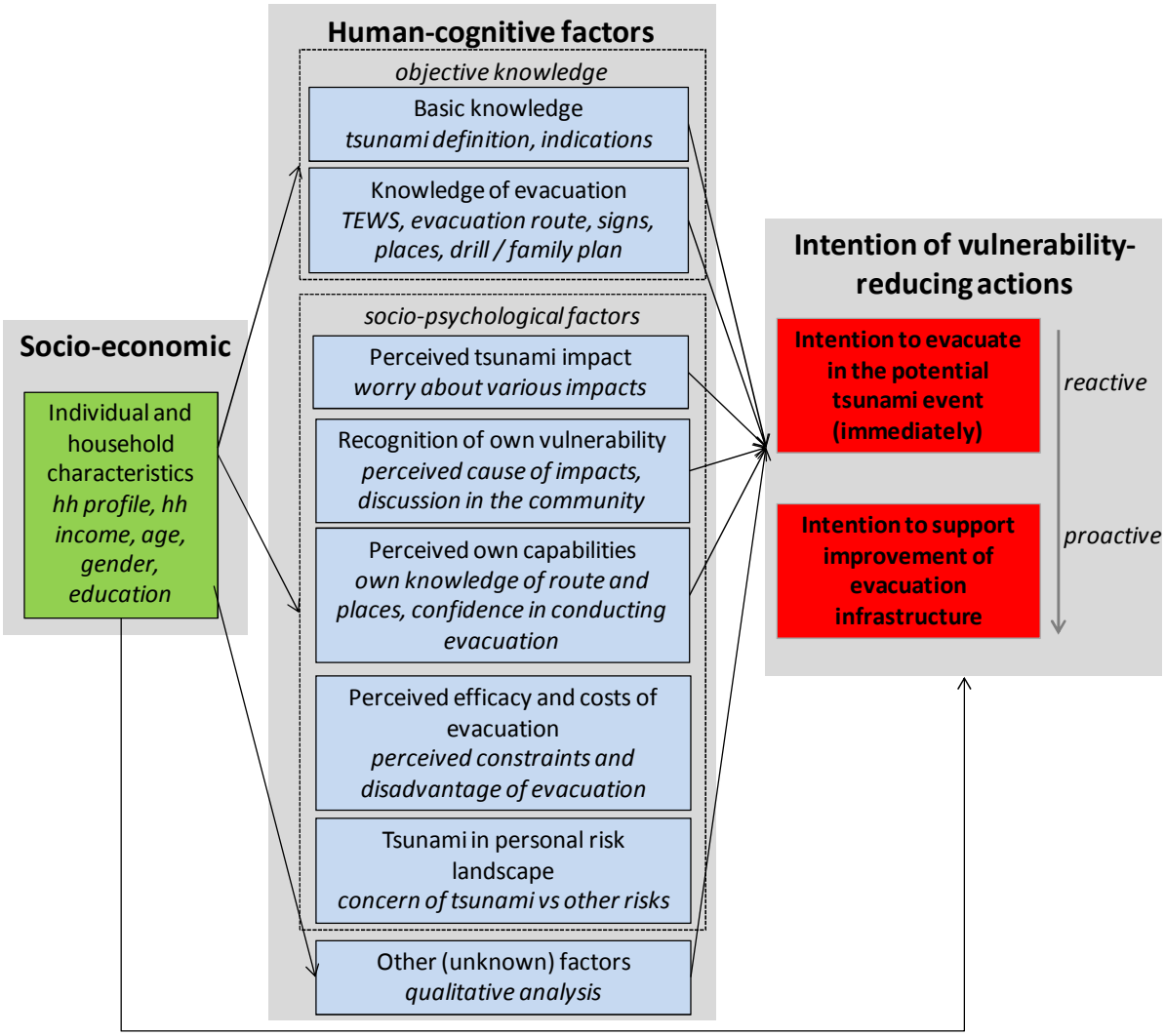
4.2 Assessment of Issues of Perception related with Vulnerability Reduction

As discussed conceptually in Sub-chapter 2.1.3, human cognitive factors are crucial in building acceptance and effective implementation of protective actions, or in this study, early warning and evacuation measures to improve the response capability of people. Analyses of the UNU-EHS Household Survey 2008 and UNU-EHS/KOGAMI Household Survey 2009, complemented by qualitative information from non-structured interviews of selected households and local actors, was conducted to get an understanding of the perception and intention of the people related with vulnerability reduction measures that involve actions on the people´s side. In this study, the focus was primarily on people's willingness to conduct evacuation in the future as well as to support the improvement of the evacuation infrastructure and facilities, which is indicative of their positive acceptance and participation in the on-going interventions.

Human cognitive factors that relate with knowledge and perception of tsunami risk as well as tsunami early warning and evacuation were analysed to identify the influence on people´s intention to conduct protective actions. Analysis was initially conducted with regard to evacuation decisions which were considered as the most vital aspect in the context of early warning and evacuation. This action was not directly linked with urban planning interventions. However, it was integrated and further extended in this study, since the observation in the field study indicated a potential association of cognitive factors with the cooperativeness of people in the overall interventions. The analysis tested statistically the cognitive model of intention to evacuate in the future tsunami warning (reactive action) and subsequently, the intention to support improvement of existing evacuation infrastructures and facilities (proactive action).

The analysis method followed approaches used in psychological studies. The framework (Figure 4-5) was developed to consider factors in existing attitude-behaviour models in the context of protective behaviour; especially the theory of planned behaviour (Ajzen 1991), theory of protection motivation (Rogers 1983; Martin, Bender and Raish 2007), and partly informed by protective action decision model (Lindell and Perry 1992; 2012) (See Sub-chapter 2.1.3). The main underlying argument of the model was that an intention of a certain protective behaviour would be influenced by various perceptions towards the existing hazard and recommended protective actions (evacuation or improvement of evacuation infrastructure). Those perceptions were indicated by the level of people´s objective knowledge about tsunamis and evacuation as well as subjective or socio-psychological factors such as perception of potential impacts, own vulnerability and need of preparedness, own capability to conduct evacuation, and perceived efficacy and costs of evacuation. The correlation of these factors by individual/household socio-economic characteristics was also tested.

Figure 4-5 Cognitive model and intention of vulnerability-reducing action



Source: own figure inspired by Azjen (1991), Rogers (1983), Lindel and Perry (1992, 2012)

The descriptive, correlation, and logistic regression analysis was done using IBM SPSS Statistics 19. As mentioned before, the model was firstly tested focussing on the intention to evacuate based on the UNU-EHS Household Survey in 2008. The aim was initially to select variables for an indicator scheme which is applicable for monitoring awareness activities. The variable of intention to evacuate in the future tsunami warning (yes/no) was assigned as a dependent variable and a set of variables representing each cognitive factor (nominal, yes/no and ordinal scale) as independent variables. The correlation analysis using cross-tabulation analysis was conducted and variables with significance at $p>0.05$ were selected for explaining the intention and further analysis. Kendall´s-tau-b coefficient was used for measuring the strength of correlation of ordinal variables and Cramer´s V or Phi coefficient for nominal variables. These selected variables were then tested further using logistic regression analysis. The model and overall intention were compared with the reality during a similar earthquake event in September 2009 using the GTZ Survey 2009 to validate the overall model and intention with the actual action. Moreover, since the aim was to make the variables applicable as

indicators for monitoring awareness activities at the community level, the applicability of and relevance of the variables for awareness activities was also added as selection criteria – according to the qualitative judgment of the researcher which was primarily influenced by informal conversations with the local actors. After deriving an acceptable model and indicator scheme for the intention to evacuate, the correlation and regression analysis of the composite indicators with the intention to support improvement of evacuation infrastructures was conducted using the UNU-EHS/KOGAMI Household Survey in 2009.

Although some significant correlations between socio-economic variables and intention to support evacuation measures were also found, these socio-economic variables were not included in the indicator scheme. These variables were considered as indirect factors that may influence perception and intention but cannot be modified by awareness activities. The findings for socio-economic variables were used to guide risk communication strategies with regard to particular social groups.

In addition, the perception of the people of possible relocation was also assessed. This topic is considered as relevant since it may emerge as a consequence of land use change in the long-term or allocation of space in already constructed areas for additional infrastructure and facilities. This provides another perspective in understanding possible hindrances perceived by various social groups which also may hamper their cooperation in urban planning interventions.

Qualitative information on tsunami risk perception and risk communication was used to provide information of the overall perception of people of tsunamis and existing preparedness efforts and to capture explanatory factors of people´s intentions regarding vulnerability reduction which could not be captured sufficiently in the quantitative or statistical analyses.

4.3 Assessment of Roles and Influence of Urban Planning in the Actual Evacuation Planning and Vulnerability Reduction

For this study, the focus is on vulnerability reduction and enhancing response capability through interventions which involve urban planning. The main objective of the assessment is to identify whether or to what extent the urban planning interventions address the needs of early warning systems identified before, identify specific points of interventions which are problematic, and whether a strong linkage of urban and emergency planning exist to ensure the sustainability of the early warning system.

The initial step is a review of the overall spatial planning orientations in the long-term in the city's Spatial Plan (*RTRW 2010-2030).* It identified interventions in this plan which are explicitly mentioned as evacuation and tsunami risk reduction measures as well as those that are not directly associated with the measures but influence development in the hazard zone and evacuation infrastructures and facilities. Potential impacts of these interventions were assessed based on the components of response capability, particularly dynamic exposure, access to safe places, and access to warning.

A stakeholder analysis of agencies, particularly government agencies, involved in the actual evacuation planning was conducted based on action plan documents and interviews with planning actors. The roles of various agencies were identified both formally and informally. Formal role means

here that it is explicitly mandated by existing regulations. Informal role means that it may not be explicitly mandated but perceived by themselves or others as important, or that the agencies have been involved in actual on-going activities. The first one is identified by reviewing planning laws and regulations, while the latter is assessed through qualitative analysis of non-structured interviews with local planning actors and community. The urban planning agents mainly observed in this study were the City Development Planning Agency (BAPPEDA), Spatial Plan and Urban design Agency (TRTB), and Public Work on Regional Settlement and Infrastructure Agencies (Kimpraswil/PU). Agencies dealing with emergency planning were also assessed to explore their linkages with urban planning. Subsequently, current plans and on-going activities were identified and linked with the roles identified previously to examine intervention areas and the linkage of actors in urban and emergency planning. Moreover, existing challenges from the planner´s perspective were extracted from non-structured interviews and discussions with the local planning actors conducted in the field visits in 2009.

4.4 Data Collection

Most data collection was conducted during field visits in the period of July 2007 to August 2009. Several short visits which were strongly linked with Last-Mile project activities in Padang were conducted in July 2007, February 2008, May 2008, November 2008, March 2009, and one field stay in June-August 2009. Additional information (mostly qualitative) was also obtained by email communications with the local actors. Table 4-3 summarizes all data used for each thematic analysis described above and the following section provides more detailed information on the data sources and data collection methods used.

Table 4-3 Overview of thematic analysis and data used

	Dynamic exposure	Access to safe places	Access to warning	Evacuation behaviour	Issues of Perception	Urban Planning Roles
Existing statistical data	X					
Household survey 2008	X		X	X	X	
Household survey 2009					X	
GTZ Household survey 2009			X		X	
Critical infrastructure survey 2008	X		X			
Spatial data from various sources	X		X			
Non-structured interviews and informal conversations 2008-2012			X	X	X	X
FGD with community 2008 & 2009	X				X	
FGD with planning actors 2008				X		

FGD with planning actors 2010			X	X
Planning documents and regulations				X
Existing modelling results	X			

Source: own figure

4.4.1 Existing Statistical Data

Existing statistical data used were data from the official statistical agency (BPS) that was collected periodically. Overall, the surveys of BPS, which are carried out at the district and district level, only provided general socio-economic information. The statistical data used were the newest ones available at the data collection period of existing statistics in 2007. The description of statistical data sources used for the study is summarized in the Table 4-4.

Table 4-4 Summary of existing statistical data sources used in the study

Data source	Collection interval	Spatial resolution	Collection Method
BPS Population Census 2000	Every 10 years	Village level	Total enumeration of population
BPS Economic Village Potential - PODES 2006	Every 3 years	Village level	Interviews of village officers / heads
BPS District in Figures - Padang Dalam Angka 2006	Every year	District and partly sub-district level	Data collection from various local government agencies

Source: own figure based on information from BPS Website

4.4.2 Household Surveys

Household surveys were conducted by UNU-EHS within the “Last-Mile – Evacuation” Project to cover specific topics related with tsunami risk and early warning that were not available in the existing statistical data. The study used two of the UNU-EHS Household Surveys as a primary data source. The first one was conducted in 2008 and used as the main source of data for most of the analysis themes, while the subsequent household survey was conducted in 2009 to validate the evacuation awareness and knowledge variables in the context of community raising awareness activities of the NGO KOGAMI but also included additional variables on people´s perception of tsunami risk reduction measures and intention to support the improvement of evacuation infrastructures.

The household surveys were developed in form of questionnaire-based surveys using methods common in the empirical social research (Bernard 2006; Bühner 2006; Diekmann 2006). A combination of answer categorization was used such as rating scale, yes-no answers, and multiple answers, according to the information needed. A rating scale was used particularly for questions with subjective answers or related with opinions. Open questions were mostly used to capture information which was not listed in the answer categories, but within the analysis, these answers were coded to enable quantitative analysis.

Figure 4-6 Questionnaires of UNU-EHS Household and Critical Facilities Surveys 2008

Source: own figure

4.4.2.1 UNU-EHS Household Survey 2008

The content of the questionnaire was developed in consultation with the project partners from the field of evacuation modelling and geo-database, as well as national and local experts during project workshops, and the phrasing of the questions in Indonesian language were refined particularly with the support of the local partners from the Social and Political Faculty of Andalas University. Before conducting the household survey, a pre-test of the questionnaire by the enumerators was done. The questionnaire covered various topics and conducted together with other project partners with other foci of interest. The following thematic clusters in the questionnaire were used for this study:

1. Socio-economic characteristics of the households and household members;
2. Daily activity patterns and mobility;
3. Experiences with tsunamis and tsunami early warning;
4. Accessing and understanding early warning;
5. Knowledge about tsunami and tsunami risk perception (including concern on other risks);
6. Knowledge and perception of tsunami early warning;
7. Perception of evacuation measures and own capability;
8. Risk communication

The implementation of the household survey took place from April 28th to May 30th, 2008 with the support of students from the Social and Political Faculty of Andalas University. The survey covered a sample size of 1000 households, of which only data from 933 households could be analysed. The sampling was done using a stratification method to be representative of the population living in the study area with varying tsunami exposure degrees as well as socio-economic and urban physical morphology characteristics identified from remote-sensing data. Spatial distribution of the

households interviewed is visualized in Figure 4-7 and Table 4-5 gives an overview of the administrative boundaries of the samples.

In the implementation, sample modification was unavoidable due to the fact that several buildings, especially the big buildings identified through remote sensing data at the beginning, were not inhabited houses but mosques, storage buildings, or other public buildings. Additionally, some of the selected households refused to be interviewed. In this case, the households were replaced by others living close by. However, this modification did not change the overall socio-economic pattern of the sample.

One strength but also limitation of the household survey was its length and the wide-spectrum of themes covered. It was difficult to ensure that the quality and level of details of the answers provided by the respondents were consistent for all the themes throughout about one hour long of questionnaire-based interviews. This may have had an impact especially on the topic of daily activity patterns (varying level of hourly details of the documented daily activities) and perceptions (e.g. rating scale of various subjective opinions). Additionally, the sampling was designed to cover households with various socio-economic characteristics, but the respondents of the sample households did not necessarily represent individual socio-economic characteristics, e.g. proportion al to age and gender (See Sub-chapter 4.4.2.3).

Figure 4-7 Sample households distribution of UNU-EHS Household Survey 2008

Source: DLR, 2008

Table 4-5 Sample of UNU-EHS Household Survey 2008 by village

Village / *Kelurahan*	Sample households
Air Tawar Barat	97
Alai Parak Kopi	64
Belakang Tangsi	45
Ganting Parak Gadang	117
Kalumbuk	79
Kampung Pondok	57
Mato Aie	103

Olo	62
Padang Pasir	79
Plamboyan Baru	49
Purus	119
Sawahan	62
Total	**933**

Source: own figure

4.4.2.2 UNU-EHS/KOGAMI Household Survey 2009

The UNU-EHS/KOGAMI Household Survey was conducted within the scope of the Public Dissemination System Program 2009/2010 in 30 pilot mosques[7]. It was supported by GTZ in cooperation with NGO KOGAMI. The programme was carried out as an effort to utilize the potential of religious facilities, particularly mosques that involve the majority of the people in Padang, to raise awareness about tsunami risk and preparedness as well as to disseminate tsunami warnings. The survey was conducted before the earthquake event in September 4 to 15, 2009. The content of the survey included socio-economic and cognitive variables for evacuation awareness and knowledge indicators that were identified in the data analysis of the UNU-EHS Household Survey 2008.

The total sample size in 14 pilot mosques located in our study area comprised 560 households with 40 households for every pilot mosque selected randomly. The location of the mosques and the sample households are displayed in Figure 4-8 and listed in the Table 4-6.

[7] For the data analysis in this study, we used only data of 14 pilot mosques. After the earthquake event in September 30, 2009, 10 mosques suffered from major damage due to the earthquake, and 6 of the remaining 20 mosques were located outside the study area.

Figure 4-8 Locations of pilot mosques of the sample households in the study area

Source: own figure based on information from KOGAMI during field visits in 2009

Table 4-6 List of pilot mosques and sample households

Pilot mosques	Sample households
Nurul Huda	40
Almoqomah	40
Nurul Washilah	40
Alkamil	40
Nurul Anhar	40
Munawarah	40
Alfirman	40
Baiturrahmi	40
Jami	40
At Taqwa	40
Baitul Makmur	40
Ikhwanul Muslimin	40
Muhajjirin	40
Afdhal	40
Total sample	560

4.4.2.3 Representativeness of the sample in the household surveys

The following table compares the socio-economic characteristics of the sample households of the UNU-EHS Household Survey in 2008 and UNU-EHS/KOGAMI Household Survey 2009 with the total population of the city of Padang according to the available local statistics:

Table 4-7 Comparison of socio-economic characteristics of the samples in the Household Surveys 2008 and 2009 with the total population of Padang city

Variables	Categories / Score	Proportion in %			
		Sample 2008 (N=933)	Sample 2009 (N=560)	Total population (Source of data)	
Age group	<20	1	2.5	40.4	BPS PDA 2006
	20-29	12.5	21.4	22.0	
	30-39	24.1	23.6	14.8	
	40-49	26.4	22.3	11.3	
	50-59	21.9	19.5	5.7	
	60+	14.2	10.7	5.6	
Gender	Male	37.2	33.8	49.4	BPS PDA 2006
	Female	62.8	66.3	50.6	
Completed education	no school / No primary school finished	5.8	6.6	22.1	BPS SUSENAS 2006
	Primary school finished	10.0	11.3	18.2	
	Junior high school finished	16.2	20.4	17.4	
	Senior high school finished	44.8	42.6	31.9	
	Higher education	23.2	19.1	10.3	
Household monthly income (missing values exist)	<800,000 Rupiah	14.5	32.8	27.1	BPS SUSENAS 2006
	800,001 – 1,600,000	35.1	37.5	35.2	
	1,600,001 – 4,000,000	34.5	22.1	31.6	
	> 4,000,000	15.8	7.6	6.2	
Household age profile	Without elderly	75.9	84.1	86.7	BPS SUSENAS 2006
	With elderly (65+)	24.1	15.9	13.3	
Household size	1-2	9.6	6.4	15.0	BPS SUSENAS 2006
	3-4	37.2	28.9	40.1	
	5-6	33.4	38.4	33.8	
	7 and more	19.7	26.4	11.1	
Ethnic/tribal group	Minangkabau	84.7	90.1	89	BPS Pop Census 2000
	Non-Minangkabau	15.3	9.9	11	
Religion	Islam	92.7	98.9	97	BPS PDA 2006
	Christian/Catholic	5.8	1.1	2.3	
	Budhist	1.4	0	0.6	
	Hindu	0.1	0	0.1	

Occupation sector (only working population 15 years and above)	agriculture, forestry, fishery	6.3	5	4.7	BPS PDA 2006
	manufacture	2.3	4	8.3	
	trading	38.2	39	31.1	
	service	48.8	51.9	54.6	
	others	4.3	0	1.3	

Source: own figure

The characteristics of the sample in both household surveys represent to some extent the total population of the city. Some differences can be identified in the composition of age groups which underestimated the population group under 20 years old, and consequently, also underestimated the proportion of people that have not completed primary school within this age group. This was due to the fact that target respondents were mostly heads of households or spouses, thus, children are not represented by the respondents, but are part of the households which are influenced by decisions made by the head of these households. Furthermore, the gender proportion shows there were more female respondents than male. During the conduct of the survey, (mostly during the working hours), there were less male working members available, which was inevitable. In the data analysis (particularly of daily activity patterns, evacuation behaviour and cognitive factors), correlation with gender was also identified and incorporated in the discussion, and e.g. in the dynamic exposure, the analysis per gender group was assessed separately anyway.

4.4.2.4 GTZ Household Survey

Through cooperation within the "Last-Mile – Evacuation" project activities, additional data from the German Technical Cooperation, GTZ Household Survey 2009 (Hoppe and Marhadiko 2010), was made available. The survey was conducted not long after the earthquake event in September 2009 in Padang and included the information of tsunami warning dissemination and conduct of evacuation during the event. It covered 200 respondents, which were selected jointly with UNU-EHS from sample households in the UNU-EHS/KOGAMI Household Survey 2009 with various evacuation awareness levels and evacuation intentions. The raw data was made available with the consent of the GTZ partners and therefore could be used as additional data source for the analysis.

4.4.3 UNU-EHS Surveys on Critical Facilities 2008

A questionnaire-based survey on critical facilities was also conducted. In the research project and studies on tsunami early warning and evacuation, critical facilities were defined as facilities and buildings that have important functions for the community or occupied by a lot of people, including vulnerable groups[8]. Such places will consequently need special evacuation procedures and assistance in case of potential tsunami events. The survey data used for this study were data of schools and hospitals. The main variables used were occupancy rate at daytime (for dynamic exposure) and

[8] This definition is similar to the definition of critical facilities in the Permen PU 06/PRT/M/2009 on guidelines for development of infrastructure in the tsunami prone area

availability of warning dissemination devices (for access to warning). Additionally, data of other surveyed facilities, industries, hotels, market places and shopping malls, were analysed to examine some aspects related with community preparedness.

The first survey was conducted from May 22 to June 25, 2008, including semi-structured interviews of selected surveyed facilities to get more qualitative information. It continued in June-August 2009 to cover additional schools in the exposed areas. The survey was conducted with the support of students of the Andalas University and some staff of the City Education Agency. The facilities surveyed were 25 hospitals (covering all identified existing hospitals in the city), 260 schools and universities, 26 industries, 9 hotels, 14 market places and 5 shopping malls (using systematic random sampling from a list of facilities in the exposed sub-districts).

4.4.4 Spatial Data

GIS shape-files of building data were made available from remote sensing analyses and building surveys of DLR/Last-Mile within the scope of the Last-Mile - Evacuation project. The data had been already processed to provide information on the semantic classification of the buildings based on their physical urban morphology which represents the socio-economic characteristics of the buildings[9]. It also contained building use information obtained from building surveys. In order to complete the information on building uses, existing datasets from the local authorities were incorporated. However, a complete dataset on buildings uses in exposed areas had still not been achieved by this means; thus, additional GPS measurements and locations identification using Google Earth with the local partners were conducted for some facilities.

Additionally, a participatory mapping using local existing satellite imagery of the city with a local expert from the Spatial Planning and Urban Design Agency (TRTB) in Padang was conducted in June 2009 to validate the semantic classification from the remote-sensing analysis and get a better qualitative picture of the socio-economic patterns in the city.

4.4.5 Non-Structured Open Interviews and Informal Conversations with Selected Households and Local Actors

Non-structured open interviews were conducted to provide qualitative information on the related evacuation planning processes and the on-going activities as well as their current situations and challenges. In this approach, overarching topics had been prepared beforehand, but the questions were freely phrased adjusting to the natural situation in the conversations and the reactions of the informants (Gläser and Laudel 2006). This method was selected to have flexibility to address the questions based on the flow of conversations and emerging topics from the interviewees and thus, to be able to capture their perceptions rather than focussing only on the preconceptions of the researcher of the situation on the ground. A few spontaneous interviews were also conducted when

[9] For a more detailed information on the semantic classification method, please refer to Taubenböck et al., ((2009a) and (2009b))

meeting suitable informants e.g. during workshops or other project activities (with the consent of the interviewees, since all the informants knew the researcher and her activities in the field). The informants were selected purposively to represent various actors and agencies involved in evacuation planning processes and also selected households and actors working at the community level. In total, 21 interviews were conducted: six with selected households in November 2008, six interviews with actors at the planning level, two at the academic level, six with actors at the community level from June to August 2009, and one additional interview with international actors in September 2012. Moreover, numerous informal conversations observations with involved actors during meetings, local activities during field study, and email communication also took place during the study period.

Figure 4-9 Interviews with Selected Household and Actor at Community Level

Source: own figure

4.4.6 Focus Group Discussions

Two focus group discussions took place within the scope of the Last-Mile – Evacuation Project, which were used as a source of qualitative information in this study. The first one took place in February 2008 with six selected local disaster management actors and transportation experts on evacuation experience and challenges of the earthquake event in September 2007. The second one was conducted in June 2010 as a project evaluation workshop with two representatives of local actors and one national actor discussing about on-going evacuation planning and future urban planning processes.

At the community level, two group discussions with the households (mostly fishermen households) in Purus in February 2008 and August 2009 were conducted on general tsunami risk perception, daily activity patterns and dependency on the coastal areas.

Figure 4-10 Group Discussions with Planning Actors and Community

Source: own figure

4.4.7 Planning Documents and Regulations

Planning documents and regulations were reviewed to give "objective" and "reference-related" views of the planning activities and processes and the roles of various actors. The documents used were the Spatial Plan Report (RTRW) 2010-2030, the Strategic Plan of Disaster Management and Action Plan 2007-2012, and the Mayor´s Regulation (Perwako Padang) 2008 on roles and responsibilities of government agencies.

4.5 Challenges in Field Research and Limitations

During the data collection, there were challenges that caused longer duration of data collection and limited the completeness or quality of the data:

- Difficulties in Finding the "Right" Source of Information and Data

  It was acknowledged by the local actors that there was no centralized spatial database in any government agency. Some data were also stored by individual staff currently in charge of or involved in certain activities. Therefore, repeated visits to several agencies or staff to get spatial data were conducted. Due to the limited period of stay in most visits in the research areas, the data obtained was often not complete and could not be followed-up directly. Some data were also redundant but varying in their completeness or preciseness, so that a combination of several data and additional manual improvement was necessary. Some established contacts had also moved on to other agencies during different field visits and new contacts had to be established to follow-up on the data.

- Role of the Researcher in the Research Project

  As a project partner of "Last-Mile - Evacuation" and at the same time individual researcher, the researcher had to deal with various interests but at the same time maintain good rapport with the local actors. Sometimes the local actors were burdened by different incoming information and requests related to the overall project, and could not always allocate time and information to the researcher. During the study period, the focus and main interest of the local actors was initially only on hazard analysis (which was not directly part of this study), while vulnerability and risk reduction options would rather be discussed after the basic hazard map had been settled. In the scope of the project, the detailed hazard assessment

result was only made available at the end of the project. This made it not always easy for the researcher to discuss directly and in-depth at the planning level about the challenges and possibility of tsunami risk reduction measures during the project period.

5 Empirical Results: Assessment of People´s Response Capability, Issues of Perception, and Urban Planning Role

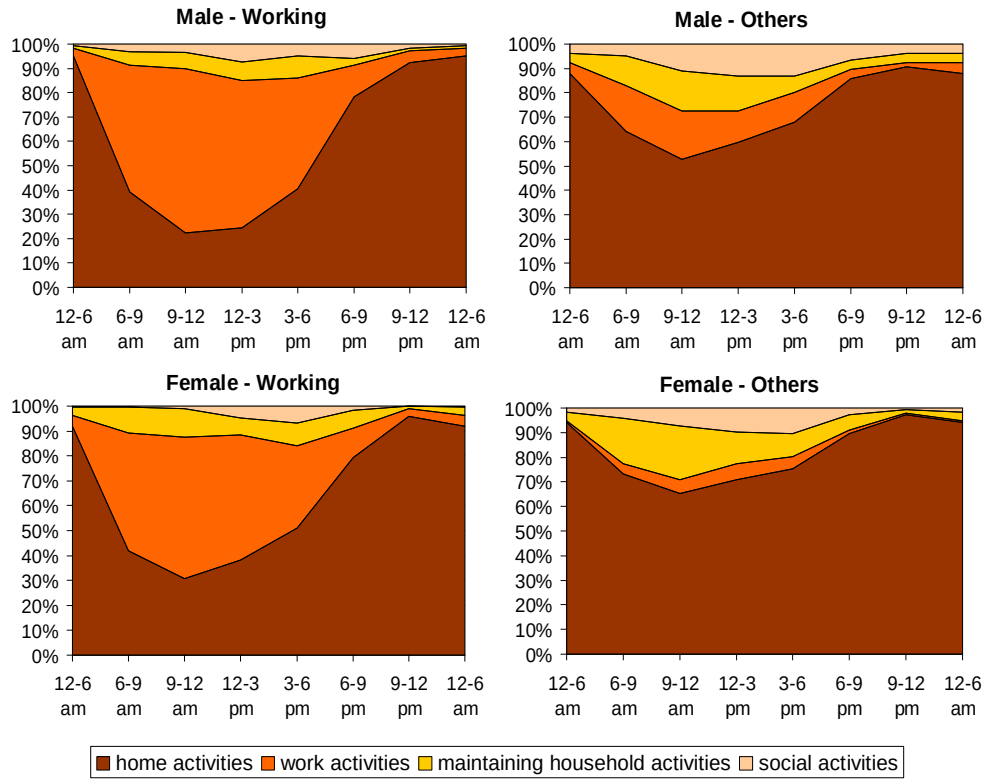
5.1 Dynamic Exposure of the Population

Exposure of the population as will be presented below shows dynamics in temporal terms (daily dynamics) as well as variation within social conditions. Following the analysis framework in Sub-chapter 4.1.1, exposure maps were generated. Additionally, socio-economic characteristics of the people in the exposed areas are also presented.

5.1.1 Exposure Map of the Population

The daily activity patterns for the working and non-working population groups were derived from an Activity Diary from the household survey. The patterns of working and non-working respondents are significantly different. The non-working respondents spend much more time on home activities, while the majority of working respondents conduct their working activities outside. Further, there is also a slight difference between male and female respondents in the same activity group, wherein the female respondents spend a little more time with home and household activities. As shown in Figure 5-1, the respondents with non-working main activities have a higher proportion of home activities than respondents with working main activities, and so are female respondents compared to male ones. Furthermore, the female population has on average a higher proportion of non-working people (housewives), and consequently carry out more activities at home in total. To derive daily activity patterns for the population groups of children and population engaged in education as their main activity, assumptions were made based on the occupancy rate of schools and universities as well as existing daily activity patterns of the working population group. This is due to the fact that the respondents were mostly household heads or spouses (see Table 4-7) and consequently, these groups were underrepresented in the activity diary data.

Figure 5-1 Daily activity patterns of male and female population by main activities



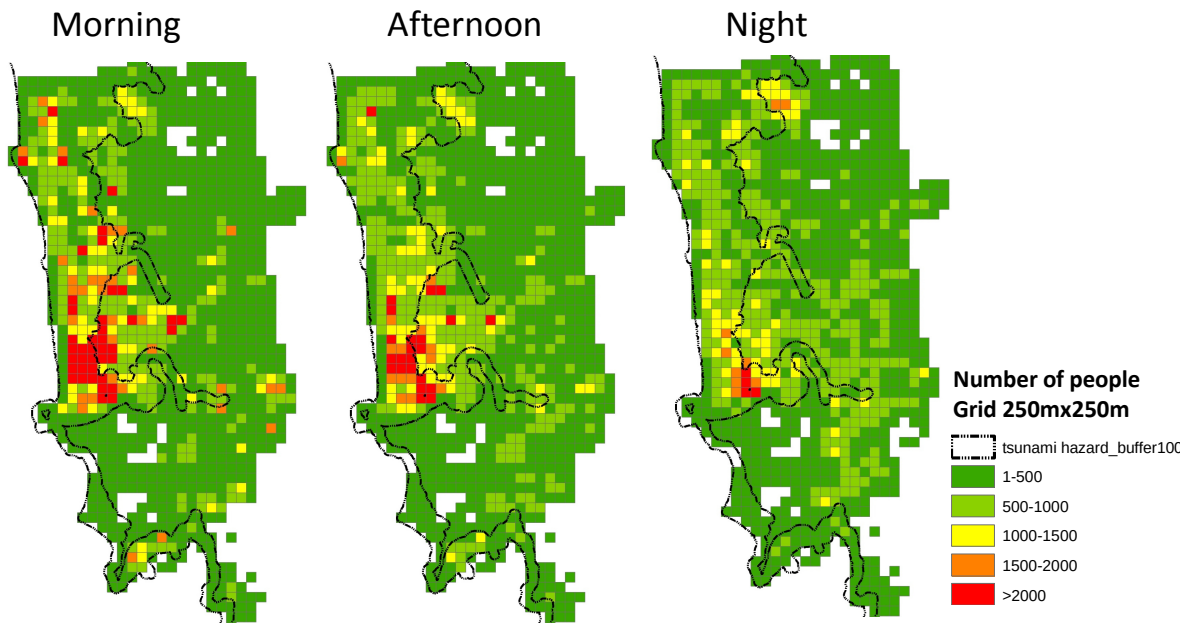
Source: own analysis based on the UNU-EHS Household Survey 2008, also presented in Setiadi et al., 2010

After linking the population groups, their daily activity patterns, and the building uses, the population distribution was calculated. At the end, the female population, children, and the elderly (including people in hospitals) were summarized as the more vulnerable population group due to their limited physical capability to conduct evacuation. Using the "Last-Mile" hazard map as a basis for the potentially tsunami inundated areas, the exposure of the population in the morning, afternoon, and night time was calculated at the building level and in a grid of 100mx100m as well as in a grid of 250mx250m. Here, the grid 250mx250m was displayed to fit the grid size of the evacuation traffic modelling.

The morning time indicates clearly that the highest number of people in the hazard zones, about 181,000, are located in the potentially affected areas of the tsunami modelling scenario of the Last-Mile project, whereof 118.000 of them (65%) are women, children, and elderly. The night time indicates the lowest number of exposed people of about 133,000 and a similar proportion of people with lower evacuation capability. In general, the coastal areas represent densely populated and built areas and therefore the level of exposure is high. By comparing the exposure at different daytimes, the concentration of people in the coastal areas and city centre during the working hours can be identified (Figure 5-2). The higher total number of exposed people in the morning time is due to additional working population living outside the exposed city areas, which conduct their working activities in the workplaces located inside the exposed areas. In the morning time, it is indicated that

population density outside the exposed areas decreases (more “dark green” area), and consequently population density in the city centre and commercial areas along the main roads increases (“orange” and “red” areas). In contrast, the population density at night time is more equally distributed.

Figure 5-2 Dynamic exposure of population by daytime



Source: own analysis

The following Table 5-1 summarizes the estimated amount of potentially affected people calculated.

Table 5-1 Estimation of potentially affected population based on daytime and building use

	Settlement		Workplaces and activity centres		Schools		Special facilities: hospitals	Total
	Men (15-64 years)	Women, children, elderly	Men (15-64 years)	Women, children, elderly	Men (15-64 years)	Women, children, elderly		
morning	19.196	47.541	32.628	30.473	11.367	39.365	600	181.170
afternoon	24.892	60.979	24.740	22.308	6.869	15.624	588	156.000
night	40.010	79.517	6.583	7.179	257	4	413	133.963

Source: own analysis

In order to validate the results of the analysis, the number of the total population and population groups (at night) was compared with the population data from the statistics for the year 2005 (last available ones during the data collection period). A detailed analysis of the number of people by building or building block as well as for the population during the day was not possible since there

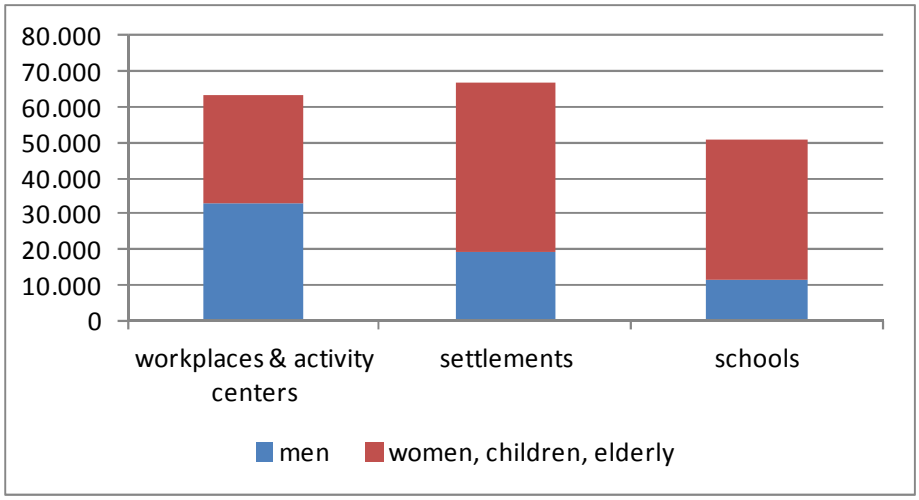
was no available basic data in the local statistics that could be used to validate the results of this analysis.

