UNIVERSITA' DEGLI STUDI DI SASSARI

Dipartimento di Architettura, Design, Urbanistica

Scuola di Dottorato Architettura e Pianificazione

Spatial Planning for Tsunami Resilience:

A Case study of Kochi City, Japan

TESI DI DOTTORATO:
Sarunwit Promsaka Na Sakonnakron

RELATRICE:
Prof. Paola Rizzi

DIRETTRICE:
Prof. Paola Pittaluga

ACKNOWLEDGEMENT

This dissertation would not have successfully been possible without the guidance and the help of several individuals who contributed their valuable advice and assistance in assorted ways to this research. It is a pleasure to convey my gratitude to them all in my humble acknowledgment.

In the first place, I would like to express my sincere thanks and appreciation to my supervisor, Professor Paolo Rizzi for her advice and guidance from the very early stage of this research as well as for her kind encouragement throughout the period of the research. I would not have achieved this far without all the support that I have always received from her.

My grateful thanks are also extended to Professor Jan H. G. Klabbers for his valuable recommendations for constructive research methodologies and content/data analysis during the development of this research work. His support helped me to achieve a clearer structure.

I take this opportunity to express my gratitude for the support of Professor Satoshi Otsuki and Prof. I. In particular, his help provided me with valuable data and suggestions while I was doing fieldwork in Japan.

Acknowledgment is also owed to my colleagues and friends; Warangkana Korkietpitak, Yuya Aso, Mana Yamasaki, Sohei Ito, and Jutarosaga family. We have talked and exchanged our opinions, and I always received corrections from the conversations. They were also an endless source of good advice, helpful, constructive comments, and suggestions. My thanks must go to them as well.

Furthermore, I wish to thank all the faculty members of the Department of Architecture, Design and Urbanism, University of Sassari for their assistance since the start of my work in 2012, especially the head of department, Professor Paola Pittaluga.

On this occasion, I would like to thank the following organizations for the scholarship granted to me: JASSO scholarship (Japan Student Services Organization) and University of Sassari, Department of Architecture, Design and Urbanism. Their financial support has made this research possible.

Last, but by no means least, I owe a great debt to my family – my mom and sisters –for warmly supporting me through difficult times. Their understanding and kindness lifted my spirit and gave me the extra push to keep moving forward. With my family's generous support, my dissertation came to its completion.

Sarunwit Promsaka Na Sakonnakron

Spatial Planning for Tsunami Resilience:

A Case study of Kochi City, Japan

Abstract:

In this research, the tsunami risk of coastal zones is taken into account. The research argues that, by adapting the resilience concept, the urban systems can be more interactive and capable to turn disaster vulnerability into a window of opportunity of creating better living environment and enhancing urban resilience against future tsunami. Addressing both theoretical debate and practical implementation of the resilience concept invovles a variety of critical issues related to the controversial definitions of vulnerability and resilience, the relevant variables for resilience, and methodologies to increase urban resilience. Hence, the research design emphasizes the above issues, aiming to enhance the effectiveness of reliable research operations.

Three research objectives are drawn up. The first objective is to describe the disaster resilience in terms of urban planning and find a way to put a concept of resilience into practice. This brings out the research hypotheses that "enhancing resilience does not always reduce existing vulnerability of cities". Therefore, the second objective is to determine tsunami vulnerable characteristics of the coastal city based on a case study of Kochi City. Finally yet importantly, the third objective is to explore whether Kochi City is tsunami resilient or not in terms of spatial planning.

Phuket Island in Thailand and Kochi City in Japan are selected as a preliminary case study and a target case respectively. Themes of the study differ considerably between case studies. The Phuket case shows how Indian Tsunami of 2004 affected the coastal zones like Phuket, while a set of resilience benchmarks is used to identify the resilience of Phuket after the destructive disaster event. With the adopted benchmarks, a resilient city to disaster is defined by the three main characteristics that comprises of the stability of physical elements, the capability to bounce back, and the institutional capability to self-organize. Vulnerability is, on the other side of the same coin, used to defined incapability and exposure elements of systems. Therefore, increasing resilience does not always decrease vulnerability and vice versa. This means the first hypothesis is accepted. The results of the preliminary study are taken as a fundamental disciplinary in designing research methodologies for the Kochi case study.

While a case study of Phuket focuses on the aftermath of 2004 tsunami, Kochi case study rather considers more on how to improve the city's capability of coping with the expectedly arrival tsunamis in a few decades. By following the second research objective, the study assesses disaster vulnerability of urban fabrics, covering from tangible physical conditions to intangible socio-economic structures. This assessment is based on the hypothesis that "socio-economic attributes of Kochi City are dominant factors, which categorize tsunami vulnerability this city". 357 sub-districts of 416 sub-districts in Kochi City within the city planning area are assessed by a total of 22 indicators and three integrated weighting techniques; equally distribution, AHP model, and SMARTER. Results of the assessment are produced as an urban vulnerability map. In addition, overlapping vulnerability map with tsunami potential map creates a tsunami risk map that defines fragmented districts into three group based on the vulnerability level and hazard potential level. As a result, the most vulnerable areas are not the coastal area, but they are the urbanized areas where infrastructure, buildings, and people are concentrated. In addition, elderly people and children are the major group of residents, who live in these most vulnerable areas.

When the vulnerability has been assessed, the next step is to explore the Kochi tsunami resilience in terms of spatial planning. A debate on spatial planning for tsunami resilience compises of the policy background, the policy formulation, and the platforms of policy implementation. The results show that a concept of integrating disaster risk management into spatial planning has been mentioned since the beginning of The First Comprehensive National Development Plan of 1962-1968. Nevertheless, the concern on this integration has not been fully realized until the emergence of The 5th Comprehensive National Development Plan (covering a period of 2010-2015). The national effort on implementing spatial planning for disaster resilience is translated into the Basic Act for National Resilience Contributing to Preventing and Mitigating Disasters for Developing Resilience in the Lives of the Citizenry (Act No. 95 on December 11, 2013). This act can be regarded as a new norm for building better living environment, while ensuring that human settlement is resilient to disasters. Furthermore, the national and regional policy formulation for spatial planning enables an opportunity for local planning authorities in integrated risk mitigation measures in their master plans, land use ordinances, and urban development projects. The effectiveness of those urban interventions for risk mitigation depends on how the local authorities utilize and adapt them to their local context. In case of Kochi City, the risk mitigation measures exist for preventing and alleviating fire risk, not tsunami risk. There is no incentive or penalty to limit the urban development in highly prone area to tsunami. Besides, some critical infrastructure such as schools and hospitals are still located in the expected tsunami-affected area. Even the local spatial planning authorities have been discussed about the relocation of that infrastructure, but there is no implementation plan.

Results of the research suggest that the relocation plan of infrastructure is necessary to lessen the tsunami loss and keep urban service functioning during the recovery process of the next tsunami events. The development in tsunami prone areas shall be limited by the use of incentive and penalty in terms of the property tax, and the development right transfer. Residents in high tsunami-prone areas should be cultivated risk awareness, whihc will lead to an increase in disaster preparedness. The relocation plan and some incentives for the relocated residents should also be taken into account. Without any incentive, a majority of residents would be disagree with it. Focusing on the vulnerable inter-city at risk of tsunami, one of solutions to mitigate risk is the provision of dual spaces. The dual spaces allow residents to use as a recreation area in their daily lives, while the space can provide functions as evacuation camps, sheltering tsunami affected-households in an emergency event. The transformability of dual spaces enables to maximize the use of urban spaces in a disaster recovery process.

Table of Content

List of Tables

Page

List of Figures

Page

Page

List of Equations

Chapter 1 :

Tsunami vulnerability of coastal cities

Since natural disasters tend to happen more frequently and severely, urban planners, administrative organizations, and local communities should cooperate closely in monitoring, preparing, and planning the disaster management strategy. Nevertheless, the previous disaster management strategy might not be good enough to handle the degree of today's natural disaster risks. Therefore, the study argues that, through a resilience approach, our urban systems will be more interactive and capable to turn the disaster vulnerability into opportunities of creating a better urban environment. Such an environment renders people to be more adaptive to abort tsunami shocks, maintain their livelihood, and recover from (un)foreseen perturbations caused by tsunami. The first chapter aims at explaining about the root of a term "resilience", its importance to urban planning in the face of disaster, and the most vulnerable urban systems in the globe that should be taken into account. Those issues bring about identifying research problems, objectives, and preliminary studies, whereas those also lead to the construction of the study model.

Key words: resilience and interactivity

1.1 Statement of problems

Cities around the globe have been developing their built environment and socio-economic capabilities. Such development has changed cities from agricultural to industrial and commercial societies, leading to an increased complexity of urban dynamics. These changes could directly affect the balance between urban resource consumption and environmental conditions such as quality, carrying capacity, which in turn will lead to major transformations of living conditions and the quality of life of the inhabitants. The transformations may have positive or negative consequences, depending on how well urban planning deals with and adapts to those changes and perturbations. It is clear that negative impacts of the transformations will increase the overall vulnerability of a city.

In fact, the vulnerability in terms of environmental changes and natural disasters did not just emerge. Environmental changes and natural disasters have been a major threat to the urban fabric of our society since rapid urbanization changed the urban landscapes and socio-economic characteristics (Mitchell, 2010). Dating back to the industrialization era in the 1970s, the capitals of major countries in the world had depended on large-scale production by light and heavy industries, which drove the urbanization. Nevertheless, the economic prosperity through the industrialization also had negative impacts with respect to the location of territories. Industrial development without proper urban management, for example, allowing developers to build factories in a residential area, could cause environmental degradation and social inequality. Inevitably, there were considerable negative side effects with respect to sufficient sanitation services for decent housing and – in general – concerning the quality of life of the inhabitants. Since the late 1970s and early 1980s many old industrial cities, especially in England, experienced the urban crisis through an accelerating decline of their traditional manufacturing industries (Bramwell & Rawding, 1996). This crisis corresponded with a growing concern about urban revitalization. As a result, since the 1980s, cities have initiated a process of urban revitalization, which aimed at restructuring their economy, emphasizing services and tourism. Nowadays, even though tourism contributes to the economic prosperity, the tourist flux and tourism cause a sharp rise in waste production as well as in the demands of urban facility and utility beyond the carrying capacity. Besides, the pressure of taking advantages of globalization stimulates huge investments in the city and creates more dense urbanized areas, especially in the disaster-prone zones.

Theoretical debates suggest that the vulnerability and disaster risk of cities are both outcomes of the previous development, and pressures shaping the progressing relationships between urbanization and urban planning. In addition, those progressing linkages become more complicated when the risk is not only caused by urban activities and environmental changes within the city, but is also caused by external environmental changes; namely natural disasters.

Since man-made and natural disasters tend to be more severe than in the past, human beings have been forced to seek for suitable strategies through which they are capable to protect human lives against the perceived risks, and to respond to these risks through detecting vulnerable spatiality, and social and economic factors that can cause a catastrophe. Such strategies have been developed over time, corresponding to a growing understanding of the interactive relations between human society and nature (Table 1-1). After the experiences from a variety of destructive disasters in 1980s, we have been aware that natural disasters are not amenable to technological quick fixes alone. The attention of risk management strategies has increasingly been paid to behavior changes and disaster risk awareness that follow upon environmental sustainability campaigns. The increase of risk awareness by world leaders has shifted the role of human society in dealing with disaster impacts from reactive to interactive.

Namely, in pre-1980's, the scarcity of technology and human notion on disaster mitigation puts limitation on human to anticipate and respond disaster events in proactive and interactive ways. In 1980's, the innovative development of technology rendered humans more capable of preventing and mitigating natural disasters through the provision of structural measures for disaster risk reduction. Nevertheless, the investment in structural measures was not effective in terms of costs and benefits, because humans either extensively overestimated or ignored the exact frequency and severity of natural hazards. Hence, the structural measures that were contracted during this period were costly (as they were well-constructed to prevent extremely rare hazards) or incapable to protect human settlements (as they aimed at preventing frequent natural hazards, while humans bore the impacts of residual risks through sustainability campaigns base on the nature of surrounding environment. Since 1990's, the birth of interactive systems through a resilience approach has created the most important type of human reactions to environmental risk. This kind of systems may interact with disaster events by providing necessary risk information, physical tools, and spaces to their users and operators in order to allow them to utilize those during the emergency. Those provisions may, in turn, be feedback to the indication of how resilient the systems should be. The more resilient the systems are, the larger a perturbation they can handle.

Nowadays, disaster management strategies are more anticipatory, prepared well before the disaster happens rather than retrospective: offering lesson learned after the disaster has stricken. In addition, it has also stimulated human thinking and understanding about social-natural relationships. Correspondingly, the risk response approaches are continuously being renewed. This innovative thinking and acting leads to a series of shifts from adaption, via sustainability, to resilience, which is regarded as a core approach defining the way we enhance our capability and aptness to cope with natural disasters. The capability to self-organize and self-adapt can render cities capable of producing innovative strategies to cope with (un)anticipated perturbations. Nevertheless, it remains to be seen whether or not the resilience concept can be put into practice.

Table 1-1: The shift of human cognition toward social-natural relations

Theme	Pre-1980's	1980's	1990's
Urbanization trend	Industrialization	Garden City	Globalization, Commercialization, and Tourism
The exist of nature and culture	Culture is nature	Nature is culture	Nature and culture have reciprocal relationships
Risk response approaches	***Adaption***	***Sustainability***	***Resilience***
Human-environment relationship	Human is re-active to the environment	Human is pro-active to the environment	Human is inter-active with the environment
Human centric perception	Environmental crises hit human	Environmental crises are caused by human	Environmental crises are caused by socio-natural interaction
The perceived risks	Environment is dangerous for human	Human is dangerous for the environment	Neither is dangerous if handled carefully, both if that is not the case
Applied tools and strategies	Apply techno fixes	No new technology	Minimalist balanced use of technology
Dynamic perspectives	"Milieu" perspective dominates	"Environment" perspective dominates	Attempts to balance both perspectives

Source: Adapted from Van der Leeuw & Aschan-Leygonie, 2000

Three major factors influence the interrelation between the disaster vulnerability of a city and the wider urban system: city location, its size, and type of economy (Yarnal, 2014). First, a type of disaster risks varies with the city location, differentiating between coastal and inland zone. Coastal cities can be subjected to sea level rise, tropical cyclones, and tsunami, whereas inland cities are vulnerable to floods, wildfires, and so forth. Second, the larger cities are likely to be more disaster vulnerable because they possibly consist of a larger number of exposure elements such as people and urban infrastructure. Because those cities are more densely populated and fabricated by a variety of urban infrastructures than small cities. On the other hand, as the city size is bigger, larger cities tend to have more resources - such as finances and human resources - to deal with the disasters, which can make them more capable and adaptable to mitigate those risks. Compared with big cities, small cities might be less sensitive to environmental risks – due to their smaller 'footprint'. However, they tend to have less adaptive capacity to recover from such a disaster. Third, cities that comprises of diverse and integrated economies are less vulnerable to natural disasters. Obviously, a city that heavily relies on tourism as its sole economic activity will be sensitive to seasonal fluctuations. Therefore, it is more vulnerable to climate change than a city that considered tourism as one of its many economic facets.

As the aforementioned debates, it can imply that nowhere else is vulnerable to environmental disasters as much as coastal cities are. The coastal zone is regarded as one of the most productive systems noun, yet highly threatened social systems in the world (Agardy, et al., 2005). This zone is combined with inland and lowland settlements, making it an urban agglomeration. Cities located along the coasts mostly become tourist attractions, where their amenities are based on a unique resource combination of land and sea. With the resource enrichment, coastal areas can provide a variety of inputs - not available to other areas - for catalyzing urban development and its economy, both qualitatively and quantitatively. This enrichment leads to an agglomeration of population, buildings, and infrastructure that stimulate urban activities and contribute to urbanization. However, this coastal urbanization is likely to be affected by destructive disasters such as tsunami. Especially, the urbanization in the Indian Ocean and the "Pacific Ring of Fire" are more vulnerable, because potential tsunami victims are larger than the other parts of the world.

International statistical data of urban settlement and population density points out that urban settlement - in large part - tends to be on or near the coasts, especially in Asia (McGranahan, et al., 2005). Regarding the definition of a coastal zone, this report typically refers either to a combination of inland, mountain, and lowland settlements or to an area extending land inward to a distance 100 kilometers from shores (McGranahan, et al., 2005). Table 1.1 shows a summary of population allocation by regions. The coastal urban system has disproportionally higher density than other settlements. The population density in coastal areas is noticeably greater than the average density of urban areas globally, because coastal cities have well-supplied resources, which lead to smart urban development and economic growth. Demographic trends suggest that coastal populations are rapidly increasing; most are through migration, increased fertility, and tourist visit (Agardy, et al., 2005). This means that demands on coastal areas for habitation, secured urban infrastructure, and even sustainable land use are increasing.

Table 1-2: Population Estimates, Densities, and Land Areas

Locations of the settlement		Population(million)				Population Density(per sq. km)		
		Total	Urban	Rural	% of Urban/Rural	Average	Urban	Rural
The global	Overall	6,052	2,828	3,224	46.7	46	770	25
	Cultivated	4,233	1,914	2,309	45.3	119	793	70
	Dryland	2,149	963	1,185	44.8	36	749	20
	Forest	1,126	401	725	35.6	27	478	18
	Inland Water	1,505	780	726	51.8	51	826	25
	Mountain	1,154	349	805	30.3	36	636	26
	Coastal zone	1,147	744	403	64.9	175	1,119	69
Case studies	Phuket Island (as of 2004)	0.261	0.114*	0.147	43.7	538	1,626*	361
	Kochi Prefecture (as of June, 2014)	0.739	0.603	0.136	81.6	104	-	-

Source: CIESIN et al. 2004 (Island systems are excluded.) cited in McGranahan, et al., 2005, Phuket Provincial Statistics Office, 2012 and Kochi Prefecture's official website, 2014

Note: *Municipal areas

Speaking about natural risks of the coastal zone, different kinds of disaster associated with natural hazards – such as flash flood, slow-onset sea level rise, landslide, and tsunami – all directly impact the physical structure and human life. They differ with respect to the severity of the impacts and their consequences. A small disaster impact may not lead to significant changes in terms of social structure and risk management policies. A great tsunami – regarded as major disasters to the affected victims and zones –can influence the way of thinking (public risk perception and awareness) and performing (adjusting social structure and risk management policies). Therefore, tsunami risk can be considered as the potential driving force of the great sociological movement in risk management strategies that enhance urban resilience of coastal zones.

While there are many urban studies that focus mainly on financial aspects, urban poverty, governance, pollution, and city transformations as a reference point, few empirical studies on the disaster vulnerability of cities pay attention to a resilience approach of urban planning. Linkages between urbanization and disaster are weakly theorized, and disaster mitigation is rarely integrated into urban development policy (Pelling, 2003). Effective urban planning and management, optimizing urban activities and services with regard to reducing city vulnerability to disaster, do not exist. Therefore, effective coastal management requires a resilience approach that integrates sectional disaster mitigation measures into spatial planning.

Recognizing the increasing vulnerability of coastal urban system to natural disaster may lead to the provision of modern disaster risk management in terms of structural measures. However, some structural measures to mitigate disaster risks might be not cost-effective in some extent, especially for developing countries (IPCC, 2007). Moreover, vulnerable cities may be disadvantageous if there is no adequate urban intervention available to them. For example, US National Institute of Building Sciences has consolidated the number of disaster losses and found that "Approximately 90% of disaster-related expenditures currently go towards relief and reconstruction, whereas for each one dollar invested in prevention, four dollars can be saved in disaster response costs", cited in World Economic Forum (2008). In contrast, increased investments in soft urban planning techniques, relying on the idea of urban resilience, can considerably reduce financial burdens in a disaster recovery process. This study, therefore, aims to apply resilience and urban risk management to the urban planning science. Based on the assumption that the resilience approach can alter the idea of urban planning and prepare our cities for confronting with disaster risks, this study aims at bringing forward urban planning guidance in the face of disaster.

1.2 Options for framing a research problem

To frame the research problem, the study adapted an idea of program framing from a seminar on methodology and research that was conducted by Jan HG Klabbers (Nuoro, September 5, 2014). According to this seminar, there were four main options for problem framing:

(1) Management science approach

(2) Behavioral & social science approach

(3) Systems science approach

(4) Political science approach

Each of these urban management approaches gives different meaning to the idea of resilience (Jan HG Klabbers). Among the four options, the study will focus on two options: 1) behavioral & social sciences approach and 2) systems science approach.

Behavioral & social sciences approach: the study focuses on the interactions between individuals and groups of decision-makers/policy-makers. This option can be used to explain effectiveness of policy implementation. Some risk management policies, even they are well constructed to solve the real-life problems, may not be successfully implemented. There are a series of possible reasons for such failures:

(1) How well do various policies convey (disseminate) risk information to the general public, and to the particular groups of people suffering from a disaster?
(2) Do those policies sufficiently take into account local norms and circumstances?
(3) Are the intended policies launched and combined with core ideas about risk management policies?

This option is useful for explaining the symbolic meaning of norms and risk awareness that influence people and society to behave differently. The greater or lesser differences of the way people think, act, and interact can lead to both social and physical vulnerabilities to man-made and natural disasters.

As a result, the study highlights the importance of social learning and interactivity for coping with risks and disasters. The objective of elaborating the behavioral and social sciences (political) approach is to find clues for enhancing social resilience.

System sciences approach: The above problems of interactions between individuals and groups of decision-makers/policy-makers can also be identified through a system science approach. When we consider human settlements as open pluralistic systems, the needs of people and their capabilities to handle risk will vary. A specific policy/plan might not be suitable for all people. Alternative policies and risk communication techniques are needed in order to improve risk perception and raise risk awareness.

The processes of cultivating risk awareness and perception are time consuming. Alternatively, risk behavior of individuals and groups can be influenced by policy background, policy formulation, and policy implementation (the rule of law, procedures, and regulation). In this context, the norm of policy-makers, decision-makers, and regulators shall consists of a great degree of risk awareness. The transformability of existing urban spaces that can provide dual functions in regular daily life and in emergency situations is regarded as a window of opportunity for the residents, enabling or hampering them to adapt those spaces to new conditions of life and work. For example, when disasters hit, public spaces can be turned into evacuation camps (shelter-in-place), safe places for the evacuated people, assembling point (landmarks for escaping disaster), and so on. This viewpoint is based upon the assumption that disaster risk assessment and the response to it are manageable through transforming physical spaces and increasing the robustness of physical infrastructure. Such robustness leads to the increase of physical vulnerability, while the transformation of urban spaces can result in the evolving physical resilience.

1.3 Research Goals and Objectives

The fundamental goal of this research is to introduce a resilience concept and its basic premise in terms of theoretical and practical approaches to urban planning by integrating it with disaster risk management. Therefore, this study further develops and applies the resilience approach to urban disaster risk management. The ultimate goal is to propose a master plan as well as some urban intervention case studies that aim to enhance the resilience of cities, while coping with natural disasters. In order to achieve the research goals, first the current conditions of urban vulnerability to natural disasters are examined, followed by the identification of urban resilience. The gathered knowledge and understanding will be used to propose a resilient master plan. Obviously, the research objectives will include the identification of crucial factors influencing disaster vulnerability, taking into account approaches that enhance resilience. Consequently, this study comprises the following research objectives.

1. To conceptualize urban resilience in relation to urban planning and risk management and find a way to put this approach into practical application
2. To assess, through case studies, tsunami vulnerability of coastal urban systems
3. To explore/identify/investigate urban resilience to tsunami through case studies
4. To propose a conceptual master plan that can turn vulnerable cities into tsunami-resilient cities, and illustrate how to apply that participative/interactive plan[1]by proposing urban intervention projects through the case studies

1.4 A study model

With regard to the shift of human cognition towards social-natural relations shown in Table 1-1, the study focuses on how constructed society and cities within the built environment can interact with environmental risks in a more resilient way. Society in this case refers to the coastal urban environment where people live, whereas tsunami is considered as an environmental risk to that inhabited area. The vulnerability of coastal urban fabrics with respect to tsunami risks manifests itself through the impact of those disasters. On the other hand, the resilience of coastal cities can be determined by how well they can cope with, adapt to, and recover from disastrous events if a tsunami occurs. The study focuses on

[1]Participative /interactive planning provides a suitable framework for social learning.

how to alter, change, and transform vulnerable characteristics of cities to make them more resilient to tsunami. Disaster impacts to an urbanized tsunami-prone area are being reviewed, and its way of recovery from catastrophe will be clarified.

As a result, a study model that addresses the above research questions is constructed. This model will draw up guidelines for carrying out the research. It begins with assessing the vulnerability of urban systems that are exposed to tsunami risks. Then it describes crucial characteristics of resilient urban systems. Through case studies, the study will subsequently investigate the resilience of cities that have suffered from a tsunami.

Taking into account qualitative and quantitative research methodologies, the study applies descriptive and inferential statistics through utilizing a variety of research tools such as, a questionnaire survey, an observation survey and an in-depth interview. In addition, primary and secondary data are gathered that further support research outcomes.

Keeping in mind the ultimate goal of this study, all materials will be used as input for a master plan that provides guidelines for dealing with tsunami, and aims at enhancing the resilience of the cities involved.

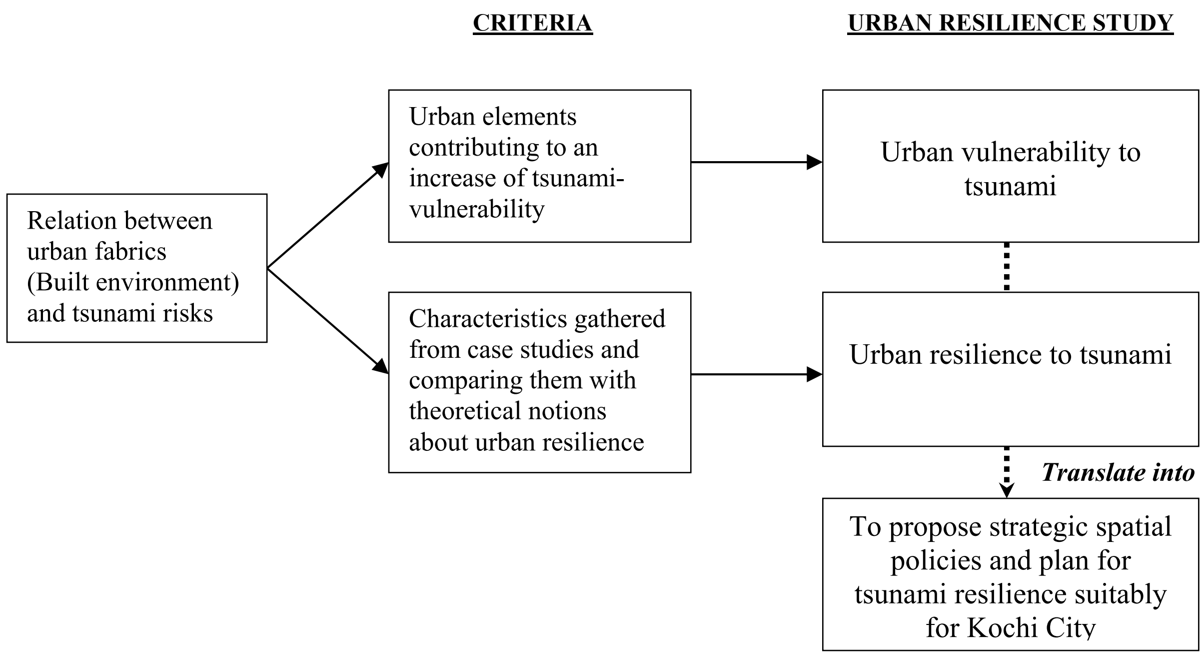


Figure 1-1: A study model for building coastal resilience to tsunami

Source: By author

1.5 A selection of case studies: Kochi City and Phuket

Regarding an urban settlement that is located in the most disaster-vulnerable area, cities in the coastal zone are considered as potential cases studies. In this zone, cities could be affected by a variety of natural disasters, such as the sea level rise, tropical cyclones, flooding, and tsunami. Among those disasters, a risk of tsunami is taken into account, because it could cause a lot of damage and destruction in its wake. Among coastal cities at risk of tsunami around the global, two Asian cities are taken as case studies: Phuket Island – Thailand, and Kochi City - Japan.