The total population number of the overall study area in the statistics was 428,452, of which 275,845 were women, children, and elderly citizens, while the calculation produced a total population of 387,450, of which 257,682 were women, children, and the elderly. A difference in the absolute population of about 10% (underestimation) exists while the ratio of people with less or more evacuation physical capability remains similar. Nevertheless, the number can give a rough estimation of the magnitude of potentially affected people by social groups, while it is more important to see the relative spatial difference of distribution in various city clusters and evacuation zones. Further, this result was used as an input parameter for the traffic modelling of the evacuation. Within the modelling, a buffer zone of 500 m beyond the actual inundation line was applied as a safety factor and it was assumed in this study that this could compensate the underestimated amount of exposed people.

5.1.2 Exposure of Women, Children, and Elderly Citizens

Moreover, as shown in Figure 5-3, variation of different population groups by building use, especially in the morning time due to variation in the daily activity patterns, could be identified. The proportion of women, elderly people and children is much higher in the residential areas and schools, and a slightly higher proportion of the male population is distributed in the workplaces and public centres which are mostly located in the city centres and along the main roads (Figure 5-3).

Figure 5-3 Number of Exposed Population Groups in Various Building Uses in the Morning

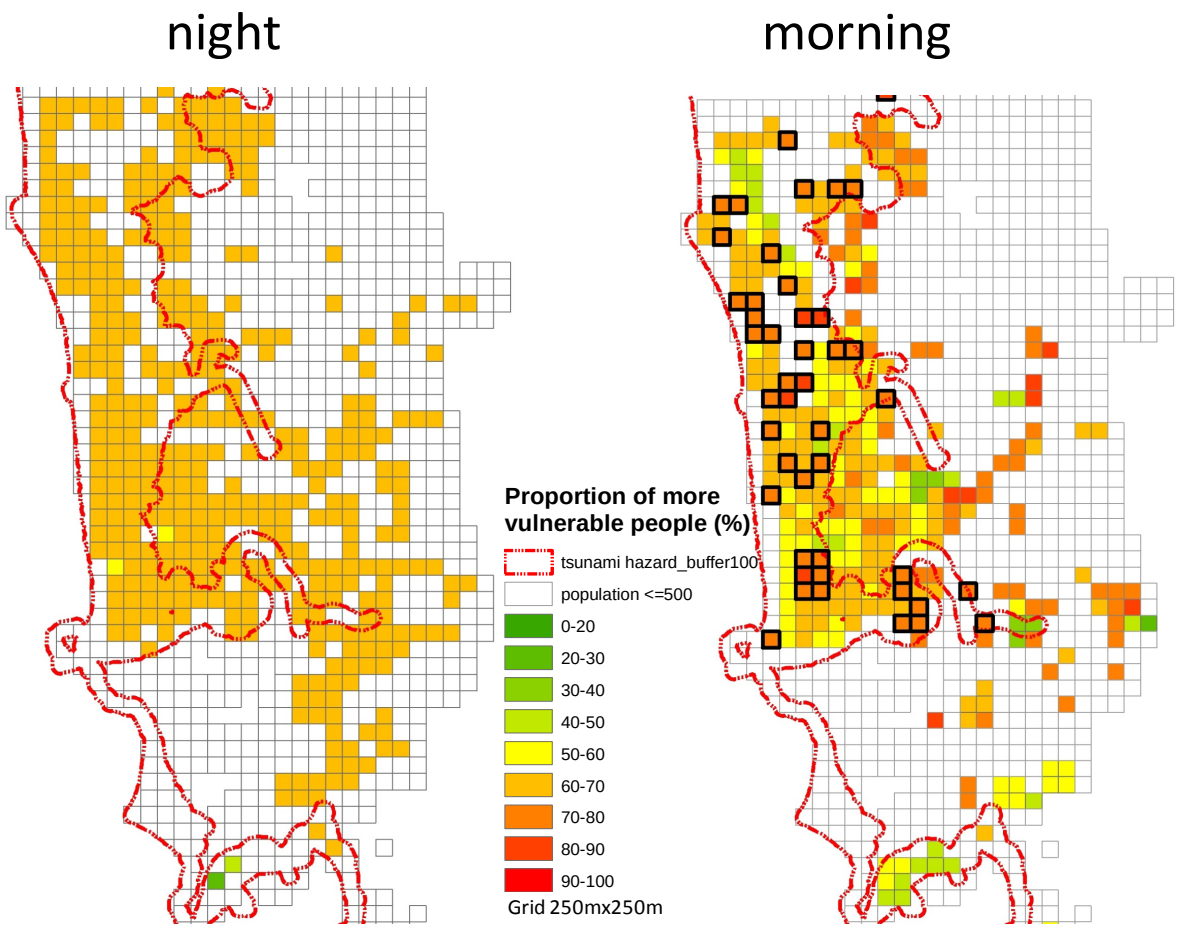


Source: own analysis

A comparison of exposure maps of the two population groups, with higher physical capability to evacuate (male population age 15-64 years) and with less physical capability (women, the elderly, and children), shows however similar spatial hotspots in the city centres and along the main roads, due to higher building occupancy rate of workplaces and activity centres in the area compared to settlement buildings. However, we can identify spatial differences in terms of the proportion of

people with lower capability to evacuate. Figure 5-4 shows the proportion per grid at night compared to the morning (only for the grid containing population of more than 500). Especially in the settlement areas and areas where schools are located, the proportion of more vulnerable people increases in the morning (during the working hours) and vice versa for the male population in the city centre and along the main roads. The grids with bold outline emphasize the exposed areas with a higher proportion of vulnerable population in the morning scenario. Even though a higher proportion of population with lower evacuation capability does not necessarily mean high and increasing exposure, it indicates potential evacuation bottlenecks. Such information is needed to identify evacuation assistance needs, especially in the areas where access to safe places is low (see Sub-chapter 5.2). Moreover, it should also be linked with the analysis of access to warning (effectiveness of warning dissemination to various population groups) and evacuation behaviour (family evacuation plan) in Sub-chapter 5.3 and 5.4.

Figure 5-4 Comparison of proportion of population with lower evacuation capability (women, children, elderly) in the morning and night



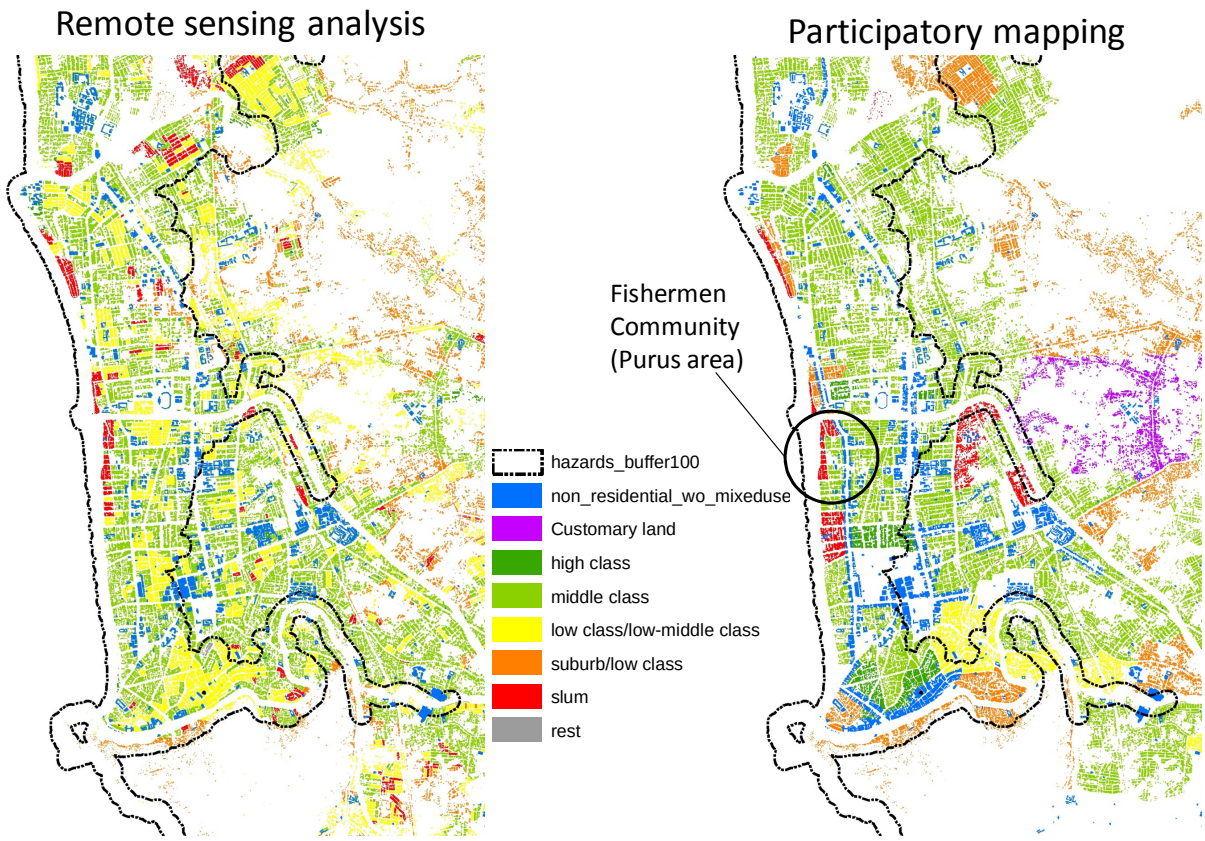
Source: own analysis

5.1.3 Exposure of People according to Different Socio-economic Status

Further, it is interesting to identify which social groups are actually living in the exposed areas. Since there was no micro level information on the household income or poverty level, data from remote sensing analysis and participatory mapping exercise was used to give a rough picture of the socio-economic patterns in the exposed areas. Figure 5-5 compares the results of socio-economic classification obtained applying two analytical methods. Using the semantic classification based on the remote sensing analysis, the proportion of exposed population with various socio-economic levels could be estimated: 2% in high class buildings, 50.1% in middle class buildings, 28.7% in low/middle class buildings, 5.4% in suburb/low class buildings, 13.6% in slums, and 0.2% unclassified rest.

While the remote sensing analysis provides more precise spatial location / coverage of each class and finer classification especially for the low and middle classes, the qualitative analysis by means of participatory mapping exercises with local experts provided additional information such as the location of special groups (fishermen community and households with majority of customary landownership), and identified non-residential buildings e.g. warehouses, which would have been identified as settlement buildings in remote sensing analysis. Nevertheless, both results point out that in the most exposed areas in the direct vicinity of the coast, there are identifiable spots of people with lower socio-economic level.

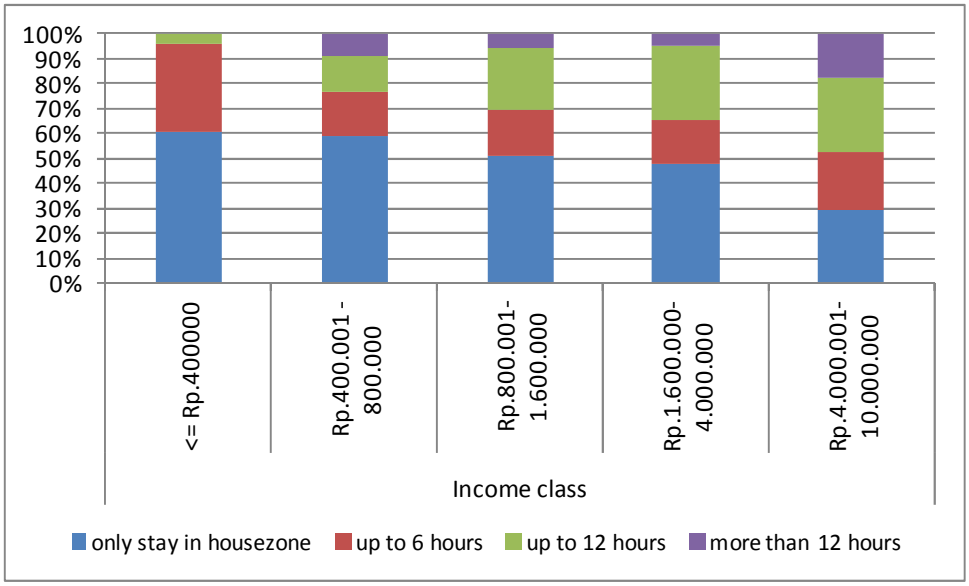
Figure 5-5 Semantic classification of the settlement areas based on socio-economic characteristics



Source: Remote sensing data and analysis DLR/Last-Mile and own qualitative analysis based on participatory mapping 2009

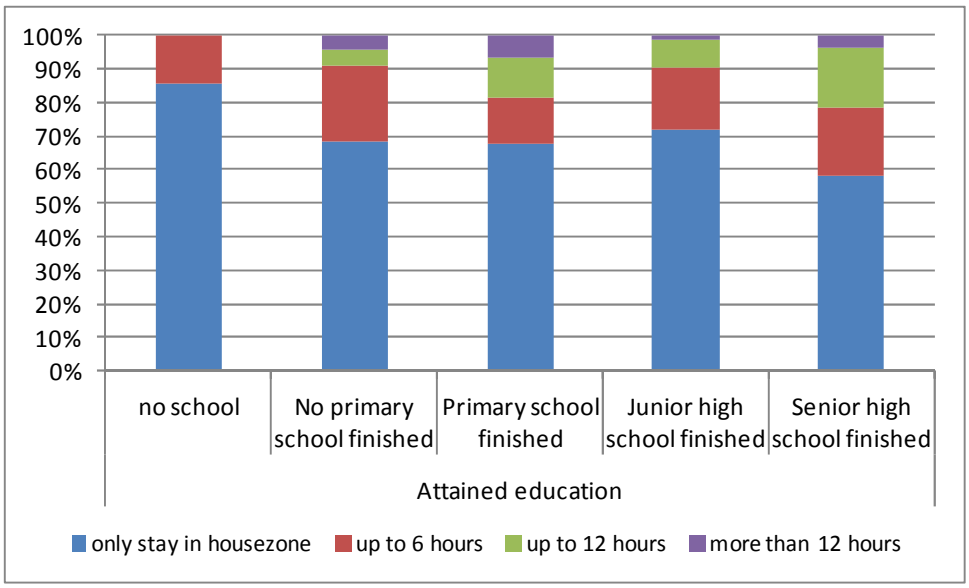
The challenges of mobility of various social groups identified above are shown by the data analysis of the UNU-EHS Household Survey 2008. As shown in the previous analysis (Chapter 5.1), the female population shows a relatively lower mobility (conducting more activities at home or in settlement areas) than the male population, since the female population has a higher proportion of people engaged in non-working main activities than males. The daily mobility is also associated with the socio-economic characteristics of people. The Household Survey found out significant correlations that the proportion of the respondents with daily activities outside the house / neighbourhood is lower for the ones with lower household income (Figure 5-6) and of lower educational level (Figure 5-7).

Figure 5-6 Duration (hours per day) spent outside the house zone by household income



Source: own analysis based on UNU-EHS Household Survey 2008 and spatial data

Figure 5-7 Duration (hours per day) spent outside the house zone by education level



Source: own analysis based on the UNU-EHS Household Survey 2008 and spatial data

Additionally, a group discussion in the fishermen neighbourhood with low socio-economic level in the Purus area derived a daily activity pattern of this particular group (see Figure 5-8). Since the male family members were working during the time of the discussion (noon time), only the female and children family members were available to participate in the exercise. Nevertheless, they could provide information on the daily activities of the other family members.

Figure 5-8 Daily activities of fishermen families

Daytime	Morning (9-12)	Noon (12-16)	Afternoon (16-19)	Evening (19-21)
Husband	Work in the sea (fishermen)	Sell fish in fishmarket	Take a rest	Prepare fishing tools / nets
Wife (not working)	Do household tasks at home / in the market	Do household tasks at home	Take a rest Gather with neighbours	Do household tasks, family time
Wife (working)	Work (selling food, oil, etc.) in kiosk at home or in the market)			Do household tasks, prepare for work
Children	Schools (morning class)	Schools (afternoon class), play with friends	Play with friends	Do homework, family time

Source: Own analysis, based on group discussion (PRA) with fishermen wives February 9, 2008

The group discussion also revealed that most activities of the female family members are conducted at home or in the neighbourhood, which was consistent with the quantitative analysis results above. The workplaces are mostly located in the coastal (exposed) areas. Also the places where they conduct their household activities like shopping for food are close by (still in exposed areas). For educational activities, it was mentioned that for children in primary school, the location of the school facilities was close to the place they live, while for the higher educational levels the locations were more varied. This may also be related to the fact that the schools at lower educational level are more and better spatially distributed, and that the higher the educational level the more varied the choice of location (better quality junior or senior high schools are located further away, whether private or public, etc.). For social activities, it is only occasionally that people travel further away to the eastern part of the city (less exposed areas) to visit extended family on school holidays, special events (weddings, Ramadan celebrations). For travel to areas further than the neighbourhood, the motorcycle is their common means of transport. This qualitative analysis also indicates a similar tendency to the quantitative results above in that households with lower income conduct less activities outside the house or have less mobility. This seems to suggest that people of the lower economic class, especially the female family members, would have rather similar day and night exposure in their settlement areas.

5.1.4 Implications of Dynamic Exposure to Evacuation Planning

Besides presenting the fact where, and related with which social groups and city activities exposure to tsunamis needs to be reduced, dynamic exposure should inform evacuation planning about how many and who have to be warned and evacuated, who will need to access safe places and the warning, and who would respond to the warning and the expected behaviour.

As illustrated, there is an increase of exposure in the morning and afternoon due to the daily activities of the people, especially in the areas where the main city services and commercial areas are

located. Additionally, in some spots there is an increasing proportion of vulnerable groups due to the variation in their daily activity patterns. Even though this does not cause a significant variation in terms of spatial hotspots, it is noteworthy that the social constellation and consequently, response capability, will differ due to this variation. The dynamics of the exposed people should serve as a basis and be linked with the other components:

Access to safe places: the quantification of exposed people was used as an important input factor to estimate the evacuation time during different daytimes and identify gaps in the existing transportation infrastructure for evacuation to safe areas. In addition to locations that need longer evacuation time, locations with high proportion of vulnerable people (dense settlement areas, schools, hospitals, and lower classes settlement areas) should be factored according to the provision of evacuation shelters, improvement of evacuation routes, and provision of vehicle support, as well as designing evacuation shelters oriented to the specific needs of these groups.

Access to warning: Utilization of devices and effectiveness of delivering the warning and warning message is influenced by the potential recipients. Therefore, information of who are located where is crucial. Delivering the warning during the night, when most people are with their family at home, is rather less complicated than during the day or in the afternoon (although the night time would have its challenges in conducting evacuation). A higher proportion of the majority of vulnerable people will rely on the availability of devices in homes, schools and hospitals. Especially the ones with lower socio-economic level would have lower access to private devices. In contrast, mixed population groups (with slightly higher proportion of male population) are located in the workplaces and activity centres and would rely on the availability of devices in these places.

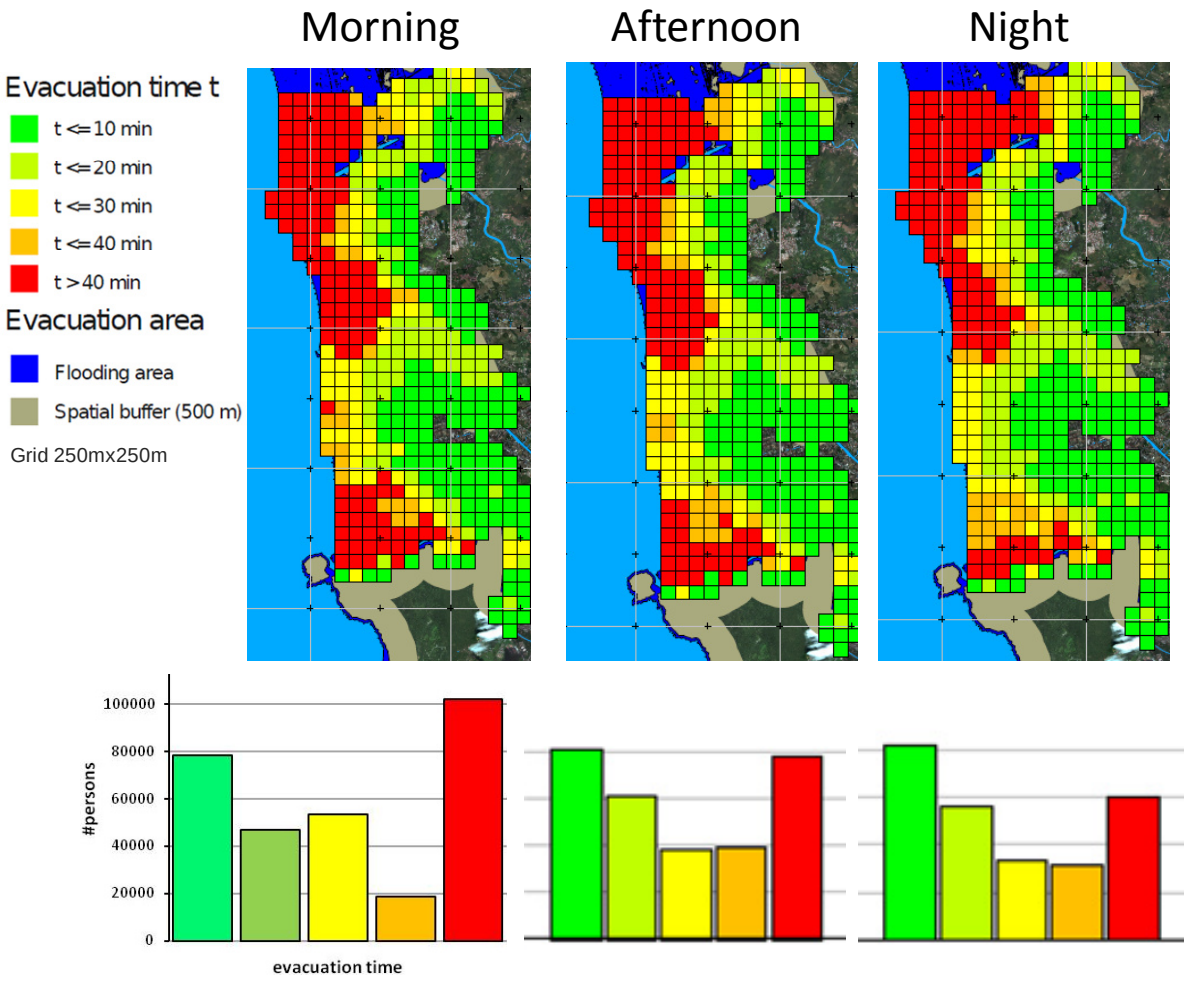
Evacuation behaviour: evacuation arrangements / family evacuation plans should take into consideration that the vulnerable family members are in many cases located in the settlement areas as well as in schools (children). At home, it is also likely that the female heads of households/spouses have to make decisions on whether and how to evacuate the family. At school, children have to be aware of the evacuation procedures and how to contact their parents. At the work places, the parents or other family members have to decide whether to go home / other places to gather other family members or to evacuate directly. In some cases, reverse traffic during evacuation from work places, schools, to settlement areas is to be expected and solutions are needed, e.g. separate evacuation, special arrangement at schools and other public facilities.

5.2 Access to Safe Places

The most-plausible tsunami-genic earthquake agreed by the scientific community for Padang implies a very short estimated tsunami arrival time (around 30 minutes). This will confront with the issue of the concentration of the population in the coastal areas. An evacuation modelling analysis using dynamic exposure as an input parameter, existing street network capacity within the potentially inundated areas (with a spatial buffer of 500 meter) was conducted by the Technical University of Berlin/Last-Mile and revealed that the current road network is still far less than sufficient to conduct mass evacuation to safe places in a short lead time (Figure 5-9). The modelling results indicated that there is a high proportion of people living or conducting activities in the coastal areas that would

need more than 30 minutes to evacuate themselves. In the morning time, the estimated number of evacuees (including the ones in the 500 meter spatial buffer) is 392,441, of which 152,356 (38.8%) need longer than 30 minutes to evacuate. In the afternoon, there are 122,976 (35.9%) out of 342,575 evacuees, and at night 95,234 (32%) out of 297,920 evacuees who need longer than 30 minutes. The most problematic areas in all three daytime scenarios are in the half northern part of the coast and in the river mouth (*Muaro*) area in the south. The city centre and old town close to the river mouth becomes a hotspot in the morning and afternoon times when people are at work or busy with other activities in the commercial areas and public facilities.

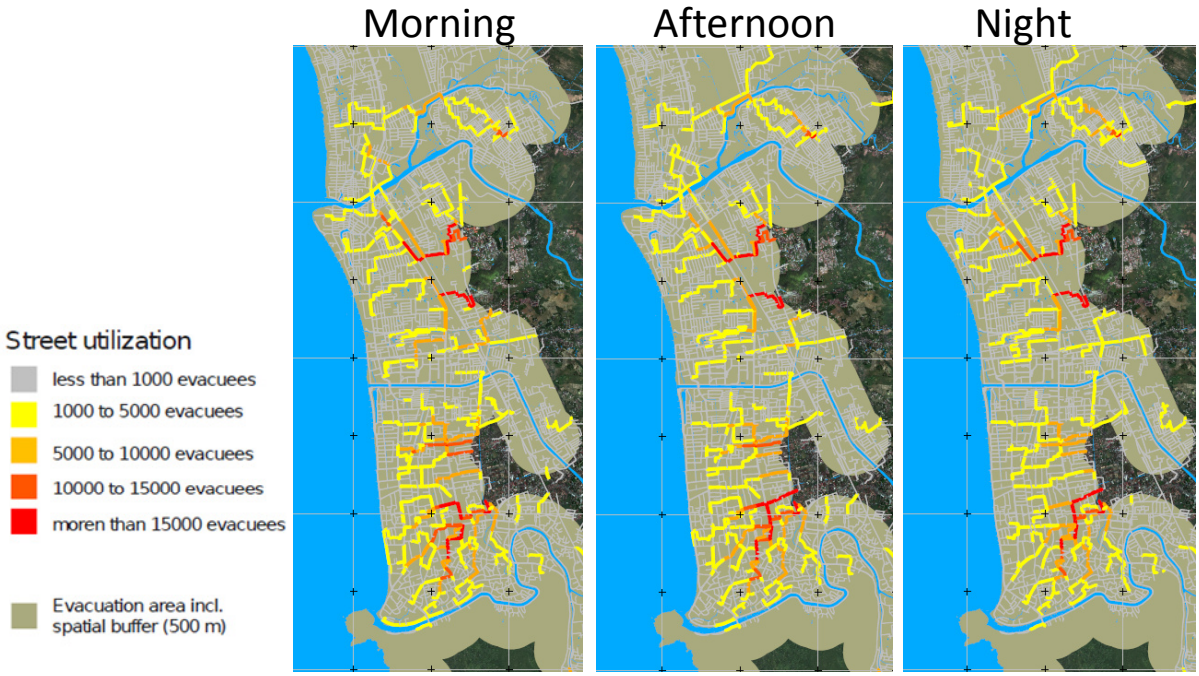
Figure 5-9 Estimated evacuation time by daytime



Source: TU-Berlin/Last-Mile, 2010

The next figure shows the utilization of the street network for evacuation (Figure 5-10). It shows which streets would be overused as evacuation routes. Especially several streets perpendicular to the coastline in the areas with the shortest evacuation distance, seem to provide more people with better access to safe places thus granting an optimized evacuation time. This indicates the need for more perpendicular road access, especially to support the most utilized evacuation routes to safe places as well as the provision of evacuation shelters for vertical evacuation.

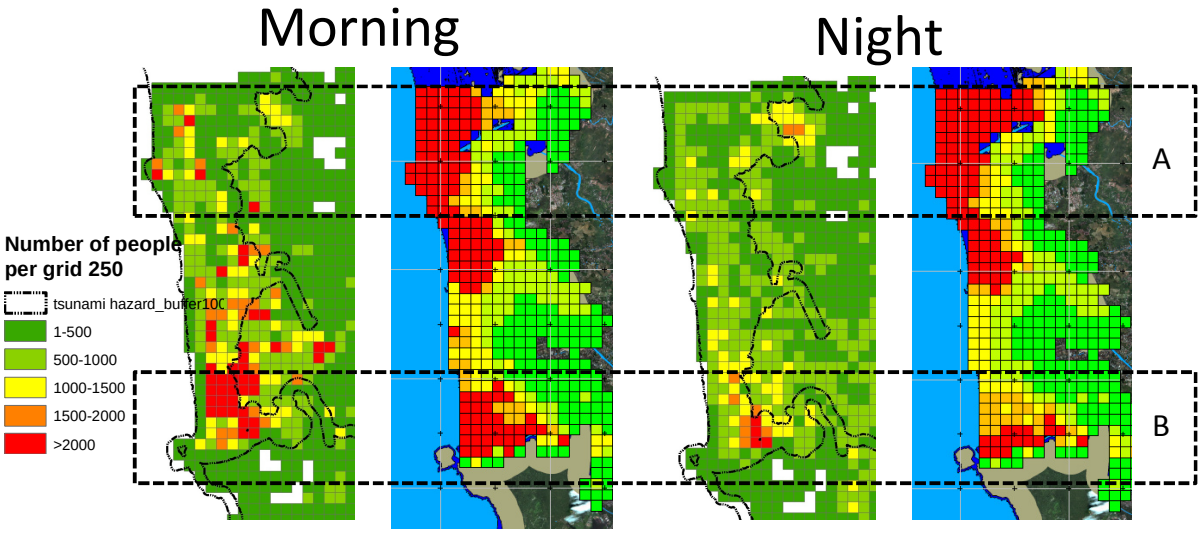
Figure 5-10 Utilization of street for evacuation



Source: TU-Berlin/Last-Mile, 2010

It is also noteworthy that the hotspots resulting from a combination of dynamic exposure and the capacity of the existing street networks may vary. This will be shown by zooming into and comparing two of the most problematic areas (Figure 5-11). The northern part (A) of the coast is problematic even though the population concentration is rather low in both the morning and night scenarios. This is attributable to firstly, the long evacuation distance due to the long penetration of potential tsunami inundations, but also clearly because the shape of the canals with very few bridges and no access to the evacuation routes (perpendicular pathways) so that people have to take longer routes to reach safe areas. The condition gets slightly (but not significantly) better in the morning time when some people are outside the settlement areas. In contrast, the river mouth area in the south (B) indicates the insufficiency of existing evacuation routes for such a population. This gets worse in the mornings due to the concentration of people commuting to the city centre.

Figure 5-11 Comparison of spatial hotspots exposed population and needed evacuation time morning and night time



Source: own figure and TU-Berlin/Last-Mile, 2010

Overall, the results show that the most problematic areas in all the three daytime scenarios are in the half northern part of the coast and in the river mouth (Muaro) area in the south. The northern part (segment A) is more influenced by the insufficiency of the transportation network crossing the canal and of perpendicular roads towards the hinterland, and in addition, the closed military area in the north of this segment poses a barrier so that the people have no other choice but to take this route. Thus, the improvement of access roads perpendicular to the coast and bridges crossing the canals is necessary in addition to the provision of evacuation shelters using the night scenario. In the southern part (segment B), congestions are primarily due to population concentration in the city centre in spite of the dense street network available, especially during working hours. Therefore, evacuation shelters close to the activity centres frequented in the morning s are required. Moreover, although the age and gender structure was not considered in the evacuation time estimation under the assumption that mass evacuation in the context of Padang would cause such heavy traffic anyway that individual evacuation velocity would not be significant anymore, variation in the proportion of women, children, and elderly people is still an important factor. The previous Figure 5-4 already indicated where people with lower evacuation capability are, pointing to the areas where evacuation support is likely to be most needed. In this regard, the provision of evacuation shelters needs to be prioritized in the locations where the proportion of these population groups is high and be designed accordingly to meet their specific needs.

With regard to potential buildings for vertical evacuation shelters, there were hardly any buildings that could be considered even relatively adequate. Based on the existing remote sensing analysis, which was conducted in combination with building surveys, only four out of about 88,000 buildings in the study areas were estimated as fulfilling the minimum structural stability requirements to resist earthquake impacts, of which only one was also tsunami resistant.

5.3 Access to the Warning

5.3.1 Availability of Private and Public Broadcasting Devices

In the past events, the people received formal and informal information from the authorities, friends or families. The information was disseminated directly through word of mouth or private devices like television, radio, telephone, and mobile phone, as well as public broadcasting devices like sirens and loudspeakers at the mosques. These media were used to disseminate information about the earthquake after its occurrence and about existing (or non-existing) tsunami potential as well as to instruct the population to be alert or to evacuate.

Analysis of the availability of private devices at home and at the workplace was based on the UNU-EHS Household Survey 2008. For critical facilities of school and hospitals, the basis data was taken from the UNU-EHS Critical Facilities Survey 2008. Table 5-2 shows the summary of availability of various private devices by building use.

Table 5-2 Availability of private devices by building

Private devices	Availability			
	Home	**Workplace**	**School**	**Hospital**
None	**1.9%**	**45.9%**	**0%**	**0%**
Radio	69.1%	23.1%	74.4%	68.00%
Television	94.3%	33.1%	47.1%	100.00%
Mobile phones	63.3%	39.0%	90.9%	100.00%
Landline phones	29.2%	9.5%	78.5%	88.00%

Source: Own analysis based on UNU-EHS Household Survey 2008 and Critical facilities Survey 2008

The results show that television provides communication to most people in the settlement areas, followed by radio, mobile phones and landline phones – regardless of the utilization pattern of the devices and robustness of the transmission network in earthquake and potential tsunami events. At the workplace, the availability of all these devices is much lower and almost half of the people even do not have access to any of them. At schools and hospitals, as in workplaces, mobile phones seem to be the most accessible dissemination medium. Also, access to landline phones is much higher in these buildings compared to the settlement areas. However, access to mobile phones is lower for the people in the lower income group. The analysis of the UNU-EHS Household Survey 2008 found a significant correlation between household income level and availability of mobile phones at home (Kendall´s tau-b: 0.200, significant at $p<0.01$) and in the workplace/school (Kendall´s tau-b: 0.232, significant at $p<0.01$).

Linking the availability of private devices with the population distribution in different types of buildings, i.e. the dynamic exposure, the estimated number of potentially affected people with access to various private devices was calculated (Table 5-3).

Table 5-3 Access to private devices in the hazard zone

Private devices	Estimated potentially affected people with access to the following devices (proportion in %)		
	morning	afternoon	night
Radio	98,891 (54.6%)	87,413 (56.0%)	86,149 (64.4%)
Television	108,383 (59.8%)	107,839 (69.1%)	117,661 (87.9%)
Mobile phones	113,638 (62.7%)	93,847 (60.1%)	81,534 (60.9%)
Landline phones	65,895 (36.4%)	47,813 (30.6%)	36,651 (27.4%)

Source: Own analysis

In the morning and afternoon, the overall access to private devices is less, since many people are at the workplace where the availability of private communication devices (especially TV and radio) is low. Moreover, it has to be considered that in workplace buildings with many people as well as schools and hospitals, in spite of those devices, the information has to be further circulated to people in the whole building upon receipt of the warning. This may cause further delay in conducting evacuation if no Standard Operational Procedures (SOP) for evacuation is available. Based on the UNU-EHS Survey on Critical Facilities 2008, other facilities such as industries, hotels, market places and shopping malls also have private means of communication (TV/radio/mobile phones) in the buildings to receive information about tsunami warnings, as is the case in schools and hospitals. However, not all facilities have additional devices such as loudspeakers, alarms, or "*kentongan*" (traditional devices made from bamboo) to be used for disseminating the warning to all visitors or staff in a centralized and quick manner. The availability of additional disseminating devices is the lowest for industries (21 out of 26 have no additional devices) and market places (none of the 14). This means that warning information in such facilities will be disseminated on an individual basis and the evacuation from these buildings may take longer.

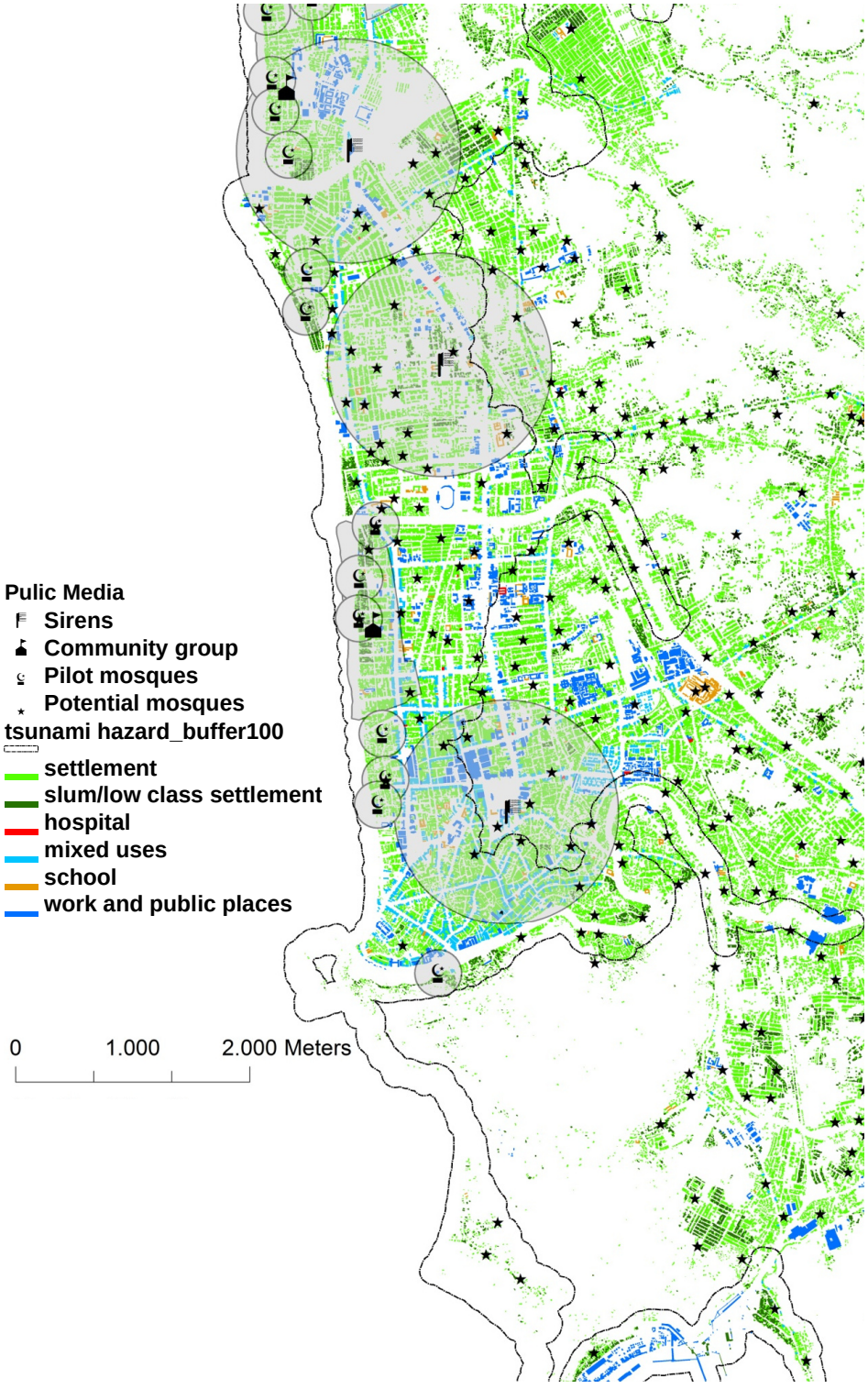
Public broadcasting devices such as mosque loudspeakers, word of mouth in the neighbourhood and community-based response teams were recently being developed and have a high potential in Padang. Through discussion with the local leaders, several community-based response teams in the city of Padang were identified. At least three teams in three villages (Kelurahan) established by the Red Cross and two teams by the local NGO KOGAMI were identified during the field study in 2009. These teams were trained and equipped with radio and handy talky to receive information in case of emergency and circulate it to the people in their neighbourhoods. In 2009-2010, capacity building activities for mosque leaders and staff in 30 pilot mosques to be involved in the tsunami early warning system in Padang were initiated by the NGO KOGAMI in cooperation with the German Technical Cooperation (GTZ).

The spatial data for analysis of public broadcasting devices, sirens and mosques, were derived from data from the City Planning Agency as well as GPS and Google-Earth identification by the local actors. Additionally, the villages (*Kelurahan*) where community-based response teams had been established

through the efforts of local NGOs were identified. The spatial coverage of the public broadcasting devices was assumed to have a loudspeaker radius of 960 m for sirens, and 200 m for mosques (derived from siren coverage figure in Alexander Kesper 2007, p.25). For the community-based response teams, it was assumed that they may serve the whole village where they are based (spatial coverage equals the administrative boundary of the corresponding *Kelurahan*).

Figure 5-12 shows the distribution and spatial coverage of the existing public broadcasting devices. The spatial coverage of the existing public devices was presented against various building uses here to provide an overview of their availability, especially in the working places and low class settlements, where access to private devices is lower. As seen in the figure, the siren coverage is quite well distributed and covers a high proportion of the workplaces and public areas. In the areas where the socio-economic level is lower, the utilization of available mosques and community-based response teams supports the access to warning of people living there. However, several areas with lack of access to public broadcasting devices could be identified, especially in the areas of Padang Barat and Padang Timur surrounding the flood canal *Banjir Kanal* (middle part in the map) and the area close to the river mouth *Muaro* (southern part in the map). The existing mosques that have not been trained and utilized yet, are illustrated to show the potential of using these public facilities as dissemination medium in the future.

Figure 5-12 Distribution and coverage of public warning dissemination devices by building use



Source: Own analysis

With regard to public devices, the estimated number of potentially affected people with access to various devices was also calculated (Table 5-4).

Table 5-4 Access to public devices

Devices	Estimated potentially affected people with access to the following public devices (proportion in %)		
	morning	afternoon	night
None	**75,511 (41.7%)**	**66,827 (36.9%)**	**58,288 (32.2%)**
Sirens (radius 960 m)	86,460 (47.7%)	70,717 (45.3%)	56,558 (42.3%)
Mosques (radius 200 m)	12,776 (7.0%)	13,875 (8.9%)	15,760 (11.8%)
Response teams (whole *Kelurahan*)	15,136 (8.4%)	14,457 (9.3%)	15,587 (11.6%)

Source: Own analysis

The overall access to public devices is much lower than to private devices. It is noteworthy that the proportion of people without access to any of the public devices is considerably high: 41.7% of people do not have access to public broadcasting devices in the morning and 32.2% at night (the settlement areas have slightly better access to mosques and community-based response teams).

At night time, most of the people have to rely on the availability of private devices at home and public devices installed at the house locations, while in the morning and afternoon, a proportion of the people who conduct activities in other places have to rely on the availability of private and public devices in those locations. Here, the morning scenario has the lowest access to communication devices, and therefore, the priority of the new sirens should be firstly in the exposed locations where people are at work. The areas without access to public broadcasting devices are considered as hotspots, and are even more problematic if they have low access to private dissemination areas. Identified hotspots are especially the trading areas in the old town, some areas in the city centres and along the rivers / canals. These areas would need additional public devices for warning dissemination the most such as installation of sirens, utilization of the existing mosque speakers, or establishment of community-based response teams.

5.3.2 Utilization and Effectiveness of Warning Dissemination Devices

Availability of a particular device does not necessarily mean that the household or respondent will actually receive a warning through these devices in case a tsunami really strikes. Generally, the local actors perceive the use of private devices as doubtful due to the possibility of a break-down of the electricity supply (non-battery operated television and radio) or the interruption of communication transmission of mobile phones following a strong earthquake. As to landline phones, the public can only receive the warning indirectly through social networks as long as the transmission line is not damaged. However, these private devices are still considered useful due to the absence of public dissemination devices that cover the whole city of Padang (or the potentially affected city areas) and

it is commonly accepted that redundancy of various dissemination devices is important to guarantee quick distribution of the warning message to all potentially affected people.

As described in the previous discussion on public devices availability, the promotion of community-based efforts in some pilot mosques and *Kelurahan* has been taking place. However, during the time of data collection, these public devices had not been (fully) utilized yet, so it was not possible to assess their effectiveness based on any quantitative data yet. Thus, the analysis below can only show the effectiveness of private devices.

Based on the UNU-EHS Household Survey 2008, 73.5% of the respondents had received a tsunami warning during the earthquake event in September 2007. Most of them had received the information through one or more devices. However, not all available devices were utilized to disseminate or receive the warning information. Indeed, the analysis of the survey revealed that the receipt of the warning through particular devices was much lower than the availability of the devices itself. The dissemination rate of various private devices was calculated as the proportion of people having the devices effectively receiving information through them (Table 5-5). As seen in Table 5-5, the effectiveness or dissemination rate of radio and television is less than half than its availability, while the effectiveness of mobile phones is even lower than 10 times of its availability. The utilization of the devices also differs by gender and age groups. The survey showed that more female respondents received the information from television (Cramer-V coefficient 0.107, significant at $p<0.01$). In contrast, the dissemination rate via mobile phones (SMS) was less for female respondents (Cramer-V coefficient -0.091, significant at $p<0.05$) and respondents older than 50 years (Cramer-V coefficient -0.113, significant at $p<0.01$).

Table 5-5 Dissemination rate of the warning information through private devices in September 2007

Devices	Dissemination rate (%)
Radio	45.3%
Television	42.2%
Mobile phone (SMS)	8.8%

Source: Own analysis based on the UNU-EHS Household Survey 2008

Additionally, it should be taken into consideration that aside from the fact that the majority of the people have access to particular devices, friends and neighbours play a big role in disseminating the warning. The survey showed that of the 67.1% of the respondents who received the warning, had also been informed about the warning by friends and neighbours.

The earthquake event in September 2009 also occurred at the same daytime (afternoon) as the event in 2007 and both events were quite comparable. Based on a household survey conducted by GTZ in 2009, 84% of the respondents had received information about the earthquake and potential tsunami. However, only 20% of the respondents received information within 30 minutes after the earthquake event. For this event, dissemination rates of the warning through various private devices

were also calculated (Table 5-6). Here, mobile phone and television had an even much lower rate due to a breakdown of the electricity supply and mobile phone transmission during the event.

Table 5-6 Dissemination rate of the warning information through private devices in September 2009

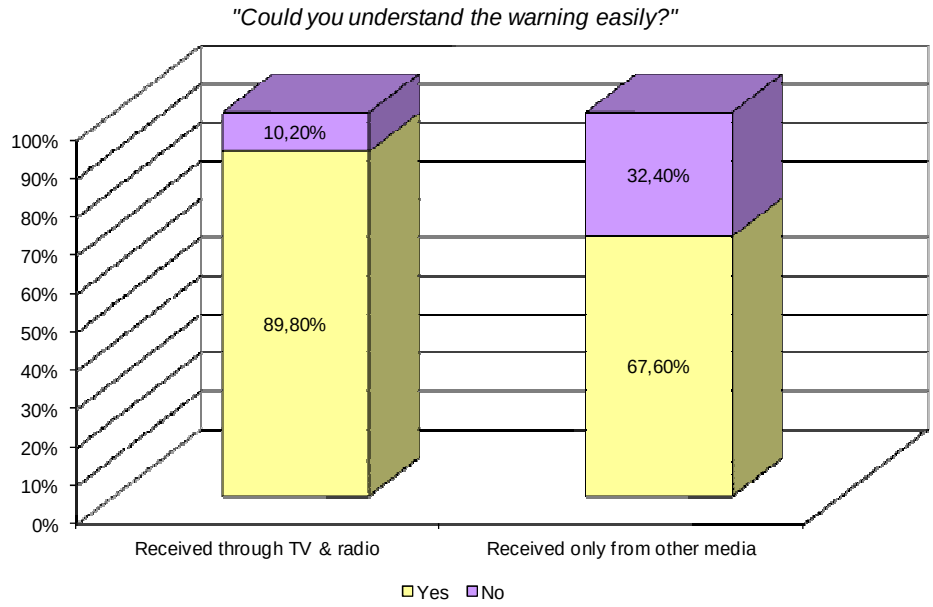
Devices	Dissemination rate (%)
Radio	39.1%
Television	4.8%
Mobile phones	0.8%
Landline phones	8.6%

Source: Own analysis based on GTZ Household Survey 2009

In both events, the radio was identified as the most effective dissemination device. This has been also confirmed by the local actors, who stated that (battery-operated) radio, and additionally handy-talky communication at the community level had proven to be the best dissemination devices (FGD with local actors Bonn, June 21-25, 2010). The dissemination of earthquake and potential tsunami information through mobile phones (SMS) is also being improved and extended to cover more people in the future. Traditional devices such as *Kentongan* (made of bamboos) is also locally used, however, there are no further indications yet on the effectiveness and utilization of this device.

Moreover, the content and clearness of the warning message vary by device. The UNU-EHS Household Survey 2008 shows that 51.3% of the respondents could be reached by television and radio, which was primarily used to disseminate direct information from the Tsunami Warning Centre and local government, and 22.2% could be reached only indirectly via other channels such as mobile phones, friends and neighbours. It was found that more people who had received the warning directly could understand the message without difficulties. Such difficulties may cause wrong interpretations of the message and lead to unexpected behaviour during evacuation.

Figure 5-13 Understanding the warning by dissemination devices



Source: Own analysis based on the UNU-EHS Household Survey 2008

Confirming the results of the quantitative analysis, the coverage of existing public devices was still perceived by the people as insufficient. For instance, some households interviewed mentioned that the sound of the siren was not clearly heard. Also, the community response groups at the local level who had been trained to help people in the neighbourhoods to evacuate, had been overwhelmed by the number of exposed people they had to support that vastly exceeded their capacity.

5.4 Evacuation Behaviour

Upon delivery of the warning, people interpreted the warning and reacted differently. The following illustrates various important aspects in evacuation behaviour based on people´s experience, which encompass decision to evacuate, evacuation arrangements at household level, evacuation destination and mode.

5.4.1 Decision to Evacuate and Evacuation Delay

Based on the analysis of the household survey on the previous "potential tsunami" earthquake experience, especially in September 2007, it was found that there was only a small proportion of people evacuating after receiving the warning (35%). The main reasons given by the respondents who did not evacuate were "did not trust the warning" and "wanted to wait and be sure about the tsunami occurrence".

Moreover, 42% of those who evacuated did not immediately proceed to evacuate but gathered the household members first, collected important items at home and/or secured the house before evacuating, etc. The analysis also found out that 98% of the respondents performed evacuation in groups; most of them (75%) evacuated with the family members. A simple correlation analysis was

performed between the variable “did you evacuate” and some independent variables, resulting in significant correlations as shown in Table 5-7 below.

Table 5-7 Correlation analysis between evacuation in the past and some selected variables

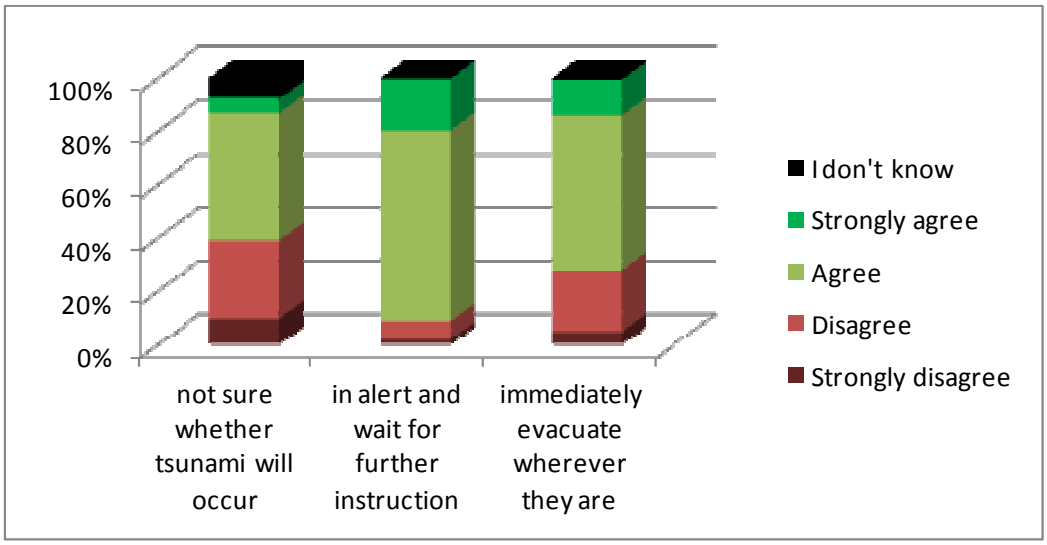
	Kramer's V	Kendall´s tau b
Distance to the coast (further from the coast, less people evacuated)		-0.133
Household income (higher income, more people evacuated)		0.082
Gender (more females evacuated)	0.128	
Understanding the received warning message (when better understood, more people evacuated)		0.122

Source: Own analysis based on the UNU-EHS Household Survey 2008

These results also show that spatial settings, socio-economic characteristics, and the format of the warning message have a direct influence on the decision to evacuate. Additionally, the households that have elderly family members (with no children) showed a tendency of lower evacuation rate, although this has not shown a significant correlation due to the small sample size for this particular group.

It is also worth considering how people perceived the evacuation urgency conveyed by the tsunami warning. The official message given by the early warning centre was “earthquake with potential tsunami”, followed by instructions from various sources at the local level to evacuate or stay in alert. Many people also received information indirectly from word of mouth, so that various interpretations were possible. Even for the official “potential tsunami”, there have been different interpretations. As seen in Figure 5-14, more than half of the respondents still perceived a “potential tsunami” as an uncertain tsunami threat. They tended to stay in alert and wait for further instructions rather than immediately evacuate. It was also emphasized in the interviews with the households and actors at the community level that clear information and evacuation guidance from the authorities or warning centre is really needed in emergency situations so that people do not panic and are able to follow instructions adequately.

Figure 5-14 Various interpretations of tsunami warning message ("Do the following statements come into your mind if you receive a "*potential tsunami*" warning?")



Source: Own analysis based on the UNU-EHS Household Survey 2008

Although the evacuation rate was very low in the past experience in 2007, 75% of the respondents intended to conduct evacuation in case of future tsunami early warnings. However, only 37.7% intended to evacuate immediately alone or with family members while 37.2% would conduct other actions before proceeding to evacuate, i.e. by seeking further information from the media or by observing the coast. An attempt to visualize the impact of the evacuation delay on the overall evacuation time was done in cooperation with TU Berlin / Last-Mile. The evacuation behaviour was derived from the intention of the respondents to evacuate and classified as immediate evacuation, evacuation with delay, and no evacuation. For each evacuation behaviour class, an assumption for the delay time in starting evacuation was arbitrarily made. The following classification of the evacuation response based on distance from the coast was used:

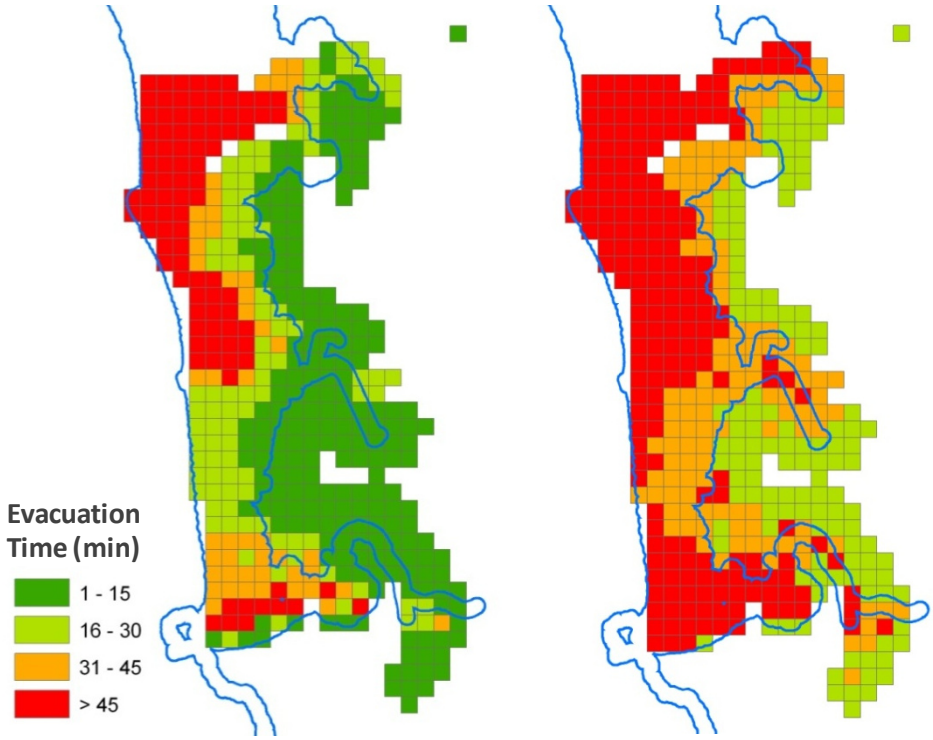
Table 5-8 Classification of evacuation behaviour for evacuation delay modelling

Intended response	Living > 3 km from the coast	Living within 3 km from the coast	Total
Not evacuating (assumed delay 25 minutes)	35.7%	21.4%	25.1%
Evacuation after finding further information (assumed delay 15 minutes)	23.9%	41.7%	37.2%
Evacuation immediately alone or with family members (no delay assumed at all)	40.3%	36.8%	37.7%

Source: Own analysis based on the UNU-EHS Household Survey 2008, assumption of delay time based on discussions with TU Berlin/Last-Mile

The evacuation modelling produced is shown in the Figure 5-15 below.

Figure 5-15 Estimated evacuation time with and without evacuation delay (morning scenario)



Source: TU Berlin / Last-Mile, 2009

The model on the left side is evacuation time without consideration of evacuation behaviour, and on the right side with consideration of evacuation behaviour. Generally, the evacuation time needed was much longer due to delays – which had been expected and assumed. However, the modelling shows the magnitude of total evacuation delay and potential losses of lives caused by evacuation delay (from about 38% of people who needed longer than 30 minutes it increased to 78%). Such a number, although it cannot be presumed to be an absolute number, serves as eye opener of how important risk communication and education of the population in parallel to physical measures really is. The issues of perception and soft measures for effective risk communication and community education are crucial factors that determine the effectiveness of physical measures.

5.4.2 Evacuation Arrangements at Household and Community Level

Qualitative analysis of the interviews with the selected households and actors at the community level shows that evacuation behaviours vary for different people depending on the available preparedness and arrangements at the household level, as well as their knowledge of tsunamis and evacuation procedures.

> "We have prepared our family to evacuate if there is a tsunami, if possible using the car, if not walk on foot. We will go to high buildings which are strong for vertical evacuation. We already have info on safe zone in Padang. We need better evacuation planning, I would pick up my children from school, but my older child

has been instructed to go by himself to Gunung Pangilun (safe area), also my wife if we are in different locations."[10]

"I would evacuate with my whole family, as far as possible not alone / separately"[11]

"I was observing the beach as people were evacuating during the earthquake. I know the indications of tsunami from the television and books. If the water retrieves it means tsunami would occur, otherwise not. I will evacuate if there are tsunami indications and the earthquake is very strong"[12]

It is also important to note that there was still no standardized arrangement in all schools, although this had been planned and initiated in some pilot schools, so that at the moment evacuation still depends on the arrangements at household or family level

"In the last experience, normally in the elementary schools, if an earthquake happened the parents picked up the children directly, so that schools handed over the children to them.(there has been discussion of potential arrangement that children´s evacuation would be organized by the schools)"[13]

The findings from the UNU-EHS Survey on Critical Facilities 2008 supported this argument: 50% of the surveyed schools mentioned that most teachers and pupils went home and gathered their family members during the last earthquake, while only 11% proceeded to direct evacuation to the higher ground or buildings. Similar behaviour was observed in the industries, market places, and shopping malls surveyed– which represent areas of working and daily activities –.As a matter of fact, the majority of the people went home and gathered with their family members, instead of conducting evacuation separately or in an organized manner as arranged by the authorities. Again, available evacuation arrangements at the household level are crucial. Apart from the fact that most people would be likely to evacuate together with their family members, this also relates the other fact that the availability of the Standard Operational Procedures and Emergency Plan in those facilities is still very low, with the exception of hospitals and pilot schools in the vicinity of the coast.

Additionally, the importance of community leaders in influencing people´s decisions is emphasized and their involvement in communicating risk or giving examples in appropriate behaviour is crucial.

"one of the cultural values in the community is to pay respect to the community leaders. Many testimonies from the people mentioned that they evacuated if the leaders evacuated, we strongly suggest considering the capacity of community leaders and their knowledge of earthquake and tsunami."[14]

Moreover, the focus group discussion with the local actors in disaster management (FGD February 2008) observed some other behaviour during evacuation in the past experience, e.g. the strong

[10] Transcript P1 - 1:4 HH3

[11] Transcript P 1- 1:4 HH4

[12] Transcript P 1- 1:9 HH4

[13] Transcript P 9 - 9:1DP

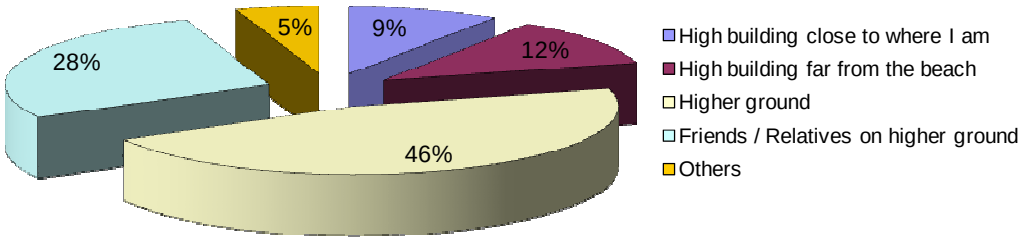
[14] Transcript P10 - 10:1 KO

earthquake also triggered evacuation before warning issuance, and also many people from the higher places or safe zones evacuated and contributed to traffic and evacuation density.

5.4.3 Evacuation Destination

The evacuation destination is also a crucial factor that can determine the time needed to conduct evacuation. The diagram below shows various evacuation destinations from the past earthquake experience, especially in September 2007, based on the UNU-EHS Household Survey in 2008 (Figure 5-16). In total, 74.2% of the people evacuating in the past event fled to a higher places or joined relatives living in those places. Generally, based on the survey, horizontal evacuation was still perceived by the people as safer than vertical evacuation to high buildings. Regardless of where they had evacuated in the past events, 78% of the respondents perceived higher ground as a safe place while only 39% perceived high buildings as safe. This was also confirmed by the local actors at community level: people would rather run as far as they could than to shelter in high buildings (FGD Bonn June 21-24, 2010)

Figure 5-16 Evacuation destinations during the previous earthquake event



Source: Own analysis based on the UNU-EHS Household Survey 2008

With regard to knowledge of the hazard, as shown previously by the household survey analysis, not all people have been exposed to any socialization or have the same level of information needed for appropriate evacuation. A household mentioned they never had any socialization by the government or that the information given was still not clear.

> "please show us where to go to evacuate, there are already some maps, but they are not clear, not all people understand what the government announce about evacuation. Please conduct more socialization and provide more evacuation signs!"[15]

Such statements were also supported by the results of the UNU-EHS Household Survey 2008. In fact, not all people were aware of the official evacuation routes and places recommended by the government, although the majority had knowledge of their own concerning the next high buildings, higher ground, or route they would probably go to in case of an evacuation. Although about 80% of the respondents knew where to find high buildings or higher ground close to where they lived or worked, only 50% or less were aware of places and routes recommended by the government.

[15] Transcript P1 – 1:1 HH2

Findings with similar arguments were presented in the work of Muhari et al. (2011a) that only 27% of the people had seen tsunami hazard maps and only 37% knew of any official evacuation sites.

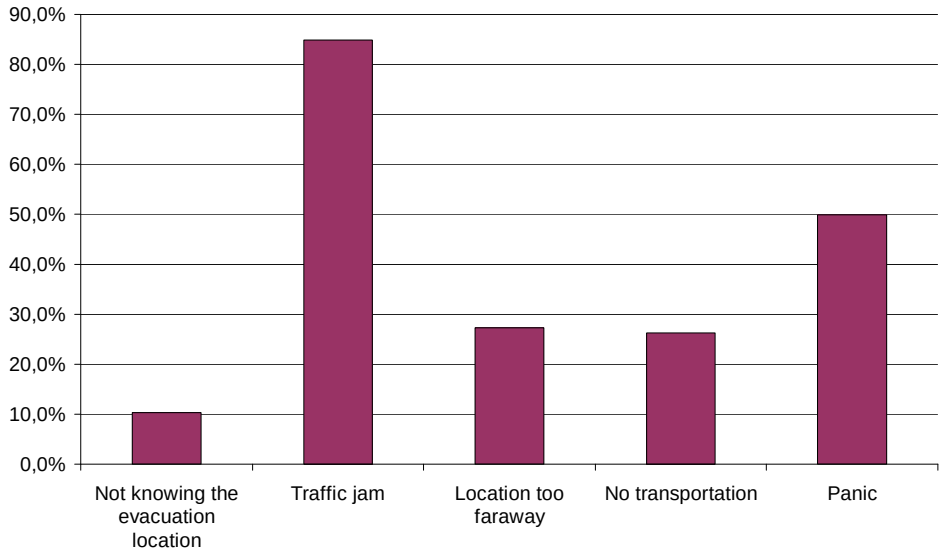
5.4.4 Mode of Evacuation

In the actual evacuation time, the mode of evacuation should be taken into account. Although it is recommended to evacuate on foot, many might use the vehicles available. This is especially likely for the households with children and elderly citizens. A local disaster management actor clearly expressed the concern of evacuating using vehicles in Padang:

> "we cannot avoid/forbid people to evacuate using their vehicles, we might recommend them to run (on foot) or use bike, but we have to consider the worst-case scenario. The current SOP / approach has not been tested and proven as effective"[16]

The last strong earthquake experiences show that many people used their vehicles to escape and this led to high traffic jams and even traffic accidents (FGD February 2008 and various informal discussions with local actors in 2009). In the UNU-EHS Household Survey 2008, traffic jams were mentioned as one of the biggest difficulties of evacuation in the last experiences (Figure 5-17). According to Muhari et al. (2011a) only 42% of the people intended to evacuate on foot while the rest would prefer motorized vehicles.

Figure 5-17 Perceived challenges of conducting evacuation



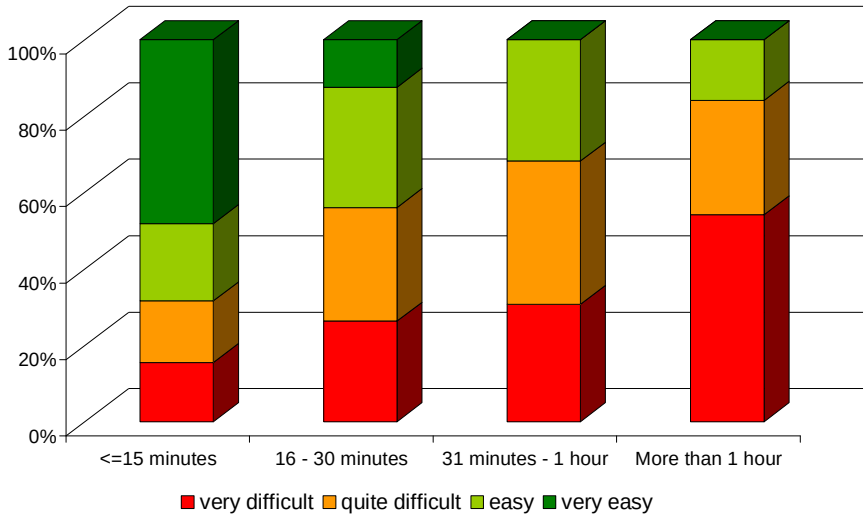
Source: Own analysis based on the UNU-EHS Household Survey 2008

In the Household Survey 2008 it was found that the people´s perception of their capability to conduct evacuation was also related to the perceived time needed to reach evacuation (Figure 5-18). Such

[16] Transcript P 6: - 6:2 BE

challenge may either trigger people to keep using their vehicle to reach safe places as quickly as possible, or even lead to fatalities in case of potential tsunami events.

Figure 5-18 Perceived capability to evacuate by perceived evacuation time needed



Source: Own analysis based on the UNU-EHS Household Survey 2008

5.4.5 Importance of Evacuation Behaviour in the Assessment of Response Capability

The findings above show the importance of considering evacuation behaviour and cognitive factors in the development of evacuation procedures as well as any structural measures. The effectiveness of early warning in triggering evacuation is linked with the prior knowledge and perception of the people towards the tsunami risk and possible evacuation. Additionally, available evacuation arrangements at the community and household level are crucial considering that the household members may be in different locations (morning scenario).

As shown in the analysis results above, evacuation behaviour will determine the utilization and effectiveness of the technical and structural measures. Even if warnings were fully disseminated and access to safe places sufficient, evacuation would not be effective if people behave in an inappropriate manner. Clear information and effective communication about the existing tsunami risk and what the people have to do in potential tsunami situations is necessary. This does not only mean clear early warning messages and evacuation guidance, but also continuous risk communication, awareness raising and education activities at the community level that would slowly change the perception and attitude of the people towards tsunami risks and measures to enhance their response capability. Such intervention has to take place first of all at the household level (raising awareness of the household decision-makers and other members) and at the community level (consideration of various social groups, involving community leaders). This issue will be analysed further in the Sub-chapter 5.5.

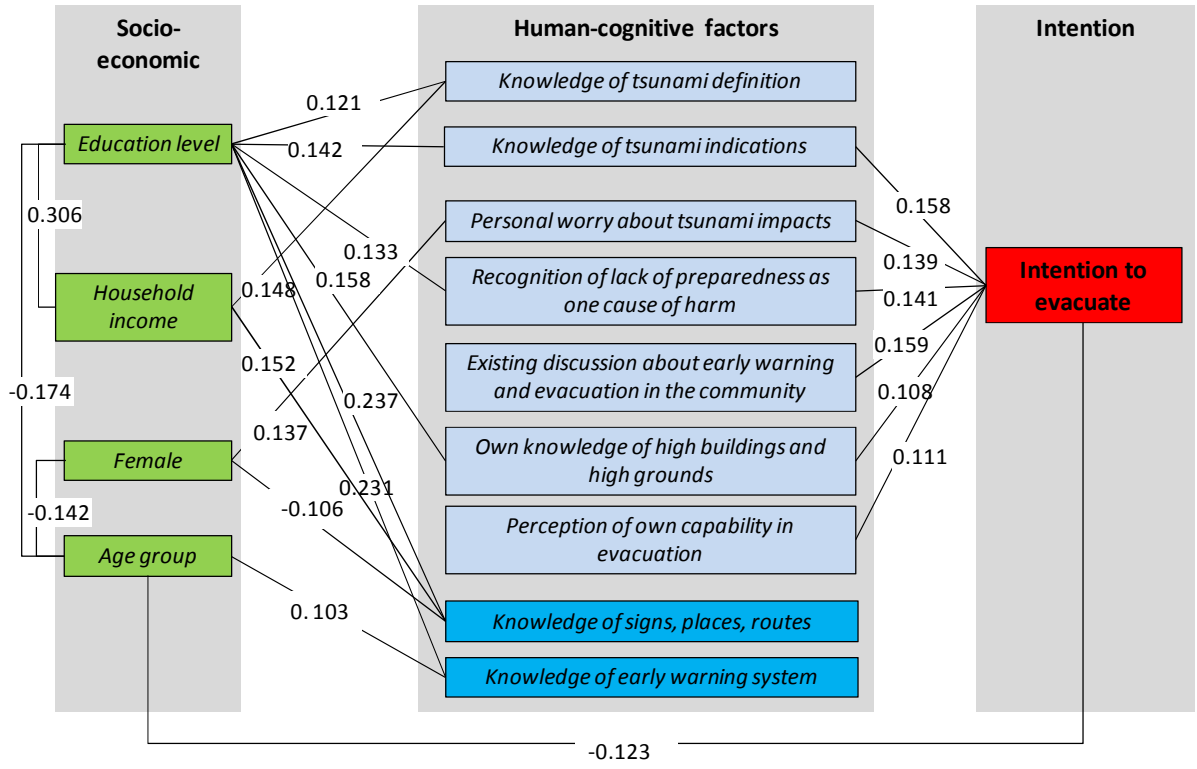
5.5 Issues of Perception related with Vulnerability Reduction

The following analysis assesses people´s intention to evacuate and support improvement of infrastructure and facilities for evacuation that is indicative of their potential cooperation and involvement in the process and of the cognitive factors that may explain people´s intentions and behaviour. Additionally, the perception of possible relocation and its constraints in various social groups was assessed. Finally, qualitative information of the overall perception of tsunami and efforts at the community level will be presented to get a better understanding of the issues of perception and how it influences people´s behaviour.

5.5.1 Intention to Conduct Evacuation

With regard to cognitive factors in vulnerability reduction, the intention of vulnerability-reducing actions was assessed. Initially, the intention to evacuate was analysed. As mentioned in the previous section (Sub-chapter 5.4.1), there is a larger proportion of people who are willing to evacuate in case of tsunami warning in the future (75%). Using the framework developed previously (See Chapter 4.2), the model of human cognitive variables for intention to evacuate and their associations with socio-economic variables was tested. The profile of the variables and the correlation analysis results can be found in Annex. The diagram below Figure 5-19 shows the correlation of the socio-economic and cognitive factors with intention to evacuate in case of a potential tsunami event (after an early warning). The variables selected are only the ones with significant correlations ($p<0.05$) with a coefficient above 0.1.

Figure 5-19 Correlation of socio-economic and cognitive factors on intention to evacuate (Kendall´s tau-b coefficient, significant at p<0.05)



Source: Own analysis based on the UNU-EHS Household Survey 2008

These variables – although with weak correlations – have a positive association with the intention to evacuate. A high proportion of people cognizant of the signs preceding a tsunami, e.g. particularly strong earthquakes with tsunami potential, manifested the intention to evacuate (Kendall´s tau-b coefficient=0.158, significant at p<0.01). This is also true for the level of personal worry or the association of potential tsunami impacts on self or family (Kendall´s tau-b coefficient=0.139, significant at p<0.01). Higher awareness levels related to the recognition of lack of preparedness as one main reason for the threat of being harmed by tsunamis (Kendall´s tau-b coefficient=0.141, significant at p<0.01). The existing discussion in the community about preparedness activities in connection with tsunami early warning and evacuation (Kendall´s tau-b coefficient=0.159, significant at p<0.01) also indicates a higher intention to evacuate. Moreover, people that assumed to know where to find higher ground or higher buildings where they could evacuate (Kendall´s tau-b coefficient=0.108, significant at p<0.01), and thought they could make it on time (Kendall´s tau-b coefficient=0.111, significant at p<0.01), showed higher intention to evacuate.