Those two cases are differentiated by the topics of study. Based on preliminary research questions, a case study in Phuket is a preliminary case study on descriptive urban resilience in a disaster recovery aspect. This can deepen understanding of resilience to tsunami as well as to re-conceptualize how a vulnerable urban system could recover from impacts of the 2004 tsunami and become more resilient. In the context of Kochi case study, the city had even experienced tsunami, and it will face the future tsunamis caused by a great Nankai earthquake every 100-year.

Hence, the case study of Kochi City is considered to be studied in a disaster preparedness aspect before the coming tsunami hits the city, and a holistic research framework of urban resilience is involved in this case study.

Table 1-3: Themes of the study varying on case studies

Theme\ Case study	**Phuket Island, Thailand**	**Kochi City, Japan**
Study timeframe regarding a disaster cycle	After tsunami in 2004 (the first-recorded tsunami of Thailand)	Before the Tsunami (caused by great 100-year Nankai earthquake)
Theme of the study	Describe the disaster resilience in terms of urban planning and find a way to put this concept into practical application	- Existing risk and the city Urban development strategy - Indicators of being resilient that can improve urban planning
Expected results	Characteristics of resilient city	A proposal of a master plan, land use ordinances and the associated land use policy

Source: By author

Other reasons behind the case selection for case-study analysis are involved with city location, city size, and the economy. The selection of case studies is further described in the following section.

1.5.1 Phuket Island, Thailand

Thailand is one of seven Asia nations having largest urban population in the Low Elevation Coastal Zone (LECZ) (McGranahan, Balk, & Anders, 2007). Amongst the major cities located in LECZ, Phuket Island - the biggest island of Thailand established as a province - is more vulnerable to disasters because more than half of the city areas, occupied by 43.7 % of 0.261 million people, are located in tsunami prone areas. The urban population density in Phuket is comparable (1,626 persons per square kilometer) to the average density of the coastal zone globally (1,119 persons per square kilometer) (Table 1-2). However, Phuket has more dense rural areas than the global average. As a result, the overall and rural population densities of Phuket are three times greater than that of the coastal zone globally. Besides the instability of the urban settlement pattern - many of urban activities heavily rely on tourism, such as hotels and restaurants. This economic activity is considered as a basic economic sector of Phuket, which has significant implications for the coastal urban system stability, and economic vitality.

An urban system is centered in urban areas where primarily sites of production and consumption activities are present (Agardy, et al., 2005; Lin, 1996). Theoretical and conceptual meaning of urban systems is mainly addressed only in terms of either ecological or economic system interacting with physical locations. In fact, the urban system has both social and biophysical dimensions, "ecosystems are understood to be biophysical systems, and the value of ecosystem services is assumed to be distinct from the value intentionally added through the application of human labor" (McGranahan, et al., 2005). It can be regarded as a closely interlinked system between ecological and socio-economic systems. The operation of the urban system of Phuket depends on tourism-based economy, the natural resources, and other infrastructure that support tourist activities. When the basic economic sector of the city collapsed, other non-basic economic activities will get affected by the changed condition; in the worst case, all of urban activities will be frozen. Bogunovich (2009) stated that "traditional urban infrastructure makes most of the city functions highly dependent on a regular supply of key resources, and a state of such high dependency is by definition a state of low resilience".

The tsunami striking the Indian Ocean in 2004 was considered to be the worst large-scale catastrophe in the millennium. Thailand was among the most severely hit and affected countries were, and one of the most serious cases appeared in Phuket island, where thousands of local residents and domestic and international tourists were affected. With a comparison of satellite images acquired before and after 2004 tsunami, the hit of tsunami on Phuket's coast could be identified on December 26, 2004. Figure 1-2B is a satellite image shows a 25 km long stretch of coast north of the Phuket airport on December 31, 2004, along with an image acquired two years earlier (Figure 1-2A), and Figure 1C was simulated to highlight the affected areas. 5,395 persons from 36 countries were confirmed dead (60% of them were tourists), another 4,600 were officially classified as missing or unidentified (BBC News, 2005; Thai Red Cross, 2005; World Tourism Organization, 2005). Community, social, and personal services were unable to run their old means. A figure of employment had been immediately dropped for three months after the ghastly incident - about 20,000 positions (Kritiamphun, 2005).

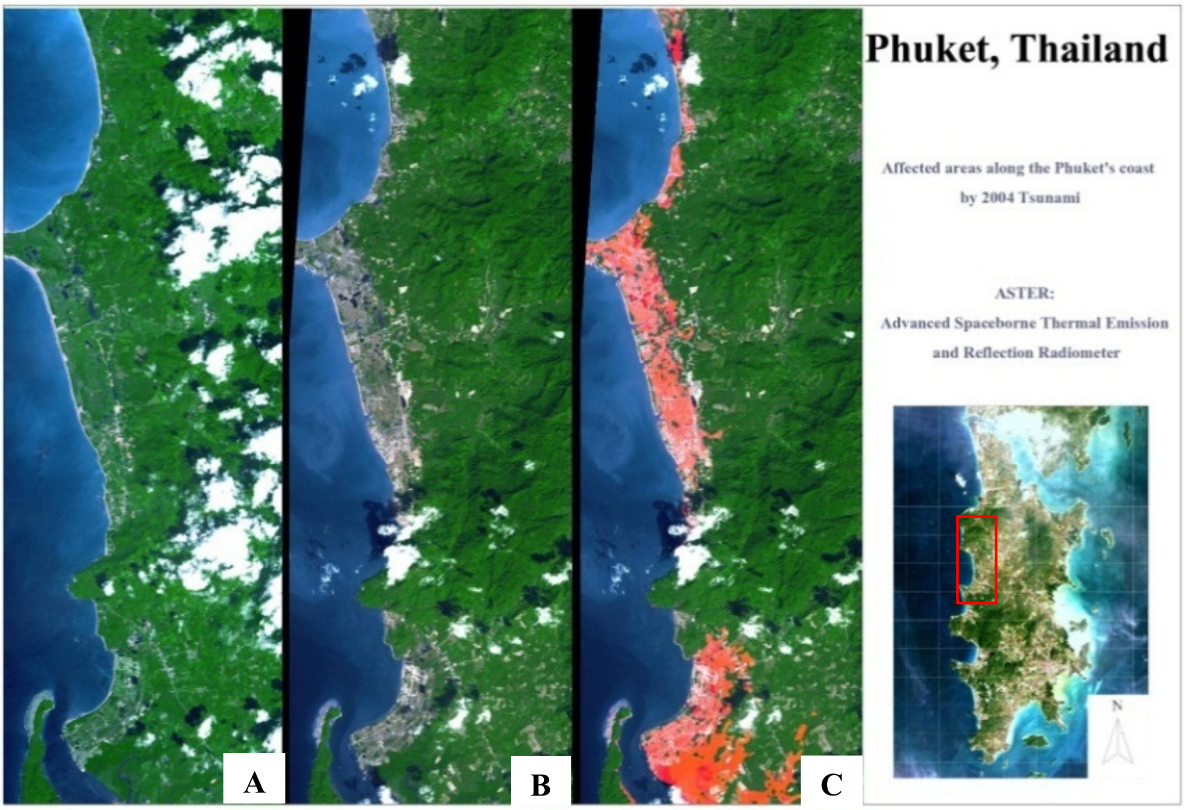


Figure 1-2: 2004 Tsunami Affected Areas

Note: 1A= an image acquired on November 15, 2002, 1B= an imageacquired on December 31,2004, and 1C= Affected areas
Source: NASA,GSFC,METI,Japan Space Systems, Jet Propulsion Laboratory, retrieved on March 2012 from: http://asterweb.jpl.nasa.gov/gallery-detail.asp?name=Phuket

Even though Phuket had recovered from the disaster, another urban problem was raised as tourists were back to the region and extensively exploited the urban resources, utilities, and facilities during their journeys. Regarding the coastal tourism industry, it is viewed as the world's largest industries that are interrelated with all sectors of urban system: natural environment, built environment and socio-economic environment. The interrelated system brings an interaction among tourists, urban activities, and resources, which generates economic benefits and creating employment. On the other hand, a transformation of tourism - without regarding to existing urban capacities - heavily affects degradations of the coastal physical environment, loss of social, cultural identity, and an emergence of dependent market economies on the tourism sector. Nevertheless, a downward tourism can potentially lead to the economic recession and social tension. The influence of tourist landscapes along well-known Andaman seacoasts is still problematic. Alternatively, a holistic approach of urban system, sustainable tourism development, and a concept of tourism carrying capacity assessment are adopted in order to shed some light on future ecotourism that can minimize tourism-induced problems and maximize the positive benefits of tourism as well as ensuring both the sustainability of the tourism industry and urban development.

1.5.2 Kochi City, Japan

Japan is regarded as a well-known country among Asian countries in terms of national development, economic prosperity, and disaster risk management. Located in the Pacific Ring of Fire, Japan is seen as a country of earthquakes. Around 23 percent of world earthquakes of magnitude over six occur in Japan (Figure 1-3). Nevertheless, the damages resulted from inland earthquakes is not comparable with the devastative impacts of tsunami earthquakes, such as Tohoku (Sendai) earthquake and tsunami in 2011. This magnitude 8.9 offshore quake was followed by aftershocks, most of them are more than magnitude 6 (AP 3news, 2011). Hundred thousands of people were affected, and at least 1,600 people were dead, while 10,000 were missing (Branigan, 2001).

Even for a country that used to earthquakes, this quake of 2011 was one of the largest tremors to hit one of the largest tremors to hit Japan in its 140 history, and the fifth horrific quake in the world since the record-keeping began in 1980 (AP 3news, 2011). It either destroyed or badly damaged more than 20,000 buildings nationwide, Nearly 600,000 people had evacuated to either evacuation camps or their relative homes (Branigan, 2001).

In case of Kochi City, it is expected that "Nankai Earthquake", a large earthquake with its consequent tsunami, will strike the city every 100-150 years. The latest occurrence was on December 21st, 1946 named "'Showa-Era Nankai Earthquake". This earthquake was of magnitude 8.0, which had an epicenter at 50 kilometers off the coast of Cape Shiono in

Wakayama. It generated 4-6 meter tsunami waves that penetrated Kochi's coastal areas and far inland, ripping 4,846 buildings off their foundations for several blocks. 679 people were killed or missing, and 1,836 were injured (Kochi International Association, 2008).

Kochi is still at high risk because there is a 40 % chance that Nankai earthquake will occur within the next three decades, according to the interview with Hiroshi Takagi, a coastal engineer, Associate Professor at the Tokyo Institute of Technology (Solomon, 2012).

Nowadays, the population of Kochi City is over a quarter of million, which means the potential tsunami-affected victims are likely to be more than the former tsunami of 1946. In addition, the new urban development is concentrated in flat land and river delta areas, which are only a few meters above main sea level. Future earthquakes with its accompanying 4-6 tsunami waves can potentially cause larger tremors than the previous ones. This implies that a great disaster impacts is left to be released.

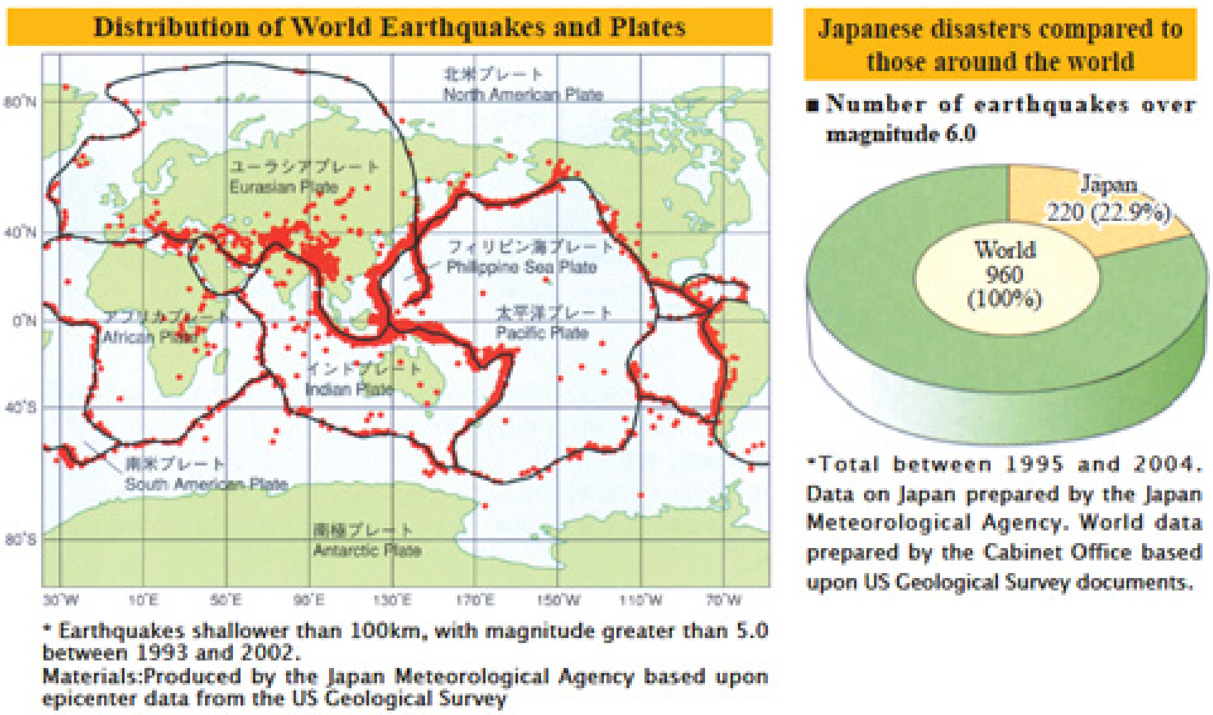


Figure 1-3: Earthquakes in Japan compared to around the world

Source: Kochi International Association (2008)

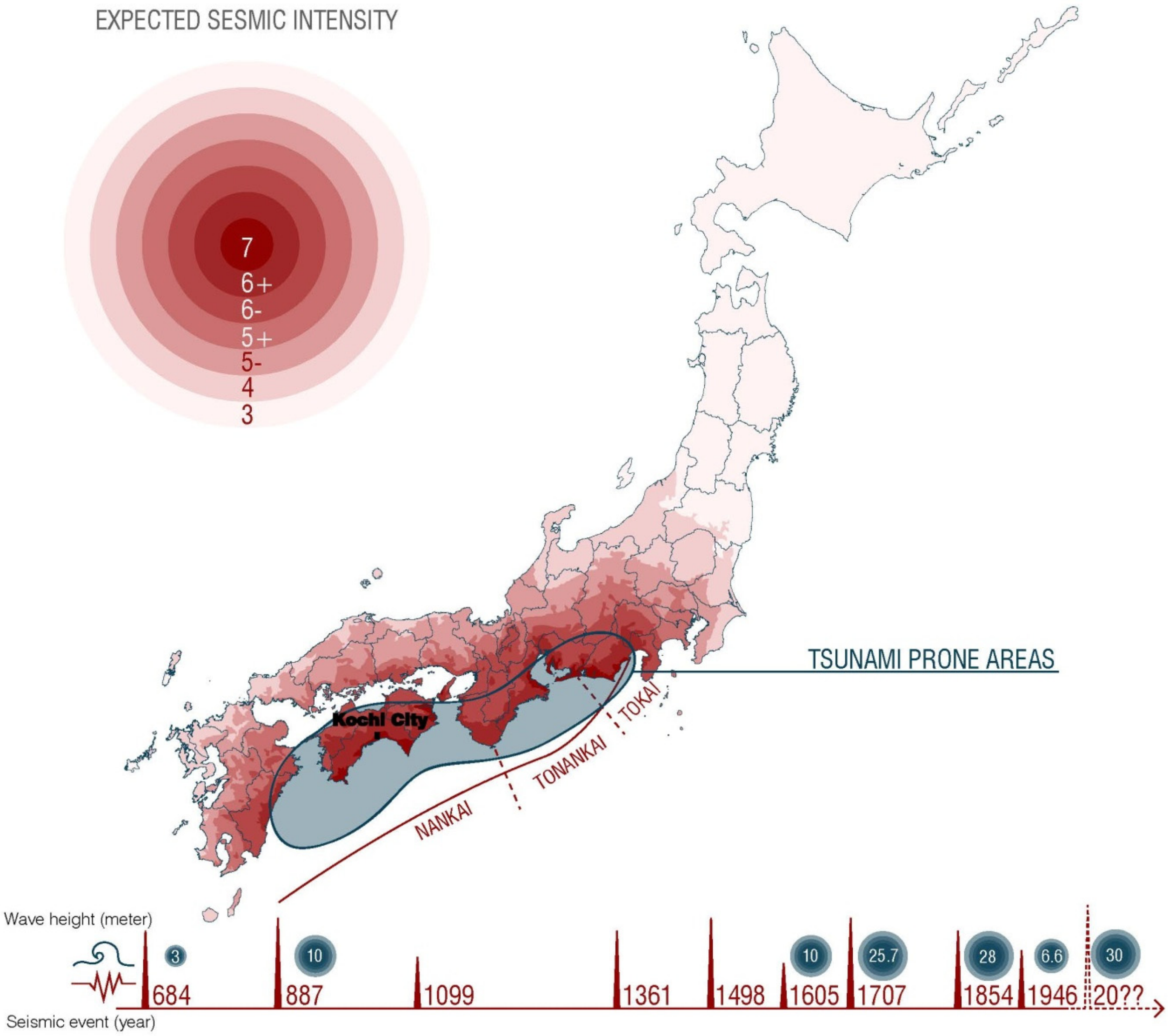


Figure 1-4: The historical record of the Nankai Earthquakes*

Note: *known as the Nakai trough

Source: Data from Solomon (2012) and Kochi International Association (2008), Designed by A. Camoglio

1.6 Research Scope and Limitations

The study aims to illustrate how the theoretical plausibility of resilience can be translated into practice. A construction of the study model leads to the identification of research design and methodology. For this study, it follows principles of an iterative mixed methods study to broaden the concept of resilience from ecological disciplines into a wider interdisciplinary research on one hand, and to deepen the understanding of disaster resilience in contexts of the urban complexity on the other. Even though this interdisciplinary approach can help the study in deliberating significant relevant issues, the study does not intend to cover all aspects and integrate those aspects into a single research. Instead of pretending to be comprehensive, the study considers only crucial matters that influence spatial planning for tsunami resilience. Therefore, some residual issues may not be addressed elaborately. For instance, the business continuity of urban commercial activities and disaster resilience in terms of transportation facilities may not be an integral part of the study. Considering the timeframe of three-year research, the study focuses more on integrating tsunami risk management in spatial policies and land use planning that can insure the lives of residents and their settlements against natural calamities (tsunami).

Common used terms

Tsunami can be described as "a series of travelling waves in the water produced by the displacement of the sea floor associated with submarine earthquakes, volcanic eruptions, or landslides" (National Oceanic and Atmospheric Administration, 2013) cited in (Dávila, Ayala, Salazar, & Ruiz-Vélez, 2014).

Chapter 2 :
Disaster Vulnerability and Resilience of the City

In this chapter, resilience and its relevant concepts that constituted a common ground of the research objectives and the study model at the beginning state are discussed, so as to shed the light on how the term "resilience" has developed, and how resilience and vulnerability are addressed in this research. Ideas and positions regarding the disaster resilience are being focused, and possible indicators and characteristics of disaster-resilient cities/communities are being identified in order to put theory into practice. In addition, the path traced in the latter helps in constructing a research framework, and determining a certain extent of the research development and aspects that should be focused upon. Through reviewing the literature on disaster resilience, crucial indicators influencing on the urban resilience are used to explain situations of a preliminary case study in Phuket Island, which will be discussed in details in the next chapter.

2.1 Urban resilience principles and systems approach

Residents in every city have always depended on the urban services provided by urban production and consumption. The composition of urban resources and the articulation of its inputs and outputs are all results of its system. The urban system may be defined as any network of interdependent functions within its spaces. Urban system approach can be a key organizing fundamental framework to understand cities better (Berry, 1964; Wyly, 2012). This leads to the development of various conceptual ideas in urban planning and management.

With an urban system approach, cities can be studied through various disciplines at a variety of hierarchical levels, structures, functions, and dynamics. For example, the urban system in the eyes of ecologist and socialist is an integration of a trinity comprising of (a) the natural environment, (b) the built environment and (c) the socio-economic environment, whereas planners and decision-makers see it slightly different. Upon a viewpoint of an urban planner and policy maker, one of regular methods for the urban system study is to apply a sectional analysis approach, which is used to examine the city performance based on three systems based on three sectional systems of provision: infrastructure, institutions, and knowledge networks. Through this approach, a city is viewed as a central metaphor of a complex metabolism network, rather than its density. This concept makes an urban system not only a set of geographical parts, but also a set of interdependent and interconnected urban places. As a result, the interconnection of various parts makes urban systems analogous to a 'set' in mathematics, where changes in one activity will have consequences for other activities in the system. On the other hand, any significant change in one city may also cause an influence on other cities.

Berry (1964) proposed an article titled "Cities as Systems within Systems of Cities", which emphasized on how a city works. Based on his argument, any scientific research logically comprised of two district approaches: "(a) simple inductive generalizations drawn from observable facts about the world, and (b) abstract logical constructs". In general, the deduction drawn from the logical construct intended to test that the theoretical reliability, whilst the inductive approach was more concerned with the generation of valid scientific theory emerging from the fact and phenomena. Due to the fact that at that time an innovative computing technology was used in facilitating the large-scale studies for urbanists and making a possibility to integrate the logical constructs with the inductive generalizations, Berry was able to construct symbolic models that provided idealized representation of his scientific point related to how cities and sets of cities can be perceived as spatial systems. He invented a variety of formulas based on inductive generalizations in search of a theory. For example, a formula of the distribution of city sizes is based on a premise that "cities are the rank-size relationship for sets of cites, and the inverse-distance relationship for population densities within cities (Berry B. , 1964)". Nevertheless, he emphasized that there is regularity among spatial variations, but the spatial variations are specific to each case. In order to analyze urban systems, inductive generalizations shall be drawn from both the facts and logical constructs, and the relevant approaches for the analysis shall be specified as the third dimension of segregation.

Based on, for example, an ecological approach, structures of an urban system can be studied through a formalized method determining the role and rule of components within overall interactive operation of dependent environmental services (Exline, Peters and Larkin; 1982 cited in Marcotullion and Boyle, 2003). These services process as systems that are imposed by organizational hierarchies; each small system is a single mechanism for the higher level of hierarchy (Lin, 1996). Urban systems, therefore, exist at several scales; those systems can be identified as either individual urban settlements or as networks of urban centers connected by flows of capital resource, commodities, human activities and consequences of activities (McGranahan, et al., Urban Systems, 2005; Armstong & McGee, 1985). The system sciences approach changes the ways in which planners address urban environmental problems from a design based solution to an aspect of urban management. This aspect of urban management aims to bring functions of each part of the entire system under control and to enhance adaptive capacity of the entire system for coping with any risky perturbations.

The efforts of urban planning and management have been trying to manage and zone our cities in such a way that allows a reasonable degree of density, public transport, and facility provision in order to put cities to the areas that optimize economic value, preserve social contexts, and lower environmental cost. However, there is some question as to whether the design, plans, and technological solutions added to the urban systems will enable sustainable settlements and turn them to be more resilient to natural disasters or not. This considerable curiosity has been paid to a coastal zone where it is perceived as a downstream recipient of negative impacts of land use that is unprotected or marginally protected (Agardy, et al., 2005). With the devastating impact of tsunami, the coastal cities face with a deeper and prolonged crisis than inland cities do. Therefore, building resilience of the urban communities to this disaster is a foremost priority.

2.2 Vulnerability to disaster

The definition of "vulnerability" is the state of susceptibility to damage from both exposure to stresses associated with environmental and social change, and the inability to adapt or cope with unforeseen circumstances or emergency events (W. Neil, 2006). For instance, the financial vulnerability to flood risk can be determined by the inability of flood-affected households to maintain the old means of their livelihood or even smooth their consumption through saving and borrowings, despite income fluctuation seems to be a crucial root of the problem that is threatening vulnerable household, especially for low-income households.

2.2.1 Definitions of Disaster Vulnerability

With the attempt to define the meaning of vulnerability and risk, a variety of possible definitions is revealed. The variety of this terminology varies considerably in terms of objectives and its main focus of assessment (for example, Bohle, 2001; Cannon T. , 2008; Cannon, Twigg, & Rowell, 2005; IPCC, 2007; Pelling, 2003). Viewing vulnerabity through multifaceted nature brings about different definitions and approaches leading to an unclear situation what vulnerability stands for (Bogardi & Birkmann, 2004). Moreover, it becomes paradoxical when there are attempts to to measure vulnerabilty, even though it cannot be defined precisely. As a result, there is no consensus on how to measure the complex vulnerability. Nevertheless, methods usually involve the relation between vulnerability and its components that later on formulate models. Those models remarkably connect the vulnerability with risk and hazard by considering risk as a dynamic spatial-temporal process, which caused by the interaction between hazard and vulnerability (Equation 2-1). In this equation, vulnerability can be further amplified by using the Federal Emergency Management Agency (FEMA) as shown in Equation 2-2.

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability}$$

Risk	= A dynamic spatial-temporal processof the probability of an event and its negative consequences. This term has two distinctive connotations: 1) it is related to a concept of chance or possibility, and 2) it is accounted by potential losses for some particular cause, place, and period(UNISDR, 2007).
Hazard	= A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage(UN/ISDR, 2009).
Vulnerability	= Elements at risk that are capable of being physically, socially, or emotionally wounded (adopted from Merrian-Webster online encyclopedia)

Equation 2-1: Common interrelations among risk, hazard, and vulnerability

$$\text{Vulnerbility} = \frac{\text{Exposure } \times \text{Sensitivity (Susceptibility)}}{\text{Capacity}}$$

Exposure	= The amount of assets in tsunami-prone areas
Sensitivity	= The relative proportion of assets in tsunami-prone areas (relative impact)
Capacity	= How well a community can withstand, adapt, recover from the losses associated with the onslaught of a tsunami (capacity may be measured as the community's resilience)

Equation 2-2: Tsunami-vulnerability and its components

Source: FEMA (Federal Emergency Management Agency)

The above equation is extensively used to explain the susceptibility of people, community units, and systems that can potentially be damaged, as a result of a hazardous event, in terms of physical, social, economic, and cultural elements. While risk, in this equation, is considered as a dynamic process that can be changed upon the time and varied by the geography of territories, vulnerability can, therefore, be viewed as an intrinsic predisposition to be affected by or to be susceptible to damage (Cardona, 2004 cited in Birkmann, 2006). This viewpoint on the vulnerability also helps to clarify the concept of hazard and disaster, because it seeks the correlation between the root causes of their vulnerability to hazards, the risk people face, and the possible impacts of risk that are later on perceived as disasters.