Although the costs or disadvantage of evacuation did not show significant or interpretable correlation, it is interesting to note that some aspects relate with the socio-economic characteristics of the respondents. Loss of income due to evacuation in case of false alarm is correlated with household income (Kendall´s tau-b coefficient=-0.110, significant at p<0.01), education level (Kendall´s tau-b coefficient=-0.155, significant at p<0.01), and age group (Kendall´s tau-b coefficient=-

0.129, is significant at p<0.01). On the other hand, the concern to buy additional food due to evacuation is correlated with gender (Kendall´s tau-b coefficient=0.114, significant at p<0.01), where female respondents on average perceived this aspect more strongly as a disadvantage of evacuation.

Multiple regression analysis was employed for the selected variables. The Chi-Square test suggests that the model is significant (p<0.000). The Hesmer-Lemeshow-test suggests that there is no evidence of lack of fit (p>0.390). The univariate Wald test statistics (Table 5-9) show that all selected variables are significant using a level of significance of 0.05.

Table 5-9 Significance and confidence interval of the odds ratio of the association of independent variables with the dependent variable of intention to evacuate

	Significance	Exp(B)	95% confidence interval for EXP(B)	
			lower	upper
Knowledge of tsunami indications	0.007	1.692	1.155	2.477
Personal worry of tsunami impacts	0.000	1.987	1.363	2.898
Recognition of lack of preparedness as one cause	0.002	2.383	1.385	4.100
Existing discussion about early warning and evacuation	0.001	1.596	1.214	2.099
Own knowledge of high buildings and grounds	0.040	1.295	1.011	1.658
Perception of own capability in evacuation	0.004	1.408	1.116	1.777

Source: Own analysis

The results of the multiple regression analysis confirms the finding that the higher the awareness and more positive the attitude of the people to tsunami risk, early warning and evacuation, the more likely is their intention to evacuate. In this study, the odds ratio was not used to derive weighting or further interpretation, but solely to provide hints on the influence of the independent variables (positive or negative). Nevertheless, the prediction level is – as may already be expected considering the weak correlations – still weak. The model could only correctly predict 11.5% of the category of the people who intended not to evacuate based on the values of the cognitive variables (See Table 5-10). It corresponds to the fact that classification rather favours classification into the larger group (Hosmer and Lemeshow 2000), or in this case, the category “evacuate”.

Table 5-10 Classification table of observed and predicted values of the intention to evacuate

Observed		Predicted		
		Not evacuate	Evacuate	% of correct prediction
Intention to evacuate	**Not evacuate**	27	207	11.5
	Evacuate	17	682	97.6
	Total			75.9

Source: own analysis

The variables selected for the model for intention to evacuate are aggregated using an index called "evacuation awareness index" in order to enable the monitoring of awareness activities. The variable of basic knowledge of the tsunami definition was maintained due to the consideration that this variable is an important starting point to raise awareness of tsunami risks, early warning and evacuation at all. For the evacuation readiness monitoring, the variables of knowledge of signs, places, and routes, are maintained in spite of a very weak or not significant correlation due to the consideration that this objective knowledge is very important to enable a timely and effective evacuation and should be promoted in awareness activities. Additionally, a new variable of "availability of family emergency/evacuation plan" was added due to repeated concern from the local actors at the community level on the importance of this variable for evacuation. These variables are also aggregated as a separate index called "evacuation knowledge index". The following Table 5-11 shows the list of the selected variables and the index calculation. The scoring was basically derived from the same weight approach. Some variables related with the own judgement, like personal worries, discussion on tsunami warning and feeling capable of gathering the family and evacuate, had a finer differentiation and were therefore given the maximum score of two. Similar to the knowledge of places to evacuate, as a combination of knowledge of higher ground and higher buildings, it has the maximum score of two.

Table 5-11 Selected parameters for evacuation awareness index and evacuation knowledge index

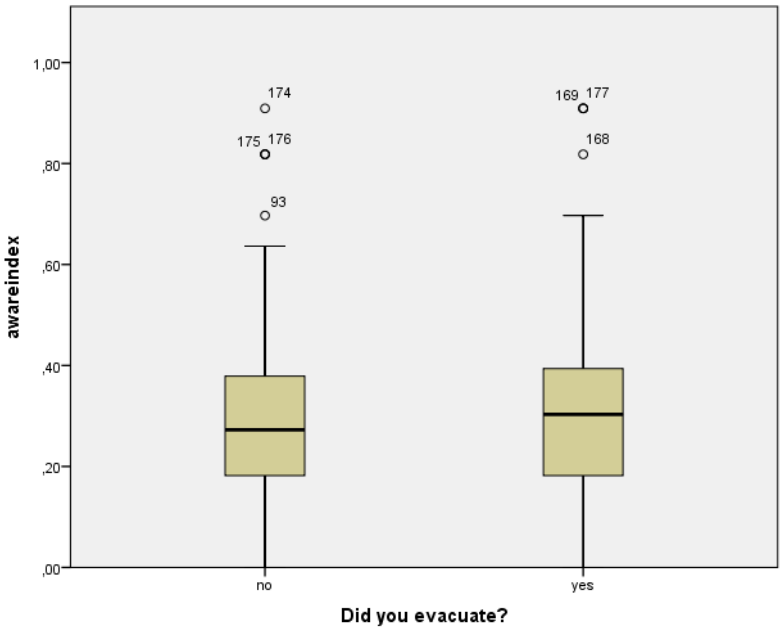
Parameter	Max. score (weight)
- Knowledge of tsunami definition	1 (0.091)
- Knowledge of tsunami indications	1 (0.091)
- Personal worry of tsunami impacts	2 (0.182)
- Recognition of lack of preparedness as one cause of harm	1 (0.091)
- Existing discussion about early warning and evacuation	2 (0.182)
- Own knowledge of high buildings and grounds	2 (0.182)
- Perception of own capability to evacuate	2 (0.182)
Evacuation awareness score (index)	**11 (1)**
- Knowledge of evacuation signs, places, routes	1 (0.333)
- Knowledge of tsunami early warning systems	1 (0.333)
- Availability of family emergency/evacuation plan	1 (0.333)
Evacuation knowledge score (index)	**3 (1)**

Source: Own figure

A strong earthquake event in 2009 has provided an opportunity to test the model against the actual evacuation behaviour. A household survey for measuring the evacuation readiness was conducted in 2009 prior to the earthquake and the "evacuation awareness index" that had been calculated previously compared with the people who evacuated in the strong earthquake events in September 2009 and those who did not. The results show that on average, the ones who evacuated ha d ahigher evacuation awareness index. However, the dispersion seems to suggest that other explanatory

parameters still need to be captured and also that intention did not necessarily trigger actual behaviour (Figure 5-20).

Figure 5-20 Comparison of mean values and descriptive statistics of evacuation awareness index between respondents who evacuated and not during the earthquake event in 2009

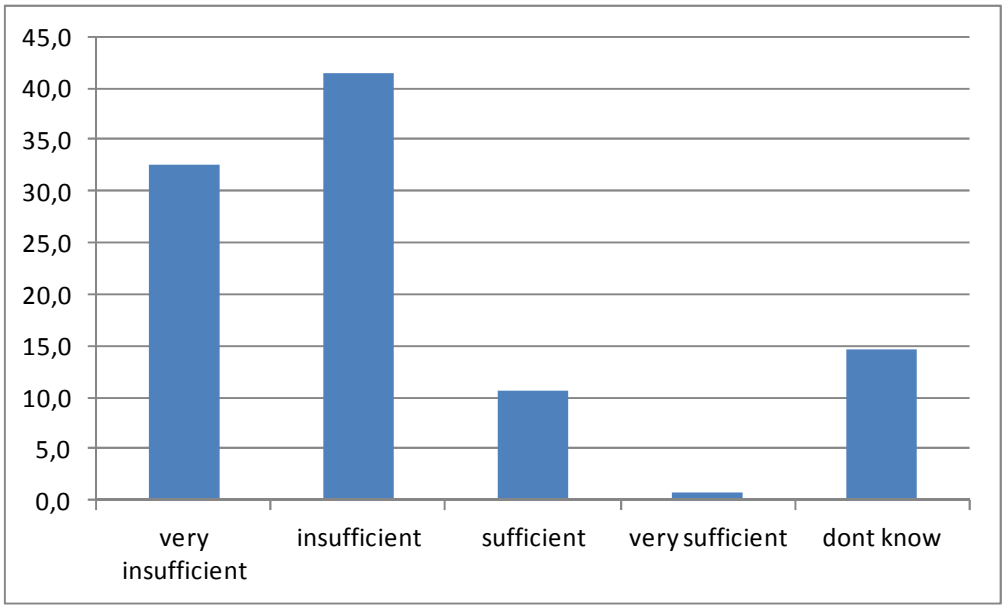


Source: Own analysis based on GTZ Household Survey 2009

5.5.2 Intention to Support the Improvement of Evacuation Infrastructure and Facilities

Examining further people´s perception of evacuation difficulties and traffic jam problems, the UNU-EHS/KOGAMI Household Survey conducted in 2009 indicated that the majority of the respondents (74%) evaluated the current infrastructure and facilities as not sufficient or not sufficient at all (Figure 5-21). This shows that the limited access to evacuation routes and places is also realized by the people.

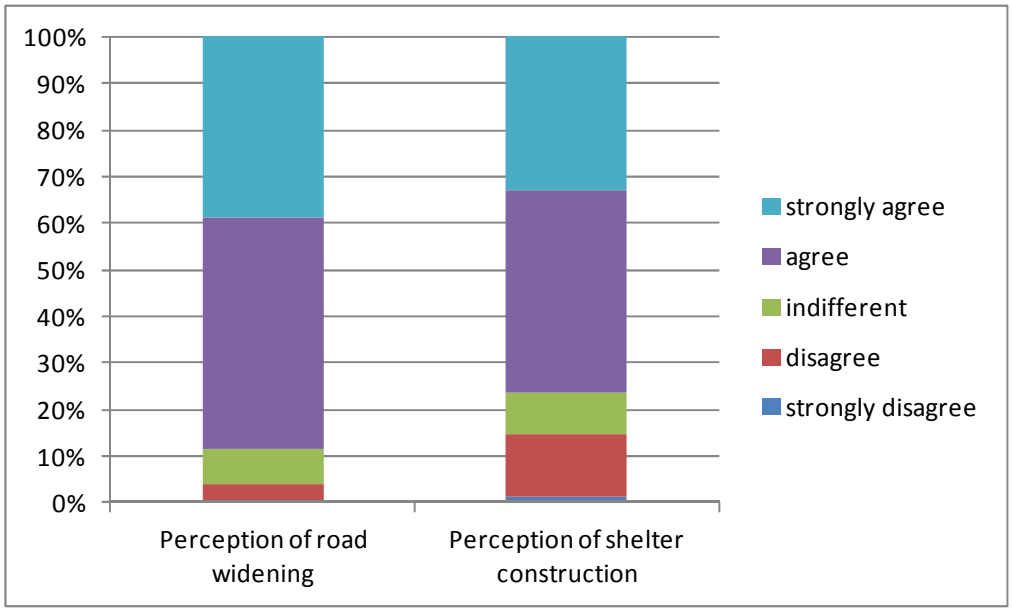
Figure 5-21 Perception of existing evacuation facilities and infrastructures (proportion of the respondents in %)



Source: Own analysis based on the UNU-EHS/KOGAMI Household Survey 2009

Also, the perception of the improvement of evacuation infrastructures through widening the existing roads and construction of escape buildings / evacuation shelters shows the agreement of the majority of the respondents (Figure 5-22).

Figure 5-22 Perception of improvement of evacuation infrastructures by widening roads and constructing evacuation shelters (proportion of respondents in %)

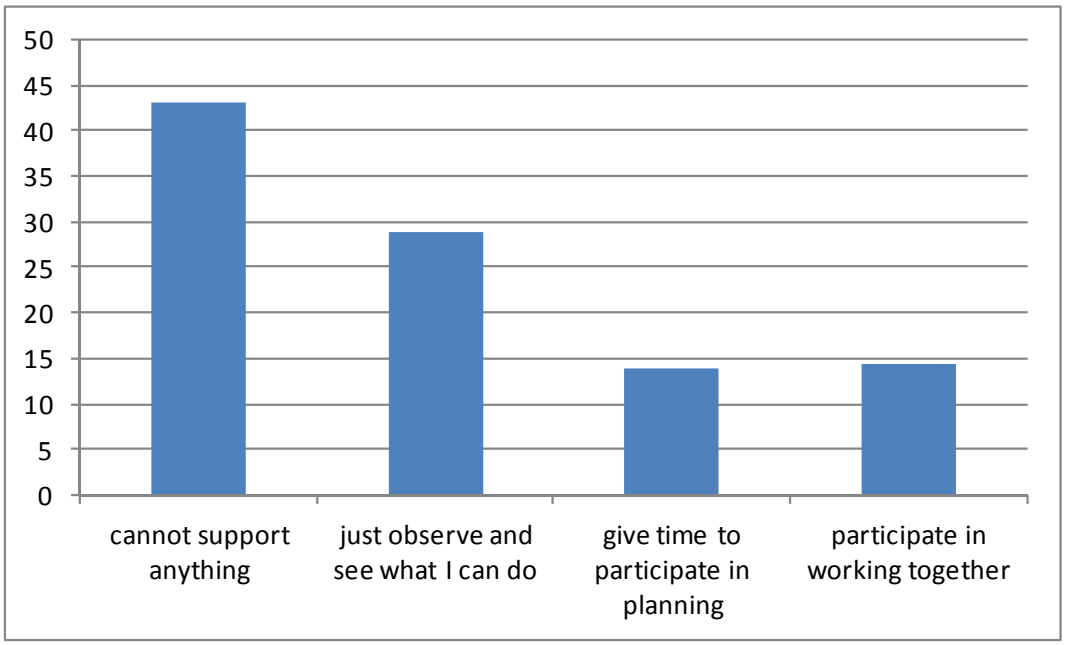


Source: Own analysis based on the UNU-EHS/KOGAMI Household Survey 2009

In general, widening existing roads seems to be a more acceptable measure for tsunami risk reduction to the majority of the people compared to shelter construction. There are less people who agree or strongly agree on construction of shelters compared to road widening. This may be explained by a quite controversial opinion on the strength and safety of shelters (high buildings) facing strong earthquakes, which have not been proven yet in Padang. Some respondents with answer categories of "disagree" or "strongly disagree" mentioned that they are worried that the high buildings as shelters would collapse due to earthquake and worsen the situation.

Moreover, when it came to more proactive participation, there were various responses (Figure 5-23). In fact, the majority of the respondents would remain passive and did not see where they could support this process.

Figure 5-23 Intention to support improvement of evacuation infrastructures and facilities (proportion of the respondents in %)



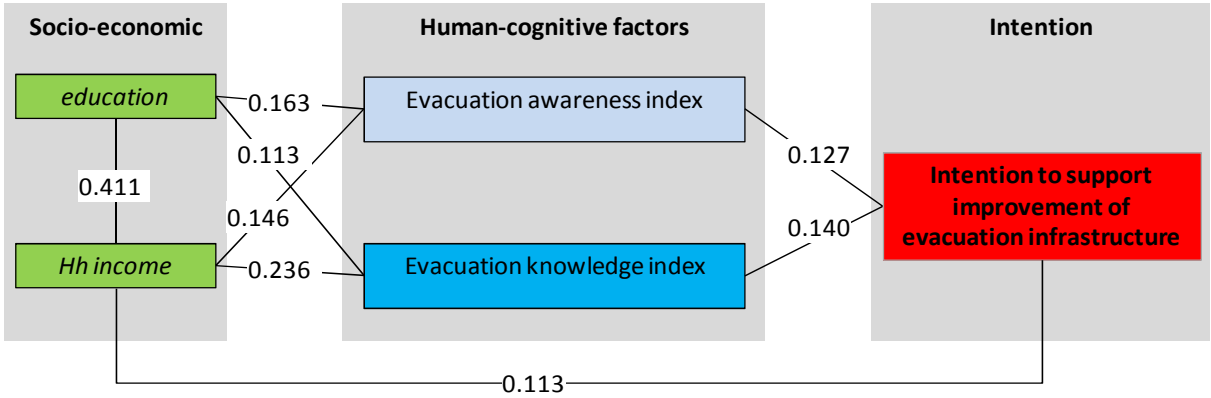
Source: Own analysis based on the UNU-EHS/KOGAMI Household Survey 2009

After the development of evacuation awareness and evacuation knowledge indices (See Sub- 5.5.1, their influence on the intention of proactive vulnerability-reducing action, intention to support improvement of evacuation infrastructures and facilities was tested using the data of the UNU-EHS/KOGAMI Household Survey 2009. The profile of the variables and the correlation analysis results can be found in Annex.

The analysis found out that both the evacuation awareness index and evacuation knowledge index are both correlated with the intention to support improvement of evacuation infrastructures. Interestingly, the evacuation knowledge index correlates with the intention to support improvement even slightly stronger (Kendall´s tau-b coefficient=0.140, significant at $p<0.01$) than the evacuation awareness index (Kendall´s tau-b coefficient=0.127, significant at $p<0.01$), while the evacuation awareness correlates stronger with perception of improvement of evacuation infrastructures

through widening of roads and construction of shelters. The results seem to suggest that awareness is more associated with subjective judgement (perception) of the measures and although awareness also correlates positively with intention to support improvement, additional knowledge plays a role so that the person would be able to acknowledge and commit to his/her role in the development of the evacuation measures.

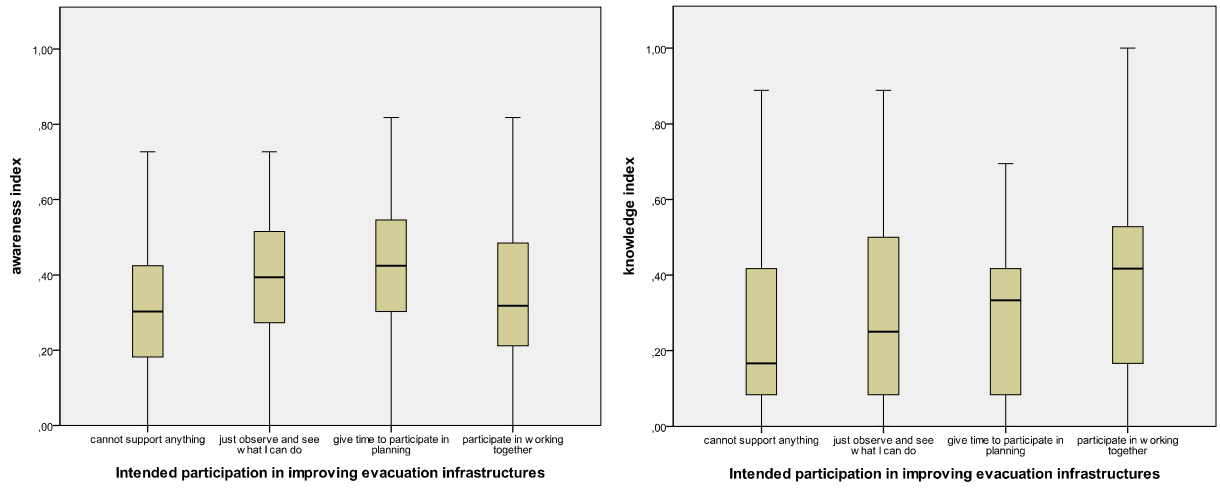
Figure 5-24 Correlation of socio-economic and cognitive factors with the intention to support the improvement of evacuation infrastructures (Kendall´s tau-b coefficient, significant at p<0.05)



Source: Own analysis

Furthermore, Figure 5-25 suggests that awareness has weaker influence on proactive action which requires more labour efforts and probably special skills ("working together") compared to the influence of evacuation knowledge that has shown stronger correlation.

Figure 5-25 Association of intention to support improvement of evacuation infrastructures with evacuation awareness and evacuation knowledge indices



Source: Own analysis based on UNU-EHS/KOGAMI Household Survey 2009

Multinomial logistic regression analysis was conducted to test the influence of both independent variables of the evacuation awareness index and the evacuation knowledge index on the dependent

variable of intention to support the improvement of evacuation infrastructures (reference category: “cannot support anything”). The result shows that the model’s fitting composed of the two independent variables is significant (p<0.000) compared to the null model. The Pearson (p=0.285) and Deviance (p=0.437) statistics do not suggest lack of fit in the model. The Chi-Quadrat statistics test comparing the model with reduced variables suggests that the influence of both variables ,evacuation awareness and evacuation knowledge, scored for the overall model is significant (p<0.01). However, for each category, the influence of one or another index may become insignificant. The following table shows the odd ratios of the index based on the intention categories referring to “cannot support anything”. It confirms that the intention to “participate in working together” is associated significantly with evacuation knowledge.

Table 5-12 Significance and confidence interval of the odds ratio of the association of evacuation awareness and knowledge indices with intention to support improvement of evacuation infrastructures

Intended participation in improving evacuation infrastructures (reference category: "cannot support anything")		significance	Exp(B)	95% confidence interval for Exp(B)	
				upper	lower
just observe and see what I can do	Awareness index	0,000	10,712	3,126	36,702
	Knowledge index	0,224	1,828	0,691	4,84
give time to participate in planning	Awareness index	0,000	31,122	6,253	154,886
	Knowledge index	0,510	1,517	0,439	5,241
participate in working together	Awareness index	0,630	1,467	0,308	6,987
	Knowledge index	0,000	10,551	3,195	34,851

Source: Own analysis

However, a similar case is the analysis of the model for intention to evacuate- This model predicted the intention of the smaller groups poorly. As seen in Table 5-10, the intention to participate categories of “give time to participate in planning” and “participate in working together” was wrongly predicted as other (larger) categories. Acknowledging other unknown influencing parameters, we could still argue that overall there is significant positive influence of evacuation awareness and knowledge on proactive intention (intention to support the improvement of evacuation infrastructures).

Table 5-13 Classification table of observed and predicted values of the intention to support improvement of evacuation infrastructures

Observed	Predicted				
	cannot support anything	just observe and see what I can do	give time to participate in planning	participate in working together	% of correct prediction
Cannot support anything	209	30	0	2	86,7%
Just observe and see what I can do	109	49	0	3	30,4%
Give time to participate in planning	51	26	0	0	0,0%
Participate in working together	59	21	0	0	0,0%
					46,2%

Source: Own analysis

5.5.3 Perception of Possible Relocation

Relocation is one possible impact of land use change and allocation of space for new evacuation facilities (evacuation shelters) or transportation networks in the exposed areas, which consist mainly of built areas. It may pose a challenge to the people who are currently living there. The analysis identified some perceived hindrances related with relocation measure which also vary according to the respective social groups.

Overall, the majority of the respondents perceived that the possibility to change the workplace due to relocation was rather difficult. Household income is associated with the capacity to relocate to new (safer) places according to the UNU-EHS Household Survey 2008. A correlation analysis between perception of ease to move and find job in case of relocation due to tsunamis was conducted against the household income variable. The result shows that the people with lower household income tend to disagree with the statement "*I could easily move and find a job*" (Kendall tau-b coefficient=0.119, significant at $p<0.01$), which suggests difficulties especially for this social group. They are also the ones who are unlikely to be able to afford commuting to the workplace.

Another group discussion with some households in Purus revealed the main reasons for the reluctance of people living there to settle to other areas which are less exposed. The results are presented by gender in the following Table 5-14. The ranking was derived based on a number of similar reasons given by the participants.

Table 5-14 Main reasons of living and keep staying at the coastal areas

Rank	Male participants (N)	Female participants (N)
1	Have been living in this place for generations / many of the family members and relatives live here (11)	Have been living in this place for generations / many of the family members and relatives live here (11)
2	Own occupation (mostly fishermen) (10)	The husbands´ occupation as fishermen (7)
3	Others: location close to the city centre (1)	Own occupation / sources of income are here (4)
4	-	Others: the people/neighbours are nice (1), do not have to rent the land, recreational areas (1)

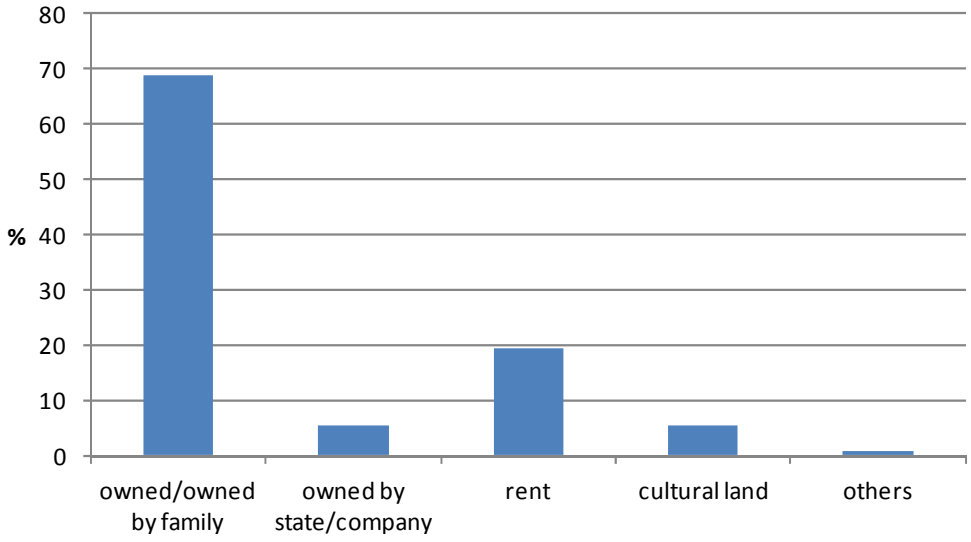
Source: Own analysis based on group discussion with Purus neighbourhood August 20, 2009

Based on this discussion it is revealed that the people value the land and location as part of their and their family´s identity. For the fishermen community, the selection of location was primarily determined by the occupation of the head of the household (fishermen) that "force" them to live close to the coast and the constrained mobility was a consequence of limited economic strength. Most people have been living there for generations; the houses were mostly inherited from their parents, who also worked as fishermen. Even though they are a minority group in the city – since fishery is no longer the main economic sector in the city of Padang – they would like to maintain their identity. Moreover, the fishermen have different lifestyles and skills and their educational level is generally low which makes it not easy to change their occupation to other sectors. The main reasons looked similar for both men and women; most of them mentioned family identity / attachment with the land and their job. The other reasons like closeness to city centre, friendly neighbourhood, recreational possibilities and rent, were also mentioned, but seem not to play a significant role. They expressed their wishes to get a better life and they did not feel the necessity to live near the coast if they had the choice (*"….better near the city centre…"*) and if they did not have to take up fishery activities anymore. Also interesting to note is that female participants considered the occupation of their husbands as more important than their own as main reason to stay. It shows to some extent a traditional pattern in that the male spouses are normally the main breadwinners and many women are still housewives or their own work is only complementary (many have small kiosks at home or along the coast, sell food in the market, or work part time as day labourers). Basically this community acknowledged that disaster mitigation, such as evacuation places and routes are needed, but they are reluctant to have roads extensions (or buffer zones) along the coast close to where they live, since it may have a side effect of land clearing of their property, which means they have to be relocated. They have experienced one land clearing brought about by coastal protection measures (building of sea walls and lifting of the streets), which has a positive side on one hand, namely flood prevention during the high tide, but on the other side, some of the fishermen were relocated to

other places with limited opportunities to earn their livelihoods. Some rent a house next to the former location instead of commuting to work, but the cost is higher.

Landownership was identified by the planning actors (discussed later in Sub-chapter 5.6.3) as one huge challenge for tsunami risk reduction, particularly related with difficulties to clear the existing land for other purposes (e.g. relocation from the coast to safer places, widening existing roads, construction of evacuation shelters). This is because people are not willing to release their land to the government at the offered compensation price, and especially with regard to cultural land the process is rather complicated. Cultural landownership is common in the province of West Sumatra, however, its existence has decreased in the city of Padang, since the majority of the land has been converted into privately or stately owned (Colombijn 1994; Zaidulfar 2002; interviews with local actors 2009). Since no statistical data or official data was found during the data collection period on landownership, the analysis was conducted using the UNU-EHS Household Survey 2008 (Figure 5-26).

Figure 5-26 Different types of current landownership



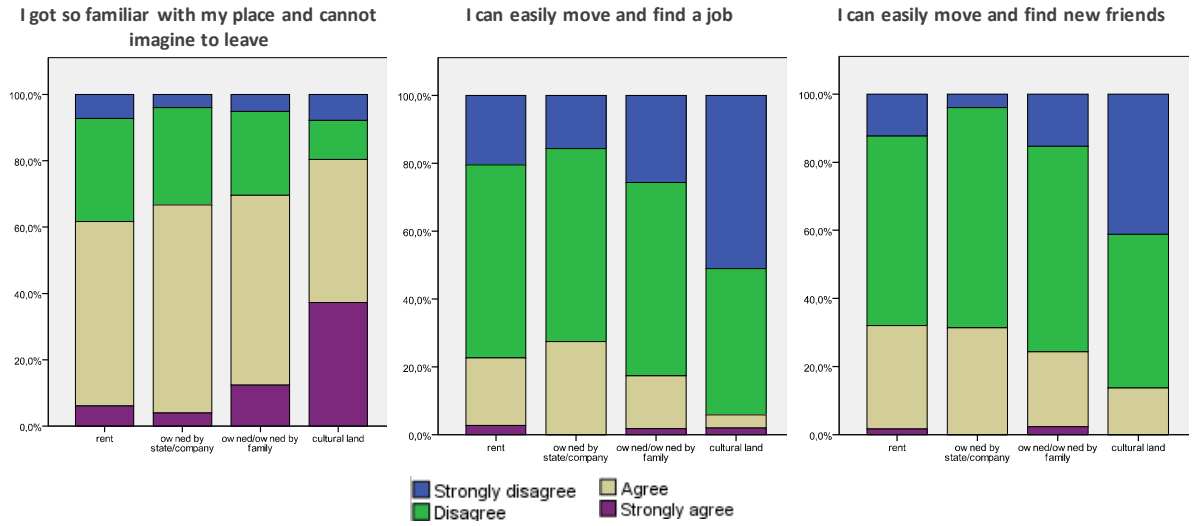
Source: Own analysis based on the UNU-EHS Household Survey 2008

The majority (68.7%) of the people (or their family) own the land where they dwell, there is a small proportion of people living in the houses provided for them by their company (or state, as is the case for some people working for the government), and quite a considerable proportion (19.5%) rent the house where they live. Only 5.6% were categorized as having cultural/customary landownership. These people belong to the major tribe of *Minang* and most of them have been living there for a long time (88.5% for longer than 15 years). However, very few of the people owning cultural land are located in the city centre or along the coast; mostly are located further away from the coast, as shown in the participatory mapping result.

With regard to the possibility of relocation (in case of release of land for tsunami risk reduction), a significant correlation of attachment to the current location was found depending on the type of landownership (Figure 5-27). Familiarity with the place and neighbourhood was the highest for the cultural land, followed by private / family ownership, then company / state ownership, and the

lowest attachment was felt for rented land. The results are inversely proportional to the ease of changing jobs and social networks, only that it seems to be slightly more challenging for the people who rent the land and have a weak socio-economic background.

Figure 5-27 Perception of ease of relocation by landownership



Source: Own analysis based on the UNU-EHS Household Survey 2008

The difficulties of relocation have also been confirmed by the results of analysis of the subsequent UNU-EHS/KOGAMI Household Survey 2009. Almost half of the respondents (47.9%) disagreed with tsunami risk reduction through relocation to safer areas. Nevertheless, this indicates that the measure is still acknowledged to some extent. Most of the challenges of tsunami risk reduction mentioned by the respondents were related to the attachment to the current place in spite of the tsunami hazards such as feeling safe, comfort, land ownership (23%), and economic reasons like the costs to change the current situation if e.g. they have to resettle, etc. (41%). This picture describes indeed the challenge also acknowledged by planners, namely that the reduction of tsunami risks through mass relocation from the hazard areas to safe places is not seen as a plausible option in the short- or medium-term. The most likely solution is to control the existing exposure and limit further intensive development that will enhance night and day population density in the hazard zone on the long-term. However, a small scale of relocation due to construction of additional evacuation infrastructure, such as new/widening roads, evacuation shelters in the densely built exposed areas is still possible.

This study did not aim to analyse further the “push-and-pull” factors of relocation; however, this descriptive analysis gives us a clear indication that the challenges are differentiated and the people who face most of the obstacles are the ones who need to be approached more strategically.

5.5.4 Overall Perception of Tsunami Preparedness

In order to better understand the results of the quantitative analysis described above, some additional factors were identified emanating from the household survey and qualitative information

from non-structured interviews with selected households and local actors. The following are some selected findings on the overall perception of tsunami s which also influences people´s behaviour.

5.5.4.1 Risk hierarchy

In general, the perception of the people of the (earthquake) tsunami risk has changed since the tsunami event in 2004 and the subsequent strong earthquake event in April 2005. After these events, there were still several earthquake occurrences in the region that increased the concern of the community regarding potential major earthquakes and tsunamis. Based on the UNU-EHS Household Survey 2008, the preoccupation with earthquakes and tsunamis was rated high by the people: 77.8% of the respondents mentioned that earthquakes and 64.5%that tsunamis were their main concern, in contrast to income insecurity (37.3%), various other environmental hazards (maximum of 11%), and social problems (maximum of 12.3%).

However, there are different responses to the tsunami risk depending on different social groups. For instance, the fishermen community with lower economic capacity and higher dependency on the sea resources are more concerned about other daily risks such as security of their livelihoods than about tsunamis. They would start to think of tsunamis when a big earthquake occurred. Even so, they would like to confirm first (based on their knowledge of the natural signs of tsunamis), whether an evacuation is necessary, since they perceive evacuation as costly. In contrast, people with higher economic status (e.g. households living in the middle class settlements) would evacuate with less consideration of the cost of evacuation. The analysis of the Household Survey shows that the main concern on income insecurity was correlated with the rate of evacuation in the past tsunami experiences (Kendall tau-b coefficient = -0.138, significant at $p<0.01$); the opinion that loss of income is one of the disadvantages of evacuation (Kendall tau-b coefficient = 0.212, significant at $p<0.01$), participation in tsunami preparedness activities (Kendall tau-b coefficient = -0.061, significant at $p<0.05$); and discussion in the community that “people do not like to discuss about tsunami occurrence since it is not in our hand” (Kendall tau-b coefficient=0.088, significant at $p<0.01$). Even though concern on income insecurity was not identified as one significant explanatory factor influencing the intention to evacuate (Sub-chapter 5.5.1), this may be indirectly linked with people´s behaviour and cooperation in implementing any protection measures.

It is still challenging for the people, especially the ones with lower socio-economic strength, to focus on reducing their risk to extreme natural hazard like tsunamis. They still have to deal daily with meeting the primary needs of their households. Different risk priorities may often lead to responsive instead of preventive or proactive behaviour. Many people would still expect compensation for their participation in preparedness activities, e.g. socialization or tsunami evacuation drills, or perceive such activities as economically costly, e.g. conducting uncertain evacuation during strong earthquake events. The following statements were made by some interviewees:

> “we heard a lot about tsunami from the media, but it is also like this in Padang, people just react or take action if there is an event, not much preparation before the event. If you would ask people in the coastal areas, they would think more about their daily life, what they are going to eat tomorrow - compared to

worry about tsunamis. Why do the people not like to talk about natural disasters? We think it is in God´s hands, what will happen happens"[17]

".. it is already difficult to deal with own livelihoods, let alone disaster preparedness socialization. Government may want to come to us, but the people would not participate, they still think about money to buy food."[18]

"The people participated in government programs often times due to compensations, not because they are aware."[19]

5.5.4.2 Cultural norms and belief

Cultural norms and beliefs also play a role in shaping people´s perception and behaviour. People's perception of tsunami risk relates with their urgency to conduct preparedness action or evacuation. It is also related with their faith – or different interpretations of their faith. Some perceptions seem positive in responding to the on-going preparedness efforts but others tend to lead to fatality behaviour. One of the existing perceptions that show negative attitudes towards preparedness linked to people´s beliefs was as follows:

"Sometimes people think that we are the ones who ask for tsunami disaster to come by preparing for it too much.people are scared..."[20]

In the Indonesian context and particularly strong in the *Minangkabau* or *Minang* community, the religious belief system has a very significant influence on the risk perception of people. Most people believe that nothing happens without God´s will and also, everything that happens is also associated with people´s deeds. One of the interviewed community actors described this matter as follows:

"some religious perceptions still influence the people´s behaviour: if we do good deeds, we will be protected. If we runaway, it means we are afraid / not faithful- this makes people ashamed to evacuate themselves immediately. We now try to cooperate with *Ulama* (religious leaders) network but it is not easy"[21]

However, religious norms and rules are not only hampering preparedness strategies. A discussion with a religious leader also indicated that religious norms can also be used to promote preparedness strategies:

[17] Transcript P 1- 1:6 HH2

[18] Transcript 7 - 7:10 HB

[19] Transcript P 2: - 2:2 KO

[20] Transcript P 7 - 7:8 HB

[21] Transcript P 2 - 2:15 KO

"everybody (should) knows, being prepared is a command from God. That is indeed in God´s hand, when disaster would happen, but we need to be in alert, do our best to save ourselves. Do not do suicide, we have to struggle."[22]

The important role of religious leaders in risk communication and in actually influencing risk response behaviour and perception building was clearly underscored by the results of the own surveys conducted in Padang. The UNU-EHS Household Survey 2008 revealed that the majority of respondents agreed (65.4%) and strongly agreed (7.2%) with the statement that religious leaders have significant influence on the topics to be discussed by the community about tsunami risk.