In order to understand disaster risk management, it is important to understand definitions of vulnerability. One of the well-known definitions is provided by UN/ISDR(2009) where it defines vulnerability as “the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. Vogel and O’Brien(2004) emphasize that the nature of vulnerability is usually 1) multi-dimensional, 2) scale dependent (in accordance with time, space, and the analysis), and 3) dynamic (changeable over time). Since the concept of vulnerability can be viewed through multi-dimensional aspects, the boundary of this concept has been broadened. Birkmann (2005) provides an overview of key spheres of the vulnerability concept, without aiming to be comprehensive (Figure 2-1).As the term vulnerability is broadened, its basis is still incorporated the same essential concepts: exposure, susceptibility, and adaptability. The mere difference is how to specify exposure units or elements at risk (Berry, Rounsevell, Harrison, & Audsley, 2006)

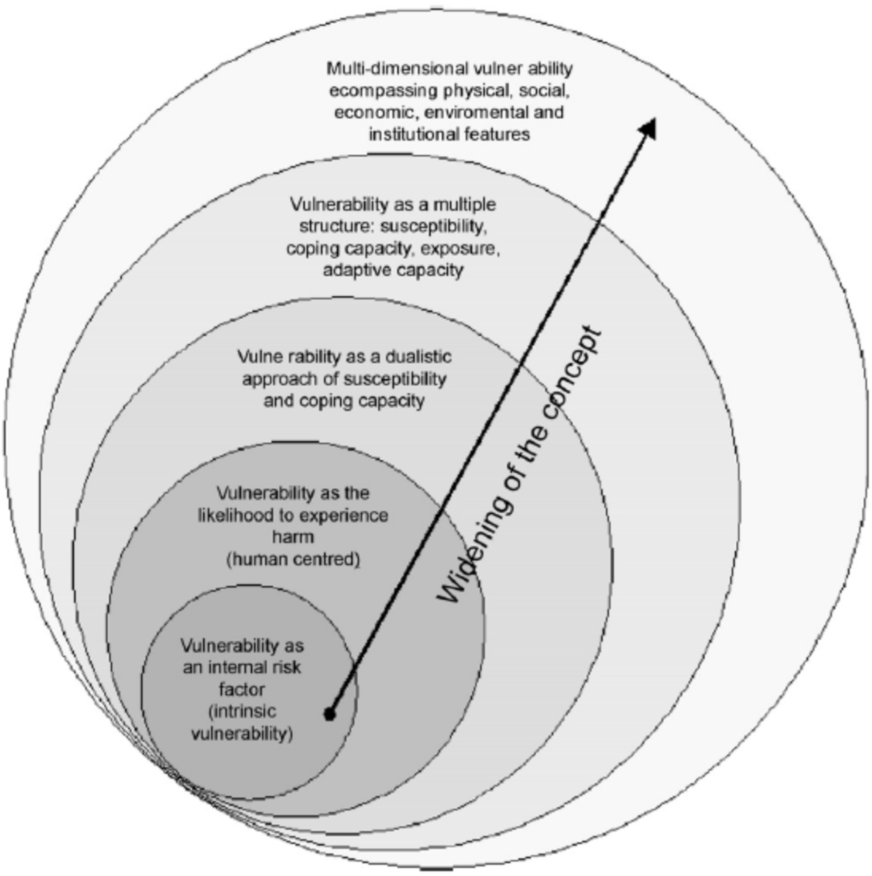


Figure 2-1: Key spheres of the concept of vulnerability

Source: Birkmann, 2005

2.2.2 Disaster Vulnerability of a City and Its Components

The different aspects of vulnerability have important implications on how city vulnerability is viewed in respect to the vulnerability of its residents. In this study, it is assumed that the vulnerability of urban fabrics can be considered in terms of land activitiesm characteristics of people, and social units dominating the urban society. Land use planning presents a possibility to mitigate disaster risk and to increase the adaptive capacity to cope with disaster impacts through promoting resilient land use and urban development. Nevertheless, a resilient land use planning practice would require understanding of exposure elements that shape disaster vulnerability as well as ways to integrate resilient development into land use planning processes. Resilient land use planning integrated with vulnerability alleviation will play a major role as pro-active risk management through physical and/or territorial-based approaches in forms of comprehensive master plans, land use ordinances, infrastructure planning, and building regulations. If land use planning is formulated with the consideration of disaster risk- implemented in accordance with the local social context and monitored by the support of public risk awareness - it has the potential to initially reduce risk and eventually enhance urban resilience.

In the guidance of land use vulnerability to flood risk, SEPA (2012) proposed that it is possible to define land use vulnerability through considering flooding impacts on different land use in terms of their relative susceptibility, resilience to flooding, and any wider community impacts caused by their damage or loss. Moreover, it gives useful advisory comment to other disaster risk assessment related to land allocations. Since it explains how a change of land use may increase vulnerability to disaster through imposing greater impacts comparing to previous use. By adapting data from Defra/Environmental Agency Research on Flood Risks to People and Policy Statement 25 [1], a classification of land use vulnerability was produced by highlighting certain types of development and land use that are likely to have more impacts to a city when a disaster occurs.

[1] Planning Policy Statement 25 is included as Technical Guidance to National Planning Policy Framework, Communities and Local Government, March 2012 (SEPA, 2012).

Table 2-1: SEPA Land Use Vulnerability Classification

Vulnerability level	Types of facilities and utilities
Most Vulnerable Uses	– Police stations, Ambulance stations and Fire stations and Command Centres and telecommunications installations required to be operational during flooding – Emergency dispersal points – Hospitals – Isolated dwelling houses in sparsely populated locations. – Dwelling houses situated behind informal embankments* – Residential institutions such as residential care homes/prisons Nurseries, children’s homes and educational establishments – Caravans, mobile homes and park homes intended for permanent residential use – Sites used for holiday or short-let caravans and camping – Installations requiring hazardous substance consent. (Where there is demonstrable need to locate such installation for bulk storage of materials with port or other similar facilities, or with energy infrastructure, that require a coastal or water-side location, or other high flood risk areas, then the facilities should be classified as “essential infrastructure”.)
Highly Vulnerable Uses	– Buildings used for dwelling houses. – Social services homes (ambulant/adult) and hostels; student halls of residence; and hotels. Non-residential uses for health service.
Less Vulnerable Uses	– Buildings used for: shops; financial, professional and other services; restaurants and cafes; hot food takeaways; drinking establishments; nightclubs; offices; general industry; storage and distribution; non-residential institutions not included in “most and highly vulnerable classes”; and assembly and leisure. – Land and buildings used for agriculture and forestry which are subject to planning control. Waste treatment (except landfill and hazardous waste facilities) – Minerals working and processing (except for sand and gravel working).
Essential infrastructure	– Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk. – Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity

Source: (SEPA, 2012)

Table 2-2: Matrix of Flood Risk - SPP Flood Risk Framework and land Use Vulnerability Classification

Flood Risk	Most Vulnerable Uses	Highly Vulnerable Uses	Less Vulnerable Uses	Essential Infrastructure
Little to No risk (>0.1%AP)	No constraints	No constraints	No constraints	No constraints
Low to Medium risk (0.1%-0.5%AP)	Generally not suitable For essential civil infrastructure. For other uses, FRA maybe required at upper end of probability/or where development or local circumstances indicate heightened risk	FRA maybe required at upper end of the probability or where the development or local circumstances indicate heightened risk.	Maybe suitable for the land development	FRA maybe required at the upper end of the probability or where the development or local circumstances indicate heightened risk.
Medium to High risk within built up area (>0.5%AP)	Generally not suitable For development unless subject to appropriate long term flood risk management strategy. Land raising maybe acceptable.	Provided flood prevention measures to appropriate standard exist or are planned, maybe suitable for residential/institutional uses. Land raising maybe acceptable. .		Generally not suitable for Ground based electrical and telecom equipment unless subject to a long-term flood risk management strategy. FRA for other utilities. Land raising maybe acceptable.
Medium to high Risk within undeveloped and sparsely developed area (>0.5%AP)	Generally not suitable for additional development.	Generally not suitable for additional development. .	Generally not suitable for additional development. Exceptions may arise for Operational reasons e.g. navigation, agriculture and transport.	Generally not suitable for ground based electrical/ telecom equipment unless subject to a long term flood Risk management strategy; some utilities infrastructure designed and constructed to remain operational during floods maybe acceptable.

Note: AP = flood annual probability

Source: (SEPA, 2012)

Assessing vulnerability, therefore, is important as it identifies the urban risk elements and classifies the areas the unit of analysis in accordance with their vulnerability level. Resilient land use planning is an integral part of the assessment, as it is a risk precautionary measure. Another extended part is a land use policy taken for mitigating vulnerability, especially in the most vulnerable areas. The land use policy is considered as the intervention of society through policy implementation.

2.2.3 Reducing vulnerability does mean enhancing resilience

A key question of this urban vulnerability study is that "can the reducing urban vulnerability contribute to the increasing resilience of communities and cities?". Previous studies provided some answers to this question and some remarks as provided below (Galderisi, Ceudech, Ferrara, & Profice, 2012):

(1) Mitigation measures - aiming to reduce one or more aspect of vulnerability - may increase other aspects of vulnerability in relation to different hazards.
(2) Mitigation measures - aiming to reduce one aspect of vulnerability - may be ineffective for enhancing resilience or even result in a decrease of the resilience.
(3) Mitigation measures - aiming to increase the resilience of the community - may relatively increase some aspects of vulnerability.

(1) **Mitigation measures limited to reducing vulnerability of specific systems or hazards**

There are some cases that the effectiveness of structural mitigation measures to reduce vulnerability can be limited to a specific hazard, which can lead to the exposure of other harmful hazards. Table 2-3 summarizes examples of hazard-oriented-mitigation measures, which can result in reducing vulnerability to one specific hazard on one hand, and increasing vulnerability to other hazards on the other hand (Galderisi, Ceudech, Ferrara, & Profice, 2012). Since none of the examples focuses on tsunami-vulnerability, the earthquake is considered as a relevant hazard to the tsunami occurrence. In the Bam earthquake (December 26th, 2003), a large number of typical constructions built by abode (sun-dried brick) were destroyed by the earthquake of 6.6 magnitude and its after-shocks of 80 magnitude. Although these kinds of materials and constructions seem to be appropriate for the climate of Southern Iran, they cannot withstand the earthquake impacts. Another example is Kobe earthquake in 1995 (January 17th). In this case, it has been reported that most traditional buildings were collapsed due to their heavy roofs. Those roofs were designed to resist typhoons by using mud and tiles. Therefore, “the large inertial loads from the heavy roofs exceeding the normal lateral-load-resisting capacity of the supporting wall” caused the severe collapse (Scawthorn & Yanev, 1995).

Table 2-3: Inconsistency of hazard-oriented mitigation measures

		Phenomena			
		Hazard mitigation		Climate adaptation	
Element	**Typology**	**Earthquakes**	**Floods**	**Typhoons/ Hurricanes**	**Heat wave/ Cold wave**
Building	Pilotis/stilts /piles	Pilotis and soft storeys to be avoided	Pilotis raise the height of the building and limit water entry in the building (UNISDR, 2004)		
	Height / number of levels	High buildings may be more vulnerable in some cases depending on the soil conditions	- High buildings with many levels allow to move valuable items out of the water (UNISDR, 2004) - Reducing the ground surface reduces flooded surface and thus drying and cleaning periods		
	Walls	- Non-homogeneous wall construction to be avoided - Rigidity of construction materials have to be homogenous on all the height of the building (to avoid the flexible level effect)	Different materials to be used (e.g. materials with low permeability up to 0.3m) (UN ISDR,2004)		
	Roof	Heavy roofs favor collapse (Coburn et al., 1993)		Heavy roofs avoid them to be blown off	
	Localization	Avoid building near a slope and on site with known site effects (Bouchut, 2006)	Better to build on high grounds; out of reach of floods	Building near a slope or a cliff can protect buildings from winds	
	Mass	Light structures are less vulnerable (Spence, 2006)	The building shouldn't be too light in order not to float and not to be too vulnerable to debris and currents	Light structures are more vulnerable to winds	Light structures reduce thermal isolation
	Mass repartition	- Mass repartition should be as homogeneous as possible - Avoid putting mass high up	Important device and installation should be put high up (MEEDDAT, 2009)		
	Shape	- AvoideT- or L-shape - Avoid elevation irregularities (Bouchut, 2006)	L-shape buildings can concentrate streams		
	Walls materials	- Structure should be tied (Coburn et al., 1993) - Bricks or concrete blocks structures are identified as the most dangerous ones and must be chained horizontally and vertically	- Drying quickly: engineering bricks, concrete blocks and gypsum plasterboards (UN ISDR, 2004) - Engineering bricks also limit water entry during flood events (UN ISDR, 2004) - Steel of reinforced structures is vulnerable to salt corrosion in case of coastal flooding	Balconies or external roofs should not be tied to the rest of the structure	Balconies or external roofs should not be tied to the rest of the structure

		Phenomena			
		Hazard mitigation		Climate adaptation	
Element	**Typology**	**Earthquakes**	**Floods**	**Typhoons/ Hurricanes**	**Heat wave/ Cold wave**
Building	Walls materials	Wood buildings are quite resistant to earthquakes	Wood structure are vulnerable to floods (ex: Sri Lanka)	Wood structures are vulnerable to strong winds (Coburn et al., 1993)	
		Adobe construction to be avoided (Coburn et al., 1993)	Adobe construction to be avoided (Coburn et al., 1993)		Adobe construction generally react well to extremes temperatures weather
	Basement	Deep foundations provide better earthquake response	Deep foundations provide better earthquake response	Basements are very resistant and constitute shelters to strong winds	Basements provide thermal isolation for extreme weather
	Openings	Better to minimize openings	Openings may be a way to let the water enter and to save the structure	Better to minimize openings in order to slow the ingress of hot gases, together with a reduction of the fire load (Pyroclastic flows)	Large openings result in less thermal isolation
Infrastructures (roads, pipelines, …)	Electric networks	Underground lines are less vulnerable (ERDF, 2008)	Underground lines are vulnerable to floods (ERDF, 2008)	Underground lines are less vulnerable to wind (ERDF, 2008)	Underground lines are more vulnerable to heat waves (ERDF, 2008)
	Bridges	Particularly vulnerable to earthquakes	Particularly vulnerable to earthquakes		
	Pipelines	Less vulnerable when built underground	Less vulnerable when built underground		
Other elements:	Slopes	Toe weight would destabilize the slope even more (wave trapping)			

Source: Galderisi, Ceudech, Ferrara, & Profice, 2012, pp. 69-70

(2) Reducing one aspect of vulnerability is ineffective for enhancing resilience

Mitigation measures aiming to reduce one aspect of vulnerability may be ineffective for enhancing resilience or even result in a decrease of the resilience. As shown in Table 2-3, some mitigation actions aimed at reducing system vulnerability may increase other aspects of vulnerability. It may, in turn, cause a decrease of resilience as a whole. For example, electric networks - installed underground - are less vulnerable to earthquakes, but they increase flood-vulnerability. It can influence negative resilience dimensions of cities and trigger chains of unexpected vulnerabilities, as a result of its inflexible networks. Hence, the complex relation between vulnerability and resilience needs to be studied.

Based on interrelations of resilience and vulnerability, the physical restoration process after natural disasters can be a good example. This process largely starts from alleviating the social vulnerability of low-income people who often settle in disaster-prone areas. One of the measures is to build more secured houses for the affected people, which may have different results in low resilient areas as it depends on reconstruction speed and capability to maintain the reconstructed structures. The reconstruction process is, domestically or internationally, operated and financed by government, NGO, and NPO, while the maintenance costs have rarely been identified in the programs.

Risk reduction programs may not always lead to an improvement of community resilience, unless the programs consider the physical vulnerability and the social condition of targeted population (Galderisi, Ceudech, Ferrara, & Profice, 2012). For example, NGO and Red Cross in Caribbean Island promoted a hurricane-mitigation program, targeting on physical vulnerability of residential buildings. This program put incentives for the structural reinforcement of the roofs. However, the reinforced roofs caused problems of everyday inconvenience and unhealthy kitchen condition as a result of lesser air ventilation. At the end, however, the Red Cross society made a decision to help people to resolve both problems (Cannon T. , 2008).

Physical measures of risk mitigation extensively promoted as part of urban resilience may not lead to resilience building, unless the measures concern on social and economic characteristics that vary across communities, cities, and countries. A typical example of these characteristics is a structural mitigation measure regarded as a decisive factor for disaster-resilient communities. Such a structural measure may force people to rely heavily on the structure, which lead to a false sense of safety and the decline of public risk awareness respectively. For example, the report of Abruzzo earthquake and Kocaeli earthquake revealed that “most of the collapsed buildings were built after 1980s, according to anti-seismic codes:

the main reason for such a failure was related to the miss-implementation of the existing building codes (Galderisi, Ceudech, Ferrara, & Profice, 2012, p. 73)". This case highlights the important of individual capacity and social learning capability that trigger desirable mitigation measures.

(3) Mitigation measures for resilience enhancement contribute to increase vulnerability

Some mitigation measures aiming to increase the resilience of the community may relatively increase some aspects of vulnerability. These measures often focus on the self-organization of communities or cities (Galderisi, Ceudech, Ferrara, & Profice, 2012). One example is mitigation or reconstruction programs based on the social cohesion, and participation and self-organization can increase physical vulnerability because the local people may not have technical knowledge to implement them. Another example is an emergency management during the earthquake. Earthquake-affected households may go back spontaneously to their damaged houses and improvise temporary shelters close to their houses without considering the possibility of collapse of these houses (Sapountzaki& Dandoulaki, 2006 cited in Galderisi, Ceudech, Ferrara, & Profice, 2012). This shows that self-organization, to some extent, does not improve the resilience: on the contrary, it increases risk conditions.

In conclusion, some actions - derived from the self-organization - may not be proper to respond to perturbations that communities and organizations face. Therefore, self-organization knowledge has to be leant and cultivated through some specific processes that highlight the significance of social learning capability. The social learning capacity shall increase risk awareness, the recognition of complex relations, and interactions among exposure elements, vulnerability, and resilience. Aiming to answer the question of "can the reducing urban vulnerability contribute to the increasing resilience of communities and cities?", the literature review imply that vulnerability mitigation measures do not always contribute to an increase of urban resilience to disasters. In order to achieve resilience through a basis of vulnerability mitigation, interaction of specific hazard-oriented exposure elements, social conditions of the locality and the social learning capacity are required. In this case, the vulnerability identification is regarded as a fundamental step to track the resilience. Without knowing the exposure elements, the resilience of communities will not be increasable.

2.3 A resilience approach to reduce disaster vulnerability of the urban system

As mentioned above, the shift of human cognition toward social-natural relations in Chapter 1 shows that the concept of disaster resilience has been proposed a couple of decades ago. There is ,however, no unique understanding of this term. Focusing on the theoretical background of the term "resilience", a concept of resilience is developed from its predecessor term "vulnerability". The term vulnerability, based on the social sciences, was proposed in order to respond to the purely hazard-oriented perception of disaster risk in 1970s (Schneiderbauer & Ehrlich, 2004). Hence, this term has increasingly been taken as a starting point for risk mitigation programs. For instance, this term is heavily promoted in "Hyogo Framework for Action 2005-2015", which stressed the need to develop indicators of vulnerability as a key activity (UNISDR: United Nations Office for Disaster Risk Reduction, 2007).

2.3.1 Vulnerability as a predecessor of Resilience (relationships between vulnerability and resilience)

Focusing on the predecessor term of resilience, vulnerability is broadly understood as the degree of or potential for loss, or as a predictive variable that can potentially be affected by external threats (Armas & Gavris, 2013; Bohle, 2001;Cutter, et al., 2008). On the other hand, vulnerability is also regarded as a state of susceptibility to be damaged both from exposure to stresses associated with environmental and social change, and from the inability to adapt or cope with unforeseen circumstances or emergency events (W. Neil, 2006). Various conceptual frameworks of vulnerability illustrate the different views of authors on how to systematize, analyze, and model it. For example, Bohle (2001) used the distinction between the exposures to external threats and the ability to cope with the threats in order to underline the double structure of vulnerability. The vulnerability in this model is the result of multiple interactions between exposure to external stressor and the ability of each social unit to respond the external stressor. On the other hand, the sustainable livelihood framework of DFID used five livelihood assets or capitals (human, natural, financial, social, and physical capital) to identify the ability to cope with and recover from shocks. However, Cannon et al.(2005) reveal that vulnerability is only partially defined by the type of hazard to imply the overall context in which an individual or a group of people experiences and responds to the negative impacts. The meaning of vulnerability, therefore, depends on how different authors use it.

In general, the conceptual framework of vulnerability is heavily based on an asset-access approach that determines the necessity of a person or social groups to cope with shocks. Nevertheless, this conceptual framework proves its weaknesses, as it partially defines a group of people or systems exposed to risk without concerning the flexibility and adaptability of those to react and respond the external stressors. Without doubt, it is necessary to underline the distinction between exposures to external threats and the adaptive capability coping with the threats. The concept of vulnerability has, therefore, been developed and brought about a concept of resilience, which does not only focus on potential impacts on a defined system, but also the coping capacities of the system under pressures from the external perturbation. Nowadays, the term "resilience" tends to gain higher recognition than "vulnerability" as it captures today's concept of disaster risk management better than its predecessor does.

2.3.2 Resilience as a developed term of vulnerability

While vulnerability can imply a state of susceptibility, which can be harmed from external stressors, resilience can be related to a state of innovative adaptability to resist and recover from those external stressors.

The term resilience was originally constructed as a concept referring to a system's capability to absorb shocks and persist in an equilibrium state that focuses on maintaining the basic function of the ecosystem. Resilience and vulnerability are, to some extent, two sides of the same coin – both are used to assess the quality of systems and determine how well the systems cope with perturbations such as disasters. Nevertheless, some scholars were misunderstood that reducing vulnerability means increasing resilience. Based on the interdisciplinary approach, resilience and vulnerability are intersected each other as they share a common ground referring to the susceptibility, but they are not overlapped with

Resilience generally refers to the adaptability and capability of the defined system that can resist and recover from changes either in terms of physical, social, or natural environment. However, when urban systems are not resilient, the status of the system does not automatically become vulnerable; its state is in a continuum between resilience and vulnerability in which this sliding state gradually changes into vulnerable. Hence, vulnerability and resilience are not a static state, but they are a dynamic process, which were misled by the measurement process.

In practice, there are a number of scholars giving a definition of the word "resilience". Its definition depends on how scholars apply the resilience concept to achieve their goals and objectives.The practical use of this concept somehow shows remarkable insight into its theoretical plausibility and the difficulties that we face in defining this term. For example, resilience in the viewpoint of Holling (1973) is "a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables". By connecting the term "resilience" to urban studies, the city resilience can be regarded as the ability of a social-ecological system, community, or society to absorb disturbances while retaining the essential structures and functions. Besides, it also includes the capacity of those affected systems or institutions to find ways of recovery from the effects of a hazard in a timely and efficient manner (UNISDR: United Nations Office for Disaster Risk Reduction, 2007; IPCC, IPCC Fourth Assessment Report: Climate Change, 2007).

The capacity to absorb disturbances makes resilience associate to the concept of robustness. The state of resilience can be defined as a state that system can still absorb perturbations before a system changes its structure by changing the variables and processes that control behavior (Holling et al., 1995 cited in Adger, 2000; Schoon, 2005). Likewise, the Intergovernmental Panel on Climate Change (IPCC, IPCC Fourth Assessment Report: Climate Change, 2007) states that a resilient recovery process might require the capacity for self-organization, and the capacity to reorganize in order to adapt to stress and change. The resilience approach identifies the resources and adaptive capacity that communities can utilize to overcome the problems that may result from changes. This adaptability builds upon the inherent capacities of communities - so-called endogenous capacities (Maguire & Cartwright, 2008). As long as the communities continue to increase their adaptability, they will be more reactive to cope with any changes, which stimulate them to create more innovative strategies to recover from the perturbations.

Similarly, a social sciences approach views that building resilience is about agency-building capacity for people to make optimal alternatives and strategies about the risks they face. Decent physical structures, spaces, and places are needed because it will help people to open up for alternatives when coping with shocks. It also may help turn the perturbation into a window of opportunity for change that later transform to a new trajectory for actions, policies, institutional regime.

Based on the views of urban planners, urban resilience to disaster mainly comprises of three adaptive capacities: 1) the stability, 2) the reactive responsibility, and 3) the innovative recoverability. The stability refers to a capability to absorb stress or destructive forces through resistance or adaptation, whereas the reactive responsibility determines a capability to manage or maintain some essential functions and structures during disastrous events. On the contrary, the term innovative recoverability is used to express complementarily a capability to recover or ‘bounce back’ quickly after disasters. To express how those three cover a great proportion of the different elements of resilience, the city state is divided into pre-, during-, and post-disaster time, and the characteristics of urban resilience can be identified by the overall state of city (Figure 2-2). However, this state based on a resilience approach may not reflect all practical situations as it merely presents the idea of reconstruction process rather than the restoration process that are more related to the theoretical resilience. The other weak points towards concepts of resilience are not represented in absolute terms, but the representation is simply compared with a status quo of the defined system’s functionality.

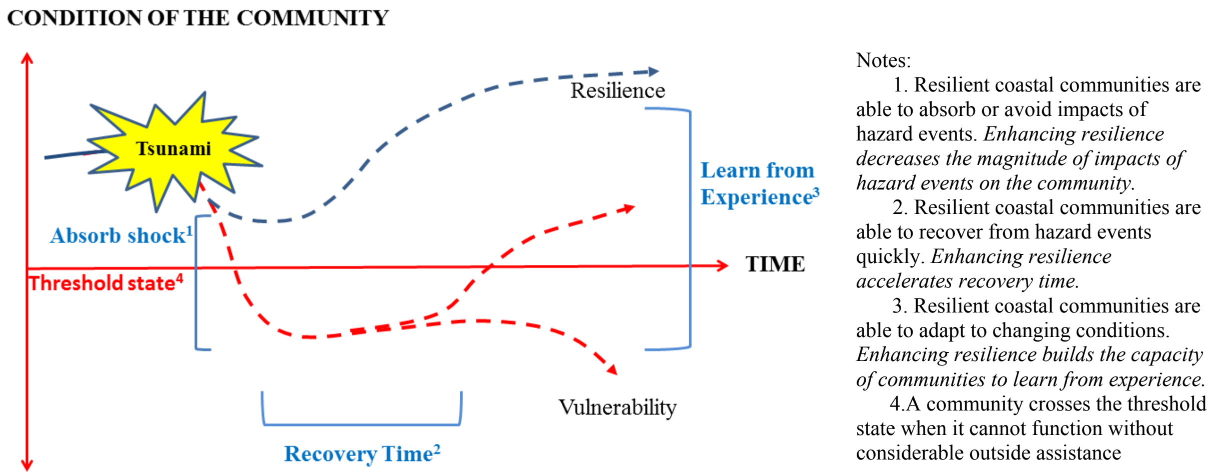


Figure 2-2: Role of Resilience in Determining Community Response to a Hazard Event

Source: USAID : the United States Agency for International Development (2007)

Figure 2-2 illustrates that the term “resilience” is closely related to the concept of vulnerability, and those two may co-exist. Besides, it also highlights that even the severity level of the disaster is not much different, but the results of disaster impact may significantly vary from one city to another. Hence, a question arisen here is “how can we define whether a defined city is being vulnerable or resilient to disaster?” In order to answer this question, It is important to understand a dynamic state of cities. In the face of disaster, vulnerability is regarded as a state of susceptibility to be damaged both from exposure to stresses associated with environmental and social change, and from the inability to adapt or cope with unforeseen circumstances or emergency events (W. Neil, 2006), while resilience refers to a state of adaptability to resist and recover from damage. However, when urban systems are not resilient, the status of the system does not automatically become vulnerable; its state is in a continuum between resilience and vulnerability in which a sliding state gradually changes into vulnerable. For the resilience approach, it includes both disaster impacts to physical elements and humanitarian activities experienced as vulnerability. In order to reach the state of resilience, Barnett (2001) adapted Wildavsky's idea (1988) and proposed six printciples of resilient systems as shown in Table 2-4.

Table 2-4: Wildavsky's principles of resilient systems

Principles	**Description**
The homeostasis	Systems are maintained by feedbacks between component parts that signal changes and can enable learning. Resilience is enhanced when feedbacks are transmitted effectively.
The omnivory	External shocks are mitigated by diversifying resource requirements and their means of delivery. Failures to source or distribute a resource can then be compensated by alternatives.
The high flux	The faster movement of resources, the more resources will be available at any given time to help cope with perturbation.
The flatness	Overly hierarchical systems are less flexible. Top-heavy systems will be less resilient.
The buffering	A system that has a capacity in excess of its needs can draw on this capacity in times of need, and so is more resilient.
The redundancy	A degree of overlapping function in a system permits the system to change by allowing vital functions to continue while formerly redundant elements take on new functions.

Source: Barnett (2001)

Nevertheless, a set of Wildavsky's principles of resilient systems is just one of many ideas that have emerged. A variety of investigations on urban resilience leads to different knowledge domains of factor contributing to the resilient state. In the view of urban communities, resilience is mainly focused on three capacities: (1) capacity to absorb stress or destructive forces through resistance or adaptation; (2) capacity to manage or maintain certain basic functions and structures during disastrous events; and (3) capacity to recover or 'bounce back' after an event (Twigg, 2007). Those three aspects cover a great proportion of the different elements of resilience. To understand how resilient city respond to natural disasters, Twigg (2009) gave a comprehensive picture of the disaster resilient community, which can be applied in the city scale, and extracted 167 resilience factors to guide data collection. The resilience based on the Hyogo Framework for Action could be covered by five thematic areas as follows; (1) governance, (2) risk assessment, (3) knowledge and education, (4) risk management and vulnerability reduction, and (5) disaster preparedness and response (Table 2-5)

Table 2-5: Characteristics of a disaster-resilient community (a shorten table)

Thematic Areas	Components for planning	Characteristics of a disaster –resilient community
Governance	- Policy, planning, priorities and political commitment	- Community takes long-term perspective; visioning a resilient community, underlying causes of vulnerability. - Local-level official understanding of, and support for community vision
	- Legal and regulatory systems	- Land-use regulations, building codes and other laws and regulations relating to Disaster Risk Reduction (DRR) enforced locally.
	- Integration with development policies and planning and Integration with emergency response and recovery	- Policy, planning and operational linkages between emergency management, DRR and development structures.
	- Institutional mechanisms, capacities and structures; allocation of responsibilities	- Human, technical, material and financial resources for DRR adequate to meet defined institutional roles and responsibilities
	- Partnerships	- Long-term civil society, NGO, private sector and community participation and inter-sectoral partnerships for DRR and emergency response.
	- Accountability and community participation	- Effective quality control or audit mechanisms for official structures, systems, etc., in place and applied - Trust within community and between community and external agencies.
Risk Assessment	- Hazards/risk data and assessment	- Hazard/risk assessments mandated in public policy, legislation, etc. - Good-quality data on hazards and risks made available to support local-level assessments.
	- Vulnerability/capacity and impact data and assessment	- Vulnerability and capacity indicators developed and systematically mapped and recorded (covering all relevant social, economic, physical and environmental, political, cultural factors). - Disaster impact data and statistical loss information available and used in community vulnerability and capacity assessments (VCAs)
	- Scientific and technical capacities and innovation	- Community members and organizations trained in hazards, risk and VCA techniques and supported to carry out assessments. - Use of indigenous knowledge and local perceptions of risk as well as other scientific knowledge, data and assessment methods.
Knowledge and Education	- Public awareness, knowledge and skills	- Community knowledge of hazards, vulnerability, risks and risk reduction actions sufficient for effective action. - Public communication programs involve dialogue with stakeholders about disaster risks and related issues
	- Information management and sharing	- Community disaster plans publicly available and widely understood.
	- Education and training	- Local schools provide education in DRR for children. - Householders and builders trained in safe construction and retrofitting techniques, and other practical steps to protect houses and property.
	- Cultures, attitudes, motivation	- Feelings of personal responsibility for preparing for disasters and reducing disaster risk. - Cultural attitudes and values enable communities to adapt to and recover from shocks and stresses.
	- Learning and research	- Encouragement of inter-disciplinary and policy-oriented research.
Risk Management and Vulnerability Reduction	- Environmental and natural resource management	- Community understanding of the potential risks associated with natural features and human interventions that affect ecosystem. - Preservation and application of indigenous knowledge and appropriate technologies relevant to environmental management.
	- Health and well being	- Physical ability to labor and good health maintained in normal times - Emergency planning systems provide buffer stocks of food, medicines, water, etc.

Thematic Areas	Components for planning	Characteristics of a disaster –resilient community
		- Community health care facilities and health workers, equipped and trained to respond to physical and mental health consequences of disasters
	- Sustainable livelihoods	- Stability in economic activity and employment levels - Adoption of hazard-resistant agricultural practices for food security. - Small enterprises have business protection and continuity/ recovery plans. - Local trade and transport links with markets for products, labor and services protected against hazards and other external shocks.
	- Social protection	- Community access to basic social services (including registration for social protection and safety net services). - Mutual assistance systems, social networks and support mechanisms that support risk reduction
	- Financial instruments	- Household and community asset bases (income, savings, convertible property) sufficiently large and diverse to support crisis coping strategies. - Costs and risks of disasters shared through collective ownership of group/ community assets. - Community access to affordable insurance
	- Physical protection; structural and technical measures	- Community decisions and planning regarding built environment take potential natural hazard risks into account. - Legal and regulatory systems protect land ownership and tenancy rights, and rights of public access.. Low/minimal level of homelessness and landlessness. - Structural mitigation measures (embankments, flood diversion channels, water harvesting tanks, etc.) and regular maintenance of hazard control structures - Security of access to public health and other emergency facilities. Safe locations were designated as evacuation places. - Compliance with international standards of building, design, planning, etc. Building codes and land use planning regulations take hazard and disaster risk into account. - ‘Hardware’ approach to disaster mitigation is accompanied by ‘software’ dimension of education, skills training, etc. - Legal, regulatory systems and economic policies recognize and respond to risks arising from patterns of population density and movement. - Resilient transport/service infrastructure and connections (roads, paths, bridges, water supplies, sanitation, power lines, communications, etc.). Locally owned or available transport sufficient for emergency needs (e.g. evacuation, supplies), at least in the event of seasonal hazards; transport repair capacity within community.
	- Planning régimes	- Land use planning regulations take hazard and disaster risk into account. Land use applications, urban and regional development plans and schemes based on hazard and risk assessment and incorporate appropriate DRR. - Effective inspection and enforcement regimes.
Disaster Preparedness and Response	- Organizational capacities and coordination	- Defined and agreed structures, roles and mandates for government and nongovernment actors in Disaster preparation (DP) and response - Emergency facilities available and managed by community - Regular training provided by/for local organizations
	- Early warning systems (EWS)	- Efficient national and regional EWS in place - Community-based and people-cantered EWS at local level - EWS based on community knowledge of relevant hazards and risks, warning signals and their meanings, and actions to be taken when warnings are issued. - Communities and other civil society stakeholders are active participants in all aspects of the development, operation, training and testing of EWS.
	- Preparedness and contingency planning	- A community contingency plan exists for all major risks through participatory methods.

Thematic Areas	Components for planning	Characteristics of a disaster –resilient community
		- Local businesses develop their own continuity and recovery plans within context of community plan.
	- Emergency resources and infrastructure	- Emergency shelters are accessible to community. - Emergency shelters for livestock. - Secure communications infrastructure and access routes for emergency services and relief workers. - Community organizations capable of managing crises and disasters, alone and/ or in partnership with other organizations. - Emergency contingency funds: These could be part of or separate from other savings and credit or micro-finance initiatives.
	- Emergency response and recovery	- Community capacity to provide effective and timely emergency response services - Response and recovery actions reach all affected members of community and prioritized according to needs - Community knowledge of how to obtain aid and other support for relief and recovery.
	- Participation, voluntarism, accountability	- Participatory mechanisms ensuring all stakeholders involved in the development of all components of disaster management planning and operations at all levels. - Local leadership of development and delivery of contingency, response, recovery plans. - Whole-community participation in development and delivery of contingency, response, recovery plans - High level of community volunteerism in all aspects of preparedness, response and recovery; representative of all sections of community. - Self-help and support groups for most vulnerable

Source: Twigg, 2009

Apart from urban resilience at the national and regional levels, community resilience is also important to be identified. Cutter and colleagues (2008) provide information on resilience indicators comprising of different aspects of resilience: ecological, social, economic, institutional, infrastructural, and competent aspects (Table 2-6). In ecologists' viewpoints, the resilient ecosystem is related to factors like biodiversity, spatiality, and carrying capacity of natural resources. Social resilience focuses more on rising public awareness and preparedness through risk communications and education, which are included in disaster management plans at three different levels of practice in sociology: micro, meso, and macro levels. In addition, social resilience can be enhanced though providing affordable and reachable insurance, and other social security instruments with respect to residents' accessibility to services. While economic resilience is typically calculated by possible loss estimation concerning on the potential disaster impacts on properties and business activities. The role of economic resilient is to mitigate monetary losses caused by disasters and their consequences as much as possible (Rose, 2006 cited in Cutter, et al., 2008). On the other hand, organizational resilience includes elements that refer to adaptive capacities of organizations, which make them operate their functions under changed conditions. The adaptive capacities are clearly intervened by dominant organizational structure, leadership, training, and experience (Tierney and Bureau, 2007 cities in Cutter, et al., 2008, p. 604). Infrastructure resilience is mainly linked to the physical systems of urban facilities and utitlities such as roads, pipelines, etc. The more critical dependent infrastucture systems, the less resilient it will be. Lastly, another form of resilience is community competence that can be measured similarly to organizational resilience; the measument focuses on how well the commuity manages their local activities to handle with disaster loss.

Table 2-6: Dimensions of resilient cities and communities

Dimensions	Candidate variables
Ecological	Wetlands acreage and loss Erosion rates percentage of impervious surface Biodiversity Coastal defense structures
Social	Demographics (age, race, class, gender, occupation) Social networks and social embededness Community values-cohesion Faith-based organizations
Economic	Employment Value of property Wealth generation Municipal finance/revenues
Institutional	Participation in hazard reduction programs (NFIP, Storm Ready) Hazard mitigation plans Emergency services Zoning and building standards Emergency response plans Interoperable communications Continuity of operations plans
Infrastructure	Lifelines and critical infrastructure Transportation network Residential housing stock and age Commercial and manufacturing establishments
Community competence	Local understanding of risk Counseling services Absence of psychopathologies (alcohol, drug, spousal abuse) Health and wellness (low rates mental illness, stress-related outcomes) Quality of life (high satisfaction)

Source: Cutter, et al., 2008

According to the aforementioned statement, thousands of scholars and philosophers have been trying to re-define the concept of resilience and invent a variety of variables to describe an ideal resilient system. This concept is re-defined to amplify the principal capability and adaptability of the system - rather than the qualitative capacity - for processing self-renewal, self-organization, and the innovative development beyond its principle from the ecological discipline. Nowadays, a resilient system is measured by its unique characteristics instead of its dynamic state during the perturbation. For example, Cutter and colleagues (2008) shed the light on resilience indicators that involves different aspects (a sectorial analysis) in the indicator development; those include ecological, social, economic, institutional, infrastructural, and competent aspects. Based on this sectorial analysis, the resilient system can systematically be surrounded by various elements and characteristics referring to, for example, the robustness, adaptability, and transformability of the defined system. Through integrating those constituents into a disaster cycle, a model of key dimensions of resilience was framed by Galderisi, Ceudech, Ferrara, & Profice(2012) (Figure 2-3).

Figure 2-3 shows how the key dimension of resilience can be arranged into a disaster cycle, which presents three main components of resilience: robustness, adaptability, and transformability. The three main components placed in the inner cycle are divided into the main goals to enhance resilience based on the different phases of the disaster cycle. Consequently, the outer circle, surrounded by the disaster management cycle, illustrates the key dimensions, which have to be taken into account in order to achieve a resilient state.

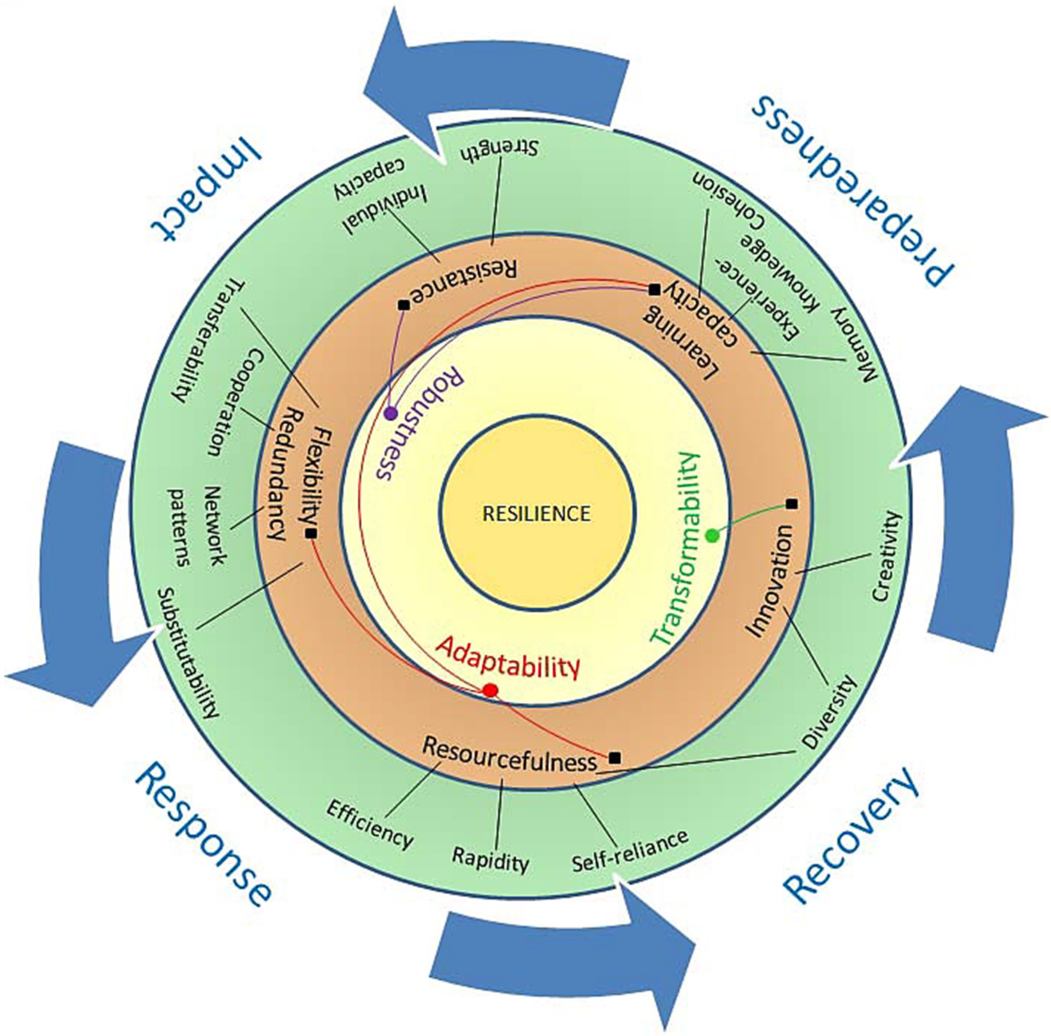


Figure 2-3: The key dimensions of resilience in the disaster cycle

Source: Galderisi, Ceudech, Ferrara, & Profice, 2012

In sum, if we divide a city state into pre-, during-, and post-disaster time, the characteristics of city resilience can be identified by the overall state of a city (Figure 2-2). The city will be resilient when three elements occur: (1) the urban systems are able to absorb or avoid impacts of hazard events, (2) the urban systems are able to adapt to changing conditions and to function without changing to other state defined by a disaster threshold and (3) urban systems are able to recover from hazard events quickly. Nevertheless, we have to keep in mind that resilience of a defined system is not only the sum of each component, but also a dynamic interaction of individual and collective processes at different levels. This contributes to the adaptability and capability of the system to withstand changes. Hence, components of each realm - such as socio-economic characteristics, built- and natural environments - contribute to the capability of the system to turn negative circumstances to opportunities. This dynamic interaction between the system and changes may eliminate or transform some components of the process in order to maintain the system's continuity and growth as an entity.

2.4 The development of urban resilience to disaster - a conceptual model

This study proposes a conceptual model of urban resilience to guard against disaster risk. Resilience in this model is interpreted as both an outcome, and a process of disaster preparedness and recovery. This recovery after disaster should be considered as a restoration process rather than a regular reconstruction. Whereas urban resilience to natural disaster means that components of urban system - built and natural environment, human capital, and socio-economic activities - are able to withstand disaster impacts without qualitatively losing its basic functionalities and physical structures that are necessary to maintain livelihood of their users. Urban resilience here is the dynamic process that shifts the urban system from vulnerable to resilient, and then advances to innovative urban transformations. Nevertheless, this active movement requires sufficient adaptive capacities and a better social learning process as a set of catalysts to a resilient urban transformation.

In the period between pre-disaster states to a disaster, vulnerability of urban systems refers to the susceptibility to be damaged. This susceptibility is an outcome of the interaction among natural hazards, exposure elements, and exogenous drivers, which contributes to human pressures experienced as vulnerability and *sensitivity* to the disaster impact. Within this interaction, the exposure elements to natural hazards, which exist in the status quo before disaster occurs, can be reduced by operating numerous disaster mitigation measures. One goal of disaster mitigation measures is to influence the physical form of cities in order to avoid urban development in hazardous areas. This goal is prioritized as the top of urban risk management in the modern urban planning disciplines, such as sustainable development and smart growth.

Adopting a resilience approach together with this goal, there is no specific pattern of defined urban form, but the form is flexible towards what and how urban systems have learnt from their experiences. In this case, a *social learning* process is one of crucial factor influencing an urban form. The advantages of a resilience approach will encourage social units to create a new paradigm to achieve urban resilience, which can transform the urban form and its system to a more desirable state in relation to the linkage of physical environment and social-natural system.

By the implementation of disaster resistant structures, the disaster sensitivity of the system can be mitigated. The structure that is able to absorb impacts of hazard events will enable the urban system to re-generate resources to maintain its infrastructure as well as to reserve standard livelihood of its residents. The effectiveness of re-generating and circulating urban resources into each component of its system can lead to *adaptive capacities* of each individual system under the changed structure. Therefore, the adaptive capacities play a key role in altering perturbations to new opportunities as well as turning a process of being vulnerable to resilient. The potentials to turn vulnerability to resilience are the result of social learning that will provide alternative ways to deal with disaster risk and its impacts as mentioned above.

After the disaster, the resilience depends on how quick and how well an urban system recovers from hazard events. In this case, social learning processes become a crucial key in strengthening rapid recovery and enabling desirable adaptive capacities that lead to the development of self-organization processes. Consequently, the ability to self-organize will serve as a ground element of a recovery process and increasing *innovative aptness*. With this aptness, it will determine how well the urban system recovers from the hazard events. On the other hand, the desirable innovative aptness can also shift a process of urban resilience to a further process of urban transformation.

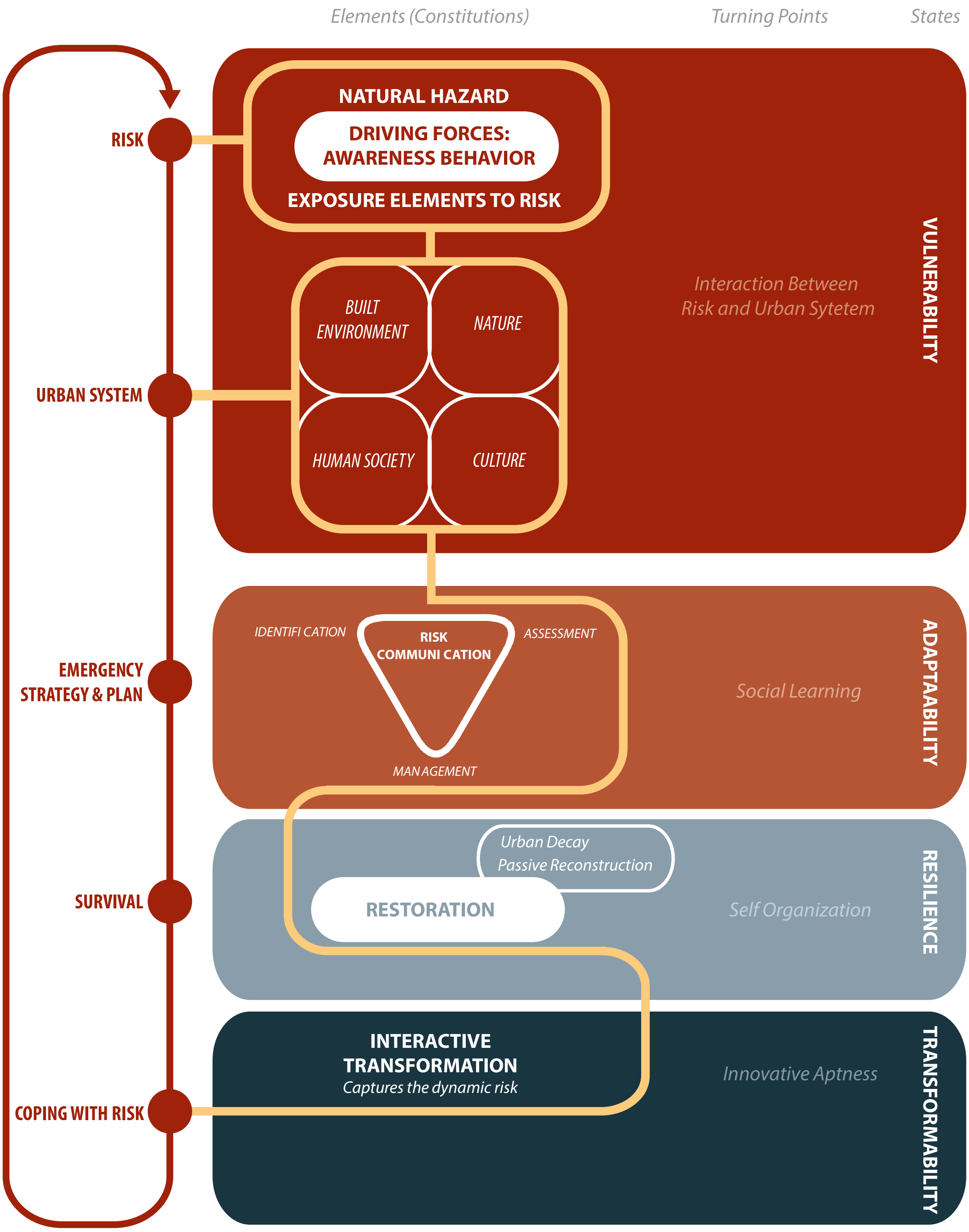


Figure 2-4: The conceptual model of urban resilience to disaster

Source: By author

2.5 Dual spaces needed for enhancing a social learning process

Based on the above framework of urban resilience to disaster, the desirable collective adaptability leads to the development of self-organization within an urban system, which directly influences the innovative aptness to cope with future disaster. The ultimate goal of urban resilience can be achieved by using the innovative aptness to shift a process of resilience to a process of urban transformation that brings about a resilient urban form and functional urban spaces suitably for urban risks of a specific urban system. As a result, the urban system responds to existing risks not simply by reconstructing its usual form, but by changing in a way that better fits into the environmental constraints. To stimulate those resilient processes, an innovative social learning process is needed.

One of the constraints of risk information sharing and transfer has been recognized as one of the crucial problems of the social learning process. Theoretically, disaster risk management can be integrated into the urban planning field for achieving disaster resilience goals depending on how well the risk assessment is conducted by and conveyed to the public. It is necessary to need to realize that the risk assessment cannot be a standalone tool of disaster risk management, and it is indispensable to take three board actions of risk analysis, communication, and management into account (Bendimerad, 2008).

Based on the top-down approach of disaster risk management, a traditional goal of urban risk management aims at producing a hazard map and risk management policies, and afterward bringing them into the locality's consideration. As a result, a delicate concept of risk zoning policy has been increasingly considered as the fundamental discipline for urban and infrastructure planning in Europe and North America in the mid-nineteenth century. However, the production of those hazard maps and its relevant policies, in many cases, ignores the essentials of public participation and implicit data arisen from the public, which results in increasing risk and vulnerability of the cities. We have experienced from thousands cases which those actual outcomes of risk zoning policies are significantly different from the plans. Besides, in some cases, the vulnerability of cities and people living in those cities is continuously increasing instead of decreasing. Those situations can refer to a breakdown of administrative management or a failure of risk communication between experts and the public.

In fact, before a formal risk analysis is initiated, risk information related to both physical attributes and social vulnerability must be obtained from the public, whereas the outcome of risk analysis should also be transferred to the public in the way that can cultivate them the risk awareness. The study proposes, therefore, a new conceptual framework of disaster risk communication, which can contribute to a better result of disaster risk management and enhance the urban resilience. Figure 2-5illustrates the role of risk communication as a means of overcoming the main problems of the contradictory risk perception and awareness between the public and risk managers, while retaining the advantages of sophisticated computer-based risk assessment. In order to enhance the public cooperation, results of dynamic modeling of risk assessment should effectively and properly be conveyed to the public in a way that can raise public awareness of environmental hazards. Thereby, the disaster risk managers and planners are expected to develop their risk communication skills as well as to invent an innovative risk communication approach, which enables local community members to get involved collectively in risk communication and management processes.