5.5.4.3 Perception of previous experiences

Although it was mentioned by the community actors that recent earthquake events have kept people in alert, past experiences of strong earthquakes with no tsunami occurrence may lessen the sense of urgency in responding to potential tsunami events. Additionally, the long time experience of the coastal community, especially fishermen with the sea shapes their confidence of knowing better what could happen – or not happen.

"In Padang there have been many earthquakes. Previously, people often escaped to the higher ground, but now people just stay at home or outside and pray that nothing would happen."[23]

"after several earthquakes, people didn't want to stay in the coast, but now I think it is already normal as before again. The people living close to the coast are less fear than people living a bit further, we (people at the coast) know better about the sea from our experiences. I am not afraid, everything is in God´s hand."[24]

"the fishermen community feel that they know better about the sea and would not react to technology (TEWS) or only earthquake"[25]

Another problem is also that the people have heard tsunami "rumours" a couple of times, e.g. that tsunamis would strike in Padang on a particular date, etc., that made them doubt the existence of real tsunami risks and the urgency of current tsunami warnings. They had also learnt from the media that the government (or the current TEWS) cannot give 100%-precise information but can only provide recommendations to stay in alert. So far, there has been no real tsunami occurrence following the strong earthquake events in 2005, 2007, and 2009.

5.5.5 Existing Efforts to Increase Response Capability at the Community Level

Preparedness activities at the local level conducted, e.g. by the local NGOs and the Red Cross, have shown significant increase in the level of awareness of the people. Various evacuation maps were produced at the community level (Figure 5-28).

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[22] Transcript P 4 - 4:7 AT

[23] Transcript P 7 - 7:2 HB

[24] Transcript P 1 - 1:11 HH4

[25] Transcript P 2 - 2:16 KO

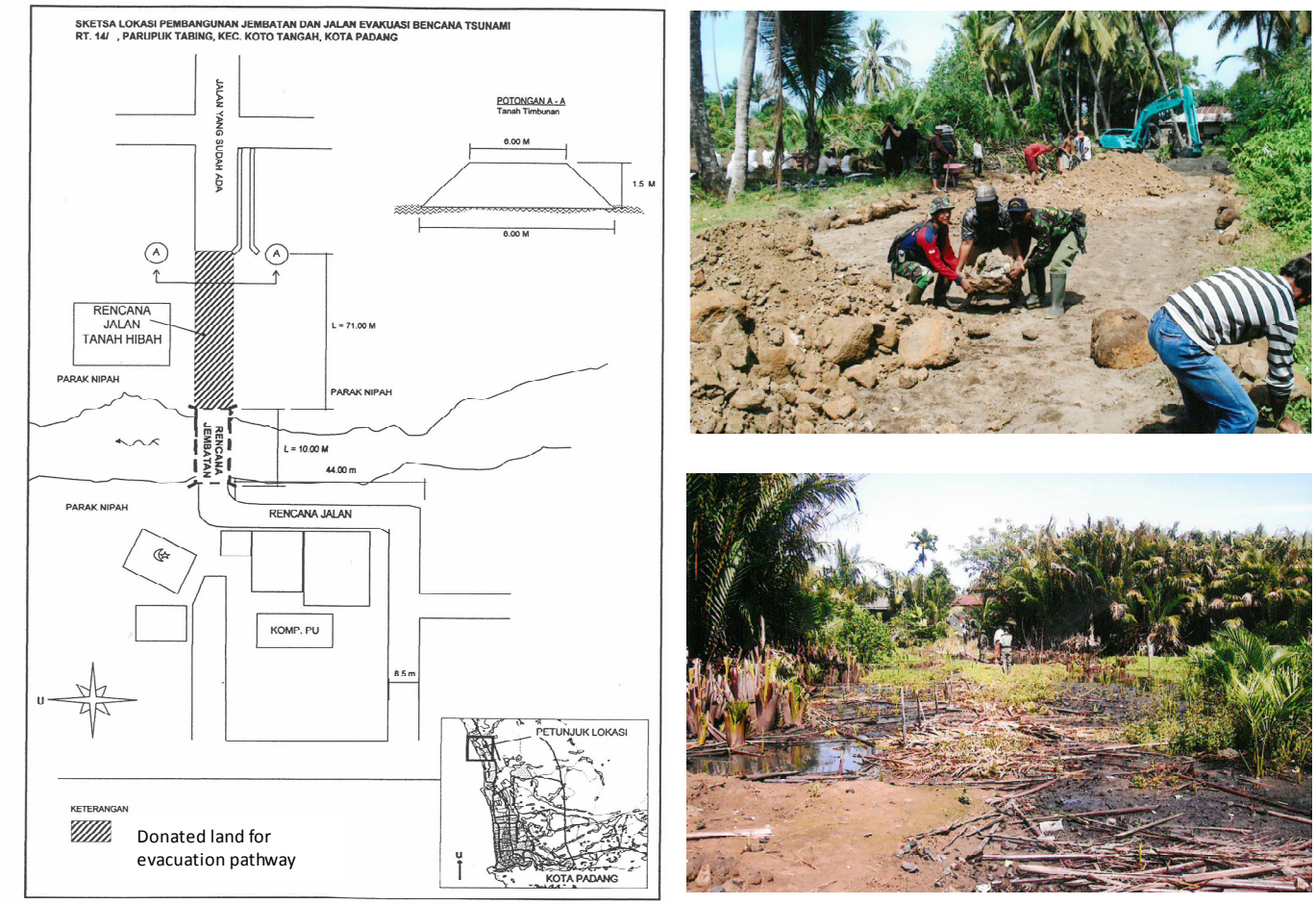
Figure 5-28 Various evacuation map developed by community with the support of NGOs

Source: Setiadi, 2009; NGO KOGAMI, 2009; NGO Muhammadiyah, 2009

Activities are evident at the household level in pilot areas e.g. community-based response team building, socialization in mosque neighbourhoods, and in several pilot schools. During discussions with the NGO KOGAMI in the field study 2009, it was described that the community in their pilot areas was sceptical at first or expected “compensation” for their community preparedness activities, but they approached the community with several community leaders and people who were aware of the importance of such activities. Within the process, significant change was observed; the community became aware and were willing to participate actively in the preparedness activities, offering their time and available resources. Interestingly, the community involved was well mixed consisting of people with not only high, but also low socio-economic level, who became aware of the existing tsunami risk and were willing to participate in preparedness efforts. Community arrangements on evacuation routes were developed and agreement between communities in the endangered and in the potential evacuation places was made. During the time of data collection, community initiatives to build physical evacuation facilities like opening evacuation paths and building local bridges were on-going (Figure 5-29). According to the people in the model community of KOGAMI, the response team *KPB Elang Laut*, and the KOGAMI staff who confirmed this information, some households even gave away a piece of land voluntarily for community initiatives. Particularly the incorporation of religious values in their overall tsunami preparedness activities with the community had been a well-received entry point and provided an indubitable basis for any other following educational and preparedness activities (Dewi, personal communication March 2012).

Similar phenomena were described in the discussions with the community-based groups SIBAT established by the Red Cross in three pilot areas in the city in the Field Study 2009. People opened more access to the safer areas on their own initiative and at their own expenses, e.g. opening pathways perpendicular to the coastline which were blocked by the bushes (Figure 5-30).

Figure 5-29 Construction of local evacuation pathways and bridges initiated by the community educated by NGO KOGAMI



Source: KPB Elang Laut RW 14 Parupuk Tabing

Figure 5-30 Opening an evacuation pathway initiated by the community educated by the Red Cross

Source: Setiadi, 2009

Preparedness activities from the city government and local NGOs have involved the public facilities to some extent; in some pilot schools, the teachers and pupils were trained on what to do during strong earthquakes and potential tsunamis, and the staff in some hospitals and hotels was trained in emergency and evacuation. In contrast, the direct involvement of other private sectors in the preparedness activities, such as industries and market traders, was still very low (UNU-EHS Survey on Critical Facilities 2008). The need for more accurate information about tsunami warning procedures and the provision of emergency facilities from the city government was articulated and there were varying perceptions of the facilities surveyed for on-going efforts on tsunami preparedness in the city (semi-structured interviews with selected facilities as part of the UNU-EHS Critical Facilities Survey 2008). This can be associated with poor involvement of these facilities in the current efforts but also with lack of awareness of the facilities themselves.

Some scattered efforts at the community level have empowered the people to increase their evacuation capabilities. Even though evident in their positive impacts, the efforts cover only limited pilot areas and not yet the whole exposed areas in the city. Most community initiatives were initiated as short-term projects and still need a legal basis to acknowledge their existence and roles. They also need continuous financial support to ensure their sustainability. The new local disaster management body (BPBD) is putting effort to integrate the existing community groups and initiatives and to set forth capacity building activities for them. Recently, some private sectors were also involved, e.g. to support socialization activities and the development of materials for community preparedness (FGD with local actors June 2010).

Moreover, special effort and strategy is needed to involve the minority group or non-*Minang* community in the city, particularly the people of Chinese descent who are partly socially disaggregated and live in exposed areas in the old town area. It seems that this community was left

behind in the existing outreach activities and is difficult to be involved in (informal conversations in the field trip 2009 and FGD with local actors June 2010). Approach through religious and ethnical society groups is needed to access these people.

5.6 Role and Influence of Urban Planning in the Actual Evacuation Planning and Vulnerability Reduction

In order to ensure that the early warning system is sustainable, early warning needs have to be integrated in the overall and long-term planning. Urban planning is an important domain to be involved in the process. A feedback loop between emergency and urban planning needs to be developed or if it exists, strengthened (Sub-chapter 2.3). This section presents to what extent the early warning needs in the previous analysis have been incorporated in urban planning and how it may influence the current early warning response capability.

Firstly, the long-term (20 years) urban spatial plan is assessed. As described in Sub-chapter 3.4 , the urban spatial plan encompasses land-use / space allocation and structural networks of various infrastructures and facilities in the city. The integration of tsunami risk reduction in the overall spatial plan is reviewed and various interventions related to evacuation and their potential impacts on each response capability components are assessed. Subsequently, in order to make transparent the roles and linkages of urban planning in the current evacuation planning process, a stakeholder analysis is conducted. It also identifies the specific roles of various agencies in the existing / planned interventions, especially those related with the reduction of exposure as well as improvement and provision of evacuation infrastructures. Moreover, current challenges with regard to the planning and implementation of the measures are described.

5.6.1 Spatial Planning Orientations Related with Tsunami Exposure and Evacuation Infrastructures in 2010-2030

The City Development Planning Agency (BAPPEDA) of Padang has expended efforts on revising the city's spatial plan. Based on conversations with the planning actors, the last spatial plan was developed for the period from 2004 to 2013 as manifested in the Regional Regulation 10/2005 (PERDA 10/2005) without consideration of tsunami and earthquake hazards. However, after the tsunami in 2004, the need to revisit the regional plan had arisen. In 2007, a new law on spatial planning (UU 26/2007) was passed that encompasses the necessity to develop spatial planning based on disaster mitigation in order to enhance security and welfare. Then, an identification of the problems and their evaluation was carried out and formulated in a Disaster Management Strategic Plan, which served as the first input for the revised spatial plan, as body of reference for the district regulation (PERDA), which will now be applied for a 20-year period.

In the current Spatial Plan 2010-2030, the aspects of earthquake and tsunami hazards have been taken into account. This Spatial Plan was also shaped by the reconstruction and rehabilitation process of the city after the major earthquake event on September 30, 2009. The concern to integrate disaster mitigation into this plan has been indicated clearly in the long-term 2010-2030 objective formulation:

"*To achieve that the city of Padang shall evolve as a metropolitan city based on disaster mitigation which is supported by the development of the trading, service, industrial, and tourism sectors*."

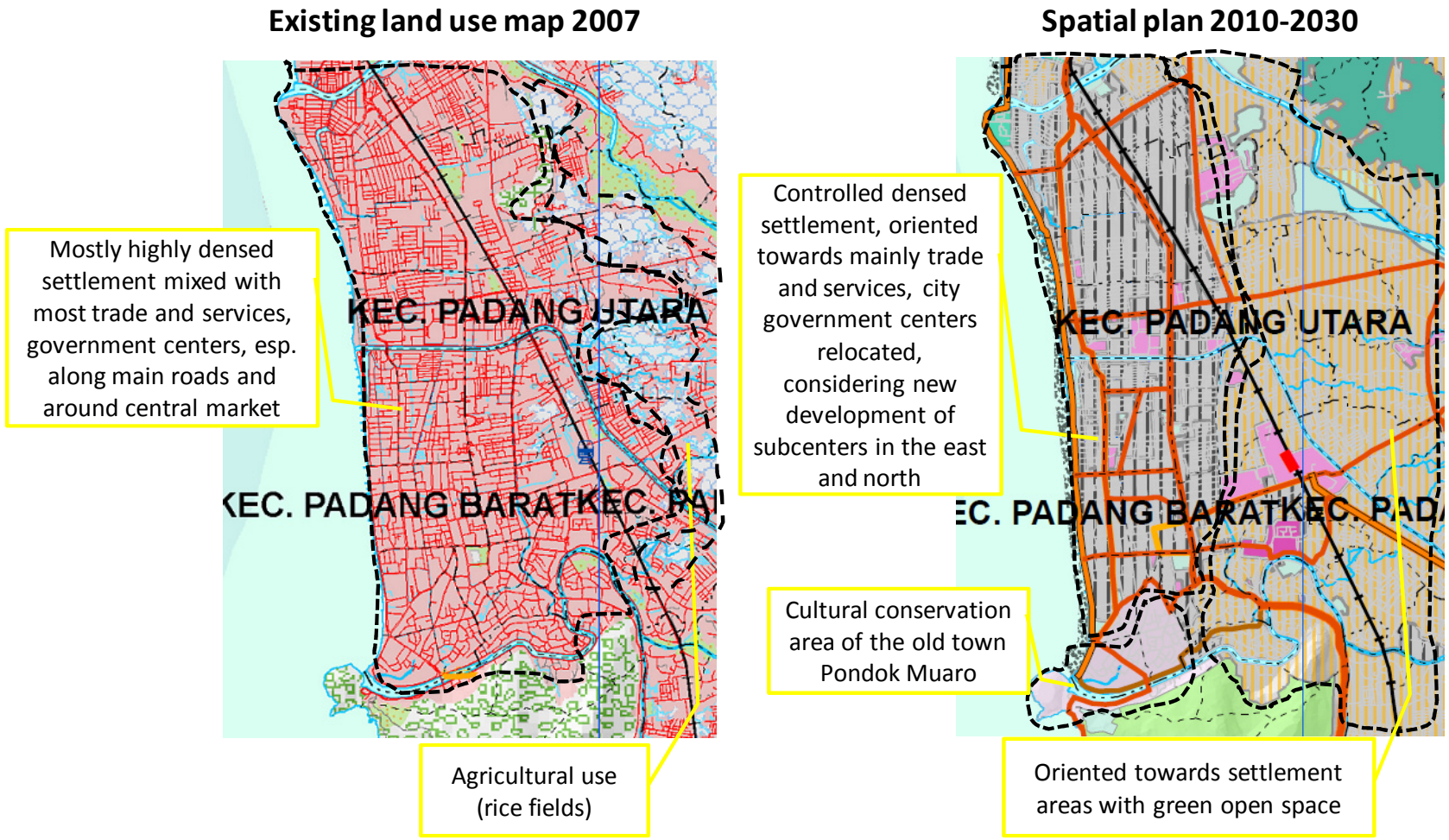
The formulation makes explicit the importance of disaster mitigation in contrast to the previous Spatial Plan 2004-2013, which stated the objective as:

"*To achieve structure and spatial use of the city as a modern and cultural coastal city*"

The Spatial Plan defines tsunami prone areas firstly as areas with topographical slopes of 0-2% from the coast that are most likely to be inundated. Furthermore, it adopted the classification of tsunami hazard levels based on the potential specific energy of a tsunami (composed of inundation depth and velocity), as proposed in the scope of the "Last-Mile – Evacuation" (Taubenböck et al. 2012) and reflected the discussions of the consensus meeting on tsunami hazard modelling results in 2010. The development of a tsunami hazard map was very locally driven using a different approach than the tsunami hazard classification suggested in the National Technical Guide of Public Work Regulations Permen PU 6/2009 (see Sub-chapter 3.1) at least in two points. First, it only considers one most plausible source scenario, rather than multi-scenario approach using probability (or return period) of tsunami occurrences of different magnitude. Second, it includes not only the potential inundation depth, but also the potential velocity represented by specific energy, thus taking into account the stability or manoeuvrability of the people (RESCDAM 2000) during evacuation.

The ideal approach to reduce tsunami risk had already been integrated in the new spatial plan, including the consideration of space for evacuation routes or shelters, the development of city sub-centres to reduce a too centralized concentration of population, seismic-resistant building codes, and the provision of infrastructures taking into consideration emergency planning. One important city development orientation in the new spatial plan is the development of settlement areas towards the eastern part of the city further away from the coast, which have been primarily used for agricultural purposes, whereas the built areas along the coast should be focusing more on trade and service functions.

Figure 5-31 Comparison of existing land use in 2007 and future land use orientation in 2010-2030



Source: Basis maps from BAPPEDA Padang 2010, own annotations

The Spatial Plan describes only orientations of spatial patterns and structures with regard to the development of various city functions and infrastructures. A detailed spatial plan and zoning regulation based on the Spatial Plan for the study area was not yet available at the time of the study period. Thus, it was not possible to assess the specific impacts on the components and needs identified in the previous Sub-chapters (particularly 5.1, 5.2, 5.3). In this section, the Spatial Plan was only reviewed focusing on its orientation with regard to various components (the assessment table can be found in Annex). Specific aspects with reference to the needs identified in the previous section are still to be incorporated in the detailed plan.

Impact on dynamic exposure

The overall orientations in the Spatial Plan suggest overall a reduced exposure to tsunamis. Areas with high and very high risk of tsunamis are recommended as conservative areas or utilized as open green areas, cropping and agricultural areas. In the already built areas, which are the largest part of the exposed areas within the study, the spatial development intensity should be limited towards non-settlement activities and not to centralized population concentration. The traffic pressure and population concentration in the current city centre should also be reduced due to the future development of settlement areas in the eastern and southern part of the city. It is planned to relocate some of the government offices to the northeast of the city (Air Pacah) and to develop further sub-service centres in the north, south and east to support the current city centre in decentralizing the city activities.

However, the increasing role of the city as a metropolitan city and regional service centre that may attract more inmigrants and commuters, as well as the intensification of trading, services, and tourism activities in the areas with potential tsunami inundation risk – in spite of the limitation of settlement growth – may have a challenging impact on the exposure of the people during the day. In this case, there may be more working areas and working population exposed in the long-term, as well as more people who do not live in the area but conduct activities there. Also, a punctual increase of exposure, e.g. due to more intensive tourism activities in Muaro and Padang Hill area is to be expected.

Impact on access to safe places

The access to safe places should be enhanced by means of improvement of the transportation network and evacuation shelters. The development is partly linked with the social and economic objectives, such as the improvement of informal trading areas, parking management, and the overall improvement of the road network. The intention to develop new roads perpendicular to the coastline and escape buildings was also mentioned, but no specified spatial allocations were formulated in this plan and the capacity of the current facilities as potential shelters would not be sufficient considering the amount of exposed people. Furthermore, there was no indication of specific protection measures referring to more intensive non-settlement activities in the exposed areas.

Impact on access to warning

The Spatial Plan also provides a clear hint towards improvement of the access to warning by increasing the capacity of the current electricity supply and telecommunication infrastructure. It identifies various sources of power in case of emergencies, mentioning emergency as one criteria to be considered in the zoning regulation for wireless tranceiver towers.

5.6.2 Role of Urban Planning and Linkages with Emergency Planning

The stakeholder analysis identified formal and actual roles of various government planning agencies in the evacuation planning process as presented in Table 5-15. The analysis clearly indicated that efforts needed for the complete evacuation planning take more than one actor, and definitely does not solely involve the disaster management body. While the local disaster management body (BPBD) is primarily responsible for early warning facilities and emergency response, urban planning actors, especially the Urban Development Planning Agency (BAPPEDA), Spatial Planning and Urban Design body (TRTB), and Settlement, Infrastructure and Regional body (Kimpraswil/PU) play the leading role in controlling exposure as well as planning and implementing the provision of evacuation facilities and infrastructures. This has been confirmed by regulation as well as discussions with the corresponding local actors.

BPBD still defined themselves as emergency managers and acknowledged their lack of capacity at the moment. This is quite understandable in view of the fact that the establishment of the early warning and the development of evacuation plans in the city of Padang as well as the establishment of the agency itself were very recent at the time of the study. Although according to the regulations this agency is supposed to be in charge of monitoring risk with regard to spatial planning and environmental management as well as hold the leading role in the planning and operationalization of tsunami early warning and evacuation, it has not had the capacity to fully implement this task yet. The agency rather perceived BAPPEDA and other sector-related agencies as the focal points and main actors when it comes to long-term planning and risk assessment. During the process, it received strong support from the existing government and non-government agencies. Nevertheless, in future it should play the stronger role of coordinating and implementing the tsunami risk management prior to, during, and after hazard events, in cooperation with other relevant agencies.

BAPPEDA as coordinator of the development of the Spatial Plan and long-term development programmes was the focal point in providing the information basis and assessments for long-term objectives for programme allocation and budgeting. It plays the big role of harmonizing various risk reduction measures. However, although the Spatial Plan provides long-term orientation for medium- and short-term programmes, these programmes are influenced by the actual city government´s priority. BAPPEDA cannot control the implementation of the Spatial Plan by individual agencies. Moreover, some challenges exist due to the lack of a centralized database and limited capacity to assess activities in different agencies. In practice, assessment and planning activities had to involve and be supported by external consultants.

TRTB as the technical and implementing hand of the Spatial Plan is in charge of controlling the spatial allocation for various city functions and the issuance of the corresponding permits. The agency is also involved in land clearing processes for particular land use allocation, e.g. new public facilities. This role is very crucial in the tsunami risk reduction; however, it also deals with the limitations of data management, as well as lack of capacity to monitor building uses once the permits have been issued.

With regard to the planning and construction of infrastructures and facilities, Kimpraswil/PU plays a major role and provides technical guidance. A building code for seismic hazards (not yet available for tsunamis) has been developed and improved by the agency. It was also involved in the planning and assessment of evacuation roads and shelters.

Support from non-governmental agencies in the technical (such as technical assessment) and institutional issues (development of Standard Operational Procedures, capacity building of the community) was also significant. The local Disaster Study Centre of the University of Andalas (academic actors) and the non-government organization KOGAMI were involved intensively throughout the planning process and provided strong technical support to the related government activities. Also, other agencies such as the Fishery and Marine Agency (DKP) from the provincial level influenced the development of an evacuation map due to its plan to provide vertical evacuation shelters. For efforts involving extreme natural hazards such as tsunamis and high investment as for instance the improvement of infrastructures and construction of evacuation shelters, support from the higher planning level was inevitably needed. This was also true for the case of Padang. Recently, the national level stated their interest and commitment in tsunami risk reduction and improvement of the early warning system. The National Body for Disaster Management (BNBP) has stated that planning activities are underway to construct evacuation shelters in the coastal areas including Padang (Ichsan; Burhani). Padang and the West Sumatra Province were mentioned as areas of concern, where there are no appropriate buildings that could be used as vertical evacuation shelters.

Allthough not included in the analysis below, external parties such as international NGOs like GTZ and international scientific communities from various countries also played significant roles from the background, among others the GITEWS and “Last-Mile – Evacuation” projects from Germany, the GeoHazard International project, and also teams from Japan and USA. The capacity building and research activities contributed to shaping tsunami risk reduction and evacuation planning processes in the city of Padang. During the field stays, no significant involvement of private sectors and business actors was observed in the development of the tsunami hazard map and planning of vulnerability reduction measures. A few were rather involved in the operational activities, such as participating in tsunami drills.

Various on-going and planned interventions involving various agencies were identified by local planning actors interviewed by the researcher and stated in the local action plan of disaster mitigation. The results clearly indicate that the urban planning agencies (BAPPEDA, TRTB, Kimpraswil/PU) play the main role in measures related with control of use in exposed zones, construction of transportation infrastructures for evacuation, and evacuation shelters. Additionally, TRTB plays the main role in involving the community in the overall disaster-mitigation based spatial

planning. On the other hand, the disaster management body (BPBD) is rather involved in the socialization of the activities to the community and provision of facilities such as evacuation maps and signs. This again emphasizes that urban planning agencies have to be involved in the evacuation planning since the beginning and that coordination among urban and emergency planning should be linked to each other.

Table 5-15 Roles of Various Local Actors in Building Early Warning Response Capability of the People

AGENCIES	ROLE DEFINITION	EXPOSURE REDUCTION	IMPROVING ACCESS TO SAFE PLACES	IMPROVING ACCESS TO WARNING	EVACUATION BEHAVIOUR
Badan Penanggulangan Bencana Daerah (BPBD) Kota Padang **Disaster management body**	By regulation	Collection of relevant data Monitoring of spatial plan and environmental mgt	Preparing emergency response and relief	Installation and examination of early warning facilities	Planning, training and socialization SOP
	In on-going / planned measures	Socialization of spatial plan, provision of land and infrastructures for relocation areas	Provision and installation of evacuation maps, billboards, and signs, socialization to community	Installation of sirens, development of radio FM-RDS, communication devices for various agencies, development of community emergency teams and facilities.	Planning, training and socialization SOP
	Current state	Lack of data and capacity, for planning and assessment referring to BAPPEDA	Needs strong support and continuous capacity building		
Badan Perencanaan Pembangunan Daerah (BAPPEDA) Kota Padang **Urban Development Planning agency**	By regulation	Coordination and development of spatial plan, long-term development programs			
	In on-going / planned measures	Development of disaster-mitigation based spatial plan and master plan/zoning Relocation and provision of facilities and infrastructures in safe areas, utilization of unused public buildings in hazard zone (e.g. for tourismus activities)			
	Current state	lack of centralized database management, limited capacity to coordinate and assess various Short- and medium-term programs influenced by city government´s priority, cannot control the implementation			
Dinas Tata Ruang dan Tata Bangunan (TRTB) Kota Padang **Spatial Planning and Urban Design**	By regulation	Allocation plan of various facilities & infrastructures location permit, occupancy	Examination of traffic density and transportation network	Provision of recommendations for electricity supply,	-

body		permit, demolition permit Monitoring building use	Planning allocation of facilities and infrastructures Permits	telephone network, radio towers and mobile phone transmission	
	In on-going / planned measures	Development of disaster-mitigation based spatial plan and master plan/zoning, monitoring of its implementation Public hearing and dialogues in development of disaster-mitigation based spatial planning, socialization of spatial plan Relocation and provision of facilities and infrastructures in safe areas, utilization of unused public buildings in hazard zone (e.g. for tourismus activities)	Land clearing and permits for new roads, widening of existing roads, vertical evacuation buildings, hills/tsunami deck Maximalization of the street utilization by clearing the existing blockage causing traffics, e.g. control of building use at crossroads, alternative space for parking lots and street vendors		
	Current state	No centralized database, limited resources Monitoring often problematic	land clearing difficult	Will be involved for the permit	-
Dinas Pekerjaan Umum Kota Padang Settlement, Infrastructure and Regional body	By regulation	Assessment and recommendation of permit Development of technical standard for settlement and infrastructure	Examination, technical guidance, and monitoring infrastructures and facilities, including roads and bridges	Development of technical standard for settlement and infrastructure	-
	In on-going / planned measures	Socialization of spatial plan, provision of land and infrastructures for relocation areas Relocation and provision of facilities and infrastructures in safe areas, utilization of	Construction of roads perpendicular to the coastline to the bypass road & widening of existing roads perpendicular to the coastline		

		unused public buildings in hazard zone (e.g. for tourismus activities)	Construction and improvement of connecting bridges Engineering examination of vertical evacuation buildings, hills/tsunami deck		
	Current state	Need technical specifications on tsunami e.g. for Building codes	Need technical specifications on tsunami e.g. for Building codes Need support from provincial & national level	-	

Source: Perwako Padang 2008 on roles and responsibilities of city government agencies, Stakeholder Analysis by Local Expert 2009, Non-Structured Interviews with the Local Actors June-August 2009, Telephone Interview in September 2012

5.6.3 Identification of Challenges from the Planner´s Point of view

With regard to the potential interventions for control and reduction of exposure to tsunamis, as well as provision of evacuation infrastructures and facilities as identified previously, two main challenges were identified from discussions with the planning actors: 1) cooperativeness of the people, and 2) capacity of the planning agencies.

5.6.3.1 Land use restrictions / change, new infrastructures and facilities vs. people´s cooperation

Due to the fact that the city centre and the development of the city originally started and were located in the coastal areas without any consideration of tsunami risks, most of the exposed areas are already built. This means that avoidance of tsunami hazards by turning the whole exposed coastal areas into conservation areas could not be materialized in the short- or medium-term. It has been considered to promote the settlement development towards safe areas, but this is not without further considerations. Some of the space in the eastern part of the city, which is still sparsely inhabited, is still being used for agricultural areas and the extent of conversion of this land use to settlement areas would also need further assessments. Releasing the existing owned land for other land use, e.g. for relocation from dangerous areas, widening roads, and shelter construction, is always difficult, time-consuming, and expensive. An example of land clearing for the on-going widening of the *Alai* road and the construction of flats in the fishermen neighbourhood (for other development purposes) took a long time and was costly. In some areas where there is cultural or customary landownership (*tanah ulayat*), the land clearing process is even more complicated. One of the planning actors interviewed described the issue of land as problematic in West Sumatra, including Padang to some extent, as follows:

> *"..the problem of land in West Sumatra is the cultural land. Land is your pride, you don't give away, you don't sell it. It is very difficult to conduct land clearing. For example, in Rusunawa project (flat for fishermen neighbourhood), they did not want to bargain with us, they asked for higher price..."*[26]

And also another planning actor said the following:

> *"...the problem is once again the land clearing from the people in Padang is very difficult. They are the ones who own the land; they ask more money to the government. We cannot possibly pay for the market land price; it is at the end for the public itself, right? ...land clearing is not completed only in one or two months, the process may need some years..if people find out there will be a land clearing, the price goes immediately up.."*[27]

In order to enforce tsunami risk reducing land use, such as restriction of settlement use and change of land use in the hazard zone as well as allocation of space for evacuation roads and shelters, people would need to accept and comply with it in a long-term. This relates with people's continuous

[26] Transcript P4 - 4:9

[27] Transcript P8 – 8:3-10

awareness of the existing tsunami risk and the necessity to take risk-reducing actions. In many cases, the planners observed ignorance among the people concerning not only earthquakes but also other existing hazards. Many people solely reacted when the hazard events occurred. Additionally, according to the planners, most of the people living in the hazard zone do not want to move from their current place. In an example of a previous earthquake event, it was observed that the people were feeling uncomfortable living in the coastal areas immediately after an earthquake event, but not long thereafter many returned to continue living and conducting activities in their old – dangerous – places as usual. Nevertheless, the tendency of land prices to decrease in the coastal areas due to tsunami risks and the move of some economically better-off people to higher ground has been observed as well. Also with regard to the improvement of evacuation routes, government needs a good cooperation with the people involved. An example observed during the field visit in 2009 also showed that not all people were actually cooperative during the development of the new evacuation route. In the Figure 5-32 below, a new perpendicular street was constructed towards the higher areas, where an old factory was still standing right in the middle of it, since the owner did not want to sell the land to the city government. An official demand had to be issued to force the owner to release the land for public need.

Figure 5-32 Development of new local street perpendicular to the coast (left) and an old factory standing in the middle of the pathway (right)

Source: Setiadi, 2009

The planning actors also mentioned the difficulties of enforcing the existing regulation whilst confronting the economic conditions of the affected people. People also have concerns about their livelihoods especially the ones with lower socio-economic strength. One planning actor described the following:

> *"....perhaps it was not allowed by the spatial planning agency (to build in the hazard prone areas)...for the city government is was problematic, should we force them to comply with*

regulations..or just let them be? both is difficult...I can feel this in the position of government, sometimes we think, we may improve first the economic conditions, let people secure their livelihoods, then we can put such things in order....”[28]

People would also not easily accept any measures provided by the government, e.g. the construction of a new terminal and transit point in *Air Pacah* (northeast part of the city, currently developed as the new city government centre) that failed because people did not utilize this new facility and preferred to stick to their old transit points close to the central market place and their activity centres. This is also true for the construction of new evacuation shelters. It is clear that people need to accept the necessity of such facilities and also trust their effectiveness, such as feeling safe to use any of the assigned high buildings escape shelters.

5.6.3.2 Planning and implementing measures vs. existing local government agencies´ capacities

In addition to support and cooperation from the community, the local government planning agencies also face their own challenges and limitations with regard to human resources, finance, cost-benefits and priorities, and coordination, up to the availability of basic data for assessment and planning.

The planners agreed upon the fact that potential tsunami risk reduction measures cannot be dealt with only using the local capacity; it involves high investment, e.g. transportation infrastructures and evacuation shelters, which would need support, i.e. funding, from the provincial and national levels. But also financial support for infrastructures from higher government levels does normally not include the costs of land clearing – which are, as described above, quite high. Against the background of limited resources, it was perceived by the planners that disaster risk reduction in general still has low priority and has to compete with many other interests and development objectives. The tsunami risk reduction plan is subject to the Mayor´s vision during his/her government period (normally a 5-year medium-term plan and 1-year short-term plan) and parliament’s decision to approve the budget. Therefore, awareness at all government levels is seen as necessary by the planning actors to push through tsunami risk reduction. The land use restrictions stipulated for tsunami hazard zones require political decision-making and have to be implemented in an integrative manner with participation of all the related government agencies. Currently, there are other development projects in the coastal areas, such as tourism, business districts, and the construction of roads along the coast, whose impacts on tsunami risk have not been specifically assessed yet.

Also, planning tsunami risk reduction measures requires technical data and assessment. At the moment, there is limited high-resolution data available on earthquakes and tsunami hazards (some was made available by external agencies through projects). Moreover, data is still scattered among institutions and GIS data and application is not widely used in many agencies. The coordination and information flow between government agencies still needs to be improved.

[28] P23 – 12:21

5.7 Intermediate Summary

This chapter presented important facts and figures from the case study in Padang, as summarized in several main points formulated below:

The empirical findings show that the current response capability of the people in Padang varies depending on the spatial and infrastructure setting of the city, as well as socio-economic characteristics of the people.

The dynamic exposure was strongly determined by the density of settlement areas as well as non-settlement activities in various locations of the city. At the moment, the settlement areas are densely built in the exposed areas and cause high exposure both in all-day time scenarios. Moreover, the city centre and the majority of the city activities are also located there and increase the exposure of the morning scenario. With regard to the exposed population and short warning lead times, it is evident that the current access to safe places provided by the existing street networks is not sufficient in all the day time scenarios with the morning scenario as the worst one. Lack of access to roads perpendicular to the coast and connecting bridges becomes visible in the evacuation model, and the need for a vertical evacuation option was addressed. Moreover, access to warning was related to how public devices are spatially distributed and utilized in various city locations in the case of potential tsunamis, which also depends on the communication network available. And further, the effective and timely utilization of the available infrastructure and facilities is also influenced by the evacuation behaviour of the people. All of these findings underline the significant influence of urban planning in altering the existing vulnerability and response capability of the people as well as the need to incorporate different corresponding criteria in spatial planning.

On the other hand, different strategies should be developed to meet the needs of different social groups. Regardless of the exposure level, a higher proportion of population groups with lower evacuation capability (women, children, and the elderly) in the morning compared to the night scenario was identified in some city areas, especially where settlement areas and schools are located. These are places where the evacuation assistance may be needed most and evacuation shelters should be designed accordingly. Variation by social groups was also evident in the availability and utilization of private devices as well as evacuation behaviour (decision to evacuate determined by past experiences).

The empirical findings show proper communication of risk with regard to people´s concerns and cultural norms and values in Padang is required.

People are likely to accept and support interventions to reduce vulnerability differently depending on their perception and level of awareness. The data analysis results suggest that people´s intentions with regard to reactive (evacuate) and proactive (support the improvement of evacuation infrastructure and facilities) vulnerability reducing action are associated with their awareness about the existing risk and preparedness. People identify the existing danger (tsunami potential), relate the danger with themselves; and assess the urgency of evacuation. They also assess whether they are

capable of conducting evacuation in certain situations. Also, further knowledge about how to conduct an effective evacuation is crucial and appears to associate with proactive action intentions.

Beyond that, the communication of tsunami risk should be embedded in the overall concerns and risk landscape of the people. Preparing for an extreme event may be perceived differently than struggling with everday´s needs like securing income and livelihoods. Getting prepared for evacuation or relocation to safer places, for example, is linked with such concerns and should also address them. Another important aspect is to make sense of preparedness actions addressing the people's cultural and belief systems. People would be more likely to understand, accept, and support the preparedness actions if these are in line with their values.

The data analysis also shows that the quantitative and statistical analysis was not able to provide a complete picture of issues of perception. This may also be due to lack of experience and still varying information about the existing tsunami hazard and early warning. For subjective factors, the significance of the variables was also sensitive to the formulation of the very questions and interpretation of the respondents. Additionally, many variables may influence others in an indirect manner, so that a more complex cognitive model might be needed. Qualitative information in this case was proven as very useful to give a better understanding and also propose further explanatory factors for the future examination.