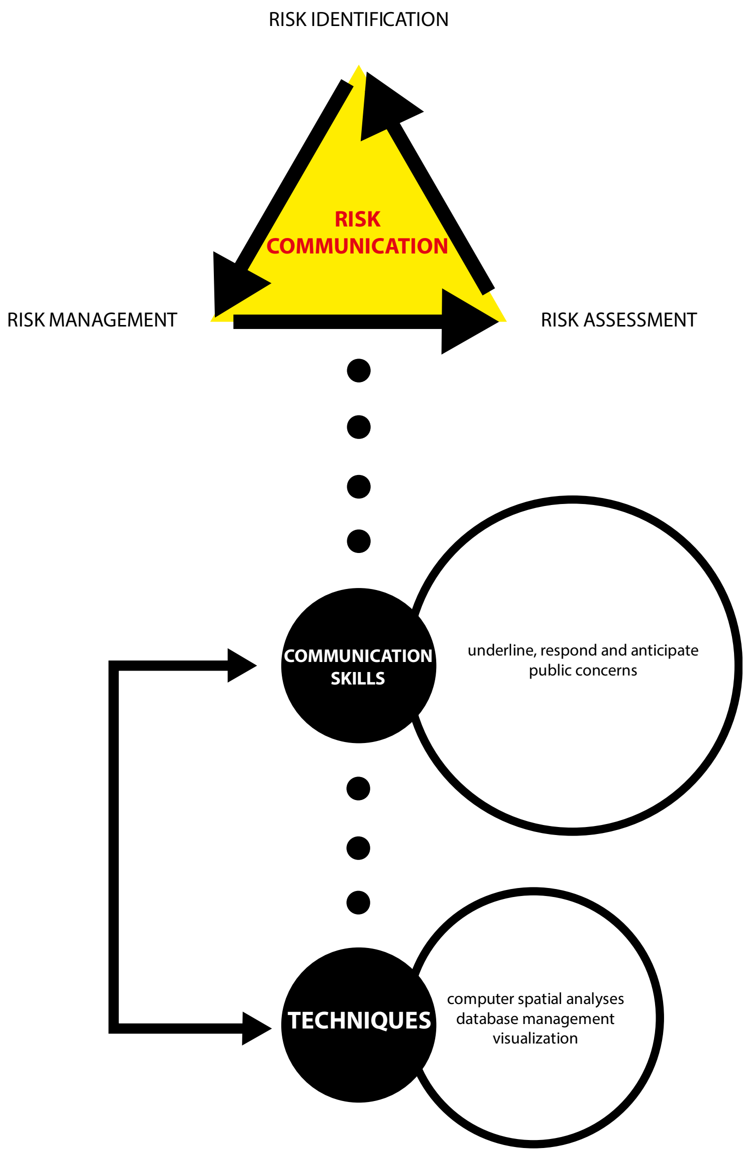


Figure 2-5: The integration of risk communication with spatial risk management

Source: By author

Risk communication plays an important role in an interactive exchange of risk information and opinions among risk assessors, risk managers, the public, and other stakeholders(World Health Organization: WHO, 2012). Applicable in the situations where either the qualitative information or precious consideration of hazards is undertaken, risk communication can be used for two different purposes: the data collection and information transfer. It is a useful action to obtain the risk information from different vulnerable groups for the increased effective risk analysis as well as to disseminate risk information among individuals, groups, and institutions in order to educate the public on possible effects of hazards (Ng & Hamby, 1997; Morrow, 2011). Therefore, the formation of risk communication should be taken into consideration as a common action in the disaster risk management. Decision makers pay little attention to the paradox in which the intricate risk modeling may provide qualities of risk assessment, but its outcome seems to be incomprehensible to the public (Figure 2-6). The pressing question is how far we can go with sophisticated risk mapping techniques in visual risk communication, while the risk information and warning can be accessible and simply understandable for them.

Among the risk modeling techniques in the Figure 2-6, the simulation is considered as a communication technique, capable of conveying a message that falls in a middle range between the understandability and complexity of modeling techniques of the reality. Usual complex models and regular master plans synthesized from the modeling will no longer be sufficient to either educate or cultivate the risk awareness and preparedness to the public. In contrast, the local community should be self-centered in disaster risk education, which can lead to an increase of the public risk awareness resulting in risk mitigation actions. To create such environment for the community, it should be an interactive dual space: where people can use in the daily life, where people can take it as a common learning room and conduct learning activates such as a risk map-making, and where people can turn it into an emergency center in the disaster time such as an evacuation space.

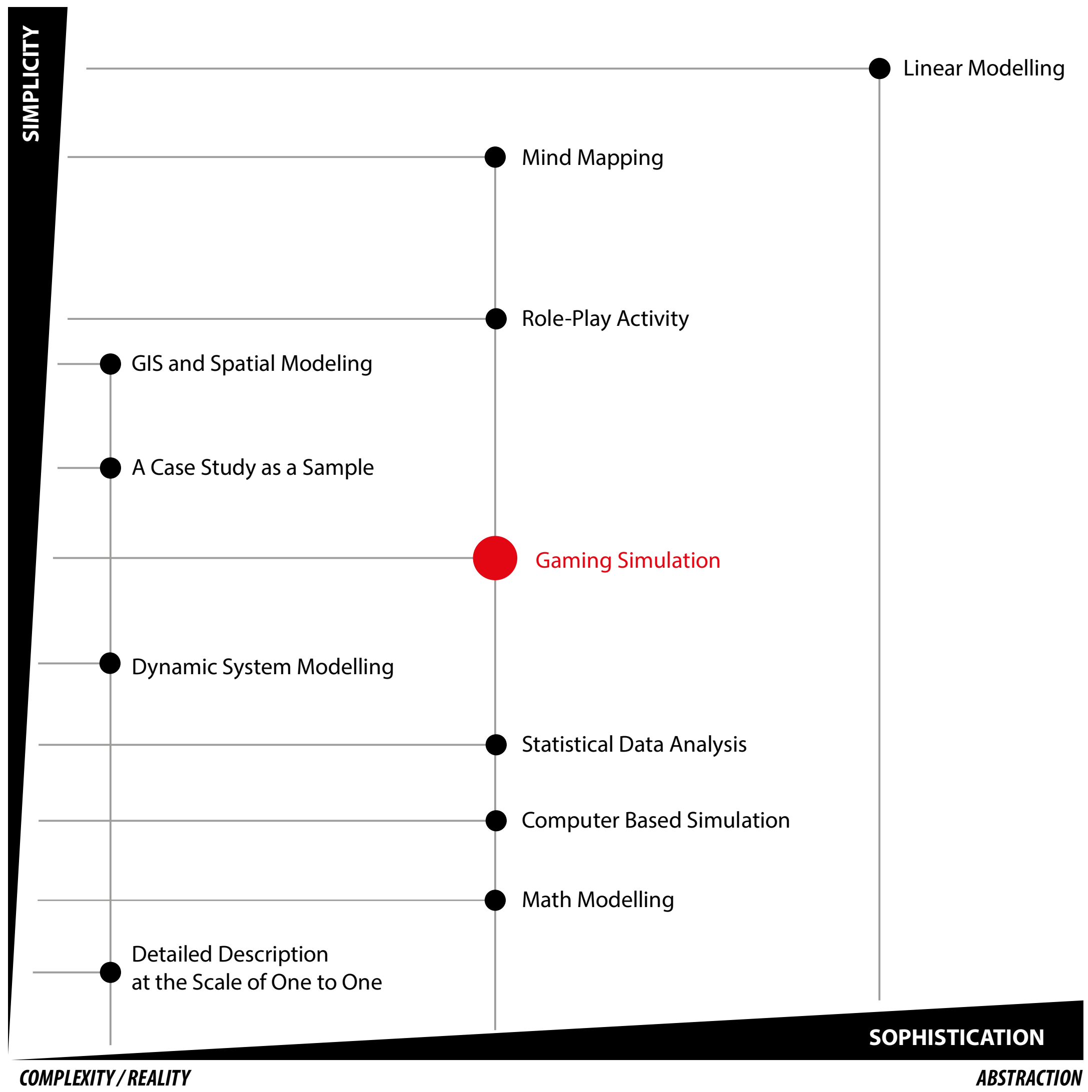


Figure 2-6: The spectrum of simplicity and complexity of risk modeling techniques for risk communication

Source: By author

2.6 Translating theoretical aspects into a research operation

Responding to the first research objective, the literature review in this chapter serves to conceptualize urban resilience in relation to urban planning and risk management. Practical applications of this concept have still been unclear. To offer a better understanding on the implication of this concept, a preliminary case study on what happened after the tsunami of 2006 in Phuket, Thailand is taken into account. This study aims at providing insights of what happened after the tsunami and how things bounced back. A series of questions is set as a reference point of this study.

1. How to translate the logical concept/ approach of resilience into plausible practice?

Due to the complexity of this question, it is needed to elaborate this question into two sub-questions as follows.

1.1 How to define the resilience of cities to natural disaster?

1.2 Did urban planners and the government manage their cities to be more resilient after the tsunami occurred in Indian Ocean?

To explain city resilience to natural disaster theoretically, and to illustrate how decision-makers, urban planners, and other stakeholders coped with threats, it is necessary to understand how cities are vulnerable to natural disaster and what factors contribute to their capabilities to bounce back (demonstrate their resilience). These questions move the resilience approach from theoretical plausibility to practical application. A case study of Phuket Island in Thailand illustrates the implication of resilience approach through integrating urban planning and risk management. In order to answer the research question, the primary research based on literature and statistical analyses was performed.

2. How well does a business-as-usual approach reflect the metabolism of cities by taking tourism into consideration?

Another research question arises from the viewpoint of urban system study based on a concept of resilience. By viewing cities as systems, the mechanisms of cities are simply represented by urban production models based on the simplified reality. Whether those models are inductive-oriented generalizations or logical constructs, the models may not be able to reflect real situations of a specific city, unless the spatial variations are taken into consideration. The second research question begins with some doubt about the efficiency of a business-as-usual approach that is extensively utilized in an urban planning field.

Planners are confronted with a potentially profitable development opportunity with planning dilemmas, which can put them in danger of not seeing the policy wood for the contextual trees (McGranahan et al, 2001 cited in Pelling, 2003). Planners should not neglect the fundamental inter-connections of complex urban components otherwise plans could fall into the trap of reductionism[2] (Pelling, 2003).

The success of urban infrastructure planning is associated with the adequate analysis of future needs and a synthesis of regional networks for supply chains. To be able to deal with a booming tourism, many attractive cities are facing a chronic problem of overconsumption beyond the carrying capacity of their urban facilities and utilities. A linear mechanistic, business-as-usual, approach to deal with this issue might not lead to effective urban infrastructure planning. Therefore, it is needed to seek for a more suitable approach that addresses emerging hazards to 'urban eco-systems'. With the intension to contribute to the current debate on the tourism, the study is going to address the tensions between the current capacity of the local infrastructure and the sharp rise of consumers' demands. In addition, the study attempts to emphasize how a tourism-based urbanization process affects the carrying capacity of the urban infrastructure.

[2] Reductionism is a philosophical approach that explains a complex system by analyzing complex data and reducing them to simpler terms through accounts of individual constituents. By this approach, the complex urban metabolisms are regarded as basic physical mechanisms of inputs, processes, and outputs. These mechanisms are fundamental production procedures that attempt at facilitating urban activities.

Chapter 3：
Preliminary research on the resilience of coastal zones: a case study of Phuket Province, Thailand

The purpose of this study is to illustrate resilience of the coastal urban system to tsunami in the context of a case study - Phuket Province in Thailand - and to explore how 2004 tsunami affected-communities and how a wide range of institutions from national to local scales took actions to recover Phuket after 2004 tsunami event. It was one of the most remembered incidents as a result of the large-scale tsunami in 2004. The study explains how stakeholders of the city: urban planners, local residents, and local government made their city resilient after tsunami event. In addition, the study identifies the city's adaptive capacity to absorb impacts of tsunami through "a resilience approach".

Based on a resilience concept, the study aims to indicate the adaptive capacity of an urban system and activities in Phuket Island that taken place in order to absorb the impacts of tsunami and to recover - to a pre-existing functional state. The study expresses resilience of Phuket by comparing the ideal community resilience to the local context. Based on the scoped benchmarks, the study found that land use policies, economic activities, and institutional adaptive capacities were crucial elements of city resilience. Urban diversity, land use ordinances, and a concern on environmental problems would enhance stability of urban system and could buffer tsunami effects with support from institutional adaptive capacities.

As mentioned earlier in the previous chapters, the urban resilience to tsunami shall be defined by the integrated capacity to absorb tsunami impacts (Stability), to maintain urban functions and services (Adaptability) and to recover from the catastrophe in a timely manner (Bouncing back). In order to apply the concept of resilience into the urban planning field with the concern on tsunami risk, this definition requires an understanding of four crucial issues. Those are 1) what is the definition of a city and an urban system, 2) what are the major types of tsunami impacts, 3) how a defined urban system or unit absorbs tsunami impacts, and 4) how the tsunami-affected cities recover to their previous states or better conditions.

Therefore, Phuket Island, hit by tsunami in 2004, was taken as a preliminary case study in order to explain the above issues and to answer the first research objective: to describe the disaster resilience in terms of urban planning and to find a way to put this concept into a practical application. Moreover, by conducting this study, it also aims to answer the other two research questions that mentioned earlier in chapter 1. Those questions are as follows:

1. How to define urban resilience to natural disaster and how did urban planners and the government manage their cities to be more resilient after the tsunami?

2. How well does a business-as-usual approach reflect the metabolism of cities under the invasion of mass tourism?

The chapter will begin with a description of disaster-resilient cities that are adapted from the theoretical aspects and adjusted to resilience benchmarks suitable for the case study. In addition, tourism is another influencing factor on urban resilience, which can accelerate a catastrophe when tourists' demand for urban infrastructure and services exceeds city's carrying capacity. Therefore, the study on tourism impacts on city infrastructure and its provision is conducted. Through a comparison of the demand projection of urban infrastructure between a traditional business-as-usual approach and an alternative weighting method, the study is able to reveal differences between them, which lead or mislead to ideas on the urban infrastructure planning.

3.1 Resilience benchmarks adapted to local context

For this study, a resilient city is a sustainable network of natural environment (resources), built environment (physical systems), and the socio-economic environment (human society and activities). Natural environment is the marine and land resources that benefit to human activities, agriculture and fishery. Built environment regarded as physical systems covers all urban infrastructures and services such as road networks, buildings, and land use systems. Meanwhile, socio-economic environment concerns on urban activities that create economic flows and social identities. In the city, the natural resources act as inputs of a city, providing opportunities to utilize them for urban development. Based on the natural resources, the physical infrastructure are constructed as a set of structures for urban metabolisms. Human activities and the urbanization process simulate the real metabolisms upon the available physical infrastructure. These metabolisms consume natural resource to provide urban functions and to produce socio-economic prosperity. During a disaster, the natural and built environment must be protected in order to provide their functions for human activities. By this analogy, a threshold state of resilient cities is based on the capability of physical systems and social systems to keep functioning under a perturbation without losing the quality of their service standards. Namely, the quality of services dominates over the quantity in maintaining the threshold state of resilience. It is also important to acknowledge that physical resilience cannot be separated from social resilience, because the physical resilience is invited by public awareness of disaster risk and organizational adaptive capacities to cope with disasters.

The city resilience, in this study, mainly focuses on built environment corresponding with urban system in terms of land use, availability of evacuation infrastructure, economic instability, diversity, and institutional adaptive capacities of the government, influencing on the local recovery process after 2004 tsunami. To explore resilience of urban system, the study adopts some potential indicators of ideal community resilience, and then develops those indicators and benchmarks for metaphorically expressing the crucial characteristics of city resilience in the context of the case study, Phuket Island. Finally, the scoped benchmarks can be shown in Table 3-1. Because no community warning system and evacuation infrastructure were in place before 2004 tsunami event; therefore, the study reveals urban resilience of a case study of Phuket without involving those emergency infrastructure.

Figure 3-1: Candidate benchmarks for assessing city resilience

Dimensions	Benchmarks
1) Land use policies and their enforcement	- Land use policies relating to Disaster Risk Reduction (DRR) are established, monitored and enforced locally (1), (3) - Developers and communities incorporate risk reduction into the location and design of structures (1) - Legal and regulatory systems protect land ownership and tenancy rights (3) - Defined structures, roles and mandates for government and nongovernment actors in coastal zone management (3)
2) Availability of evacuation infrastructure	- Community warning and evacuation infrastructure is in place and maintained (1)
3) Economy	- Stability and diversity in economic activities and employment (1) (3)
4) Institutional adaptive capacities	- Defined structures, roles and mandates for government and nongovernment actors in disaster preparation and response (3) - Disaster recovery plan is established that addresses economic, environmental, and social concerns of the community (1), (3) - Self-help and Social embeddedness supporting vulnerable groups (2), (3)

Sources: Adopted from (1) USAID : the United States Agency for International Development, 2007; (2) Cutter, et al., 2008; and (3) Twigg, 2009

3.2 Tourism development and failures of urban management

Tourism is a worldwide phenomenon, but the interrelationship between tourism and urban planning is not well understood. This study aims at exploring differences of the infrastructure planning between traditional urban planning standards and the proposed contemporary planning under a scenario of tourism urbanization. Furthermore, common failures of land-use ordinances and land abuse arising from the lack of enforcement should be taken into account.

Population density is the utmost crucial factor determining carrying capacity of city infrastructure. In order to provide sufficient facilities and services, urban planners usually estimate the number of population in the future and assume that The more attractive the place is, the more population will be settle in (population agglomeration). On the other hand, with the use of mathematic models, the population projection can be made simply through an independent separated estimation by each area.

With the intention to conceptualize the spatial planning for tourism resilience, the study applied different mathematic models of population projection in order to illustrate the need of urban infrastructure and services in the future. There are three dimensions when discussion the term "population": local residents, tourists, and a combination of local residents and tourists. Including tourists as population of the city shall consider that the tourists and residents need urban infrastructure and services differently. Therefore, the study proposes three scenarios of population projection categorized by the definition of a word "population". There are three dimensions when discussion the term "population": local residents, tourists, and a combination of local residents and tourists.

3.3 Resilience of Phuket against the Indian Ocean Tsunami of 2004

Tsunami in 2004 revealed Phuket's vulnerabilities to tsunami. It brought forth a powerful national and international response, and the momentum of which built city resilience in the day following the tsunami has been continuing. Funds and technical expertise were rapidly mobilized for long-terms rehabitation and restoration. The results of this study explored how Phuket government authorities, local residents and business groups collectively tried to restore their city from the catastrophe by improving three components of the urban system; (1) land use policies and their enforcement, (2) economic stability and diversity, and (3) institutional and community adaptive capacities.

3.3.1 Land use policies

Although there are a number of acts have been declared to manage the use of land and natural resources (Figure 3-2), some local authorities still lack the capacity to take advantage from the acts and make use of the acts in their local context. Coastal zone management in Thailand was first attempted in the 1980s with the establishment of the Coastal Development Division under the Department of Land Development. However, there is lack of guidance on how to integrate the work of the division with the other government agencies (United Nations Environment Programme, 2006). Meanwhile, major developments have taken place in the coastal areas. Activities and land use in the coastal zone are exercised -either legally or illegally - by local government, local mafias, and other groups that have more power as a result of government decentralization (Paphavasit, Chotiyaputta, & Siriboon, 2006), making coastal zone management more of a tool for resolving land use conflicts than a tool for holistic planning with environment risk concerns.

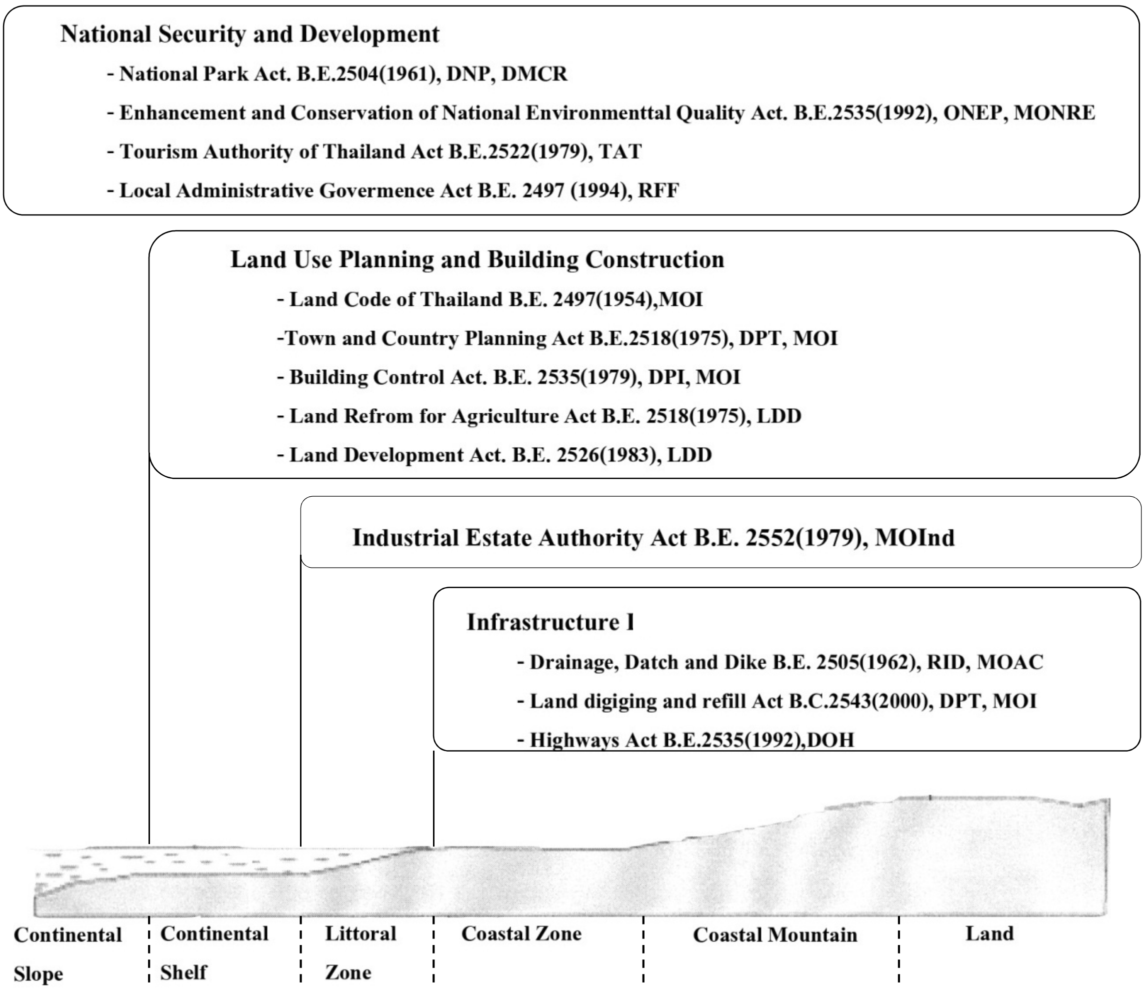
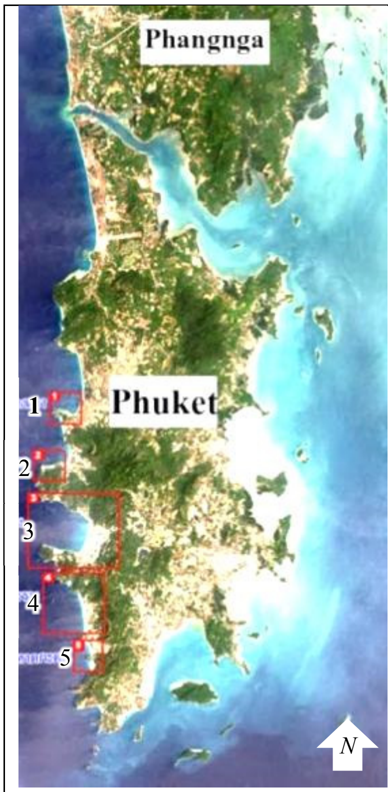


Figure 3-2: Legislative administration of the coastal zone in Thailand

Source: Adopted from Paphavasit, Chotiyaputta, & Siriboon, 2006, p. 207

Phuket government authorities have creatively taken advantages of the tsunami's destruction in guiding and enforcing the restoration process rather than following regular reconstruction process. The restoration has been in such a way as to improve the tourism facilities by better coastal zoning and master plans with environmental concerns (World Tourism Organization, 2005). Although the scale of available funding for these master plans appears to be unclear, Thai government has expressed intention to fund some of these master plans in order to place urban conditions and activities on a more environmentally sustainable basis (World Tourism Organization, 2005).

After 2004 tsunami event, a number of studies have indicated how Phuket is at risk of tsunami and how tsunami impacts affect the urban system in Phuket. 2004 tsunami reached wave heights of between 5 and 12 m and inundated the area to a maximum distance of 1,200 km inland (Thanawood, Yongchalermchai, & Densrisereekul, 2006; Norwegian Geotechnical Institue, 2006). Five beaches along the western coastline of Phuket were defined as severe affected areas (Figure 4.2). The affected area accounted for 1,556.23 ha; the largest affected area was Kamala beach. More than 70% of affected communities became totally demolished. Work places and tourist accommodations were the most affected, accounting for 87.7 % of the losses (Paphavasit, Chotiyaputta, & Siriboon, 2006). According to earthquake and tsunami scenarios estimated by Norwegian Geotechnical Institute (2006), the largest earthquake within the next 50-100 years, which could generate a tsunami and hit the coasts of Thailand, is conservatively estimated to be a magnitude M 8.5 event. If this even occurs at normal high tide, the total inundation would reach 2.5 to 3.0 meters above the mean sea level. Moreover, in the next 100 - 200 years, the potential tsunami will gradually increase the risk of devastation from the level of tolerable to unacceptable. This implies that coastal communities living in low-lying area of 3 meters above sea level should have prevention and mitigation measures through the efficient and well-functioning planning.



Estimation of 2004 Tsunami Affected Areas in Patong and Kamala beaches

	Patong beach (ha)	%	Kamala beach (ha)	%
Built-up area	305	40.2%	942	78.3%
Agricultural area	44	5.8%	30	2.5%
Water body	13	1.7%	14	1.2%
Miscellaneous	396	52.2%	217	18.0%
Total	758	100%	1203	100%

Note: Affected area in Phuket Province totally accounted for 1,556.23 ha.

Legend

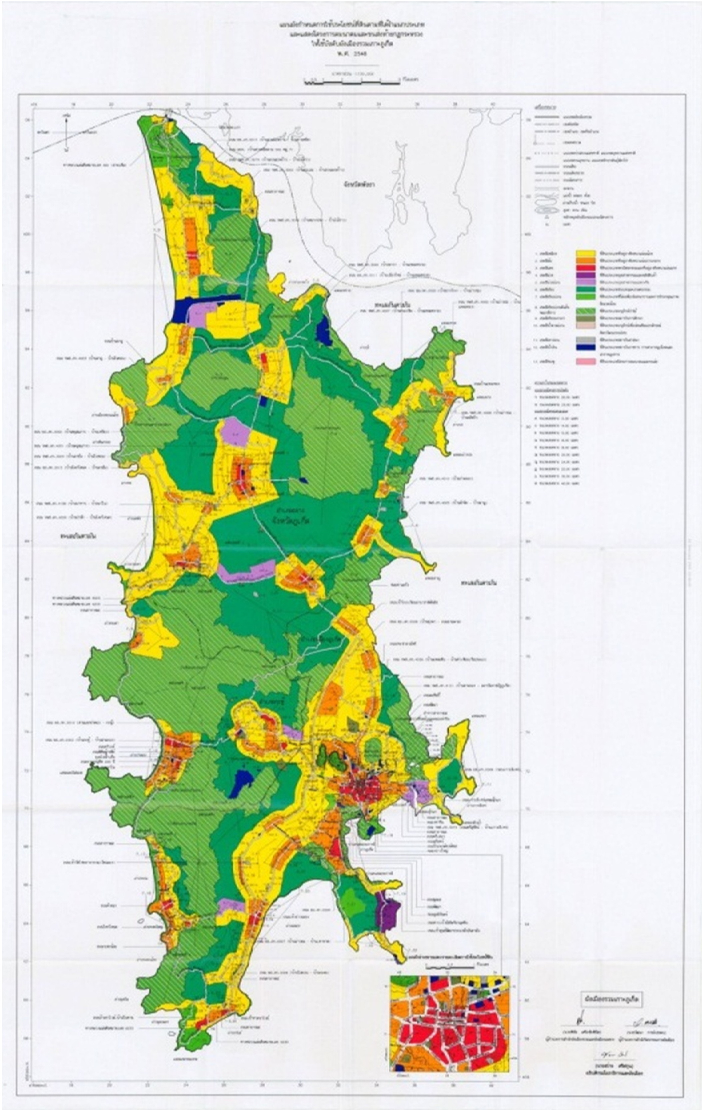
Five affected areas:

1= Bangtao Beach
2= Kamala Beach
3= Patong Beach
4= Karon Beach
5= Kata Beach

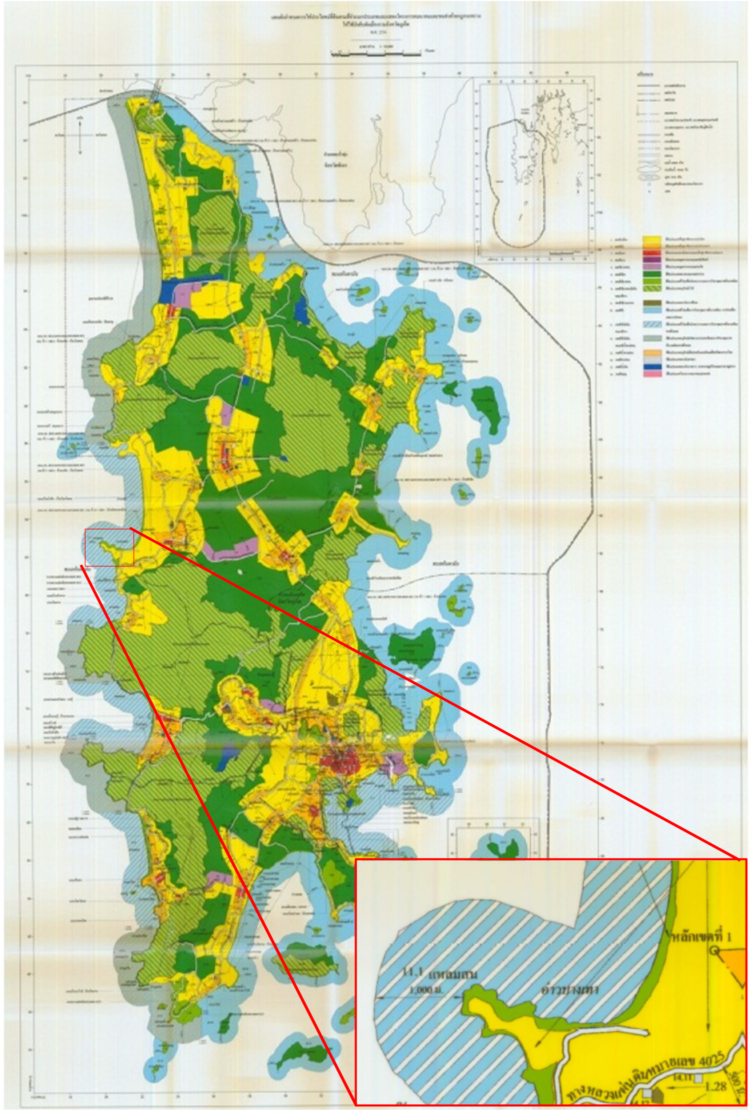
Figure 3-3: Phuket Island and five affected areas by 2004 Tsunami

Source: Land Development Department (LDD), Thailand, 2005; Ikonos satellite image acquired on 29 December 2004: www.gisthai.org

Master plans and land-use ordinances are tools to organize urban activities especially land-use and housing management with regard to the public interest. These plans and ordinances can be integrated with disaster risk mitigation measures in order to build cities more resilience to disasters, while avoiding significant investment in vulnerable areas. To bring urban development under controls, local authorities of Phuket revised the master plan and land-use ordinances over time. A comparison of master plans and land-use ordinances between 2005 and 2011 revealed some differences, especially the land-use ordinances in 2011 was more sophisticated in terms of integrating environmental degradation and disaster risk into sptial planning. A master plan in 2011 did not only focus on human activities in inland area, but it focused more deeply on the effect of human activities to both the continental shelf and coastal zones. Inland areas along the coastline (Green) were indicated as recreation areas for coastal environment preservation; however, this designation did not involve the identification of buffer area and setback area from the coastal lines. In this context, the national setback standard (6 meters from the public water way) is applied, but the 6-meter setback is not likely to wide enough for buffering the environmental problems caused by human activities (Figure 3-4). Apart from the inland area, the littoral zone (Alternate colors: blue and white) was meaningful for ecotourism and fishery activities in which Phuket had never paid an attention to that area in the previous plan. In addition, the types of land use were elaborately divided into 16 categories, replacing the previous 13 categories; one of the added categories was the environmental sustainable area along the coastline. The 2011 master plan was more strict than the previous one in terms of controlling urban development, and enforcing land-use activities. A minor land use activity that is different from the designated land use category can be permitted up to 5-15% of the main category, while the previous master plan accepted 30-50% of minor use in each lot of land (See Figure 3-5). This movement can bring rapid urban sprawl and urban development under controls if an effective enforcement monitoring system is available. Phuket vulnerability to tsunami can be gradually reduced, and would enhance city resilience.



5A: Phuket Master Plan in 2005 (five-year plan)



5B: Phuket Master Plan in 2011 (five-year plan)

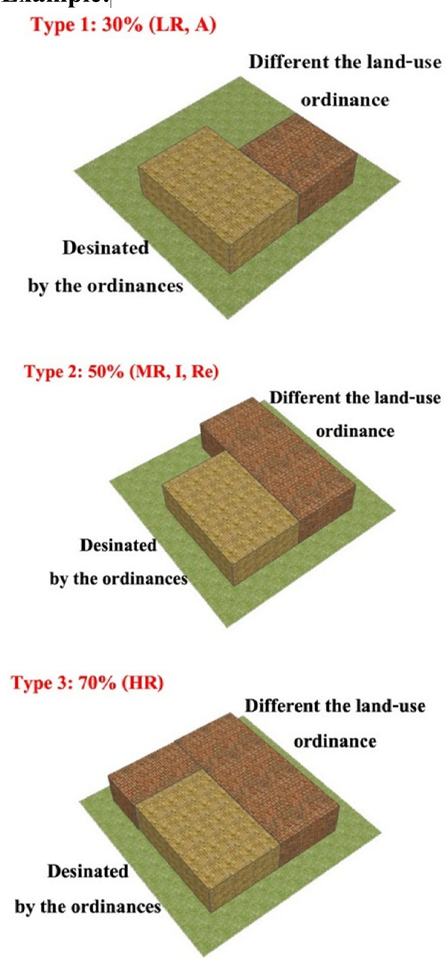
Figure 3-4: A comparison of master plans declared between in 2005 and 2011

Source: Department of Public Works and Town and Country Planning; retrieved March 2012, from http://www.dpt.go.th/index.php

	2005 master plan	2011 master plan
Enforced area	Inland area	Littoral zone and inland area
Land-use classification	13 categories	16 categories
Criteria	**add up to specified % (below) of land lot**	**top up to specified % (below) of total designated land-use**
Low-density residential area (LR)	30%	5%
Medium-density residential area (MR)	50%	15%
High-density residential and commercial area (HR)	70%	10%
Light industrial area (I)	50%	10%
Agricultural area (A)	30%	5%
Recreation area (Re)	50%	5%

Permission to use different from designated land-use ordinance

Example:



Example:

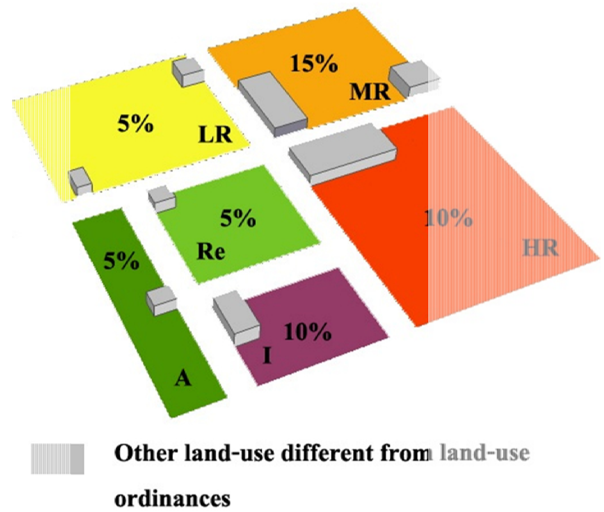


Figure 3-5: A comparison between 2005 and 2006 master plans in Phuket

3.3.2 Regulatory enforcement of land-use policies: the coastal zone management and land tenure problems

The coastal zone management concerning tourism facility and the informal settlement in the disaster prone area can lead to the vulnerability reduction. There were numerousefforts to manage beach facilities. To illustrate one of the efforts, Patong's strategy on beach facility management reflected in the reduction of beach umbrellas from 8,000 to 2,500 and as a consequence, 55 private concessionaires need to portion out the reduced quotas (World Tourism Organization, 2005). This would clearly affect these small businesses in economic terms, but its benefits on social return could be larger than the individual profits. Because the exposure elements to tsunami were significantly reduced, this could potentially speed up evacuation process comparing to the previous condition. Another example is related to informal settlements and insecure land tenure along the coastline. In Thailand, land tenure security put pressure on local authorities to restrain inappropriate settlements and land use in which is the most vulnerable area of the coastal cities (World Tourism Organization, 2005; United Nations Country, 2005; Rice & Haynes, 2005; Paphavasit, Chotiyaputta, & Siriboon, 2006; Handmer and Choong, 2006). Land tenure and rights, therefore, became the most important causes of social problems after tsunami. Of the 63 affected communities in Phuket, 12 communities with unsecure land tenure (accounted for 19.05 % of affected communities) were facing with problems related to the reconstructions and rehabitation (Figure 3-6). These were mostly fishing communities where they had resided on prime beachfront land for decades, but they typically had no legal title deeds or lease contracts, and therefore could be considered as illegal squatters (Paphavasit, Chotiyaputta, & Siriboon, 2006; United Nations Country, 2005).

The tsunami offered an opportunity for urban planners and private developers to take control of these areas through seizing such lands and evicting the previous occupants who might have lived on the lands for generations (Handmer and Choong, 2006; Mitchell, 2010; Rice & Haynes, 2005). If the urban planners had taken control over these areas, the society might have benefited from such act. Unfortunately, the relocation and the security of rehabitation for those previous occupants are not clear. It would be a breakdown in governance influencing on city resilience.

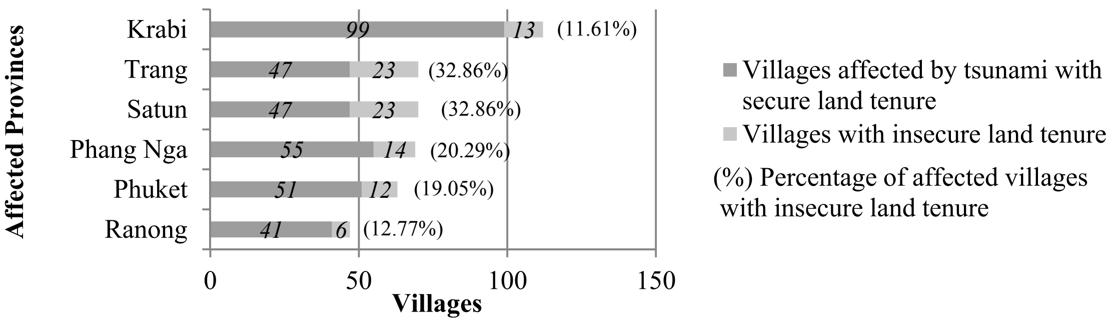


Figure 3-6: 2004 Tsunami affected-villages and land tenure insecurity

Source: United Nations Country, 2005
Note: 91 villages out of 431 affected villages (21.11%) had insecure land tenure.

In sum, land use and coastal development planning is clearly connected to the resilience of Phuket's coastal urban system. The Indian Ocean Tsunami of 2004 revealed failures of the previous coastal zone management and land-use regulations, which tragically impacted on human life and urban infrastructure. Therefore, an extensive attention has been given to urban planning with more environmental concerns, which in turn emphasizing the need of integrated coastal zone management (ICZM). Local authorities of Phuket Province have been providing more holistic land-use planning and coastal management, leading to increased resilience of urban system. However, an effectiveness of land-use planning and coastal management is still questionable as there is lack of data on how developers and communities coordinate with the local authorities. The local authorities should put this challenge into perspective in order to meet their defined institutional roles and responsibilities.

3.3.3 Economic stability and diversity

Understanding how the economic activities could respond effectively to tsunami impacts and adapt to its consequences can be useful for expressing city resilience. An ideal resilient economy comprises of economic activities which can stay operating in a stable state, maintaining or growing their profits and business size despite disturbance. For the business, a degree of the adaptability to disaster depends on the economic loss and the holding capitals after the loss. In 2004 tsunami, it was estimated that the immediate damages in Thailand cost about USD 5008 million, while total economic losses were approximately USD 2,198 million. These total losses were approximately equal to 1.4% of the national GDP in 2005. For the Phuket, the economic losses from the 2004 tsunami was equal to 90 % of GPP. This comparative percentage of economic loss was higher than the severe affected areas in Karbi

Province and Phang Nga Province. The losses of those provinces were about 70 % of GPP (Nidhiprabha, 2007). As the above comparison, Phuket economy found a difficulty to process the disaster recovery.

Depended on tourism industry as its sole economic structure, Phuket encountered overwhelming economic losses and damages. Since all economic centers were located along the coastline, Phuket economy was vulnerable to tsunami. Figure 6 shows proportions of Phuket GPP, which were divided into 16 different economic sectors during 2004 to 2007. Clearly, the major economic sectors of Phuket comprised of (1) hotels and restaurants, (2) transportation, warehouse storages and communications, and (3) wholesale and retail trades respectively. Those three economic sectors accounted for over half of total GPP. Revenues from hotels and restaurants were the largest GPP proportion, accounting for 38.5% to 46.9%. Other revenues from transportation, warehouse storages, and communications accounted for 10.3% to 14.8% of Phuket GPP, and the shares of wholesale and retail trades were about 8.4% to 10.1% of total GPP. Although the revenues from a hotel and restaurant sector had declined throughout the whole period, it remained a key sector for Phuket GPP while the other two sectors began to rise. Hence, there were concerns over its tourism resilience to natural disasters, financial liquidity, and economic instability.

With a beautiful landscape of a coastal zone, a number of hotels, resorts, restaurants and other supportive tourist activities were located along the beachfront where there was no awareness of tsunami and no precautionary measure in place before 2004-tsunami event. In Phuket, tourism activity was mostly concentrated along the west coast beach, and Patong beach was developed as its center of tourism activity. Tourism development and its benefits offered incentive for commercial building constructions in vulnerable coastal areas that resulted in raising exposure elements to tsunami. As a result of 2004 tsunami, about 10% of public tourist facility on the Phuket Island was damaged (World Tourism Organization, 2005), and a number of buildings of developers and local residents were also severe affected. Total physical destruction was calculated about USD 250-264 million, and 72 % of the loss belonged to individual businesses, of all sizes (Phuket Picture, 2012; World Tourism Organization, 2005). The ability to rebuild the economy depended on the capability of formal and informal economic base activities. The problem was the economic base activities of Phuket is tourism. After the tsunami, the subsequent international tourist arrivals dramatically fell by 67.2 % in the first half of 2005 (Henderson, J., 2007). With the tsunami impacts, the resulting environmental degradation and damages on accommodations in tourist attractions imposed further constraints on urban activities. Phuket economic activities were unable to maintain the urban economic system and flourishing monetary flows. Phuket GPP in 2005 dropped quickly by 8.35 % (Figure 3-7).

In addition, many resorts in unaffected areas also experienced the second wave of indirect effect as their occupancy rates dropped significantly to as low as 10 % during January 2005, when they might have expected 95% plus (World Tourism Organization, 2005). Many businesses faced with a down-sizing situation, and some of those ceased their businesses. For example, the study of Main and Dearden (2007) on tsunami impacts on Phuket's diving industry reported that seven out of 85 (8.2 %) dive enterprises shut down completely, another sixteen (18.8 %) down-sizing their operations. In order to help SMEs articulate their problems collectively, the Phuket Tourist Association took a community-based approach, establishing a database of SMEs in Phuket Province and organizing them into "The Association of Small Businesses Affected by the Tsunami" (United Nations Country, 2005; World Tourism Organization, 2005). There were about 300 entrepreneurs organized in line with the approach, which greatly improved their ability to articulate their needs collectively. An international tourist fall-off did not only affected to formal economy, the informal economy also suffered because of less tourist spending and less cash circulated in the whole urban economic system (Handmer and Choong, 2006). Thousands of employees, who were migrant workers, especially from the north east of Thailand and from neighboring Myanmar, were affected directly by the economic recession which led to undermining individual livelihoods and financial liquidity (World Tourism Organization, 2005).

To recover economic situations, the national government and local authorities attempted to provide effective marketing strategy to bring tourists back to the region. An extra USD 19.5 million was added to the 2005 marketing and promotion budget. The main objectives of the post-tsunami marketing strategy comprised of 1) focusing on the new tourist markets of China, Japan, Australia, and New Zealand; 2) promoting new products and services; 3) targeting high-spending visitors, golfers and honeymooners; and 4) building new marinas and expanding Phuket and Krabi airports (Rice & Haynes, 2005). As a result, almost 90% of the hotel rooms were back in service. The GPP of Phuket subsequently recovered in 2006, regaining its previous level, although it had been argued that those strategies were without subsidy and technical assistance.

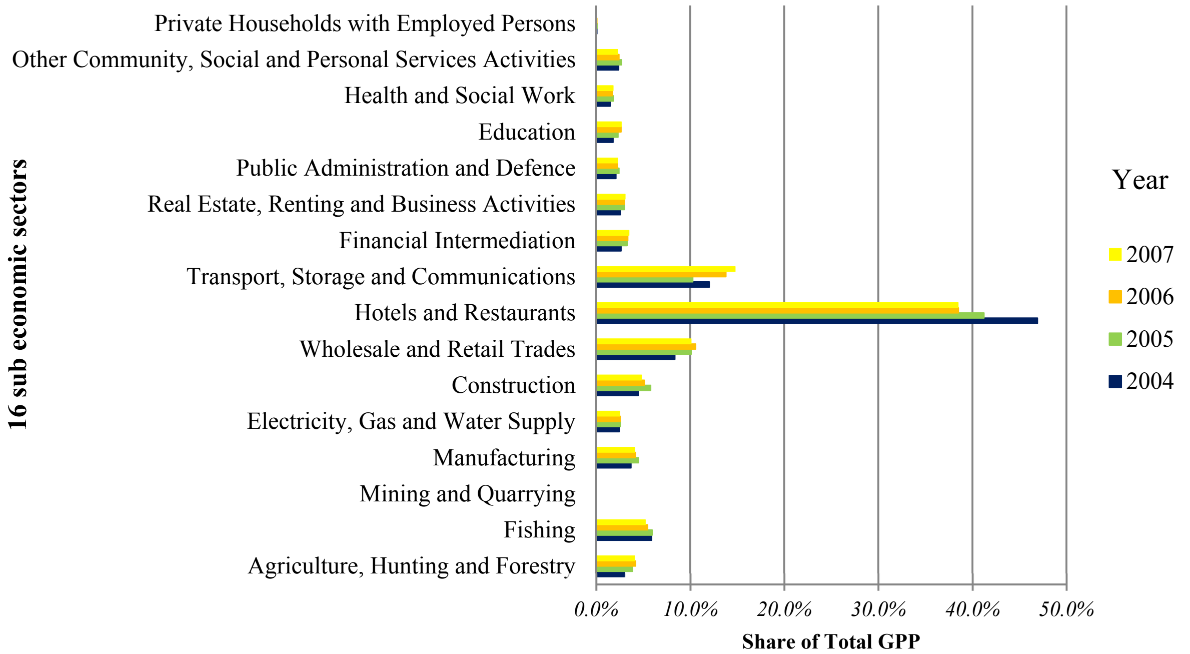


Figure 3-7: Phuket GPP distribution by activities and sectors (16 sub economic sectors)

Note: GPP: Gross Provincial Products (growth rate) in 2004 = USD 1,785 million, in 2005 = USD 1,636 million (-8.35%), in 2006 = USD 1,855 million (13.42%) and in 2007 = USD 2,015 million (8.62%)
Source: A comparison by authors

Focusing on local employment after the tsunami, Table 3-1 describes how employment distributions changed over the period of one year after tsunami event on December 26, 2004. An employment structure was settling down to a stable period during 2004-2005. Majority of Phuket people worked in a trade and service sector; this sector accounted for 28.5 % of total employment. Other sectors such as an agricultural-fishery sector and a machine operation and assembly sector also faced a difficult time as the employment of those sections during the fourth quarter in 2004 (the period that tsunami hit). Besides, the employment level in a sector of trades and services was in a disproportionately growth, compared with the employment levels in another high season. However, the employment level of those sectors was bounced back after a sudden plunge by three to six months.

Table 3-1: Employment Number in Phuket Province by Occupations

Occupation	2004 (Year)					2005 (Year)				
	first quarter	second quarter	three quarter	fourth quarter	Avg. share	first quarter	second quarter	three quarter	fourth quarter	Avg. share
	(persons)				(%)	(persons)				(%)
Legislators, senior officials and managers	9,647	9,434	9,439	10,921	10%	10,691	9,620	17,186	16,339	10%
Professionals	2,838	3,838	3,961	3,488	3%	3,803	5,002	5,268	5,589	4%
Technicians and associate professionals	8,993	9,199	9,634	9,080	9%	6,625	7,256	8,993	8,843	8%
Clerks	6,488	6,219	5,965	7,518	6%	10,327	10,117	8,727	8,736	7%
Service providers and traders	***31,306****	27,442	28,584	***30,157****	**28%**	***35,047****	37,642	35,954	***38,443****	**29%**
Skilled agricultural and fishery workers	***6,194****	9,011	7,173	***3,917****	6%	***6,338****	6,044	7,207	***6,878****	6%
Craft and related trades	12,047	15,719	13,405	16,057	14%	13,848	15,196	13,834	12,706	14%
Plant and machine operators and assemblers	9,438	6,635	10,089	***7,800****	8%	***7,335****	***9,035****	***8,814****	11,293	8%
Elementary occupations	15,965	15,706	14,931	14,469	15%	19,819	21,850	13,469	14,884	15%
Total	102,916	103,203	103,181	103,407	100%	113,833	121,762	119,452	123,711	100%

Source: Population and Housing Census, Phuket Provincial Statistics Office, 2004-2005

The study found the relations among diversity of economic activity, stability and economic shocks. The economic structure of Phuket relied heavily on tourism industry which made economic activities less diversified. The economic shocks of Phuket occurred when its tourism industry - located in the vulnerable beachfront area - was affected by 2004 tsunami. The case of Phuket provides the evident that the less diverse economy can lead to the instability of the economical activities. A number of affected tourism businesses were unable to run its old means, spending over three months before it returned to the pre-existing state. Three occupations faced with disproportionate employment level: service providers and traders, skilled agricultural and fishery workers, and plant-machine operators and assemblers. It can imply that the 2004 tsunami tested the adaptability of urban economy and local entrepreneurs.

Noticeably, SMEs took a threat of recession as a challenge to enhance their capacity through grouping together and helping each other collectively based on a community-based approach. Even though, Phuket has once again become a premier tourist destination with the rising number of international tourists, the past economic recession will still remind the people that vulnerability and instability of its economy is a result of its less diverse economy.

3.3.4 Institutional and community adaptive capacities

Local communities in Phuket Island had no warning systems and evacuation infrastructure in place when 2004 tsunami occurred, despite Thailand's membership of the Pacific Tsunami Warning System (UNEP, 2005). Disaster management at that time had focused mainly on the emergency response and post-disaster recovery, overlooking the potentials of mitigation and preparedness (Thanawood, Yongchalermchai, & Densrisereekul, 2006). Since the kingdom had never been hit by a severe catastrophic event like the 2004 tsunami, it was considered as an extremely rare occurrence in Thailand (Tibballs, 2006). As a result, thousands of people were missing, and many more were found dead. In fact, a number of lives would have been saved, if a tsunami warning system was available (Alverson, 2005).

Consequently, the Thai government became more active in promoting the Nation Disaster Warning Center established in 2005 to administer risk communications across the country (Nation Disaster Warning of Thailand, 2005). This led to establishments of several programs aiming to strengthen efforts to reduce city vulnerability in future tsunami events. Disaster risk management should be proactive rather than reactive disaster response, thus the policy framework for disaster risk reduction (DRR) in Thailand constitutes the disaster risk management in the consideration of four aspects: mitigation or prevention, preparedness, response, and recovery. According to a study on governing and building resilience in Thailand (Larsen, Calgaro, & Thomalla, 2011) the National Tsunami Prevention and Mitigation Strategy (2008-2012) reflects proactive approaches of transferring knowledge, enhancing community understanding, installing early warning systems, designating evacuation places and supporting community-based disaster risk reduction. At the provincial level, the Provincial Disaster Prevention and Mitigation Office was found under the Provincial Governors' Office. The provincial plan focuses on community-based disaster risk reduction as a core activity. In addition, the Department of Local Administration is responsible for instructing local authorities to develop local disaster preparedness policy. These plans aim to integrate infrastructure, communication system, and capacity building that are the foundation for overcoming institutional and community resilience.

Apart from the domestic policies, international policies such as Phuket Action Plan was produced by United Nations World Tourism Organization (UNWTO) in order to guide a recovery action for Indonesia, Thailand, Sri Lanka and Maldives. The main goal was to speed up recovery process in the affected destinations, and the action plan put priority in five areas: marketing and communication, community relief, professional training, sustainable redevelopment, and risk management (Rice & Haynes, 2005). As a consequence, the influence of this action plan in increasing institutional adaptive capacities on community recovery process and city resilience was emphasized by Handmer and Choong (2006) that;

> "The Phuket Action Plan provides a good framework on paper for the recovery process, with its emphasis on the money flows that employ people and sustain local enterprises, rather than on asset construction—which may give the appearance of a building boom and local economic resilience…"

To recover livelihood of people in affected areas, Thai government with support from voluntary donation and NGO could quickly provide immediate disaster reliefs into the affected communities in a variety of ways. Immediate cash handouts, temporary shelter, food rations, clean water supplies and clothing were sent from unaffected areas. Regarding the implementation of the Phuket Action Plan (World Tourism Organization, 2005) - under the government affordability - each affected victim was provided an immediate monetary relief of THB 2,000 (USD51). This was followed by a THB 20,000 (USD 510) grant to all small businesses. The government also offered lost wage compensation to affected employees, equal to the minimum wage of THB 175 ($4.50) per day, a payment that continued for another couple of months.