The empirical findings show that the role of urban planning in Padang in enhancing early warning response capability has been recognized; however, specific vulnerability considerations still need to be incorporated in detailed planning and synergy with other development objectives needs to be ensured.

The role of urban planning in exposure reduction and in providing spatial and infrastructure requirements for appropriate early warning response is evident in the context of Padang. Specific points of interventions of urban planning agencies have been clearly formulated in the existing regulations and incorporated in the planning activities. These include the provision of information of risk and incorporation into various planning activities, allocation and control of land use in the exposed area, land clearing of already built areas, as well as ensuring technical requirements of constructions (building code) and infrastructure. Presently, the incorporation of tsunami risk reduction in the overall spatial plan is reflected in the long-term development orientations. However, the specific needs identified in the assessment are yet to be integrated in the detailed planning. Currently, vulnerability assessment and assessment of response capability has not been explicitly integrated as part of the planning. Some potential conflicts have been identified such as the expected increase of exposure in tourism areas. High demand of protective measures also remains necessary if non-settlement activities are to be intensified in the coastal areas in spite of the limitations of settlement growth. An optimum level of risk has to be met to harmonize various development objectives.

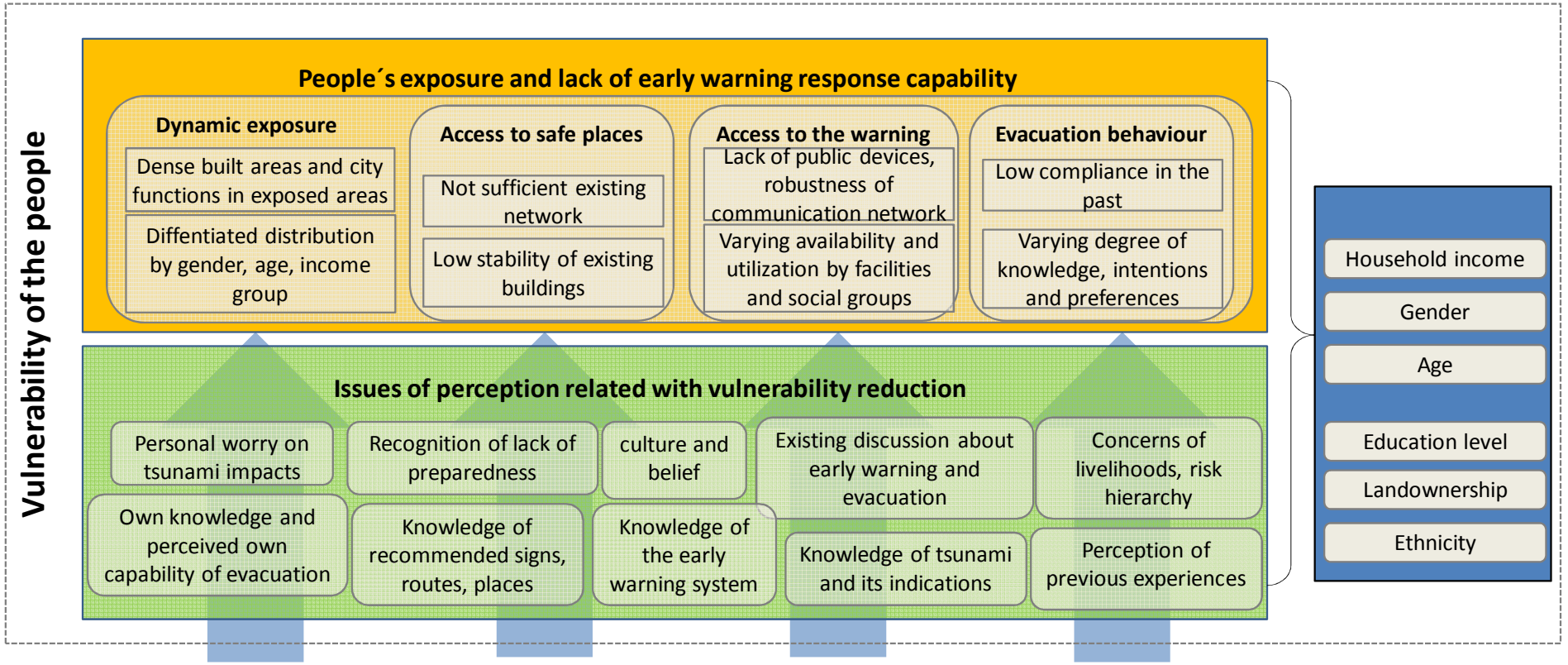
6 Discussion

The objective of this study was the development of an assessment framework and methodologies to measure the early warning response capability of the people, which can be useful to guide urban planning to sustainably integrate the early warning needs in the long-term planning. The framework and approaches were developed in the previous chapters and operationalized to identify problematic areas and social bottlenecks of evacuation in the city of Padang. The summary of the empirical findings presented in Chapter 5 were incorporated in the framework as shown in Figure 6-1 and Figure 6-2. Figure 6-1 visualizes the conditions and factors at the community level which influence the current response capability of the people in Padang related to dynamic exposure, access to safe places, access to warning, and evacuation behaviour, and also the potential effectiveness of vulnerability reduction regarding the issues of perception. These components are associated with socio-economic characteristics, i.e. differ by social groups. On the other hand, Figure 6-2 shows ongoing interventions related to these components that may or may not be sufficient, depending on available capacity, coordination, and support from political and higher levels, to ensure appropriate early warning response capability.

In the context of Padang, the current vulnerability to tsunami with regard to people´s response capability is high due to its high exposure to potential tsunamis and the extent of mass evacuation required in a very short lead time. Efforts to provide early warning dissemination and raising awareness of the people have been undertaken. Such efforts have to be promoted and conducted continuously in order to build an embedded “culture” of tsunami preparedness in the area. But beyond this, another big challenge at the moment is to provide sufficient facilities and infrastructure to ensure appropriate responses to tsunami early warning. Besides the required improvement of the communication network for warning dissemination, the current infrastructure (evacuation route and facilities) accompanying the established tsunami early warning system is far from adequate for the high number of potentially affected people. The need for additional infrastructure and facilities emerges against the need for reducing the current exposure. This underlines the necessity to integrate the spatial and infrastructure requirements of early warning within the urban planning.

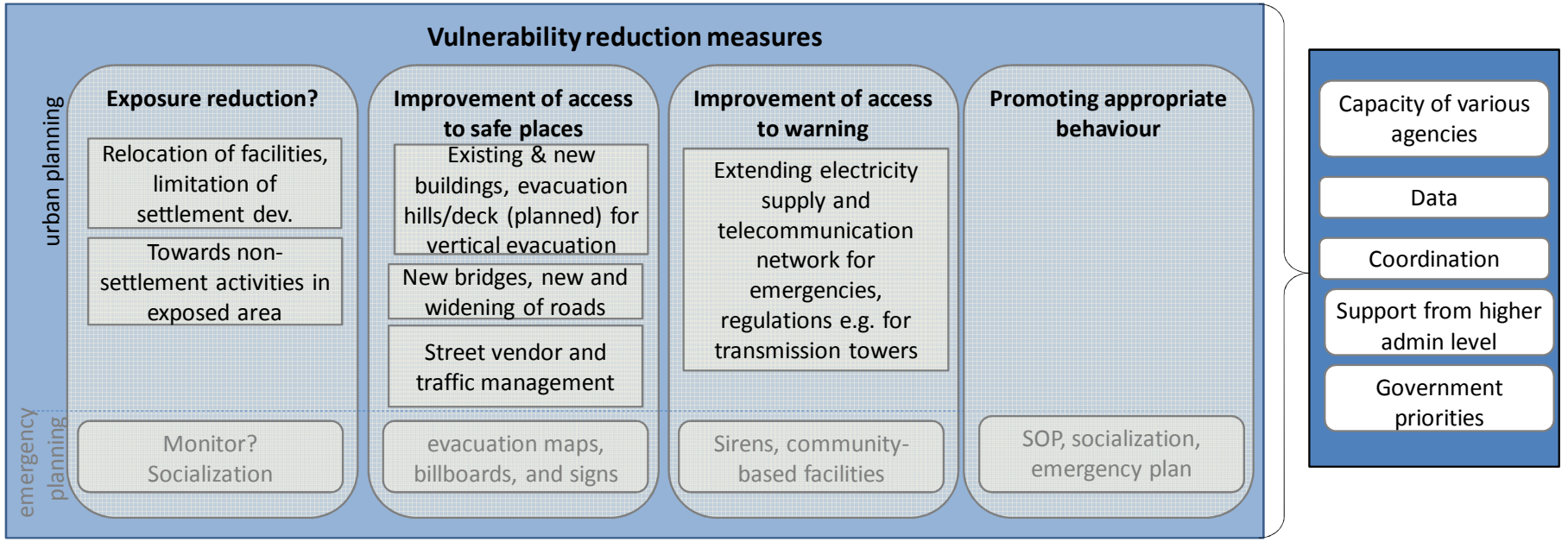
In the following, these results are discussed further and reflected to draw recommendations for urban planning (including risk communication strategies in strong cooperation with emergency planning) related to various components based on the empirical results, also taking into account the differentiated response capability of the social groups. They are firstly applicable to the context of Padang, but may also be generalized as important aspects of a tsunami early warning system in general. At the end, the strengths, limitations, and improvement potential of the assessment framework and methods are discussed.

Figure 6-1 Summary of the main findings for the case study of Padang: people´s exposure and lack of early warning response capability



Source: own figure

Figure 6-2 Summary of the main findings for the case study of Padang: vulnerability reduction measures



Source: own figure

6.1 Differentiated Response Capability by Social Groups

6.1.1 Gender Perspective

As shown in the empirical analysis, it is worthwhile to review early warning response also from gender perspective. It is revealed that the gender plays a role in the distribution of the population in various city areas or functions and their dynamic exposure to potential tsunamis. In the case of Padang, women are much less engaged in the working activity outside home compared to men. With regard to the gender role, women seem to still play a major role in household care or family responsibility while men dominate the working activities outside of home, although the participation rate in working activities of women has been increasing. Based on Population Census 2000, 29.4% of the females age 15-64 years are employed and 46.8% are categorized have other main activities (mostly as housewives), while 63.9% of the males are employed. Also, the working females have on average a slightly lower mobility and conduct more proportion of activities at home (conducting household tasks) than working males. Thus, sufficient access to safe places and to warning in the settlement areas is important for this group. Also, the utilization of warning dissemination devices (TV, mobile phones) is different by gender. It should be taken into account that in many cases, female household members may need to take decision concerning evacuating the family from home in case of potential tsunamis. It is also probable that due to their caretaker role, the women have to evacuate with their children, which consequently may slow down the evacuation velocity.

It is noteworthy to examine the evacuation behaviour of this group in the last earthquake event in 2007; they were the ones that rather conducted evacuation although the event occurred in the evening time (18 pm local time) when many of the household members were at home. In the analysis of issues of perception it was shown that the females had higher level of worry on the impacts of possible tsunami event, and this may be one explanation for such evacuation behaviour. In other study on hurricane evacuation (Bateman and Edwards 2002), women have shown a heightened perception of risk and are more likely to evacuate. It was also mentioned in informal conversations, that in some households, the male household heads asked the wives and children to escape to safe areas first, while men were searching for further information and confirming the tsunami occurrence. However, in the analysis of cognitive factors, it was also found that the females rather had a lower level of objective knowledge about evacuation (signs, places, routes). In the group discussion with the planning actors in 2010, the different evacuation capability between male and female was confirmed, but rather only for the morning scenario (evacuation in the dark night was perceived to the same level of difficulties for all population groups). Thus, it is important to empower this group and provide them with more information and facilities concerning evacuation.

Additionally, it is also interesting to see that the main concern on providing daily care for the family during evacuation (concern to buy additional food due to evacuation) in case of no tsunami occurrence or “false alarm”. The role of gender is again emphasized in this regard and this concern is worth considering.

6.1.2 Age Group

Age group is important firstly due to the limited mobility or physical capability of elderly population in case of evacuation. As shown in the analysis of issues of perception, age group was the one socio-economic characteristic that showed significant negative correlation, directly with the intention to evacuate in the future event, in spite of positive correlation of age group with the knowledge of early warning system. Many elderly people perceived their limited mobility as an obstacle in conducting evacuation. Also having uncertainty of tsunami occurrence in mind, they would rather not conduct evacuation, if no sufficient facility (e.g. vehicle) was provided. As the female population, the elderly population also conduct more activities at home and are more dependent on the access to safe places and to warning information in the settlement areas.

6.1.3 Income Group

The people with lower income level are more vulnerable in several aspects: the living locations with a considerable proportion of low class / slum areas highly exposed to potential tsunamis (along the coast) and their lower daily mobility, their lower access to private devices (mobile phones) to receive the warning, their concern on loss of income and costs of evacuation with regard to uncertainty of tsunami occurrence, and also their limitations – also related with their livelihood concerns – in supporting the on-going efforts on improving evacuation infrastructure and facilities.

6.1.4 Ethnic Group

Although not further explored within the scope of this study, there was an indication that minority groups, for instance the people of Chinese descent living in the old town areas may have different access to and perception of information about tsunami and on-going preparedness activities. Thus, risk communication strategies to promote involvement of minority groups are also important.

6.2 Considerations for Urban Planning

6.2.1 Considerations in Exposure Monitoring and Reduction

Overall, the exposure of the city of Padang is high due to already densely built areas along the coast which are exposed to potential tsunamis. These built areas are composed of settlements, commercial areas and city service centres. The level of exposure is high, especially due to the location of the city centre and of most commercial buildings in the exposed area. The exposure also varies at the different daytimes due to daily activities. The exposure in the city centre and commercial areas along the main roads becomes even higher during the working hours, when the working population from outside the exposed area conduct their occupational activities there.

The existence of main city functions located at the coastal areas plays a major role in the exposure of the population especially during the daytime. In the long-term, it is also a significant pull factor for further occupancy of the exposed area and may trigger the development of more dense settlement areas. The overall high exposure and identified hotspots show that current settlement and non-settlement activities in the areas are overall very dense and need to be reduced in the long-term. The current plan to develop sub-centres in the eastern part of the city anticipates the expected additional pressure brought about by the growing functions of the city as a metropolitan city and regional

service centre that also covers demands from neighbouring districts. But it also needs to be considered to what extent exposure in the current densely built areas and active city centre can be reduced.

As presented in Sub-chapter 5.1, the analysis findings show that there is variation in daily activity patterns and spatial distribution of various population groups: working versus non-working, male versus female, low versus high income households. The women (15-64 years old) and the elderly (65+) have a lower engagement in working activities compared to men (15-64 years old) and they have on average a higher proportion of activities conducted at home, while children mostly participate in education activities. Thus, in the morning time (working hours), there is a higher proportion of women, children, and elderly people in areas with more settlements, especially in the lower class neighbourhoods, where many households live in relatively smaller houses with high density, as well as in schools. In contrast, there is a slightly higher proportion of male population in the working and public areas. Also, the people with lower household income are more likely to spend the day in the vicinity of their living places, meaning that these people who live in potentially affected areas will have high exposure throughout the day. The locations of these people can be identified qualitatively by identifying them as low class settlements and slum areas.

The results of Padang confirm existing studies that mobility and travel behaviour are related to socio-demographic factors. Firstly, with regard to the gender, a higher proportion of male population with a longer duration throughout the day are engaged in the working activities outside of home (distributed in commercial and office buildings), in contrast to female population. Gender difference in daily activity and mobility patterns was found in many studies and the issue of gender has been increasingly promoted for incorporation in transportation planning due to different gender roles and behaviour (e.g. World Bank 2010; Deike 2001). Furthermore, it shows variation among age groups, the elderly at retirement age are also less engaged in working activities and school-age children age are mostly engaged in education activities. Additionally, the influence of the socio-economic level on mobility was already indicated in this study. The results of the dynamic exposure analysis emphasize that assessment based on social groups is needed in developing strategies to reduce exposure in the long-term. The following recommendations were derived from the results:

Recommendation 1 Limitation and relocation of dense settlement areas in the exposed areas in the long-term and provision of sufficient public facilities to support the daily activities of vulnerable groups outside the exposed areas .

Due to the longer duration of activities conducted at home or in the vicinity by the majority of the female, children and elderly population, the settlement areas pose relatively higher exposure levels and should be reduced in the long-term. However, infrastructure that provides for household needs, such as market places, houses with mixed uses *("Ruko"=houses and stores)* complementing future settlements outside the exposed areas is required.

Recommendation 2 Reduction of low-income settlements in the exposed areas and provision of more income generating opportunities outside the exposed areas.

The results suggest to reduce exposure by decreasing settlement density in the potentially affected areas, but to give particular attention to the slum and low class settlement areas. These people face the greatest difficulties due to their lower mobility and limited employment opportunities. Additionally, these people are the ones most likely to be reluctant to move from the place where they live due to difficulties in securing their livelihoods. Slum upgrading efforts of the city government were ongoing, e.g. construction of flats for inhabitants in slum areas in Purus, and intended to increase livelihoods. However, besides some other challenges in the implementation (Padang Express, 2013)) it needs to be taken into consideration that the construction of this facility is located in the same exposed areas and may even add to the level of exposure due to vertical development and higher occupation rate of the building, and the earthquake and tsunami resistance of the building has not been tested yet. Therefore, it is recommended to put more emphasis on developing more income generating opportunities and such facilities outside the exposed areas.

Recommendation 3 Relocation of schools and hospitals from the exposed areas

The exposure reduction of these important facilities needs to be among the top priorities. It has been indicated in the study that there are spots in the exposed areas where these facilities are located causing high exposure of more vulnerable people potentially facing difficulties in evacuation. In the long-term, allocation of space for these facilities in the potentially affected areas needs to be limited.

Recommendation 4 Continuous assessment and consideration of dynamic exposure in evacuation planning.

The strong linkage of dynamic exposure with the other components of early warning response capability has been emphasized. This also implies that any changes in land use and building uses in the exposed areas will change the constellation of the social groups there and in return alter the overall vulnerability and response capability. Thus, continuous assessment of dynamic exposure following the planning period is important and this should also continuously inform the existing evacuation planning. And consequently, every development that increases exposure and reduces response capability of the population should be limited and compensated by additional protection measures.

6.2.2 Considerations in Improving Access to Safe Places

Access to safe places is strongly linked with the level of exposure; the higher the exposure, the more people have to be evacuated. But this also depends on the capacity of the transportation networks in the exposed areas towards the hinterland. In spite of dense street networks in the densely built areas, there is still lack of access to roads perpendicular to the coastline towards the hinterland and only very few bridges connecting the area along the existing canals and rivers. The deficiency of the current street network is shown by a high number of people who need longer than 30 minutes to evacuate outside the exposed areas as presented in Sub-chapter 5.2. Thus, the access to safe places is still far less than sufficient considering the short lead time available for mass evacuation. In areas where exposure is high, the evacuation time needed was also estimated as high. Thus, continuous exposure reduction in those areas would be necessary. Furthermore, locations with high proportion

of vulnerable people (dense settlement areas, schools, hospitals, and lower class settlement areas) were identified. This should be factored in the provision of evacuation shelters, improvement of evacuation routes, and provision of vehicle support, as well as designing evacuation shelters oriented to meet the specific needs of these groups. Based on the results, the following recommendations are derived:

Recommendation 5: Enhancing the capacity of existing street networks and provision of vertical evacuation shelters prioritizing the locations with high proportion of vulnerable population taking into account their specific needs.

Improvement of access to safe places through construction of new bridges, widening existing roads, construction of additional roads perpendicular to the coastline, in opposition to provision of vertical evacuation shelters, is necessary. Recently, further engineering studies and analysis have been conducted to assess various options for improving access to safe places in Padang and their effectiveness in shortening the evacuation time, which are particularly discussed in Di Mauro et al. (2013) and Muhari et al. (2012). Di Mauro et al (2013) conducted various evacuation simulations while incorporating possible interventions as mentioned above. They suggested, however, that the widening of roads and building of new bridges was likely to be ineffective due to the large distances that have to be covered in a short time and the high investment in such constructions, and recommended to build vertical evacuation shelters. Nevertheless, this study suggests the enhancement of the capacity of the existing street network, especially the streets which are exposed to traffic pressures anyway even under normal conditions or the ones which are needed for other development objectives (e.g. improvement of access to neighbouring districts). This may be considered as a "non-regret" measure of vulnerability reduction. Additionally, further assessment of the impact of further non-settlement developments in the tsunami prone areas versus the capacity of the planned infrastructures and facilities to meet the demand of evacuation is necessary.

With regard to vertical evacuation shelters, the city government has identified several potential buildings in the current Spatial Plan. However, the strength of the identified potential buildings to withstand future major earthquakes and tsunamis have not been technically certified. The results of building surveys and remote sensing analyses rather suggest that hardly any buildings in the study area are stable against strong earthquakes and tsunamis. Even so, the capacity would not be sufficient considering the number of potentially affected people. Therefore, the new construction of vertical evacuation shelters or retrofitting of the existing constructions is inevitable. Assigning proper building codes is a prerequisite for any type of construction to be used as a vertical evacuation shelter.

Mauro et al. (2013) also suggested that the construction of big high-raised buildings would be rather ineffective due to the uncertainty of the construction quality as well as the low trust of the people in such structures. There have also been recommendations for evacuation hills in the northern part of the city, but they have so far not been implemented yet. Furthermore, Muhari et al. (2012) suggested the advantages of a tsunami deck as an alternative solution, a combination of pedestrian bridge and a tsunami tower. Moreover, due to the long-term orientation aiming for more focus on

non-settlement activities (like tourism) in the already built exposed areas, some punctual concentration of the exposed people is expected. As such, higher capacity of vertical evacuation shelters is required. Thus, small constructions may not be sufficient and a tsunami deck may be a more suitable solution for this case.

Regardless of the vertical evacuation shelter type, priority should be given to locations close to schools, hospitals, and densely built settlements, especially slum and low class settlement areas. In such locations, a higher proportion of people with lower physical capability to conduct long-distance evacuation on foot (women, elderly citizens, small children, patients) exist. Considering the possibility of no tsunami occurrence in spite of strong earthquake events or false alarms and the importance of maintaining the evacuation compliance of the people, the costs and efforts to access the shelters need to be minimized and therefore should be located as easy accessibly as possible in consideration of these groups.

Recommendation 6: Minimizing congestions in the evacuation route

While the optimum evacuation route can be assessed further using an evacuation and traffic modelling approach (Lämmel 2011; Di Mauro et al. 2013), the optimum evacuation route has to be visualized clearly in the official evacuation maps and socialized among the people. Evacuation signs have to be installed along the evacuation route so that people are able to orient themselves during evacuation and unexpected congestions in some particular evacuation route segments can be minimized. Moreover, the restriction of activities along the evacuation routes that may cause congestions such as street vendors, businesses without sufficient parking space, etc. needs to be regulated and enforced.

6.2.3 Considerations in Improving Access to Warning

Access to warning depends firstly on spatial aspects, on the locations of the recipients and availability of private and public broadcasting devices. It has been shown in the case study in Padang that the dynamics of people in different locations cause different levels of access to warning (Sub-chapter 5.3). The utilization of devices and the effectiveness in delivering the warning and warning message depend on the potential recipients. Therefore, information of who is located where is crucial. Delivering the warning during the night, when most people are with their family at home, is rather less complicated than during the day or in the afternoon (although the night time would have its challenges in the conduct of evacuation). A higher proportion of vulnerable people will rely on the availability of devices at home, as well as in schools and hospitals. In contrast, mixed population groups (with slightly higher proportion of male population) are located in the working areas and activity centres and would rely on the availability of devices in these places.

People in the morning have lower access to communication devices as they conduct their working activities at that time rather than at night since the access to private devices at home is higher than at work. This has not been fully compensated by the public broadcasting devices or community-based media available in Padang so far. Moreover, access and utilization of private devices to receive warning information is proven to be related with socio-economic characteristics (income, gender,

age). Especially people with lower income would have less access to private devices. Thus, the allocation of public broadcasting devices needs to take into consideration these limitations. Also, qualitative information provided by local actors emphasized the importance of the robustness of communication networks and infrastructure in earthquake and emergency situations that needs to be taken into account when planning the corresponding infrastructure.

The following recommendations are derived based on the empirical results:

Recommendation 7: Ensuring robustness of communication infrastructure for the utilization of private devices in the case of emergencies.

The overall access to private devices is still higher compared to public broadcasting devices, and people would still rely on these as long as there is no sufficient city-wide provision of public broadcasting devices. Moreover, a higher proportion of the vulnerable group relies on the private devices at home, in schools and hospitals. This means that private devices still play a major role in disseminating the warning and information in case of emergency especially for some groups. Ensuring the security and robustness of the communication infrastructure is important.

Recommendation 8: Provision of more public broadcasting devices in the settlement areas with lower socio-economic level and public areas as well as promoting the involvement of the private sector in the dissemination of warning at work and in public places.

Population groups with lower socio-economic level have a relatively lower availability of private media and are therefore more reliant on public broadcasting devices. This is also the case for the people located in the working and public areas during working hours. Moreover, in the larger working and public areas, additional devices for larger dissemination to people occupying the buildings are not yet fully provided. Therefore, for these areas, public broadcasting devices, especially sirens, would have a significant impact. As well, the private sector represented at work and public areas needs to be involved in the development of the early warning system so that businesses are equipped with the necessary devices and procedures to disseminate the warning to staff and visitors in a quick manner. This is crucial regarding the long-term orientation of more intensive non-settlement activities in the exposed areas.

Recommendation 9: Consideration of the utilization pattern of private devices among various social groups in the development of warning messages and dissemination strategies.

The different utilization patterns of private devices was evident in the case of Padang. More female and elderly population as well as low income groups, who carry out a higher proportion of their daily activities at home, would be more likely to be reached by having private communication devices at home. The private devices of these groups consist particularly of television and radio, and a smaller proportion is reachable by mobile phones. Battery-operated radios that are less dependent on electricity shortages in case of emergency need to be promoted especially for these groups. Furthermore, clear warning messages need to be developed to be easily understandable for the receiving groups in order to trigger the appropriate actions.

6.2.4 Role of Evacuation Behaviour in Planning

Evacuation behaviour is not influenced directly by spatial and infrastructure settings but poses a rather limiting factor and has to be considered as part of the planning. Evacuation behaviour determines the utilization and effectiveness of the existing infrastructure and technical measures. It has to be considered, for example, that the analysis of access to safe places are based on the assumption that all people proceed to evacuate on foot with no barriers in the streets, and that they are well trained to find an optimum evacuation route. The data analysis in Sub-chapter 5.4 showed that evacuation bottlenecks are likely to occur due to the delays in evacuation decisions at household level, lack of harmonized evacuation arrangements, gaps in knowledge of recommended safe places, and the preferred use of available motorized vehicles as mode of evacuation. Thus, following recommendations are derived:

Recommendation 10: While intensive socialization on appropriate behaviour is needed on a continuous basis, evacuation delays are still to be expected and shorter time to access safe places have to be strived for.

As it became evident in the previous strong earthquake events and in the analysis of the intention to evacuate in the household survey, that a quick decision by the people to immediately evacuate after the issuance of a possible tsunami warning is still not likely to be the case in the future. This means that in evacuation, the planning and provision of access to safe places, a shorter time frame than e.g. only 30 minutes for evacuation lead time should be assumed. Meanwhile, intensive socialization, regular evacuation drills, and clear messages during warning issuance are essential and should be implemented continuously (further recommendations on the related subject are given in Sub-chapter 6.2.5).

Recommendation 11: Evacuation arrangements at the family and community level as well as in the facilities are crucial, especially considering the spatial distribution of family members during the day.

Evacuation planning should take into consideration that family members are scattered around over the day. Especially many of the non-working women and the elderly are located in the settlement areas as well as children in schools , while men and working women are at work. At home, it is also likely that many housewives have to make decisions on whether and how to evacuate the family. At school, children have to be aware of the evacuation procedures and of how they contact their parents. At the workplace, the parents or other family members have to decide whether to go home / other places to gather other family members or to evacuate directly. If there are no clear arrangements at the family and community level and in the facilities, reverse traffic during evacuation is to be expected from workplace, schools, and to settlement areas caused by the gathering of family members. Therefore, standard operational procedures are crucial that include provisions for the possible separate evacuation of family members, special arrangements at schools and other public facilities, as well as for the registration of family members, and the possibility of contacts during the sheltering process. Moreover, the role of community leaders is significant and thus their involvement in the planning is required.

Recommendation 12: Vertical evacuation shelters need to be accompanied by reliable building codes and intensive socialization.

Due to the fact that according to research, many people still consider horizontal evacuation a safer option than vertical evacuation, a proportion of people attempting horizontal evacuation in spite of the provided vertical evacuation shelters is still likely to happen in the future. While anticipating such evacuation behaviour, ensuring the stability of the vertical evacuation shelters and pursuing the corresponding intensive socialization is necessary so that people learn to trust these structures.

Recommendation 13: Using vehicles is still the preferred means to evacuate; thus, the evacuation distance to vertical evacuation shelters needs to be minimized and intensive socialization should foster appropriate behaviour.

The use of vehicles, although proven as not time-efficient for mass evacuation considering the street congestion, it is still preferred by many people. Especially where women, children and the elderly need to evacuate and cover long distances, the use of motorized vehicles is more likely. Therefore, it is recommended to minimize the distance to vertical evacuation shelters. This supports the recommendation of Di Mauro et al. (2013) of advocating the provision of many small structures as vertical evacuation shelters, so that people would be more confident to evacuate without using their motor vehicles. In any case, intensive socialization on appropriate evacuation behaviour is mandatory.

6.2.5 Building Perceptions and Promoting Participation in the Vulnerability Reduction

The results of the case study in Padang show a significant influence of cognitive factors influencing the intention to conduct reactive (evacuation after a warning) and proactive (support and participation in the improvement of evacuation infrastructures) action. Even though the cognitive model used in the data analysis was not able to fully explain the intention – let alone the actual behaviour – in the case study of Padang, it conforms to some extent with the underlying theories. Firstly, the behavioural intentions (Sub-chapters 5.5.1 and 5.5.2) correspond to the attitude towards behaviour and the subjective norms for that behaviour which are described in the "Theory of Reasoned Action/Planned Behaviour" and "Protection Motivation Theory". In the case of Padang, the high level of basic knowledge about precursors of a tsunami indicates in the first place that the people are aware of the potential tsunami occurrence or received information about tsunamis, which was communicated through various public media and awareness raising activities in Padang. Further, significant correlations were proven between the intention to evacuate and socio-psychological cognitive factors such as the perceived impact of a tsunami (personal concerns about tsunami impacts), perceived vulnerability (recognition of lack of preparedness as one cause of tsunami harm), perceived efficacy of evacuation (on-going discussions about early warning and evacuation in the community), and individual efficacy (own knowledge of where to find high buildings and high grounds, as well as perceived own capability to evacuate). The correlations of some factors with socio-economic characteristics, especially education level, household income, gender, and age group, show that different social groups may have different concerns or level of interest towards various

themes of tsunami and its preparedness, and therefore may require different approaches. With regard to the intention to support the on-going efforts to improve evacuation infrastructure and facilities, further knowledge related with early warning and evacuation also plays a significant role. Based on descriptive analysis and qualitative data (Sub-chapters 5.5.3, 5.5.4, and 5.5.5), the issues of embedding tsunami risks in the overall risk landscape of the people, concerns of securing livelihoods related with particular measures, cultural and belief systems, and promoting the reliability of the current tsunami early warning system were also outlined. In order to further incorporate the cognitive factors into the development of risk communication strategies, following recommendations were derived, related in particular with clear warning messages as well as with building perceptions of existing tsunami risks conducive to undertake actions related with evacuation measures.

Recommendation 14: Provision of clear and understandable messages and recommendation of evacuation actions consistent with the information given during socialization and evacuation drills.

Most people in Padang have been exposed to information about tsunamis and early warning provided by the public media and raising awareness activities. People were informed about potential major earthquakes that can generate major tsunamis. This may have triggered their anticipation of a forthcoming significant threat. Information whether there is tsunami potential is with no doubt expected by the people following any strong earthquake events, a message that was also conveyed by the existing early warning system. However, this was not yet fully understandable and there was varying interpretations of signs like strong earthquake characteristics preceding tsunamis (e.g. there was also strong earthquake as in 2009 did not trigger tsunami). Also, the interpretation the warning message of “tsunami potential” as an urgency to immediately evacuate still varied from case to case. Besides, information such as earthquake profiles does not say much to the people. Specific information with regard to the conduct of evacuation (evacuation route, places, signs, emergency plan, etc.) and about long-term measures to reduce vulnerability and enhancing evacuation capability (improvement of infrastructures, reduction of exposure, etc.) is necessary. The study indicated that specific information about tsunami early warning, evacuation and the corresponding measures were still scattered and not fully clear to all the people at the receiving end.

Clear information and city-wide socialization should be conducted continuously accompanying the establishment of early warning detection and dissemination technology. This has to take place in an institutionalized way, meaning that clear Standard Operational Procedures (SOPs) should be developed by the city taking into consideration local wisdom and existing informal arrangements at the household level. Additionally, any follow-up measures, such as construction of new structures for vertical evacuation shelters etc. have to be socialized and be consistent with the information given about the early warning system and existing evacuation plan and SOPs.

Recommendation 15: Acknowledge the limited available knowledge about tsunamis, but emphasize that risk exists and may have impacts on the people if no preparedness actions were taken, thus, participation of all people in preparedness efforts is necessary.

It was evident that the people were generally concerned about earthquake and tsunamis and that the level of concern about tsunami plays a role in their intention to evacuate and the acceptance that vulnerability reduction to tsunamis is necessary. Witnessing the devastating impact of the tsunami 2004 on the neighbouring region of Aceh through the public media and experiences of strong earthquakes in Padang have given people an intrusive picture of what might happen in case of a potential tsunami. This has been a triggering factor for concern about tsunami risk among the people in the area. However, a major tsunami is a rare and extreme event and has never been experienced by the current generation. There is still limited local knowledge about the hazard characteristics, occurrence of the potential extreme event, and appropriate protective actions, a fact that brings about elements of uncertainty. The development of a tsunami hazard and evacuation map for the city underwent a long process and the map has not yet fully communicated to the wide community. There were still different opinions on how to define safe places. This is also shown by the existing knowledge gap about recommended evacuation places. However, it is basically accepted that low-lying areas along the coast are potentially affected and preparedness action has to be conducted there. It is important that all people living in the low-lying coastal areas be aware of the existing risk and of the importance of participating in the preparedness efforts to increase their capacity to face such an extreme event.

Recommendation 16: Link the potential tsunami event and necessary preparedness with cultural values and belief systems and involve community religious leaders.

How the people perceive the tsunami potential also determines how they deal with it. This perception is also related with the existing cultural norms and beliefs with the question of whether they consider a threat as a "given" or as an occurrence one can do something about. Most of the people associate extreme natural events with God´s will or as a consequence of people´s deeds. This may be interpreted in such a way that there is nothing that they can do to avoid it or that they will be protected by their good deeds in general. However, it was also evident in the case of Padang that the linkage of preparedness activities and cultural and religious values has opened up the people to accept the on-going efforts positively and participate actively. Cooperation with and capacity building of the community leaders is crucial to promote the awareness that protective actions are needed and tied to their cultural and religious values. Discussions about the necessary preparedness actions should be triggered at the community level with the support of community and religious leaders. The role of local media, such as local radio, television, and newspaper should be promoted.

Recommendation 17: Provide clear information about options to prepare, support the on-going efforts and plans of the city government, and enhance the confidence of the people that such actions are "doable".

The acknowledgement of existing risk and necessary preparedness also has to be followed up with information about "doable" options so that people prepare themselves and support the preparedness efforts conducted by the city government. Socialization of the existing facilities provided by the city government is also necessary to bridge the existing knowledge gap and to inform the people that the city government is also supporting them. Lack of supporting facilities and

infrastructures to foster response capability may also lead to the people´s perceived lack of capability to conduct evacuation. It is very important to inform the people on the various on-going efforts undertaken by the city in order to improve people´s response capability.

Recommendation 18: Recognize and address the existing daily concerns and risks (other than tsunami risk).

Although the people are aware of tsunamis, this concern has to compete with their other daily pressures. Concern about livelihoods and income security was perceived by people, particularly the lower income classes, as a real daily issue they need to address first before discussing much about tsunami preparedness. Embedding the issue of tsunamis in the people´s risk landscape is not an easy task. Thus, the communication of existing tsunami risk should be conducted continuously and be linked with their daily activities. For example, raising awareness of where the safe places are from their home, workplaces, or school, the development of a family emergency plan in case of strong earthquakes and potential tsunamis, are some examples that can be linked with people´s daily activities. Moreover, different preparedness options may be needed for different social groups the same as incentive mechanisms that can partly compensate for the costs emerging from preparedness activities for the people at lower socio-economic levels. Involvement of people in the planning process (next recommendation 6) would also give them a chance to address their concerns and feel acknowledged.

Recommendation 19: Involve the people in the planning process to synergize community-based with government efforts and provide a forum to address people´s concerns.

At the moment, efforts are also occurring both at the planning and community level. Any conflicting arrangements at both levels may also cause ineffectiveness during the evacuation planning and conduction. Thus, participation of the community in the planning processes is crucial. It was proven in the case study of Padang that a community with high awareness would also be likely to cooperate and would even be willing to engage in community-level efforts.