No disaster recovery plan was in place before 2004 tsunami event, despite the civil protection authorities had been present. The impacts of 2004 tsunami put pressures on government actions in recovering affected cities from the catastrophe. Because of adaptive capacities of national government and local authorities, and support from NGOs and international cooperation, many kinds of disaster reliefs and disaster recovery plans were provided to the affected areas. In addition, a number of re-development plans with disaster risk deduction measures were produced. The government's position then moved from a reactive manager to a proactive planer. Therefore, recovery processes in Phuket Island dovetailed into mitigation and preparedness work for future events. However, the monetary relief provided by the government was criticized that even though it might benefit to local communities by increasing its financial liquidity and accelerating recovery time, its vulnerability did not decrease. Increased financial resilience of local communities though obtaining exogenous support could not be sustained and prolonged, because it did not come from their adaptive capacity.

3.3.5 More resilient, but still vulnerable

Even though some local authorities actively responded to post-tsunami recovery for building resilience, the residual vulnerabilities still existed. One of these examples can be found in Patong Municipality. After the tsunami of 2004, Patong Municipality became involved and was responsible for the disaster risk management. To ensure human security and the continuity of urban activities, the need to promote good governance policies was identified as an essential step in managing disaster events at the local level. The local government system in Thailand at that time was still in its infancy, which was a serious challenge to the pre-existing governance structure. Even though, Thailand's decentralization process has been started since 1990s, "it was still fiscally asymmetrical because the central government was devolving responsibility and authority for expenditure, but not for revenue (Asian Disaster Preparedness Center (ADPC), 2007)". Therefore, the local governments, in general, were lack of funds to invest in urban development and risk management in a proactive manner due to the regulations and the unavailability of trained staff. Hence, there was a need to encourage civil society to participate in in the affairs of local authorities.

Guided by "A Recovery Plan for Economic, Social, Natural Resource, and Basic Infrastructure of Phuket Province", Patong Manucipality implemented 44 projects for the tsunami recovery. Those projects made significant progress with a high level of response. Public and private sectors, particularly hotel and tourism industry, were involved in making the city safer. Therefore, these interventions were not exclusively conducted by the municipality, but they were interconnected and integrated with a mission to establish an "international marine tourism center with high living quality, unique culture, and sustainable development" (Asian Disaster Preparedness Center (ADPC), 2007).

Since Patong Municipality was committed to provide a safer city for inhabitants and visitors, the municipality worked further with the Department of Disaster Prevention and Mitigation (DDPM) and the Tourism Authority of Thailand (TAT). The municipality has followed TAT guidelines on designing tsunami mitigation initiatives within a coastal zone. Private sectors were encouraged to select some design options as appropriate. For example, wooden beach benches were replaced by the plastic ones in order to avoid causing injuries in the future events. In addition, seven early warning towers and sirens have been constructed and installed, while evacuation routes are marked. Language barriers and communication problems were taken into account; the early warning massage was intended to broadcast in five languages - Thai, English, Chinese, Japanese & German - and more may follow.

Nevertheless, according to the observation survey in 2013, it was quite difficult to identify the evacuation route and places. The problem was a result of advertising broads and labels, and there was no evacuation map provided to people. Besides, the evacuation drills should have been undertaken more than once a year and in different scenarios such as in daytime and nighttime. There was no publication related to a tsunami evacuation manual for the residents and tourists, which could be inferred that people did not realized its crucial risk information. For most individuals' recovery processes, damaged buildings were reconstructed to their previous states, instead of improving them. The interview with local officers from the sections of urban planning and property tax collection revealed that there was no tangible incentive to motivate private sectors to cooperate in hazard-resistant building practices and/or to devote their buildings as tsunami escape buildings. It is clear that the idea to integrate structural and non-structural mitigation measures for the tsunami risk reduction should have been more broaden and integrated with the land use policies.

Although Patong Municipality tended to be tsunami resilient in terms of institutional capacity to encourage public-private partnership in the recovery, some residual vulnerabilities particularly in terms of physical elements was still exist. In Patong case, enhancing resilience does not always reduce its existing vulnerability; some resilience enhancement may even increase vulnerability. For example, the guidelines for the resilient design and execution of tsunami mitigation initiatives within the coastal zone should be produced, while the technique assistance in spatial planning for disaster resilience shall be provided.

3.3.6 Discussions

With a concern on methods of and apparatus for identifying and enhancing city resilience which has been the subject of the professional debates among urban planners for more than a decade, the study aims at exploring resilience of a real case study - Phuket Island - through addressing various characteristics of case study. The evidence presented in this study has illustrated how urban planning policies, economic development, and institutional adaptive capacities were the crucial determinant of urban systems for resilience building in Phuket after the 2004 tsunami.

In the past, Phuket city was vulnerable to disaster as there was lack of concerns on disaster vulnerability in the planning process; the economic benefits overrode other considerations and impacts that a city might have to suffer. The 2004 tsunami event directed Thai planners' attention to resilience building from tsunami to potential climate change impacts. Prior land use policies and land use ordinances were reformed in order to enforce developers and communities to follow a new master plan on disaster risk reduction. The results of an empirical study show that the undiversified economic activity creates economic instability, especially the capitalist economy. Its dependency on tourism can put it in severe state when international tourism decline. The study suggests that a shift toward a broader service-oriented economy in Phuket will reduce its economic sensitivity and buffer an economic system from perturbations. Disaster impacts on economic activities encourages a formation among SME enterprisers for helping each other in the business recover process, which leads to a speedy recovery. The resilience is not only spatially scaled but it is also, based on the institutional capacity, able to adapt to changed circumstances when disasters hit the city. Past experiences of the national government and local authorities have led to broader and more effective strategies in terms of disaster risk reduction.

3.4 Resilience to man-made disaster: Tourism impacts on urban management

3.4.1 An ideal contemporary infrastructure planning

To estimate tourist allocation in the Phuket Island, figures of tourist attractions and accommodations were applied under a basic assumption that the attractiveness of each area, which depends on its tourism activities and services, determines a greater number of tourists. Table 1 shows that 49.58% of tourists, as projected, will be allocated in Mueang Phuket, while 44.79% of tourists will travel around Kathu. Using an exponential model, the study estimated the number of tourists and allocated them into three districts. The estimated tourist allocation estimated by using Equation 3-1. This equation can be a guideline for urban planners to prepare for sufficient tourist infrastructure (See Table 3-2 and Table 3-3).

It was found that the local population density could no longer be the only factor used in forecasting the demand of urban infrastructure, since numbers of non-residents – tourists and temporary worker – are growing. Particularly in coastal cities, numbers of tourists increased significantly and they need to be factored in for a more accurate estimation. The following figures (4.8 and 4.9) represent the population density of Phuket in 2012 and 2020 respectively. Even though tourism development creates significant profits to the city, it also increases the internal tourism consumption, waste, and pollution.

Table 3-2: Numbers of tourist attractions and hotels categorized by administrative districts

Administrative districts	Tourist attractions (a)[1]				Accommodations (b)[1]	Weighting scores (a*50%)+(b*50%)
	Natural sites	Historical sites	Cultural and heritage sites	Total (60 places/ 100%)	Hotel (Units) (96 units/ 100%)	
Mueang Phuket	29	0	3	32 (53.33%)	44 (45.83%)	49.58%
Kathu	2	1	0	3 (5.00%)	6 (6.25%)	5.63%
Thalang	16	5	4	25 (41.67%)	46 (47.92%)	44.79%
Weighting proportion	**50%**				**50%**	**100%**

Note: Data as of 2004
The weighting score was the sum of tourist attraction and accommodation score under a 50/50 weighting system.
[1]National Statistical Office of Thailand (www.nso.go.th)

Source: By authors

$$Tourist\ density\ (\text{Per sq. km.}) = \frac{\text{Number of Tourists in each district} * \text{The length of stay}}{\text{Area of each district}}$$

The average length of stay = 4.26 days
Area of each district = Mueang Phuket (224 sq. km.), Kathu (67.034 sq. km.) and Thalang (252 sq. km.)

Equation 3-1: Tourist density

Source: By authors

Table 3-3: A projection on tourism allocations between 2009- 2022

Year	Tourists in each district per year (Persons)			Tourist density (Per sq. km.)		
	Mueang Phuket	Kathu	Thalang	Mueang Phuket	Kathu	Thalang
2008	2,467,372	279,912	2,228,928	132	50	106
2009	2,629,920	298,352	2,375,768	140	53	113
2010	2,803,177	318,008	2,532,282	150	57	120
2011	2,987,848	338,958	2,699,107	160	61	128
2012	3,184,685	361,288	2,876,922	170	64	137
2013	3,394,490	385,089	3,066,451	181	69	146
2014	3,618,116	410,459	3,268,466	193	73	155
2015	3,856,475	437,499	3,483,790	206	78	165
2016	4,110,536	466,321	3,713,300	220	83	176
2017	4,381,335	497,042	3,957,929	234	89	188
2018	4,669,974	529,787	4,218,674	249	95	200
2019	4,977,628	564,689	4,496,597	266	101	214
2020	5,305,550	601,890	4,792,829	283	107	228
2021	5,655,076	641,542	5,108,577	302	115	243
2022	6,027,628	683,807	5,445,126	322	122	259

Note: - The number of tourists in 2009-2022 is a projection number.
- The projection is based on an exponential model based on a figure of tourists between 1998 and 2008. (National Statistical Office of Thailand and Phuket municipality)
- The length of stay in here was 4.26 days with regard to the Tourism Statistics in 2010 derived from Phuket municipality.
- Tourist density was calculated by using Formula 1.
Source: By authors

Table 3-4: A projection on local resident adjustment allocations between 2009- 2022

Year	Number of residents			Resident density (Per sq. km.)		
	Mueang Phuket	Kathu	Thalang	Mueang Phuket	Kathu	Thalang
2008	203,289	45,627	62,036	908	681	246
2009	209,727	48,053	63,798	936	717	253
2010	216,368	50,607	65,609	966	755	260
2011	223,220	53,298	67,472	997	795	268
2012	230,288	56,132	69,388	1,028	837	275
2013	237,581	59,116	71,358	1,061	882	283
2014	245,104	62,259	73,385	1,094	929	291
2015	252,866	65,569	75,468	1,129	978	299
2016	260,874	69,055	77,611	1,165	1,030	308
2017	269,135	72,726	79,815	1,201	1,085	317
2018	277,658	76,593	82,082	1,240	1,143	326
2019	286,450	80,665	84,412	1,279	1,203	335
2020	295,521	84,953	86,809	1,319	1,267	344
2021	203,289	45,627	62,036	1,361	1,335	354
2022	209,727	48,053	63,798	1,404	1,406	364

Source: By authors

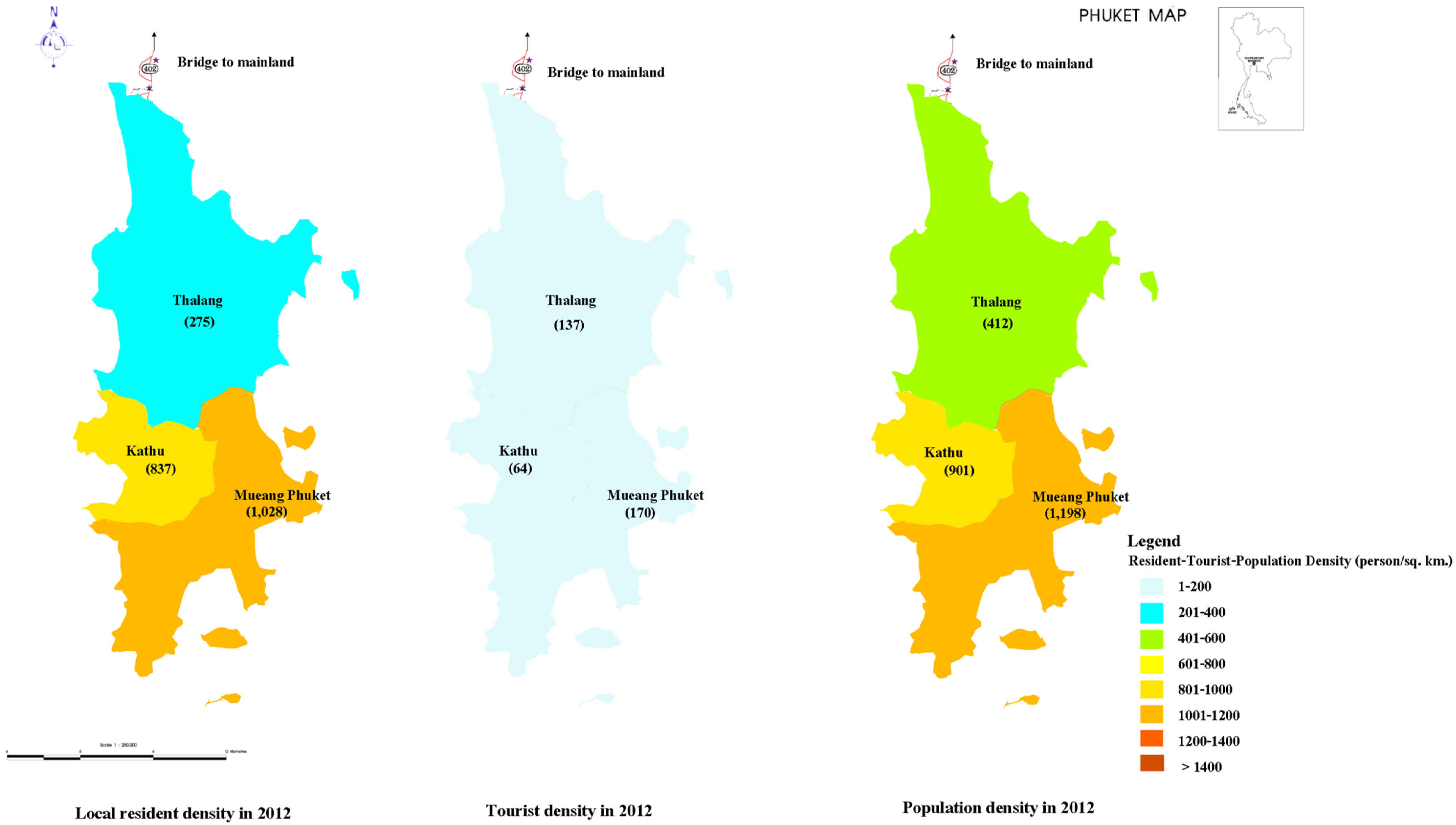


Figure 3-8: Actual population density in Phuket Island of 2012

Source: By authors

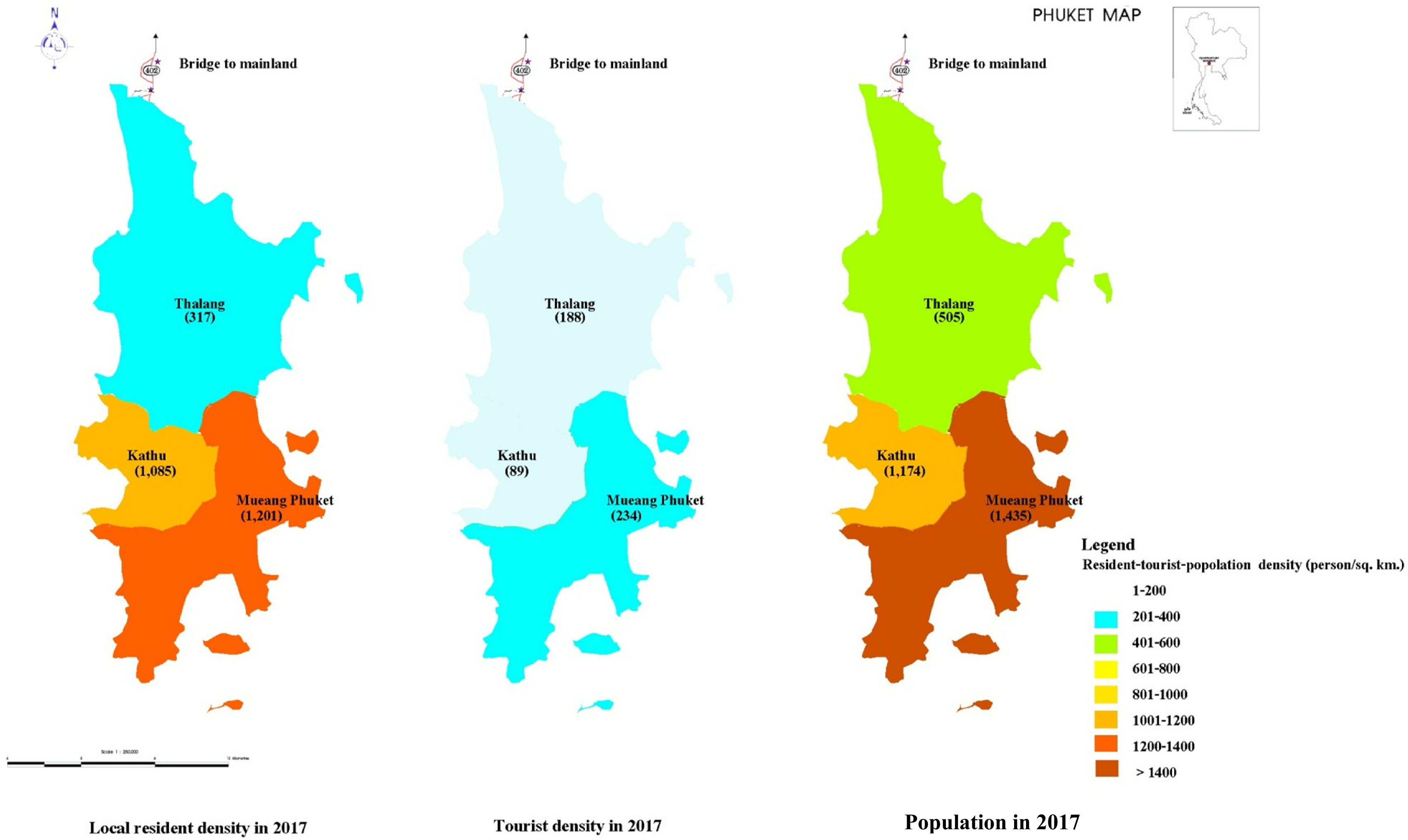


Figure 3-9: Actual population density in Phuket Island of 2017

Source: By authors

3.4.2 The criticism on failures of land-use management and enforcement in coastal cities

The main problem in coastal cities was that many local businesses conducted their business activities on footpaths and other public spaces. Focusing on cities along Andaman coastline, it was found that many street vendors illegally occupied and used footpaths for conducting their businesses; this was then resulted to a safety issue as pedestrians had to walk onto the roads. In Andaman's and Mediterranean's coastal cities, beachfront areas belonged to business owners such as restaurants, hotels or resorts. Their properties separated the beaches from the main land, and obstructed tourists and local people from accessing the beaches. Till now, the issue of private land use versus public access to the beaches is still controversial. Granted land use rights are subject to government revenues, but is it worthwhile to pay for the cost of environmental improvement?

3.4.3 Alternative urban infrastructure planning in the age of tourism

Since the urbanization has been increasingly transformed the economy from industrialization-based to tourism-based development, the tourism needs, therefore, should be factored into the concept of urban infrastructure planning. The traditional population census regarded as a basic tool for planning infrastructure and services is unable to capture rapid urban expansion, because cities may also be shaped by tourist demands. Without reliable information, analysis and synthesis, the infrastructure planning is difficult to meet with future demands. The study pointed out that a comprehensive viewpoint of urban infrastructure plan with regard to an increasing tourism demand could be more likely to maintain the city's future economic viability. Revision of a business-as-usual approach is one of alternatives to explain the urban metabolism more precisely. The availability of historical data could give adequate weight to the cost and benefic of tourism development.

3.5 Discussions

The tsunami and tourism impacts show some of the fundamental characteristics of urban risk and vulnerability. These remind us that cities, especially in coastal areas, are not immune to the forces of nature and human behavior. In addition, those communities of the marginalized and squatter settlement live with greater threats of natural disaster than the wealthy communities, because of the construction materials used are not strong enough to withstand disaster.

The case study of Phuket Island on tsunami impacts revealed how power led to the creation of certain social groups within the city. The power can be divided into material power and non-material power. The material power is an ability to pay for recovery cost, to secure housing during an evacuation process, and to access to basic services. Meanwhile, the non-material power is an ability to control, or adapt to changed circumstances and perturbations. The institutional capability is more important than material structures, because ideas shape the ways how such structures are used. The study reveals that institutional adaptive capability, diversified economic activities, and effective land-use ordinance linked to laws and regulations can buffer the impacts of natural disaster. Results of the study correspond to the idea of Pelling (2003, p. 45) that "the socio-economic consequences of disaster are shaped by a degree the pre-disaster characteristics of the urban economy and politics".

Another case study is on tourism impacts to urban metabolism. The flows of urban inputs and outputs are too complex to be analyzed and synthesized by a set of simple models. We should be well aware not to fall into the trap of reductionism when technology may provide misleading scenarios. Cities are changing over time, some traditional planning approach should be revised due to the changes of socio-economic characteristics, urban landscape, and the use of land in the cities. The study considers tourism impacts to urban management as a chronic problem associated with the over use of urban infrastructure, the deficiency of urban services and landscape degradation. This hazard is less visible than natural disaster; however, it may lead to catastrophic event by lowering city resilience. Here, a business-as-usual approach is adopted to estimate demands on urban utility and facility. The estimation is integrated with a concept of new urban metabolism in terms of tourism urbanization. The figures of local residents and tourists are combined in order to reflect real existing situations. The study emphasizes the need to estimate the non-registered population- number of tourists - before forecasting city infrastructure demands. Consequently, the crucial information for this assessment is a figure of tourist attractions, the period of stay, and physical tourism locations.

A Phuket case study and literature reviews are regarded as guidance for the research and development. The next chapter will explain how to build resilient city. Table 3-5 show three crucial elements of resilient urban systems. For this study, the resilience can be broken down into three components: stability, reaction, and recovery. Based on these components, a resilient community is able to adapt to a changed circumstance in order to keep the community continuity. The resilience approach identifies the resources and adaptive capacity that a community can utilize to overcome the problems that may result from any perturbations. This approach builds upon the inherent capacities of a community, rather than rely on only external interventions to overcome its vulnerabilities (Maguire and Cartwright, 2008).

Focusing on the resilience components, the stability is related geographical locations and physical infrastructure of the city. The stability can be developed through a process of qualitative improvement and structural mitigation measure carried out by individuals or the public-private policy such as building codes, land-use ordinances. A way in which cities respond to disaster can reflect the capability to cope with disaster. This capability can be divided into institutional capability and individual capability. Meanwhile, the success of recover after disasters depends on the ability of actors, the effectiveness of relief plan and preparation, immediate rescue actions, and recovery strategies made in response to hazard.

In conclusion, there are three ways to enhance city resilience. First, physical improvement to enhance the robustness of critical infrastructure (built environment: road networks, open space allocations, urban form, and geographic configuration). Second, by building community capability, it will increase the recover and rehabilitate process more swiftly and efficiently. Third, developing social learning system can lead to restructuring emergency plans and enhancing coordination among sectorial authorities, which raise the public risk awareness and offer a better procedure of disaster evacuation.

1. Stability: a system can ***tolerate*** ('absorb') before it shifts to another state (unable to return its functions) (Holling, 2003 in Folke, 2006, p.254, in Maguire and Cartwright, 2008)

2. Recovery: a community's ***ability to*** 'bounce back' from a change or stressor to ***return*** to its original state.

3. Reaction: an adaptive capacity of a community to ***respond*** proactively and positively to a change. Adaptation includes actions taken to reduce vulnerabilities and to increase resilience (Smit and Wandel 2006)

Table 3-5: Three components of "resilience"

Components	Criteria	Solutions to build a resilient city
Stability (Buffer capacity)	Qualitative improvement	"Development" in social-environmental urban facility and utility
Recovery (Bouncing back)	Quantitative increase in physical scale and Qualitative enhancement of public/ social networks	"Business Continuity" of economic sectors and Self-organization
Reaction (Adaptability)	Endogenous capacity enhancement	"Innovative social learning"

Source: By author

Chapter 4 :
An alternative application for enhancing urban resilience against tsunami

In this chapter, the basic ideas and assumptions that lay the foundation of this study are discussed in order to illustrate how urban resilience to tsunami is addressed at the beginning. Furthermore, the literature review and the preliminary study in Phuket Island are taken into account for constructing a research framework and methodology. Consequently, a certain research theme and approaches explicitly identified allow the research framework to draw up a methodology for data collection. All data collected from primary and secondary sources are going to be analyzed later on in the next chapter.

4.1 A construction of research questions and research hypotheses

In Chapter 2, the study proposed a conceptual model of urban resilience arising from the focus of the linkage between vulnerability and resilience. Resilience in this model can be interpreted as both an outcome and a process of restoration, not just a reconstruction. This restoration process is generally related to the bouncing back capacity that somehow reflects the vulnerability of a given system. Whereas urban resilience to natural disaster means that components of urban system: the built and natural environment, human capital and socio-economic activities, are able to withstand disaster impacts without losing basic functions and physical structures of the system that are necessary to maintain livelihood of their users. Urban resilience to tsunami addressed here is a dynamic process that shifts the state of urban system from vulnerable, to resilient, and then advances to innovative urban transformation.

Nevertheless, the success of such desirable movements is still questionable because a cogwheel turning a state of the defined system from one to another requires a set of constituents. Those constituents and their driving forces need to be studied elaborately in details. Therefore, the research questions and hypotheses are addressed according to a comprehensive discipline of research operations (See Table 4.1).

Table 4-1: The relations among research objectives, questions, and hypotheses

Research Objectives	Research Questions	Research Hypotheses
1. To describe the disaster resilience in terms of urban planning and find a way to put this concept into practice	1. How can the theoretical plausibility of resilience be translated into practice?	1. Enhancing resilience is a dynamic process that requires crucial mechanisms to turn a dynamic state of cities from vulnerability to resilience.
2. To determine tsunami vulnerable characteristics of the coastal city based on a case study of Kochi City 2.1 To identify crucial elements of the urban vulnerability to tsunami 2.2 To evaluate the urban vulnerability to tsunami 2.3 To compare vulnerability levels of each sub-district in Kochi City	2. How vulnerable to tsunami Kochi City is? 2.1 What are crucial characteristics of areas that make a city more vulnerable to tsunami (Which vulnerable characteristics make highly vulnerable districts different from the others?) 2.2, Where is the most tsunami-risk area in Kochi City?	2. Socio-economic attributes of Kochi City categorize vulnerability of the urban fabric of this city. 2.1.1 Socio-economic characteristics of residents in individual districts make the highly vulnerable districts different from the others. 2.1.2 Critical infrastructure is a major determiner of vulnerability level. 2.2 Sub-districts near by a coastal zone are more vulnerable to tsunami than inland districts.
3. To investigate tsunami resilience of case studies	3.1 How to determine or describe tsunami resilience of the case studies? 3.2 How resilient is Kochi City in terms of urban planning against tsunami?	3. The resilience is measurable in terms of a narrative assessment by using either Key Performance Index, Benchmark, or a set of indicators.
4. To propose spatial development strategies that can turn a vulnerable city into tsunami-resilient cities, and illustrate how to apply these strategies to Kochi City.	-	4. The competency and resilience of social structures; comprising of the rule of law, procedures, and social actors, are essence for the city to adapt to disaster risks, while the robustness and transformability of physical infrastructure can enhance the ways that social units cope with disaster risks. In this context, predominantly competency and resilience of social structures should initially be enhance.