6.2.6 Linking Assessment with Urban Planning Decision-Making

In the previous Sub-chapter 2.3, the view of risk assessment within the urban spatial planning perspective was discussed. The assessment and planning scheme of Greiving and Fleischhauer (Figure 2-4) is used to reflect and show the position of the vulnerability and risk assessment in this study within the planning process. The incorporation of risk management in urban spatial planning consists of risk analysis, risk assessment, and planning and implementation of mitigation measures, to be accompanied by emergency response and planning.

In order to evaluate urban development and land-use plan, various aspects listed have to be considered based on assessment of people´s response capability as well as issues of perception. The following questionnaire (Figure 6-3) summarizes the main aspects to be incorporated in the overall urban planning and considerations for decision-making in urban development from the perspective of early warning response capability.

In the context of urban evacuation, the focus is on finding the balance between long-term exposure reduction in dangerous areas and additional protection measures for mass evacuation. The questionnaire contains various aspects for assessing the need of reducing exposure to trade off providing protection measures of additional infrastructure and facilities for evacuation, and vice versa. Both are relevant for urban planning, since both are related with the allocation of space and infrastructure for certain uses. An optimum and acceptable level of the required exposure reduction level and protection measures has to be achieved. Any future urban development plan has to consider the capacity of existing routes and shelters for evacuation of the population and find (or negotiate) the most appropriate and optimal vulnerability reduction levels by combining the capacity of emergency response with the long-term regulation of growth and land use in the dangerous areas. Within this planning process, the current response capability of the people measured in terms of dynamic exposure, access to early warning, response to the warning, and existing evacuation infrastructure and facilities towards the existing tsunami hazard should be assessed.

Furthermore, any measures would require that people have a certain level of awareness that they would be willing to support the measures. This links with the assessment of cognitive factors and variation among social groups with regard to the proposed measures. One important role of urban planning is also to involve the community in the planning process, especially because the cooperativeness of the people has been identified as one main challenge in vulnerability reduction. Urban planning agencies need to work together with the emergency planning agency to raise the risk awareness of the people and encourage their positive participation. There already are existing efforts at the community level which are successful and can be linked with the efforts of the city government. Mainstreaming disaster risk reduction especially for low-frequency extreme hazards in urban planning may be challenging, especially when people do not perceive the related measures as beneficial for them. Lack of awareness and low risk perception, especially of hazard events which have never been experienced before, can constitute additional hindrances to the existing socio-economic constraints. Thus, mitigation measures should be accompanied by sufficient communication strategies and community involvement in the planning.

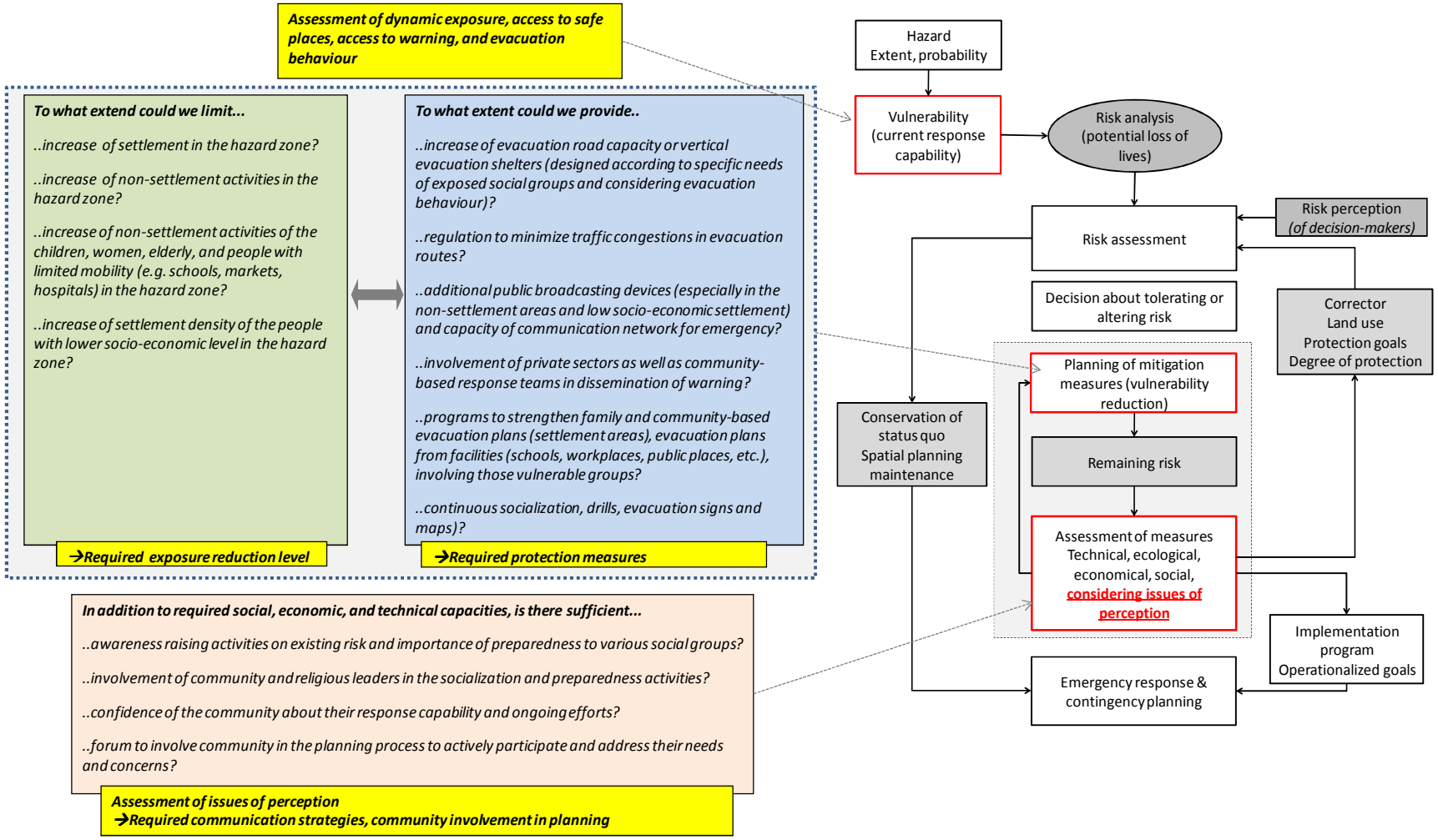
With regard to the planning instruments in the context of Padang, or generally in Indonesia, the considerations here cannot only be addressed in the long-term spatial plan (RTRW), but have to be further integrated in and operationalized through a detailed plan (RDTR); zoning and other district regulations (PERDA), e.g. restrictions of building permits of critical facilities and settlement in the hazard zones; allocation of space specifically for vertical evacuation shelters; standard criteria for installing public broadcasting devices in the non-settlement areas; etc.

In addition, close cooperation and communication among urban and emergency planning actors in the assessment and later on implementation and monitoring is required. Considering the role of various agencies as described in the Sub-chapter 5.6, each agency makes specific contributions in various aspects. The City Development Planning agency (BAPPEDA) plays here a coordinating role since it has the best overview of the overall planning objectives and development plans and will be able to assess and allocate the extent of spatial and infrastructure capacity and availability for

various land uses and protection measures in the long-term. The Spatial Planning and Urban Design body (TRTB) also plays a major role in assessing the feasibility of spatial and infrastructure allocation of any measures in the short-and medium-term as well as in fulfilling the need to give feedback on the agency´s capacity to implement and monitor those measures, while the Settlement, Infrastructure and Regional body (Kimpraswil/PU) provides the corresponding technical requirements. On the other hand, the local disaster management body (BPBD) should provide feedback on their capacity in providing early warning and evacuation facilities, community preparedness, as well as emergency response when dealing with the remaining risk.

One main challenge is that provision of infrastructures and exposure reduction, often also requires a high investment and may have an impact on other (e.g. business or real estate) investments. This creates problematic planning and decision-making, especially in cities with limited resources like Padang. In this case, one needs to formulate clear protection goals and limits to risk, involving the temporal aspect of planning specific mitigation measures. One of the advanced methodologies is for instance the approach of the Alpine avalanche safety services in Switzerland (Rheinberger, Bründl and Rhyner 2009). There, baseline avalanche risk or likelihood of various hazard characteristics and impacts were estimated, the impact of various mitigation strategies and their cost-benefit are analysed. Based on this, acceptable costs for different risk categories (individual and collective, level of exposure voluntariness) were derived as an orientation for planning most “appropriate” disaster mitigation solution. However, this may work better in the context of well-known hazard, where data and experiences with the natural hazard events exist as in the case of Alpine avalanche. In the context of unknown hazards (such as major tsunamis), there will be, if any, very limited information basis on the likelihood of hazard and impact that require consensus in building most plausible scenario to plan for and analysing the costs and benefit of various options. In this case, qualitative judgement of local experts and scenario based approach may be needed. Another important consideration is that the exact point in time of the occurrence of major tsunamis cannot be predicted and thus, tsunami risk reduction has to be integrated continuously in the urban planning scheme taking into account such uncertainty. Thereby, “no regret” measures or combined measures with other development objectives such as slum upgrading, suburb development (in the safe areas), improvement of transportation network, etc., should be preferred as much as possible.

Figure 6-3 Questionnaire of early warning requirements in urban planning decision-making



Source: Own figure (left), Greiving and Fleischhauer 2006 modified (right)

6.3 Evaluation of the Assessment Framework and Methods

6.3.1 Reflection on the Conceptual Framework

The development of the conceptual framework and the definition of various components of vulnerability and early warning response capability have been in themselves valuable products of this study. The literature review on the existing concepts of vulnerability as well as on early warning and evacuation provided a good starting point to develop the assessment framework. The existing concept of vulnerability has been striving to develop a holistic framework and a set of criteria that can be measured and is useful for monitoring risk and assessing disaster management measures. This study attempted to contribute to the latter objective by developing an assessment framework that links the vulnerability concept with the specific disaster management intervention of the tsunami early warning system. The BBC framework has been useful for the development of the conceptual framework especially in the way it emphasizes the feedback loop of vulnerability, which means that vulnerability can be identified and reduced accordingly prior to disaster occurrence through various interventions related to the social, economic, and environmental dimensions. There have been several modifications incorporated in the conceptual framework of this study (please refer to Chapter 2), particularly with regard to the vulnerability components and the incorporation of issues of perception.

Vulnerability in this study was viewed from the lens of tsunami early warning intervention at the local level. In this sense, the exposure, susceptibility, and coping capacity components of vulnerability were defined following the processes attributed to people´s response to the early warning at the local level and aimed firstly at focussing on saving lives. Thus, exposure, susceptibility, and coping capacity of the people were not measured per se, but are integrative parts of the process of responding to the early warning. The case study has demonstrated how these components were translated to describe the spatial and temporal distribution of various social groups in the potentially affected areas with differential evacuation capabilities (dynamic exposure), whether they have the possibility to evacuate themselves from the exposed area considering the available road infrastructure and evacuation facilities (access to safe places), whether they can be reached by the warning media available (access to warning), and whether they would be likely to conduct appropriate action with a short lead time (evacuation behaviour). These components also show how different factors (socio-demographic characteristics, urban land use settings, existing facilities, knowledge and perception) interact with each other and cause bottlenecks within the early warning chain and evacuation conduct. They identify what kind of and where measures are needed to increase people´s capabilities and reduce potential losses of lives. The issues of perception also play a significant role. They are decisive for the effectiveness of on-going and future measures to reduce vulnerability and risk, and are therefore part of the capacity to change to be considered in the assessment of vulnerability and the development of vulnerability reduction. The assessment framework also provided an added-value instrumental to identify specific needs related to spatial and infrastructure requirements, while monitoring various aspects of dissemination and

communication, response capability, as well as governance and institutional arrangements as listed in the early warning check-list of UN/ISDR.

The conceptual framework has addressed the main concern of the vulnerability concept, namely to mainstream vulnerability reduction in the disaster risk reduction agenda– instead of focusing solely on hazard – by understanding the characteristics of people´s exposure to the hazard, considering their susceptibility, and increasing their coping capacity to deal with the potential hazard event. However, due to its strong linkage with a specific intervention (early warning and people´s response capability) it is to be noted that the assessment framework only covers a part and not the whole vulnerability of people affected by tsunamis. In the context of the tsunami early warning system, the focus was only on saving lives and thus, the results give no hint of people´s vulnerability with regard to livelihoods or the access of various social groups to livelihood assets in case of tsunami damages. The novelty of the approach is that the information generated can be interpreted and used to monitor the effectiveness of the early warning (in meeting its goal of reducing losses of lives) at the local level and to indicate where specific measures are needed in particular areas and by particular social groups within the scope of this intervention. Furthermore, the study also recognizes the superficial take up of the concept of vulnerability in the conceptual framework. The framework can only provide a picture of people´s response capability as an "outcome" of vulnerability, but does not analyse in depth the causal processes or underlying root causes (See Wisner et al. 2004) e.g. underlying reasons such as lack of access to livelihood assets or marginalization that lead to high exposure and lack of response capability, or the constellation of the current people´s risk landscape. Wisner et al. (2004) already argued that notions such as disaster management cycle are rather technical constructs imposed on different cultural, economic, political and gender realities that fail to comprehend the reality of disaster and engage the people concerned. Nevertheless, the study also shows that this construct can be assessed and linked with the vulnerability concept to some extent, but still maintaining its practical use for the planners. Also, the cultural and psychological factors influencing risk and vulnerability reduction (See Cannon 2008) are taken into account in order to embed the culture of preparedness in the existing social and cultural settings. Thereby, the linkage of vulnerability reduction and long-term development is demonstrated in such a way that the need to ensure sufficient early warning response capability of the people is considered as part of the long-term urban planning and is being continuously incorporated in land use and infrastructure planning.

6.3.2 Validity of the Results

Two types of information were generated from the analysis, namely thematic maps on spatial identification of problematic areas and a qualitative description of the existing variance by social groups and their linkage with the existing urban settings. Both serve as information basis to evaluate the current or future development plan from the perspective of an early warning system. The results were not presented in the classical form of indices or composite vulnerability indicators, but rather as thematic maps and quantitative or qualitative descriptions. This reflects the intention to give an overall, not simplified, picture and to derive a better understanding of the existing gaps.

At this stage, the results could only enable qualitative interpretations about potential evacuation bottlenecks which may occur at various stages of the early warning and evacuation process. Apart from deriving considerations to be incorporated in planning and decision-making, such information can potentially be used to derive various plausible scenarios for simulations using modelling tools. However, the quantification of the number of people who could not evacuate on time due to insufficient lack of access to safe places, lack of access to warning and inappropriate evacuation behaviour could only be estimated using such hypothetical assumptions. Since there was no data of real events capturing detailed information about population dynamics as well as early warning response in major tsunamis in the area or other areas with similar context, an overall calibration of the analysis framework and analysis results was not possible. Thus, many sources of uncertainty remain in estimating potential losses of lives based on the analysis results generated from each component examined.

Dynamic exposure analysis was based on linear distribution of population groups in various buildings uses and the average occupancy rate of different buildings proportional to their size. As mentioned in the empirical Chapter 5.1, the estimation of the total population in the study area using the analytical method underestimated the actual total population number and additional surveys to validate the dynamic distribution of various population groups were not feasible within the scope of the study. Some issues that may be further incorporated in the analysis are for instance the distribution of population groups with activities outside buildings including the ones travelling on the streets and in open spaces, as well as the incorporation of commuters or tourists coming from outside the city who conduct activities in the exposed areas. The uncertainty in the dynamic exposure is also transferred to other components, since the analysis of access to safe places, access to warning, and evacuation behaviour components is linked with the results of dynamic exposure.

Access to safe places was based on the assumption that there were no damages in the street network, no blockage of the streets due to heavy traffic during the earthquakes, and optimal utilization of the evacuation route (ideal evacuation behaviour). With regard to access to warning, spatial coverage of different public broadcasting devices was assumed. However, further technical requirements need to be incorporated in a future assessment. For instance, depending on the location and technical specifications of the devices, coverage of sirens and mosque loudspeakers may differ due to e.g. the position of the device, noise level and location of tall buildings in the surroundings, et al. With regard to the community-based response team, the capacity of warning dissemination in the real emergency event is also to be evaluated. Moreover, the more data are collected on information dissemination in the earthquake events in the future, the better the robustness and effectiveness of private and public media devices can be evaluated. Longitudinal studies of the actual conditions and behaviour of the people in emergency situations is required to validate the existing findings and gain knowledge of the unidentified factors that may influence access to safe places, access to warning, and evacuation behaviour.

The issues of perception were investigated, providing a better understanding of people´s intentions with regard to evacuation and their support in on-going efforts. But the factors identified have not

been able to explain all the variations in the intentions to evacuate nor the intention to support the improvement of evacuation efforts. Furthermore, it is to be noted that the intention is also only a predictive hint for behaviour, but there is still uncertainty on whether the actual behaviour would reflect the intention in its entirety. Concerning the evacuation decision, every emergency situation may have different characteristics which may trigger different responses. Drabek (1986) pointed out that actions in disaster events may be governed by emergent norms. On the other hand, the intention to undertake a more proactive action like supporting the improvement of evacuation infrastructures and facilities does not mean that the people would react positively to on-going efforts and participate in the actual activities. Influencing factors need to be explored further, like incorporating the issue of cost (in terms of time and efforts needed) of the action, various other concerns (risk landscape) of the people, and the impact of different risk communication or participation approaches.

6.3.3 Evaluation of Various Types of Data

The operationalization of the conceptual framework was only possible using a mixed approach where various types of information are complementing each other to complete the picture of the level of people´s vulnerability and response capability. The study has demonstrated the possibility of combining various types of data and data analyses, using both quantitative and qualitative approaches. Some challenges in the data collection or other issues related for example with the spatial data availability and the design of household surveys have been discussed in the methodological Chapter 4. The following table shows the evaluation of various data types used, based on the experience gathered in the case study area.

	Type of extracted information	Accessibility	Accuracy / reliability	Availability/ feasibility of periodical collection	Remark for future application
Local building inventory data	Building use, building classification based on planning norms	Not easily accessible for external (data on building classification was not obtained and used in this study), no centralized and complete database was available	Varying, depending on the technical capacity of the government agencies	Supposed to be updated in every planning period	Such data may be potentially useful since it is regularly used for spatial planning by the city planning agency
Remote sensing data	Building semantic classifications representing socio-economic characteristics of the people at the building level	Not always available at the local level; in this study, it was made available by the project otherwise it might be expensive	Extract well and accurately the building's physical morphology information	Can be made available periodically, however, may need sufficient financial and technical capacity	Combination with building and households survey on site is needed to validate the building use and socio-economic characteristics
Participatory mapping	Socio-economic characteristics of the people at the city clusters, identification of public buildings	Good if local experts are available and are willing to give information	Only qualitative judgement possible, imprecise, depending on level of knowledge of the expert	Can be made available periodically with a low budget	This approach would be rather helpful at a smaller scale, i.e. examination in several locations or sub-districts, rather than city-wide
Building/facility survey	Building use, occupancy rate of various building uses, further information about and tsunamis preparedness	Good if survey permit is available	Good, however building variation is possible	At the moment only related with projects, no funding for periodical surveys	For public facilities in the exposed areas, a building census and analysis at the individual building scale would be

					recommended
Household survey	Various kinds of information, from activity diary, socio-economic characteristics, tsunami preparedness, up to perception issues	Easy, but reluctance of a few households to participate still possible, no answer for sensitive questions possible, e.g. income	Accuracy of subjective variables (perception) is still an open question, limited representative-ness of the samples	At the moment only related with projects, no funding for periodical surveys	Longitudinal data collection necessary, representativeness should be improved in the design of the survey in the future corresponding to specific themes
Local statistic data	General socio-economic characteristics	Easy, only population census data is quite costly	Good and representative	Data collected periodically, however, e.g. census data only collected every 10 years	
Non-structured interviews	Qualitative information about experience, tsunami preparedness, required measures and challenges, perception issues	Varying, depending on the existing contacts and approach used	Information obtained was rather general and imprecise, limited sample, adequate follow-up discussions were not possible	At the moment only related with projects	Non-structured interviews can be linked with follow-up semi-structured interviews and focus group discussions if time and resources allow
Group discussions	Qualitative information about daily activity, experience, tsunami preparedness	Need longer time to build trust and rapport with the people in order to extract specific information	Very limited, due to limited field stay	At the moment only related with projects	This can be linked as follow-up of other methods e.g. non-structured interviews (see above).

6.3.4 Potential Advancement of the Methods

As mentioned before, the methods developed were only a first attempt to capture an integrative picture of people´s early warning response capability. Further advancement of the methods is still required.

From the social perspective, further (and longitudinal) study on people´s behaviour in emergency situations, people´s perception of risk, early warning and corresponding risk reduction measures is still required to provide a better understanding of the conditions and influencing factors of early warning response capability. Some specific issues to be incorporated in various components have been mentioned in the previous Section 6.3.2. Also, further detailed institutional analysis is still needed of the planning procedures and regulations, network analyses of various planning actors, and how they deal with planning related with emergency infrastructure and facilities. Better knowledge of the institutional setting of urban and emergency planning will contribute to the design and format of the assessment framework for an effective utilization by the target users. Additionally, such an assessment may also be used for assessing future bottlenecks that may happen as consequences of future development. Modelling or projection of for instance future demographic changes could be incorporated, but also urban development pathway scenarios development with the local actors would be useful to build awareness and assess qualitatively the possible consequences of various planning interventions in this scope.

From the modelling and engineering perspective, the qualitative information about evacuation behaviour may be extended and specified to be suitable for input parameters in evacuation modelling using various scenarios. For instance, the development of latent variables for evacuation behaviour for evacuation modelling using MATSim (Koot, Kowald and Axhausen 2012) and the extension of the MATSim code, e.g. for re-planning routes during travel (Dobler et al. 2012) – in our case evacuation – has been carried out. Such modelling tools may open an opportunity to estimate street congestions and the evacuation time needed according to various evacuation behaviours. Moreover, one may think of further exploration of dynamic exposure and the impact of further urban development of the response capability and evacuation bottlenecks. Presently, there is the possibility of combining land-use modelling with traffic modelling to examine the impacts of policies on the urban development, e.g. coupling of land use modelling of UrbanSim with traffic modelling of MATSim (MATSim4UrbanSim). However, this currently only addresses the issue of traffic management with limited MATSim functions so that evacuation simulation is not yet possible (Nicolai 2012; Nicolai, personal communication September 2012). It needs to be further explored how qualitative information on people´s behaviour may be utilized more using such tools, thus enabling to support the urban planning decision-making process in a meaningful way.

6.3.5 Transferability

The applicability of the research conceptual framework and analysis methodology in the context of Padang city is affirmed by this study. The conceptual framework and the main factors are applicable to and represent the conditions of medium sized cities in developing countries where a tsunami early warning system is in place. Nevertheless, modifications of some variables according to the

development stage of the early warning and the number of previous tsunami early warning experiences may be needed. For instance, in the more advanced stages of the tsunami early warning system, the component of access to safe places would include assessment of existing official evacuation routes and shelters. Likewise, the component of access to warning would be able to assess more specifically the effectiveness of all the warning dissemination media utilized in previous experiences. On the other hand, in the early stages of the tsunami early warning system, more basic knowledge and perception of the people, e.g. whether they are aware of tsunamis and tsunami early warning at all, may play a more significant role in the assessment of evacuation behaviour and issues of perception. Additionally, differences may also occur if the lead early warning time is longer. In the case of Padang, a very short lead time is assumed (estimated tsunami arrival time of about 20-30 minutes after a strong earthquake occurrence); thus, quick access to vertical evacuation shelters, the effectiveness of tsunami warning dissemination, and appropriate evacuation behaviour considering the spatial distribution of family members is emphasized. The main focus is also to save lives and not so much to secure properties due to the very short available time. This may look different in case of longer warning times (e.g. 1-2 hours).

Furthermore, the methods used can also vary according to the availability of data and resources in other study areas. A mixed method with more qualitative data may be feasible in a place where limited data and resources are available.

7 Conclusion

This study linked and defined the vulnerability concept within the process of people responding to the early warning in potential tsunami events. It sought specific conditions that shape the vulnerability of the people related with their early warning response capability. In this regard, a conceptual framework based on literature study has been developed and contextualized for the case study of Padang. As described empirically through the case study, the study outlined those conditions as the spatial and temporal distribution of various social groups in the potentially affected areas with differential physical capacity and mobility (dynamic exposure); their possibility to timely evacuate themselves from the exposed area considering the available road infrastructure and evacuation facilities (access to safe places); the potential of reaching these people through the available warning media (access to warning); and their strategies to conduct appropriate action in a short lead time (evacuation behaviour). These components were all linked with various (potential) interventions to reduce vulnerability prior to the hazard events.

Concerning various interventions, the issues of perception were also proven to contribute to the success of vulnerability reduction and are a crucial component to be integrated in the vulnerability assessment. The case of Padang, in especial, showed the role of cognitive factors in the process of building compliance with the early warning measures and the positive involvement of people in the on-going evacuation planning efforts. Also, the linkages between spatial and social bottlenecks are made visible in the case study, i.e. the spatial distribution of the people and various social groups relate to their differentiated access to the protection measures (safe places and early warning). On the other hand, the social configuration of people (including perception and behaviour) determines how they accept, comply with, and participate in the protective action, as well as how they utilize the available technical and structural measures.

The significant role of urban planning in altering the response capability through exposure reduction and providing spatial and infrastructure requirements for appropriate early warning response is also underlined in the case of Padang. It highlighted that the establishment of an early warning system should involve not only actors in preparedness and emergency planning, but also the relevant urban planning actors, in order to ensure the sustainability of the early warning and incorporate its needs in the long-term. Response capability to early warning requires both emergency preparedness plans (evacuation plan, drill, etc.) as well as the incorporation of spatial and infrastructure needs in the long-term and continuous planning.

The assessment serves in the first place as a tool to monitor the progress of the tsunami early warning system in ensuring response capability of the people at the local level. Furthermore, the considerations and criteria derived from the assessment of various components contributed to develop practical recommendations to be incorporated in the overall urban planning from the perspective of early warning and indicate points of intervention where stronger cooperation of the urban planning is needed. By doing so, the assessment tool supports the increasing role of urban planning and its synergy with emergency planning in disaster preparedness.

The study also demonstrated the possibility to operationalize the conceptual framework and usefulness of the combination of quantitative and qualitative approaches to measure these conditions and factors. Measuring and understanding how different spatial and social, objective and subjective, technical and non-technical factors interact and link with each other, was not always quantitatively feasible. The study explored the possibility of linking information on “soft” factors like variation among social groups and issues of perception, with spatial data and modelling approaches. In using a mixed approach, a more complete picture could be generated using a combination of various available data sources and types of information that can be easily adjusted to the local context and resources.

The limitations of this approach should be acknowledged, which are also partly related to the nature of the hazard, i.e., extreme and of low-frequency, and the early stage of the early warning development, so that there were no data available to validate precisely the various selected variables and results. Hence, uncertainty remains a challenge. Longitudinal studies are still needed, also making use of experiences with smaller earthquakes not ensued by potential tsunamis and in events where there is no threat, in order to identify temporal changes and other influencing factors that have not been captured in this study. Advancement of the approach is still possible and the potential for using various methods was addressed.

Finally, this study contributes to recent research activities on early warning and vulnerability assessment methods in i) providing a more in-depth picture of the response capability elements of early warning and methods on how to monitor them; as well as in ii) enhancing the link of vulnerability assessment with early warning and related risk reduction measures (e.g. with urban planning) and showcase how such information can be utilized to derive practical recommendations beyond the specific case of the city of Padang.

References

Adger, W. (2006). Vulnerability. *Global Environmental Change, 16*, 268–281.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*, 179–211.

Albers, G., & Wékel, J. (2011). *Stadtplanung: Eine illustrierte Einführung* (2nd edn). Darmstadt: Wiss. Buchges.

Alexander Kesper (2007). *Warning Dissemination Technologies for Tsunami Early Warning in Local Communities*. GTZ Working Paper No. 12. German–Indonesian Cooperation for Tsunami Early Warning System (GITEWS) .

Alexander, D. (2009). Principles of Emergency Planning: Standardisation, Integration and Sustainability. In Urbano Fra Paleo (Ed.) (Vol. 58, pp. 162–174, NATO Science Series E: Human and Societal Dynamics): IOS Press.

Ambikapathy, A., Catherine, J., Gahalaut, V., Narsaiah, M., Bansal, A., & Mahesh, P. (2010). The 2007 Bengkulu earthquake, its rupture model and implications for seismic hazard. *Journal of Earth System Science*, doi: 10.1007/s12040-010-0037-2.

Anderson, J. (1971). Space – Time Budgets and Activity Studies in Urban Geography and Planning. *Environment and Planning, 3*(4), 353–368.

Arakida, M. (2006). Measuring vulnerability: The ADRC perspective for the theoretical basis and principles of indicator development: 15. In J. Birkmann (Ed.), *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies* : United Nations University Press.

Arentze, T., Timmermanns, H., Hofman, F., & Kalfs, N. (2000). Data Needs, Data Collection, and Data Quality Requirements of Activity-Based Transport Demand Models. In *International Conference on Transport Survey Quality and Innovation, May 24-30, 1997* (pp. II-J/1-II-J/35). Grainau, Germany: Transportation Research E-Circular.

Bahlburg, C. H. (2003). Klimaänderungen und die Aufgaben der räumlichen Planung: Welchen Beitrag kann die räumliche Planung zu einem raumorientierten Risikomanagement in Technik und Umwelt, insbesondere in Hinblick auf eine Klimaänderung leisten? In H. Karl & J. Pohl (Eds.), *Raumorientiertes Risikomanagement in Technik und Umwelt*: *Katastrophenvorsorge durch Raumplanung* (pp. 132–153, Forschungs- und Sitzungsberichte Band 220). Hannover: ARL.

Baker, E. J. (1991). Hurricane Evacuation Behavior. *International Journal of Mass Emergencies and Disasters, 9*(2), 287–310.

Basher, R. (2006). Global early warning systems for natural hazards: systematic and people-centred. *Philosophical Transactions of the Royal Society A, 364*, 2167–2182.

Bateman, J. M., & Edwards, B. (2002). Gender and Evacuation: A Closer Look at Why Women Are More Likely to Evacuate for Hurricanes. *Natural Hazards Review*, doi: 10.1061/(ASCE)1527-6988(2002)3:3(107).

Berke, P., & Smith, G. (2009). Hazard Mitigation, Planning, and Disaster Resiliency: Challenges and Strategic Coices for the 21st Century. In Urbano Fra Paleo (Ed.) (Vol. 58, pp. 1–20, NATO Science Series E: Human and Societal Dynamics): IOS Press.

Bernard, H. R. (2006). *Research Methods In Anthropology: Qualitative And Quantitative Approaches* (4th edn): Rowman Altamira.

Bhatti, A. (2001). Risk Perception, Culture and Communication: A South Asian Experience. In *Fifth Conference of European Sociological Association, Helsinki, Finnland* .

Birkmann, J. (Ed.) (2006). *Measuring Vulnerability to Hazards of Natural Origin – Towards Disaster-Resilient Societies*. Tokyo: UNU press.

Birkmann, J. (2008). Globaler Umweltwandel, Naturgefahren, Vulnerabilität und Katastrophenresilienz. *Raumforschung und Raumordnung*, doi: 10.1007/BF03184043.

Birkmann, J., Chang Seng, D., & Setiadi, N. (2012). Enhancing early warning in the light of migration and environmental shocks. *Environmental Science & Policy*, doi: 10.1016/j.envsci.2012.04.002.

Birkmann, J., Fernando, N., Hettige, S., Amarasinghe, S., Jayasingam, T., Paranagama, D., et al. (2007). *Rapid Vulnerability Assessment in Sri Lanka. Post-Tsunami Study of Two Cities: Galle and Batticaloa* (7/2007).

Birkmann, J., Setiadi, N., & Gebert, N. (2008). Socio-economic Vulnerability Assessment at the Local Level in Context of Tsunami Early Warning and Evacuation Planning in the City of Padang, West Sumatra. In ICTW (Ed.), *International Conference on Tsunami Warning (ICTW), Bali, Indonesia, November 12-14, 2008* .

Birkmann, J., Welle, T., Krause, D., Wolfertz, J., Suarez, D.-C., & Setiadi, N. (2011). WorldRiskIndex:Concepts and Results. In *WorldRiskReport 2011*: *Focus: Governance and Civil Society* (pp. 13–42). Berlin: Bündnis Entwicklung Hilft.

Blaikie, P., Cannon, T., Davis, I., & Wisner, B. (1994). *At Risk: Natural Hazards, People's Vulnerability and Disasters*. New York: Routledge.

Bogardi, J., & Birkmann, J. (2004). Vulnerability Assessment: The First Step Towards Sustainable Risk Reduction. In D. Malzahn & T. Plapp (Eds.), *Disasters and Society - From Hazard Assessment to Risk Reduction* (pp. 75–82). Berlin.

Bogardi, J., Birkmann, J., Gebert, N., & Setiadi, N. (2009). Preparing for Low-Frequency, Extreme Natural Hazards: Contributing to Human Security by Enhancing 'Freedom from Hazard Impact'. In H. Brauch, Ú. Spring, J. Grin, C. Mesjasz, P. Kameri-Mbote, N. Behera, et al. (Eds.), *Facing Global Environmental Change* (Vol. 4, pp. 283–294, Hexagon Series on Human and Environmental Security and Peace): Springer Berlin Heidelberg.

Bohle, H.-G. (2001). Vulnerability and Criticality. *Newsletter of the International Human Dimensions Programme on Global Environmental Change*(2/2001).

Bollin, C., & Hidajat, R. (2006). Community-based risk index: Pilot implementation in Indonesia: 14. In J. Birkmann (Ed.), *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies* : United Nations University Press.

Borrero, J., Sieh, K., Chlieh, M., & Synolakis, C. (Eds.) (2006) (Proceedings of the National Academy of Sciencesof the United States of America).

Britton, N. R., & Lindsay, J. (1995). Integrating City Planning and Emergency Preparedness: Some of the Reasons Why. *International Journal of Mass Emergencies and Disasters, 13*(1), 93–106.

Buckle, P. (1998). Re-defining Community and Vulnerability in the Context of Emergency Management. *Australian Journal of Emergency Management, Summer 1998/1999*, 21–26.

Bühner, M. (2006). *Einführung in die Test- und Fragebogenkonstruktion* (2nd edn): Pearson Studium.

Bundesministerium für Bildung und Forschung (BMBF) (2011). *Deutschland übergibt Tsunami-Frühwarnsystem an Indonesien*. Pressemitteilung 040/2011 .

Burby, R. J. (2006). Hurricane Katrina and the Paradoxes of Government Disaster Policy: Bringing About Wise Governmental Decisions for Hazardous Areas. *The ANNALS of the American Academy of Political and Social Science*, doi: 10.1177/0002716205284676.

Burhani, R. BNPB desain program pembangunan hunian sementara tsunami. *Antara news, June 26, 2012.* http://www.antaranews.com/berita/318315/bnpb-desain-program-pembangunan-hunian-sementara-tsunami. Accessed 29 July 2013.

Burton, I., Kates, R. W., & White, G. F. (1993). *The environment as hazard* (2nd edn). New York: Guilford Press.

Cannon, T. (2008). Vulnerability, "innocent" disasters and the imperative of cultural understanding. *Disaster Prevention and Management*, doi: 10.1108/09653560810887275.

Cardona, O. (1999). Environmental Management and Disaster Prevention: Two Related Topics: A Holistic Risk Assessment and Management Approach: Natural Disaster Management. In J. Ingleton (Ed.). London: International Decade for Natural Disaster Reduction (IDNDR), Tudor Rose.

Cardona, O. (2001). Estimación Holística del Riesgo Sísmico Utilizando Sistemas Dinámicos Complejos. http://www.desenredando.org/public/varios/2001/ehrisusd/index.html.

Cardona, O. D. (2004). The Need for Rethinking the Concepts of Vulnerability and Risk from a Holistic Perspective: A Necessary Review and Critism for Effective Risk Management. In G. Bankoff, G.

Frerks, & T. Hilhorst (Eds.), *Mapping vulnerability*: *Disasters, development, and people* (pp. 37–51). London, Sterling, VA: Earthscan Publications.

Cardona, O. D. (2006). A system of indicators for disaster risk management in the Americas: 10. In J. Birkmann (Ed.), *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies* : United Nations University Press.

Chang Seng, D. (2010). *Disaster Risk Preparedness: The Role of Risk Governance, Multi-Institutional Arrangements and Polycentric Frameworks for a Resilient Tsunami Early Warning System in Indonesia*. Dissertation. Rheinischen Friedrich-Wilhelms-Universität Bonn, Bonn.

Chang Seng, D. (2012). Improving the Governance Context and Framework Conditions of Natural Hazard Early Warning Systems. *Journal of Integrated Disaster Risk Management*, doi: 10.5595/idrim.2012.0020.

Chapin, F. (1974). *Human Activity Patterns in the City: Things People Do in Time and in Space*. New York: John Wiley and Sons.

Colombijn, F. (1994). *Patches of Padang: The History of an Indonesian Town in the Twentieth Century and the Use of Urban Space* (CNWS publications): Research School CNWS, Leiden University.

Cross, J. (2001). Megacities and small towns: different perspectives on hazard vulnerability. *Global Environmental Change Part B: Environmental Hazards*, doi: 10.1016/S1464-2867(01)00020-1.

Cutter, S. L. (1996). Vulnerability to environmental hazards. *Progress in Human Geography*, doi: 10.1177/030913259602000407.

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social Vulnerability to Environmental Hazards. *Social Science Quarterly, 84*(2), 242–261.

Cutter, S. L., Emrich, C. T., Webb, J. J., & Morath, D. (2009). *Social Vulnerability to Climate Variability Hazards: A Review of the Literature: Final Report to Oxfam America*. Columbia.

Cutter, S. L., & Finch, C. (2008). Temporal and spatial changes in social vulnerability to natural hazards. *PNAS, 105*(7), 2301–2306.

Deike, P. (2001). *Gender and Transport in Less Developed Countries: A Background Paper in Preparation for CSD-9*. Background Paper for the Expert Workshop "Gender Perspectives for Earth Summit 2002: Energy, Transport, Information for Decision-Making", Berlin, Germany, 10 - 12 January 2001 .

Di Mauro, M., Megawati, K., Cedillos, V., & Tucker, B. (2013). Tsunami risk reduction for densely populated Southeast Asian cities: analysis of vehicular and pedestrian evacuation for the city of Padang, Indonesia, and assessment of interventions. *Natural Hazards*, doi: 10.1007/s11069-013-0632-z.

Diekmann, A. (2006). *Empirische Sozialforschung. Grundlagen, Methoden und Anwendungen* (16th edn). Reinbeck bei Hamburg: Rowohlt Taschenbuchverlag.

Dobler, C., Kowald, M., Rieser-Schüssler, N., & Axhausen, K. W. (2012). Within-Day Replanning of Exceptional Events. *Transportation Research Record: Journal of the Transportation Research Board*, doi: 10.3141/2302-15.

Drabek, T. E. (1986). *Human System Responses to Disaster: An Inventory of Sociological Findings* (Springer Series on Environmental Management): Springer.

Fekete, A. (2009). *Assessment of Social Vulnerability for River-Floods in Germany*. Dissertation. Rheinischen Friedrichs-Wilhelm-Universität zu Bonn, Bonn.

Fernando, N. (2010). *Forced Relocation after Indian Ocean Tsunami, 2004 - Case Study of Vulnerable Populations in Three Relocation Settlements in Galle, Sri Lanka*. Dissertation. Rheinischen Friedrich-Wilhelms-Universität Bonn, Bonn.

Field, C., Barros, V., Stocker, T., Qin, D., Dokken, D., Ebi, K., et al. (Eds.) (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Cambridge, UK,and New York, NY, USA: Cambridge University Press.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: an introduction to theory and research* (Addison-Wesley series in social psychology): Addison-Wesley Pub. Co.

Fleischhauer, M. (2004). Indikatoren räumlicher Risiken als Grundlage raumrelevanter Entscheidungen. In Deutsches Komitee Katastrophenvorsorge (Ed.), *5. Forum Katastrophenvorsorge Naturgefahren im Focus der Wissenschaft - Strategien der Sensibilisierung und räumlichen Vorsorge., Mainz, 14. Oktober 2004* (pp. 65–67, DDKV Publication Series, Vol. 31). Bonn: DKKV.

Fürst, D., & Scholles, F. (2008). *Handbuch Theorien und Methoden der Raum- und Umweltplanung* (3rd edn). Dortmund: Rohn.

Gallopin, G. (2003). *A Systems Approach to Sustainability and Sustainable Development*. Santiago, Chile: United Nations Publications.

Gallopin, G. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change, 16*, 293–303.

Gebert, N. (in preparation). *Risk Assessment for Enhancing the Effectiveness of Risk Management - Case study from the German-Indonesian Tsunami Early Warning System (GITEWS) Project*. Dissertation. Georg-August Universität Göttingen, Göttingen.

Gebert, N. (2011). *Risk and Vulnerability Assessment.* Contributions to LIPI / DLR / UNU-EHS Guideline for Tsunami Risk Assessment in Indonesia: scientific proposal for practitioner and end users. .

Geurs, K., & van Ritsema Eck, J. (2001). *Accessibility measures: review and applications. Evaluation of accessibility impacts of land-use transport scenarios, and related social and economic impacts*. RIVM Report 408505 006. Bilthoven, Netherlands.

Gläser, J., & Laudel, G. (2006). *Experteninterviews und qualitative Inhaltsanalyse* : VS Verlag.

Goseberg, N., & Schlurmann, T. (2008). Relevant Factors on the Extent of Inundation Based on Tsunami Scenarios for the City of Padang, West Sumatra. In ICTW (Ed.), *International Conference on Tsunami Warning (ICTW), Bali, Indonesia, November 12-14, 2008* .

Goseberg, N., Stahlmann, A., Schimmels, S., & Schlurmann, T. (2008). Highly-resolved numerical modeling of tsunami run-up and inundation scenarios in the city of Padang, West Sumatra. In *International Conference on Coastal Engineering, Hamburg, 31. August 2008* .

Gregg, C., Houghton, B., Paton, D., Johnston, D., Swanson, D., & Yanagi, B. (2007). Tsunami Warnings: Understanding in Hawai´i. *Natural Hazards*, doi: 10.1007/s11069-006-0005-y.

Greiving, S. (2002). *Räumliche Planung und Risiko* : Gerling-Akad.-Verlag.

Greiving, S., & Fleischhauer, M. (2006). Spatial planning response towards natural and technological hazards. In P. Schmidt-Thomé (Ed.), *Natural and Technological Hazards and Risks Affecting the Spatial Development of European Regions* (Special Paper 42, pp. 109–123). Espoo: Geological Survey of Finland.

Grothmann, T., & Patt, A. (2005). Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environmental Change*, doi: 10.1016/j.gloenvcha.2005.01.002.

Guha-Sapir, D., Parry, L., Degomme, O., Joshi, P., & Arnold, J. S. (2006). *Risk Factor for Mortality and Injury: Post-Tsunami Findings from Tamil Nadu*. Brussels: Centre for Research on Epidemiology of Disasters (CRED).

Hägerstrand, T. (1970). What About People in Regional Science? *Regional Science Association Papers, 24*, 7–21.

Hamzah, L., Puspito, N., & Imamura, F. (2000). Tsunami catalog and zones in Indonesia. *Journal of Natural Disaster Science, 22*(1), 25–43.

Helmholtz Association of German Research Centres (2008). New Approach In Tsunami-early Warning System. November 11, 2008. http://www.sciencedaily.com-/releases/2008/11/081110153720.htm. Accessed 28 July 2013.

Hewitt, K. (1983). *Interpretations of calamity from the viewpoint of human ecology*. Boston: Allen & Unwin.

Hidayati, D., Permana, H., Pribadi, K., Ismail, F., Meyers, K., Widayatun, et al. (2006). *Assessing and Recognizing Community Preparedness in Natural Disasters in Indonesia. Kajian Kesiapsiagaan*

Masyarakat Dalam Mengantisipasi Bencana Gempa Bumi dan Tsunami di Indonesia. Jakarta: LIPI-UNESCO/ISDR.

Hoppe, M. W., & Marhadiko, H. S. (2010). *30 Minutes in the City of Padang: Lessons for Tsunami Preparedness and Early Warning from the Earthquake on September 30, 2009*. GTZ Working Document No. 25. German–Indonesian Cooperation for Tsunami Early Warning System (GITEWS) .

Hosmer, D., & Lemeshow, S. (2000). *Applied Logistic Regression*. Wiley Series in Probability and Statistics (2nd edn). New York: John Wiley and Sons.

Ichsan, A. S. Antisipasi Tsunami, BNPB Siapkan Shelter. *Republika online news, April 19, 2012.* http://www.republika.co.id/berita/nasional/umum/12/04/19/m2pyq6-antisipasi-tsunami-bnpb-siapkan-shelter. Accessed 29 July 2013.

ISDR (2004). *Living with Risk: A global review of disaster reduction initiatives*. Geneva: UNISDR.

Janssen, M. A. (2007). An update on the scholarly networks on resilience, vulnerability, and adaptation within the human dimensions of global environmental change. *Ecology and Society, 12*(2), 9.

Jha, A. K., Miner, T. W., & Stanton-Geddes, Z. (Eds.) (2013). *Building Urban Resilience*. Washington, DC: World Bank.

Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R., et al. (1988). The Social Amplification of Risk: A Conceptual Framework. *Risk Analysis*, doi: 10.1111/j.1539-6924.1988.tb01168.x.

Khomaruddin, M., Strunz, G., Post, J., Zobender, K., & Ludwig, R. (2008). Spatial improvement of information on population distribution using GIS approaches: An input for tsunami people exposure assessment. In ICTW (Ed.), *International Conference on Tsunami Warning (ICTW), Bali, Indonesia, November 12-14, 2008* .

King, D. (2008). How People Responded To The April 2007 Tsunami Warning In Cairns And Townsville. *The Australian Journal of Emergency Management, 23*(1), 10–20.

Klein, R. J. T. (2002). *Coastal Vulnerability, Resilience and Adaptation to Climate Change*. Kumulative Dissertation. Christian-Albrechts-Universität zu Kiel, Kiel, Germany.

Klein, R., Nicholls, R., & Thomalla, F. (2003). The Resilience of Coastal Megacities to Weather-Related Hazards. In A. Kreimer, M. Arnold, & A. Carlin (Eds.), *Building Safer Cities: The Future of Disaster Risk* (pp. 101–120). Washington, D.C.: The World Bank.

Klüpfel, H. L. (2003). *A Cellular Automaton Model for Crowd Movement and Egress Simulation*. Dissertation. Universität Duisburg–Essen, Duisburg.

Kötter, T. (2003). *Prevention of Environmental Disasters by Spatial Planning and Land Management*. TS13.1 Prevention of Environmental Disasters by Spatial Planning and Land Management. Paper on 2nd FIG Regional Conference Marrakech, Morocco, December 2-5, 2003 .

Koot, J. M., Kowald, M., & Axhausen, K. W. (2012). Modelling behaviour during a large-scale evacuation: A latent class model to predict evacuation behavior. In STRC 2012 (Ed.), *Swiss Transport Research Conference 2012, Monte Verità, 09 - 11 May 2012* .

Kötter, T. (2005). *Disaster Risk Reduction and Mitigation by Strategies of Regional and Town Planning*. TS 32: Disaster Management and GIS Applications. Presentation on FIG Working Week 2005, Cairo, Egypt .

Kraas, F. (2003). Megacities as Global Risk Areas. *Petermanns Geographische Mitteilungen, 147*(4), 6–15.

Lämmel, G. (2011). *Escaping the Tsunami: Evacuation Strategies for Large Urban Areas Concepts and Implementation of a Multi-Agent Based Approach*. Dissertation. Technische Universität Berlin, Berlin.

Lavell, A. (1999). Environmental degradation, risks and urban disasters. issues and concepts: Towards the definition of a research agenda. In: Cities at Risk: Environmental Degradation, Urban Risks and Disasters in Latin America [Fernandez, M.A. (ed.)]. A/H Editorial, La RED, US AID, Quito, Ecuador, pp. 19-58. In M. Fernández (Ed.), *Cities at Risk: Environmental Degradation, Urban Risks, and Disaster in Latin America* (pp. 19–58): AH/editorial.

Lewis, J. (1999). *Development in Disaster-Prone Places: Studies of Vulnerability*. London: IT Publications.

Lewis, J., O'Keefe, P., & Westgate, K. N. (1977). A Philosophy of Precautionary Planning. *Mass Emergencies, 2*, 95–104.

Lindell, M. K., Lu, J.-C., & Prater, C. S. (2005). Household Decision Making and Evacuation in Response to Hurricane Lili. *Natural Hazards Review*, doi: 10.1061/(ASCE)1527-6988(2005)6:4(171).

Lindell, M. K., & Perry, R. W. (1992). *Behavioural Foundationsof Community Emergency Management*. Washington, D.C: Hemisphere Publishing Corporation.

Lindell, M. K., & Perry, R. W. (2000). Household Adjustment to Earthquake Hazard: A Review of Research. *Environment and Behavior*, doi: 10.1177/00139160021972621.

Lindell, M. K., & Perry, R. W. (2012). The Protective Action Decision Model: Theoretical Modifications and Additional Evidence. *Risk Analysis*, doi: 10.1111/j.1539-6924.2011.01647.x.

Lindell, M., & Perry, R. W. (2004). *Communicating Environmental Risk in Multiethnic Communities*. Thousand Oaks, London, Delhi: Sage Publications.

M. A. Janssen, M. L. Schoon, W. Ke, & K. Börner (2006). Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change. *Global Environmental Change, 16*, 240–252.

Martin, I. M., Bender, H., & Raish, C. (2007). What Motivates Individuals to Protect Themselves from Risks: The Case of Wildland Fires. *Risk Analysis*, doi: 10.1111/j.1539-6924.2007.00930.x.

McCloskey, J., Antonioli, A., Piatanesi, A., Sieh, K., Steacy, S., Nalbant, S., et al. (2008). Tsunami threat in the Indian Ocean from a future megathrust earthquake west of Sumatra. *Earth and Planetary Science Letters, 265*, 61–81.

McCloskey, J., Lange, D., Tilmann, F., Nalbant, S. S., Bell, A. F., Natawidjaja, D. H., et al. (2010). The September 2009 Padang earthquake. *Nature Geoscience*, doi: 10.1038/ngeo753.

McGranahan, G., Balk, D., & Anderson, B. (2007). The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization*, doi: 10.1177/0956247807076960.

Mileti, D. S., & O'Brien, P. W. (1992). Warnings During Disaster: Normailizing Comunicated Risk. *Social Problems, 39*, 40–57.

Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., et al. (2010). Resilience and vulnerability: complementary or conflicting concepts? *Ecology and Society, 15(3)*(11).

Mitchell, J. K. (Ed.) (1999). *Crucibles of hazard: Mega-cities and disasters in transition*. Tokyo: New York; United Nations University Press.

Mück, M., Taubenböck, H., Post, J., Wegscheider, S., Strunz, G., Sumaryono, S., et al. (2013). Assessing building vulnerability to earthquake and tsunami hazard using remotely sensed data. *Natural Hazards*, doi: 10.1007/s11069-012-0481-1.

Muhari, A., Gusman, A., Istiyanto, D., Triawan, F., Febriani, F., Hastiadi, F., et al. *Belajar dari Bencana Jepang 11.03.2011 Gempabumi – Tsunami – Radiasi Nuklir*. Chiba.

Muhari, A., Imamura, F., Ismail, F. A., & Mas, E. (2011a). *Potential tsunami hazard and risk prediction to human in the city of Padang, Indonesia.* Disaster management and Climate Change Conference, multi-disciplinary hazard reduction from earthquake and volcanoes in Indonesia, 2011. .

Muhari, A., Imamura, F., Koshimura, S., & Post, J. (2011b). Examination of three practical run-up models for assessing tsunami impact on highly populated areas. *Natural Hazards and Earth System Science*, doi: 10.5194/nhess-11-3107-2011.

Muhari, A., Koshimura, S., & Imamura, F. (2012). Performance evaluation of pedestrian bridge as vertical evacuation site during the 2011 tsunami in Japan. *Journal of Natural Disaster Science, 34*(1), 79–90.

Neuwirth, K., Dunwoody, S., & Griffin, R. J. (2000). Protection Motivation and Risk Communication. *Risk Analysis*, doi: 10.1111/0272-4332.205065.

Nicholls, R. J., & Small, C. (2002). Improved estimates of coastal population and exposure to hazards released. *Eos, Transactions American Geophysical Union*, doi: 10.1029/2002EO000216.

Nicolai, T. W. (2012). *Using MATSim as a travel model plug-in to UrbanSim*. Chapter for deliverable D7.2 SustainCity Project (FP7-244557) .

O'Keefe, P., Westgate, K., & Wisner, B. (1976). Taking the naturalness out of natural disasters. *Nature*, doi: 10.1038/260566a0.

Oßenbrügge, J., & Haferburg, C. (2005). *Synthesebericht Stadtentwicklung in raum-zeitlicher Perspektive (Alltagswelt-Aktionsräume-Ökologie)* (VERA - Verzeitlichung des Raumes 4). Hamburg.

Oxfam (2005). The tsunami's impact on women: Oxfam Briefing Note March 2005 .

n.n. (2013). Penghuni Rusunawa tak Tepat Sasaran. *Padang Express, April 2, 2013.* http://padangekspres.co.id/?news=berita&id=42155. Accessed 1 August 2013.

Parashar, S., Uy, N., Nguyen, H., Fernandez, G., Mulyasari, F., Joerin, J., et al. (2011). *Mega Disaster in a Resilient Community: The Great East Japan (Tohoku Kanto) Earthquake and Tsunami of 11th March 2011*. Kyoto: Kyoto University.

Post, J. C., & Lundin, C. G. (1996). Guidelines for Integrated Coastal Zone Management. Washington, D.C: The World Bank. *Environmentally Sustainable Development Studies and Monographs Series No. 9*.

Pred, A. R. (Ed.) (1981). *Space and time in geography: Essays dedicated to Torsten Hägerstrand*. Lund, Sweden: Gleerup.

Quarantelli, E. (1987). Disaster Studies: An Analysis of the Social Historical Factors Affecting the Development of Research in the Area. *International Journal of Mass Emergencies and Disasters, 5*(3), 285–310.

Rajib Shaw, Koichi Shiwaku Hirohide Kobayashi, & Masami Kobayashi (2004). Linking Experience, Education, Perception And Earthquake Preparedness. *Disaster Prevention and Management*, doi: 10.1108/09653560410521689.

Renn, O. (2008). *Risk Governance: Coping with Uncertainty in a Complex World* : Earthscan.

RESCDAM (2000). *Final report of Helsinki University of Technology: The Use of Physical Models in Dam-Break Flood Analysis* .

Rheinberger, C. M., Bründl, M., & Rhyner, J. (2009). Dealing with the White Death: Avalanche Risk Management for Traffic Routes. *Risk Analysis*, doi: 10.1111/j.1539-6924.2008.01127.x.

Riad, J., & Norris, F. (1998). Hurricane Threat and Evacuation Intentions: An Analysis of Risk Perception, Preparedness, Social Influence and Resources. Newark: University of Delaware Disaster Research Center.

Rofi, A., Doocy, S., & Robinson, C. (2006). Tsunami mortality and displacement in Aceh province, Indonesia. *Disasters, 30*(3), 340–350.

Rogers, R. (1983). Cognitive And Physiological Processes In Fear Appeals And Attitude Change: A Revised Theory Of Protection Motivation: Social Psychophysiology. In J. Cacioppo & R. Petty (Eds.). New York: Guilford Press.

Roy Lachman, Maurice Tatsuoka, & William J. Bonk (1960). Human behavior during the tsunami of May 1960. *Science, 133*(3462), 1405–1409.

Sánchez-Rodríguez, R., Seto, K. C., Simon, D., Solecki, W. D., Kraas, F., & Laumann, G. (2005). *Science Plan - Urbanization and Global Environmental Change*. Bonn: IHDP.

Santos, G., & Aguirre, B. (2004). A critical review of emergency evacuation simulation models. In. Gaithersburg, USA: University of Delaware Disaster Research Center.

Schlurmann, T., Kongko, W., Goseberg, N., Natawidjaja, D. H., & Sieh, K. (2010). Near-Field Tsunami Hazard Map Padang, West Sumatra: Utilizing High Resolution Geospatial Data and Reasonable Source Scenarios. In ICCE (Ed.), *32nd Conference on Coastal Engineering, Shanghai, China, June 30 - July 5, 2010* .

Schneiderbauer, S., & Ehrlich, D. (2006). Social levels and hazard (in)dependence in determining vulnerability: 3. In J. Birkmann (Ed.), *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies* : United Nations University Press.

Setiadi, N., Taubenböck, H., Raupp, S., & Birkmann, J. (2010). Integrating Socio-Economic Data in Spatial Analysis: An Exposure Analysis Method for Planning Urban Risk Mitigation. In Manfred

Schrenk, Vasily V. Popovich, Dirk Engelke, & Pietro Elisei (Eds.), *REAL CORP 2010, Vienna, 18-20 May 2010* .

Shah, H. (2006). The last mile: earthquake risk mitigation assistance in developing countries. *Philosophical Transactions of the Royal Society, 364*, 2183–2189.

Sieh, K. (2006). Sumatran megathrust earthquakes: from science to saving lives. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, doi: 10.1098/rsta.2006.1807.

Slovic, P. (1987). Perception of Risk. *Science, 236*(4799), 280–285.

Small, C., & Cohen, J. (1999). Continental Physiography, Climate and the Global Distribution of Human Population. In *International Symposium on Digital Earth, Beijing, China* (pp. 965–971).

Smith, K., & Petley, D. N. (2009). *Environmental Hazards: Assessing Risk and Reducing Disaster* (5th edn): Routledge, Taylor & Francis Group.

Sorensen, J. (1991). When shall we leave? Factors affecting the timing of evacuation departures. *International Journal of Mass Emergencies and Disasters, 9*(2), 153–165.

Sorensen, J. (2000). Hazard warning systems: review of 20 years of progress. *Natural Hazards Review, 1*(2).

Sugimoto, T., Murakami, H., Kozuki, Y., Nishikawa, K., & Shimada, T. (2003). A Human Damage Prediction Method for Tsunami Disasters Incorporating Evacuation Activities. *Natural Hazards, 29*, 585–600.

Taubenböck, H. (2011). The Vulnerability of a city – diagnosis from a bird's eye view. In N.-A. Mörner (Ed.), *The Tsunami Threat - Research and Technology* (pp. 107–128): InTech.

Taubenböck, H., Goseberg, N., Lämmel, G., Setiadi, N., Schlurmann, T., Nagel, K., et al. (2012). Risk reduction at the "Last-Mile": an attempt to turn science into action by the example of Padang, Indonesia. *Natural Hazards*, doi: 10.1007/s11069-012-0377-0.

Taubenböck, H., Goseberg, N., Setiadi, N., Lämmel, G., Moder, F., Oczipka, M., et al. (2009a). "Last-Mile" preparation for a potential disaster – Interdisciplinary approach towards tsunami early warning and an evacuation information system for the coastal city of Padang, Indonesia. *Natural Hazards and Earth System Sciences, 9*, 1509–1528.

Taubenböck, H., Post, J., Roth, A., Strunz, G., Kief, R., Dech, S., et al. (2008). Multi-scale Assessment of Population Distribution Utilizing Remotely Sensed Data: The Case Study Padang, West Sumatra, Indonesia. In ICTW (Ed.), *International Conference on Tsunami Warning (ICTW), Bali, Indonesia, November 12-14, 2008* .

Taubenböck, H., Wurm, M., Setiadi, N., Gebert, N., Roth, A., Strunz, G., et al. (2009b). Integrating Remote Sensing and Social Science – The correlation of urban morphology with socioeconomic parameters. In *Urban Remote Sensing Joint Event, Shanghai, China, 2009* .

Thomalla, F., & Larsen, R. K. (2010). Resilience in the context of tsunami early warning systems and community disaster preparedness in the Indian Ocean Region. *Environmental Hazards*, doi: 10.3763/ehaz.2010.0051.

Tierney, K. J., Lindell, M. K., & Perry, R. W. (2001). *Facing the Unexpected: Disaster Preparedness and Response in the United States* (Natural Hazards and Disasters). Washington, D.C: Joseph Henry Press.

Turner, R. K., Subak, S., & Adger, W. N. (1996). Pressures, trends, and impacts in coastal zones: Interactions between socioeconomic and natural systems. *Environmental Management*, doi: 10.1007/BF01204001.

UN/ISDR (2005). Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters. Hyogo: UN/ISDR.

UN/ISDR (2006a). Developing Early Warning Systems: A Checklist. EWC III Third International Conference on Early Warning From Concept to Action, 27-29 March 2006, Bonn, Germany : United Nations.

UN/ISDR (2006b). Global Survey of Early Warnings Systems: An assessment of capacities, gaps and opportunities towards building a comprehensive global early warning system for all natural hazards : UN/ISDR Platform for the Promotion of Early Warning.

UN/ISDR (2007). Words Into Action: A Guide for Implementing the Hyogo Framework.: Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters. Geneva, Swizerland: UN/ISDR.

UN/ISDR (2009). UNISDR Terminology on Disaster Risk Reduction : United Nations, International Strategy for Disaster Reduction.

United States Geological Survey (USGS). Indonesia: Seismotectonics of the Indonesian Region. USGS. http://earthquake.usgs.gov/earthquakes/world/indonesia/seismotectonics.php. Accessed 28 July 2013.

Villagrán de León, J. C. (2011). Vulnerability Assessment in Sri Lanka in the Context of Tsunami Early Warning. In H. G. Brauch, Ú. Oswald Spring, C. Mesjasz, J. Grin, P. Kameri-Mbote, B. Chourou, et al. (Eds.), *Coping with Global Environmental Change, Disasters and Security* (Vol. 5, pp. 1441–1449, Hexagon Series on Human and Environmental Security and Peace): Springer Berlin Heidelberg.

Villagran de León, J. C., Bogardi, J., Dannenmann, S., & Basher, R. (2006). Early Warning Systems in the context of Disaster Risk Management. *Entwicklung & ländlicher raum, 2*, 23–25.

Villagrán de León, J. C., Weerawarnakula, S., & Chandrapala, L. (2006). *Elements to develop a Tsunami-Early Warning Plan for the city of Galle in Sri Lanka: Paper for Workshop on Human Impact of Tsunami and Disaster Risk Reduction in Bangkok, 16-17 June 2006*. http://www.unisdr.org/2006/ppew/tsunami/project-overview/dp-archive-project-highlights.htm. Accessed 25 July 2013.

Watts, M., & Bohle, H.-G. (1993). The space of vulnerability: The causal structure of hunger and famine. *Progress in Human Geography, 17*, 43–67.

White, G. (1974). *Natural hazards, local, national, global*. New York, London, Toronto: Oxford University Press.

White, G., & Haas, J. (1975). *Assessment of Research on Natural Hazards* (Environmental Studies Series): Mit Press.

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At Risk: Natural Hazards, People´s Vulnerability, and Disasters* (2nd edn). London: Routledge.

World Bank (2010). *Mainstreaming Gender in Road Transport: Operational Guidance for World Bank Staff*. Transport Paper: TP-28/March 2010. Washington, D.C: The World Bank Group.

Zaidulfar, E. A. (2002). *Morfologi Kota Padang*. Dissertation. Universitas Gadjah Mada, Yogyakarta, Indonesia.

Zelinsky, W., & Kosiński, L. (1991). *The Emergency Evacuation of Cities: A Cross-National Historical and Geographical Study* : Rowman & Littlefield Pub Incorporated.

Zemp, H. (2010). ICT and effective disaster management in a changing media world: The critical function of disaster communications in dynamic and diverse contexts by its users. In R. Custer, C. Sutter, & W. J. Ammann (Eds.). Davos Dorf.

Appendices

Table A-1 Descriptive analysis of socio-economic and human cognitive variables for intention to evacuate

Variables	**N**	**Categories / Score**	**%**
1: agegroup	933	1-9	0.1
		10-19	0.9
		20-29	12.5
		30-39	24.1
		40-49	26.4
		50-59	21.9
		60-69	10.0
		70 and above	4.2
2: female	933	0	37.2
		1	62.8
3:education	933	no school	0.8
		No primary school finished	5.0
		Primary school finished	10.0
		Junior high school finished	16.2
		Senior high school finished	44.8
		Bachelor	21.4
		Master	1.8
4:income	834 (missing: did not know & did not want to answer)	<800,000 Rupiah	14.5
		800,001 - 1,600,000	35.1
		1,600,001 - 4,000,000	34.5
		> 4,000,000	15.8
		Gesamt	100.0
5:hh w. elderly 65+	933	0	75.9
		1	24.1
6:hh size	933	1-2	9.6
		3-4	37.2
		5-6	33.4
		7 and more	19.7
7:tsunami definition	933	0	14.3
		1	85.7
8:tsunami indications	933	0	17.8
		1	82.2
9:worry	933	0	28.8
		1	57.7
		2	13.5
10: harm - lack preparedness	933	0	83.7
		1	16.3
11:discussion on TEWS	933	0	16.6
		1	64.2

		2	19.2
12:own knowledge place	933	0	6.5
		1	23.5
		2	70.0
13:perceived capability	933	very difficult	12.4
		quite difficult	46.8
		easy	36.4
		very easy	4.3
14:knowledge of place,route,sign	933	0	55.3
		1	44.7
15:knowledge of TEWS	933	0	44.2
		1	55.8

Source: own analysis based on UNU-EHS Household Survey 2008

Table A-2: Correlation table of the selected variables for intention to evacuate (Kendall tau-b coefficient; ** significant with p<0.01, * p<0.05)

		Socio-economic						Cognitives									IE
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Socio-economic	1: agegroup	-															
	2: female	-,142**	-														
	3:education	-,174**	-,083**	-													
	4:income	-,040	-,044	,306**	-												
	5:hh w. elderly 65+	,251**	-,085**	-,023	-,019	-											
	6:hh size	-,071**	,032	,016	,181**	,073*	-										
Cognitives	7:tsunami definition	-,035	-,066*	,121**	,008	-,078*	,008	-									
	8:tsunami indications	-,049	-,022	,142**	,148**	-,019	,026	,171**	-								
	9:worry	-,044	,137**	,050	,028	-,004	,044	-,021	,076**	-							
	10: harm - lack preparedness	-,046	-,045	,133**	,037	-,032	,051	,080*	,114**	,054	-						
	11:discussion on TEWS	,006	-,033	,008	,056	,025	,003	-,076*	,167**	,110**	,107**	-					
	12:own knowledge place	-,035	-,073*	,158**	,088**	-,069*	-,038	,039	,128**	,093**	,102**	,014	-				
	13:perceived capability	-,059*	-,023	,046	,017	,012	-,046	-,061*	,043	,052	,057	,093**	,073*	-			
	14:knowledge of place,route,sign	-,075**	-,106**	,237**	,152**	-,053	-,010	,114**	,088**	,017	,080**	-,015	,252**	,049	-		
	15:knowledge of TEWS	-,103**	-,072*	,231**	,088**	-,054	,047	,156**	,094**	,001	,123**	,009	,148**	,045	,208**	-	
Intention to evacuate (IE)		-,123**	,025	,065*	,070*	-,096**	,070*	,068*	,158**	,139**	,141**	,159**	,108**	,111**	-,028	,068*	-

Source: own analysis based on UNU-EHS Household Survey 2008

Table A-3 Descriptive analysis of socio-economic and evacuation indices for intention to support improvement of evacuation infrastructure and facilities

Variables	N	Categories / Score	%
1: agegroup	560	15-34	34.3
		35-64	59.8
		65+	5.9
2: female	560	0	33.8
		1	66.3
3:education	559 (missing: did not answer)	Never went to school	1.1
		Not completed primary	5.5
		Completed primary	11.3
		Completed junior high	20.4
		Completed senior high	42.6
		Higher education	19.1
4:income	448 (missing: did not know/did not want to answer)	< Rp 800.000	32.8
		Rp 80.001-1.600.000	37.5
		Rp 1.600.001-4.000.000	22.1
		> Rp 4.000.000	7.6
5:hh w. Elderly	560	0	84.1
		1	15.9
6:hh size	560	1	1.3
		2	5.9
		3	13.6
		4	17.0
		5	21.3
		>=6	41.1
evacuation awareness index	560	mean	0.36
		standard deviation	0.18
evacuation knowledge index	560	mean	0.28
		standard deviation	0.22

Source: own analysis based on UNU-EHS/KOGAMI Household Survey 2009

Table A-4 Correlation table of the selected variables for intention to support improvement of evacuation infrastructure and facilities (Kendall tau-b coefficient; ** significant with p<0.01, * p<0.05)

		Socio-economic						Cognitives		WR	SK	IP
		1	2	3	4	5	6	7	8			
Socio-economic	1: agegroup	-										
	2: female	-,074	-									
	3:education	-,196**	-,089*	-								
	4:income	-,038	-,092*	,411**	-							
	5:hh w. Elderly	,182**	-,062	,007	,059	-						
	6:hh size	,031	,008	-,044	,041	,167**	-					
Cognitives	7:evacuation awareness scores	-,058	-,006	,163**	,146**	,011	,014	-				
	8:evacuation knowledge scores	-,033	-,005	,113**	,236**	,051	,060	,224**	-			
Perception of widening roads (WR)		-,078*	-,040	,092*	,047	-,049	-,080*	,285**	,064	-		
Perception of shelter construction (SK)		-,069	-,106**	,069	,118**	-,032	,001	,305**	,104**	,395**	-	
Intention to actively participate (IP)		-,046	-,067	,088*	,113**	-,005	,018	,127**	,140**	,211**	,068	-

Source: own analysis based on UNU-EHS/KOGAMI Household Survey 2009

Table A-5 Future Orientations in the Spatial Plan 2010-2030 and Their Expected Impacts on People´s Response Capability

City functions	Orientations / Plans	Expected impacts
DYNAMIC EXPOSURE		
Control of land-use in hazard zone	Generally areas with high and very high risk to natural hazards are recommended as conservative areas or utilized areas with non-settlement use such as open green areas, cropping and agricultural areas In already built areas located in utilized areas, the spatial development intensity should be limited, oriented towards non-settlement activities and not centralized population consentration, while in already built areas located in conservative areas, the function is assigned as conservative areas.	Reduction of overall exposure
Settlements	Development of settlement areas towards non-built areas in the eastern and southern part that is not prone to tsunami hazard	Reduction of overall exposure
Government service centers	Relocation of city government service centers from the city center to northeast of the city (Air Pacah) Maintenance of provincial government service centers in the current places (Jl. Jend. Sudirman dan Jl. Khatib Sulaiman) and other offices so far not located in hazard prone areas	Reduction of exposure during the working hours
Economic centers	Service centers related with trade, business, services, social-cultural, tourism and recreational activities are maintained and further developed in the city center (Kecamatan Padang Barat, Padang Utara, Padang Timur, Padang Selatan), but within the second decades other service centers in the north, south and east will be developed to also meet demands from neighbouring districts (due to the status of metropolitan city) and city center will be dominated by local scale activities (mobility is limited to local scale activities). Central market place (Pasaraya), which was damaged by earthquake in September 2009, will be revitalized, but also taking into account development of (traditional) market places in the city peripherial areas. Traffic pressures will be considered. Large shopping centers will be developed in the city center and sub-centers areas. Relocation of big and medium –scale industrial activities from the city centers to industrial areas in Kecamatan Bungus Teluk Kabung and Lubuk Kilangan & Teluk Bayur Port.	Reduction and control of exposure during the working hours With increase of economic activities as a metropolitan city - more inmigrants and commuters may cause more working places and working population exposed in the long-term Industrial activities – relocated to the coastal areas in the south – shift / redistribution of risk?

Tourism	In the Padang Hill area, a sub-city service center will be developed for tourim activities integrated with Muaro port, old town Pondok Muaro conservation and Padang hill tourism area. Development of natural tourism activities in Padang beach, Padang hill, Air Manis beach, Pisang river, Air Jambak Beach, Taman Hutan Raya Bung Hatta Development of cultural tourism activities in old town area (Pondok, Muaro), Lapangan Imam Bonjol, cultural settlement areas in Bungus Teluk Kabung and Koto Tangah	Increase of exposure, especially during the day, in high seasons for tourism
Other public facilities	Development of public transportation terminal in Kecamatan Padang Barat (Goan Hoat) to serve transportation between city centers and sub-centers Development of Muaro port to serve local and interinsuler activities including passanger and freight, boats and yacht, especially supporting tourism activities. Development of fishermen port in Muara Anai for local fishery actitivities	Punctual high exposure during the day
IMPROVEMENT OF ACCESS TO SAFE PLACES		
Transportation management	Development of areas for informal trading sector in old town areas, central market place, tourist areas, assigned streets based on regulation, special areas developed by private trading organizations Management of on-street parking and development of off-street parking facilities in trading, service, industrial, government centers areas.	Reduction of overall traffic pressures also in the evacuation routes
Transportation network	Development of existing and new main transportation network (primary arteri min width 40 m, secondary artery min width 28 m) mostly parallel to the coastline and in the city center area, collector roads (primary collector min width 18 m, secondary collector min width 12 m) connecting city service centers and sub-centers.	May increase evacuation capability in the old town and city center, however not sufficient for hotspots along the rivers/ canals, if no additional bridges and perpendicular roads are made available
Evacuation roads	Development of new evacuation routes perpendicular to the coastline towards higher locations or escape buildings, which are multi-functional, if no evacuation may be used as open green areas.	Increase overall evacuation capability
Evacuation places	Development of evacuation locations for Kecamatan Padang Utara, Padang Barat and Padang	Current capacity is not sufficient

	Selatan in By-Pass road, Limau Manis Pauh, and Indarung. For other Kecamatans in Lubuk Minturun, chinese cemetery in Bungus and surrounding hills Development of evacuation places as escape buildings (using public buildings such as mosques, schools, offices, etc.) or open space, which will be further specified in detailed plan. Currently, potential of existing open space with total capacity of 12,200 people and buildings with total capacity of 13,200 has been identified.	considering estimated evacuees, new facilities to be assessed
IMPROVEMENT OF ACCESS TO WARNING		
Electricity supply	Extend the electricity network among others to ensure electricity supply during emergencies: additional electricity supply from various sources and provision of generators	Increase of effectiveness of media
Telecommnication infrastructure	Provision of telecommunication facilities for emergencies, zoning regulation for installation of towers of base transceiver station for wireless connection especially in the city centers also considering criteria related with emergencies	Higher access to warning through wireless media (mobile phones, internet)

Source: own analysis based on RTRW Kota Padang 2010-2030