Source: By author

After translating the conceptual model and indicators, which are extracted from the literature review, into research questions and hypotheses, the further step is to construct a research framework of enhancing urban resilience to tsunami, and to take this framework as a platform to set up a suitable methodology for the data collection and data analysis. Those operational methodologies will be identified and explained in the next sections.

4.2 Research Framework Description

The research framework developed in this chapter represents the final output of a long process of the literature review, study model construction, and preliminary case study. Not only the knowledge and critical thought about resilience and vulnerability discussed in the literature review but also a lesson-learnt of the preliminary study are used in the framework construction. Through this combination between theoretical aspects and practice of disaster resilience identification, the relation of resilience and vulnerability regarded as the relation of resilience and vulnerability regarded as the opposite sides of the same coin is amplified. Therefore, a traditional risk management approach is taken as a research boundary that helps to scope a procedure of research operation. In addition, the lesson-learnt of the preliminary study is utilized as a foundation of the framework. This foundation provides a practical guidance on how to identify the disaster resilience of a city and how a tsunami-affected city could "Bounce Back". By this way, ideal resilience indicators and characteristics are translated into practice, and enabling a possibility to enhance city resilience against tsunami.

The operational way for this conceptual framework is constructed based on a connection between a study model (In chapter 1), various ideas gathering from the literature review, the conceptual model for urban resilience to disaster (In chapter 2), and the lesson learnt from the preliminary case study (In chapter 3). Three turning points of innovative urban transformation mentioned in the conceptual model of urban resilience to disaster – the interaction among risk and urban system, social learning, and self-organization – are integrated in the framework, and these are translated into three schematic studies in order to enhance urban resilience to tsunami (See Figure 4-1)

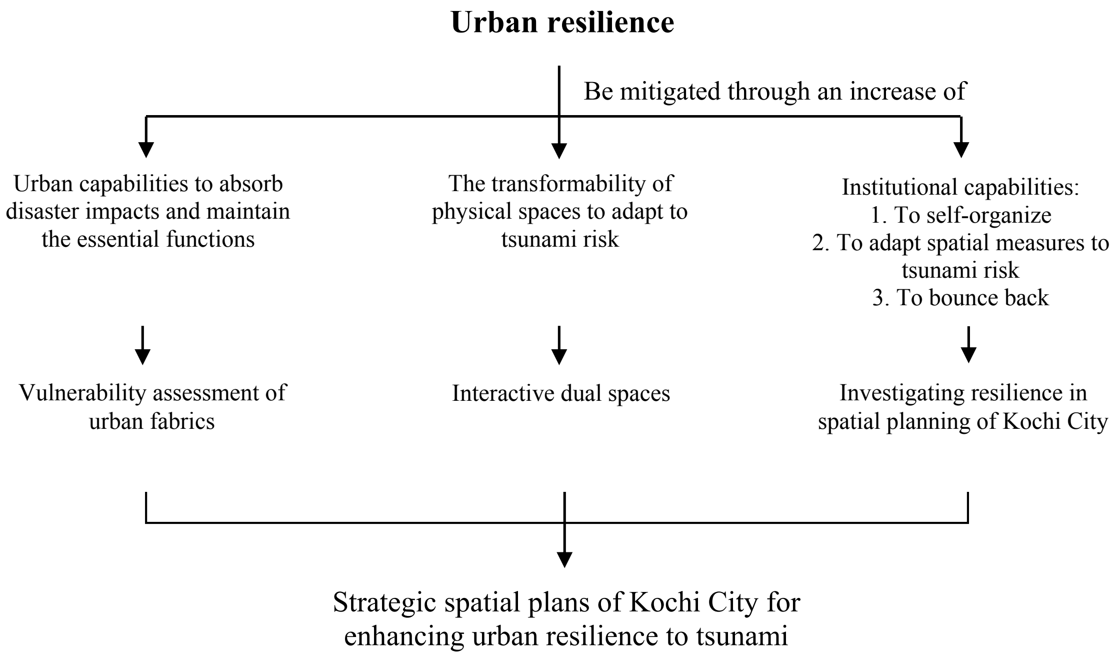


Figure 4-1: Research design

Source: By Author

First, the study takes a vulnerability assessment as a first step to understand the vulnerability of built environment and social construction. This assessment is initiated under a risk management framework suggesting that a risk identification and assessment should be a common ground of risk communication before a risk mitigation process takes place. The study considers that a hazard risk in this case is the tsunami risk, which can potentially turn to be disaster when the urban vulnerability is unfolded. Hence, a set of urban elements – such as urban infrastructure and social construct – that constraints vulnerable attributes of tsunami risk is going to be studied. By this study, one of fundamental characteristics of urban resilience – the capability of urban elements to absorb disaster impacts and to maintain the essential functions of the city – will be investigated.

Second, after the tsunami-vulnerability assessment completed, the next step is to bring this assessment to the public's concerns as well as to make a fruitful risk communication, which will lead to cultivating desirable risk awareness and perceptions of the residents. By following these ideas, the importance of social learning – identified in the conceptual model of urban resilience to disaster (In Chapter 2) as a turning point moving from being adaptive to resilient – is taken as a sub-research subject. This subject aims at turning the existing public space to be a dual space that residents nearby can use it both in the daily life and in an emergency event when the tsunami hits a city. Besides, functions of the dual space are likely to enable a decent social learning process on risk mitigation and management. With this process, it will render residents capable of adapting to tsunami risk and creating a better risk mitigation strategy to cope with the risk.

Lastly, the recovery process after the tsunami should not be just the conservative reconstruction of collapsed buildings and systems to the status quo. On the contrary, the recovery process should characterize in a rather restorative and innovative way that allow the city to be more apt to cope with the expected tsunami risk in the future. Therefore, this study focuses on the inference capability of self-organizing in urban planning and disaster risk management at an initiate state before the tsunami occurs. In order to presume the resilience of the regional and local institutional organizations governing Kochi City, a set of benchmarks for measuring resilience in governance – especially in terms of self-organizing in inventing urban planning measures for tsunami mitigation – is utilized.

In sum, the core of this study aims at enhancing urban resilience to tsunami based on a case study in Kochi City. With this intention, three mini studies are conducted in accordance with the research framework: 1) Vulnerability assessment of urban fabrics, 2) Interactive dual space beneficial for everyday life and emergency events, and 3) Investigating resilience in urban planning of Kochi City.

4.3 Research Methodology

The research methodology varies upon the differences among three sub-research subjects arisen from the conceptual framework. This section explains how those different subjects will be handled. Moreover, the research methodology and data collection are about to be defined.

4.3.1 A Vulnerability Assessment of Urban Fabric against Tsunami

Before identifying and enhancing urban resilience to tsunami, it is necessary to make better understanding on what vulnerable elements of the case study, i.e. Kochi City, are. Hence, a tool, which can be used in assessing vulnerability of the urban fabric, is needed to be conceptualized. The importance of vulnerability assessment for proposing risk mitigation measures has been emphasized in many disaster risk studies. To illustrate those, a conceptual model of UNESCO shown in Figure 4-2 is taken as an example. In this model, the process of disaster risk management begins with risk identification and vulnerability assessment dealing with the analysis on vulnerable physical and social elements, which characterize the urban fabric. However, the vulnerability assessment is not an ultimate outcome of the work, but results of the assessment will be used further on during a decision making process of risk response strategies based upon the defined level of risk acceptance. In this case, if the level of risk is lower or equal to the acceptable level, risk mitigation measures shall mainly rely on a non-structural approach. On the other hand, structural measures shall be applied when the risk that is higher than the acceptable level.

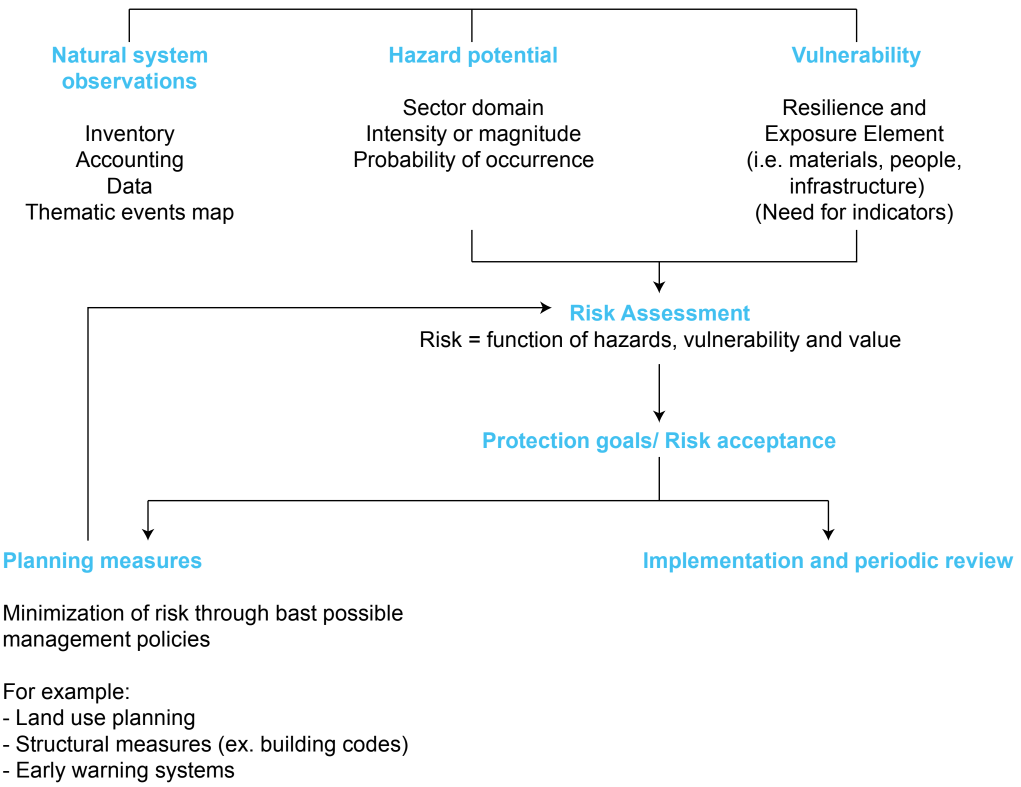


Figure 4-2: Measuring vulnerability as the fundamentals of specifying mitigation measures

Source: Adapted from UNESCO, 2003

The definition and application of vulnerability indicators undeniably become an essential part for improving mitigation measures at the larger level of urban risk management framework. Measuring vulnerability of urban fabric in terms of built environment and social structures should help to identify critical weak attributes that are needed special attention for further improvement before any natural disaster happens. The information about any vulnerability is regarded as a foundation of risk management and relevant discussions relating to resource allocation (human and finance) and mitigation measures that can ensure preparedness and an effectiveness of disaster response and recovery. This means that tools and indicators for vulnerability assessment are needed as an information database for facilitate decision makers in the provision of mitigation measures.

The previous literature review couples theoretical reflection between the vulnerability and resilience concepts as well as identifies some indicators and parameters that can be applied. Nonetheless, the correspondence between indicators and parameters and the theoretical part is not actually clear. Additionally, using indicators taken from another studies without further investigation can create another residual problems in explaining outcomes of the analysis, because there is no set of indicators that fits all cases. Apart from setting criteria for indicator selection, selecting approaches for the vulnerability assessment become a critical point in determining a comprehensiveness of the assessment. In recent decades, the disaster vulnerability studies have been largely based on the quantitative approach assessing the robustness of physical elements and structures. Despite a mere quantitative approach for vulnerability assessment, the inferential qualitative approach – which helps a conceptual explanation of vulnerable social attributes – should also be integrated as part of the vulnerability assessment.

This study based on a case study of Kochi City concerns that vulnerability assessment cannot be relied on a mere quantitative approach, as an inferential qualitative approach are also required in order to reveal the social vulnerability of the city. Therefore, the urban vulnerability to tsunami in this case is going to be assessed by a set of aggregating complex indicators of two different methods: the social vulnerability index (SoVI model) and the spatial multi-criteria social vulnerability index (SEVI model) (See Table 4-2). By aggregating two different methods into one, tons of variables are needed to be studied whether or not they bear any resemblance to the vulnerability of Kochi City. Crucial variables are chosen out of the original sets through the literature review, the observation survey (during November 2013 until January 2014) and the interviews with Kochi Prefecture's officers, who involve in urban planning process, infrastructure provision, community planning or disaster mitigation (the interviews is conducted in December 2013 and January 2014).

Table 4-2: A comparison of the approaches to assessing urban vulnerability

	SoVI model	SEVI model
Theme of Indicators	Social vulnerability index	Complex spatial multi-criteria
Methodology	Not involve factor weighting, using linear sum for scoring	Spatial and social decision rules to assess weights
Result of the assessment	May not accurately reflect the reality, if the indicator selection is imbalance	More freedom of intervention on procedures, which makes it more responsive regarding to expert-let accuracy
Similarity	Indices are limited to the availability of data that influence the indicator selection and the degree of indicative representation.	
Remark	Uncertainty can be triggered by the standardization, normalization, weighting, and aggregation included into a classification and a calculation algorithm	

Source: By author

During the development of indicators, the study finds out about many ambiguities and contradictions in identifying indicators and factors that can be used as indicators for social vulnerability assessment, even if there is a consensus between social scientists and disaster scholars about the influence of those indicators on social vulnerability. In addition, because different scholars define indicators in terms of social vulnerability differently, the selection of specific variables to represent individuals' concepts is varied, which can lead to disagreements among the scholars (Cutter, Boruff, & Shirley, 2003). Nevertheless, general characteristics largely used as indicators in social vulnerability studies can be summarized as listed in Table 4-3.

Table 4-3: Common variables for Social Vulnerability Studies

Concept	**Description**	**Increases (+) or Decreases (-) Social Vulnerability**	**Relevant studies**
Socioeconomic status (income, political power and prestige)	The ability to absorb losses and enhance resilience to hazard impacts. Wealth enables communities to absorb and recover from losses more quickly due to insurance, social safety nets, and entitlement programs.	High status (+/-) Low income or status (+)	Cutter, Mitchell, and Scott (2000), Burton, Kates, and White (1993), Blaikie et al. (1994), Peacock, Morrow, and Gladwin (1997, 2000), Hewitt (1997), Puente (1999), and Platt (1999).
Gender	Women can have a more difficult time during recovery rather than men, often due to sector-specific employment, lower wages, and family care responsibilities.	Gender (+)	Blaikie et al. (1994), Enarson and Morrow (1998), Enarson and Scanlon (1999), Morrow and Phillips (1999), Fothergill (1996), Peacock, Morrow, and Gladwin (1997, 2000), Hewitt (1997), and Cutter (1996).
Race and ethnicity	Imposes language and cultural barriers that affect access to post-disaster funding and residential locations in high hazard areas.	Nonwhite (+) Non-Anglo (-)	Pulido (2000), Peacock, Morrow, and Gladwin (1997, 2000), Bolin with Stanford (1998), and Bolin (1993).

Concept	Description	Increases (+) or Decreases (-) Social Vulnerability	Relevant studies
Age	The extreme of the age spectrum affects the movement out of harm's way. Parents lose time and money caring for children when day care facilities[1] are affected; elderly may have mobility constraints or mobility concerns increasing the burden of care and lack of resilience.	Elderly (-) Children (-)	Cutter, Mitchell, and Scott (2000), O'Brien and Mileti (1992), Hewitt (1997), and Ngo (2001).
Commercial and industrial development	The value, quality, and density of commercial and industrial buildings provides an indicator of the state of economic health of a community, and potential losses in the business community, and longer-term issues with recovery after an event.	High density (-) High value (+/-)	Heinz Center for Science, Economics, and the Environment (2000) and Webb, Tierney, and Dahlhamer (2000).
Employment loss	The potential loss of employment following a disaster exacerbates the number of unemployed workers in a community, contributing to a slower recovery from the disaster.	Employment loss (+)	Mileti (1999).
Rural/urban	Rural residents may be more vulnerable due to lower incomes and more dependent on locally based resource extraction economies (e.g., farming, fishing). High-density areas (urban) complicate evacuation out of harm's way.	Rural (+) Urban (+)	Cutter, Mitchell, and Scott (2000), Cova and Church (1997), and Mitchell (1999).
Residential property	The value, quality, and density of residential construction affects potential losses and recovery. Expensive homes on the coast are costly to replace; mobile homes are easily destroyed and less resilient to hazards.	Mobile homes (+)	Heinz Center for Science, Economics, and the Environment (2000), Cutter, Mitchell, and Scott (2000), and Bolin and Stanford (1991).
Infrastructure and lifelines	Loss of sewers, bridges, water, communications, and transportation infrastructure compounds potential disaster losses. The loss of infrastructure may place an insurmountable financial burden on smaller communities that lack the financial resources to rebuild.	Extensive infrastructure (+)	Heinz Center for Science, Economics, and the Environment (2000) and Platt (1995).
Renters	People that rent may either be transients or people who do not have the financial resources. They often lack access to information about financial aid during recovery. In the most extreme case, renters lack sufficient shelter options when lodging becomes uninhabitable or too costly to afford.	Renters (+)	Heinz Center for Science, Economics, and the Environment (2000) and Morrow (1999).
Occupation	Some occupations, especially those involving resource extractions, may be severely impacted by a hazard event. Self-employed fisherman suffer when their means of production is lost and may not have the requisite capital to resume work in a timely fashion and thus will seek alternative employment. Those migrant workers engaged in agriculture and low skilled service jobs (housekeeping, childcare, and gardening) may similarly suffer, when disposable income fades and the need for services declines. Immigration status also affects occupational recovery.	Professional or managerial (+) Clerical or laborer (+) Service sector (+)	Heinz Center for Science, Economics, and the Environment (2000), Hewitt (1997), and Puente (1999).

[1] Day care facilities aim to provide care or education during the day for young children or elderly.

Concept	Description	Increases (+) or Decreases (-) Social Vulnerability	Relevant studies
Family structure	Families with large numbers of dependents or single-parent households often have limited finances to outsource care for dependents, and thus must juggle work responsibilities and care for family members. All affect the resilience to and recovery from hazards.	High birth rates (+) Large families (+) Single-parent households (+)	Source: Blaikie et al. (1994), Morrow (1999), Heinz Center for Science, Economics, and the Environment (2000), and Puente (1999).
Education	Education is linked to socioeconomic status, with higher educational attainment resulting in greater lifetime earnings. Lower education constrains the ability to understand warning information and access to recovery assistance.	Little education (+) Highly educated (-)	Source: Heinz Center for Science, Economics, and the Environment (2000).
Population growth	Counties experiencing rapid growth lack available quality housing, and the social services network may not have had time to adjust to the increase of population. New migrants may not speak the language and not be familiar with bureaucracies for obtaining relief or recovery information, all of which increase vulnerability.	Rapid growth (+)	Source: Heinz Center for Science, Economics, and the Environment (2000), Cutter, Mitchell, and Scott (2000), Morrow (1999), and Puente (1999).
Medical services	Health care providers, including physicians, nursing homes, and hospitals, are important post-event sources of relief. The lack of proximate medical services will delay immediate relief and longer-term recovery from disasters.	Higher density of medical(+)	Source: Heinz Center for Science, Economics, and the Environment (2000), Morrow (1999), and Hewitt (1997).
Social dependence	Those people who are totally dependent on social services for survival are already economically and socially marginalized. They then require additional support in the post-disaster period.	High dependence (+) Low dependence (+)	Source: Morrow (1999), Heinz Center for Science, Economics, and the Environment (2000), Drabek (1996), and Hewitt (2000).
Special needs populations	Special needs populations (infirm, institutionalized, transient, homeless), are difficult to be identified and measured. Because of their invisibility in communities, these people are disproportionately affected during disasters and mostly ignored during recovery.	Large special needs population (+)	Source: Morrow (1999) and Tobin and Ollenburger (1993).

Source: Cutter, Boruff, & Shirley (2001); Heinz Center for Science, Economics, and the Environment (2002) cited in Cutter, Boruff, & Shirley (2003)

In order to select the indicators for vulnerability assessment, the operational framework is taken into consideration. The indicators applied in this study are based on the urban planning concern related to the urban fabric: the social construction, economy and urban infrastructure. Those indicators can be classified into two main groups: 1) a set of physical attributes gathered from the geographic information of Kochi City and 2) a set of social attributes (economic characteristics are included) based on the available statistic data from the secondary sources. Those two attributes are used as an indicator framework. With the aim to compare vulnerability of sub-districts within Kochi City's boundary, indicators, which are available at sub-district level, are privileged to be selected. At the same time, with the aim to enhance urban resilience against tsunami through spatial configuration, indicators that can be influenced by urban planning measures are also taken as potential indicators. Apart from those mentioned criteria of urban fabric, the balance between qualitative and qualitative indicators is taken into account.

In this study, the set of physical attributes is mainly related to land use/ building use activities and transportation network, whereas the set of social attributes deals with demography characteristics, the economic structure, and the quantitative capacity of the urban services that possibly have an influence on urban vulnerability. By integrating physical and social attributes into the vulnerability assessment, the study forms a particular set of indicators, which can be divided into six groups: (1) Urban density, (2) Facilities, (3) Building condition related to earthquake resistance, (4) Demography, (5) Economy, and (6) Cultural heritage. Table 4-4 shows 25 indicators that are selected out of a total set of variables derived from journal articles and theories on tsunami vulnerability and/or vulnerability to other natural disasters. Each column refers to the seven dimensions of vulnerability and six main types of potential indicators considered in this study. Noticeably, some main indicators comprises of a set of sub-indicators. Overall, a total of 25 indicators are used to measure the urban vulnerability to tsunami of urbanized areas within Kochi City. Besides, Table 4-5 is taken as a reference of a complete list used to quantify critical facilities (adapted from SEPA, 2012 and Dávila, Ayala, Salazar, & Ruiz-Vélez, 2014).

Table 4-4: The potential indicator description applied in the vulnerability assessment

Indicator group	Potential indicator	Description	Measurement
Physical attributes	(1) Urban density - Population density - Building density (divided by building uses) - Residential building - Commercial building - Mixed-use building - Industrial building - Heavy industry - Light industry and service industry - Agricultural building	Urban density is regarded as a reflection of urban environment where people live in. The population density determines how dense the city is, whereas building density can be used to refer to the urban activities that make economic growth.	– Population Density: measured through the number of residents divided by the administrative area – Building density: measured through the ratio of total floor area of each building use to the administrative area
	(2) Facilities (serve different purposes) - Supply and Utility - Facility for treatment and garbage - Industrial storage and treatment facility of hazardous materials - Health care facility - Education facility - Social welfare - Logistic facilities and transport facility - Facilities for telecommunication - General stores	Facilities are regarded as important elements during the disaster response and recovery. Different types of facilities can contribute to an increase of recovery speed at different level. Some facilities are needed in order to keep urban system functioning, whereas some of them may cause catastrophes if they are not well mentioned in a good condition, such as Industrial storage and treatment facility of hazardous materials.	– Facilities: measured through the total floor area of each building use
	(3) Building condition - Percentage of buildings built before 1978 (a regulation of building structure reinforcement)	The building condition in this case refers to the vulnerable buildings that were constructed prior the earthquake-resistant construction in 1981. The study assumes they are vulnerably potential to be collapse by the earthquakes.	– Building condition: measured through the percentage of old buildings constructed before the implementation of building reinforcement regulation (built before 1981)
Social attributes	(4) Demography - Age - Gender - Household size	As mentioned in several literatures, characteristics of population, such as age, gender, and household size, can be used to determine their capacity to cope with natural disaster. For example, the aged may find more difficult to evacuate to the safe place, when an emergency evacuation order is released.	– Age: measured through the percentage of the extreme of age spectrum (children and the aged – Gender: measured through the percentage of women – Household size: measured through the average family size of each administrative area
	(5) Economy - Household income* - Residential property* - Land price distribution	Due to the data availability, only land price is selected as an indicator that represents the state of economy. Constructions in the expensive land are costly, and this tends to cause more economic loss rather than other constructions in remote areas.	– Land price: measured through an official survey by the prefecture or a public notice
	(6) Cultural heritage	Few studies concern about losing the community identity. The cultural heritage is regarded as one of the identity of the community, which somehow influence the sense of belonging and sense of place of the local residents.	– Cultural heritage: measured through the number of cultural facility in the GIS database

Note: Data related to household income and residential property was not available at the local level (for those variables commonly used in the literature). Notice that total individual salaries and wages are never used.

Table 4-5: Indicators used to quantify critical facilities

Most vulnerable uses	Highly vulnerable uses	Less vulnerable uses
- Security facility - Health care facility - Industrial storage and treatment facility (for hazardous materials) - Supply and Utility - Logistic facilities (distribution terminals) and other transportation facilities - Facilities for telecommunication	- Waste treatment and management facility - Social welfare - Education facility - Government offices	- General stores - Storage and warehouse

Source: Adopt from SEPA (2012) and Dávila, Ayala, Salazar, & Ruiz-Vélez (2014)

According to data sources for the vulnerability assessment, most population data is obtained from the census in 2014. Demographic profile will be explained by the population statistic between 2006 to 2014, while the other indicators will be based on GIS data. A result of this assessment will be produced as a vulnerability map. This vulnerability map is further on used to compare with a series of hazard maps that were provided by the government through an overlapping technique. This comparison will classify areas of Kochi City into nine specific categories corresponding with the vulnerability level and hazard potential level (as shown in Table 4-6). Those nine categories can also be re-arranged into three different divisions of risk level represented the intensity of color (a grey scale). The darker the tone is, the more the area is at risk of tsunami.

Table 4-6: Matching the vulnerability level with hazard potential level

Vulnerability / Hazard potential	High	Median	Low
High	**HH***	MH	**LH***
Median	HM	MM	LM
Low	**Hl***	ML	LL

Source: By author

4.3.2 A study on the interactive dual space

According to the conceptual model of urban resilience to disaster proposed in Chapter 2, social learning is regarded as a significant mechanism in turning a vulnerable city to be more resilient through increasing the urban capability to adapt to changed situations caused by a natural hazard. Considering the social learning theory proposed by Albert Bandura (Bandura & Walters, Social learning and personality development, 1963), the social learning posits that people regularly learn from one another based on a cognitive process through observation, imitation, direct instruction, or modeling. Therefore, to raise this adaptability, this cognitive process should be taken in a place that offers a better learning environment, suitable for a local social context together with residents' behavior and cognition. In addition to the external environmental reinforcement, the intrinsic reinforcement, such as pride, a sense of accomplishment and satisfaction, also has an influence on the process (Bandura, 1969).

For this study, the social learning here can be viewed as a mutual process that results in both deepening cognition (linking to a social cognitive theory) and changing behavior (linking to a behavioral theory). The effective mutual process of social learning encompasses three constituents (Buckler, 1996): focus, environment, and techniques.

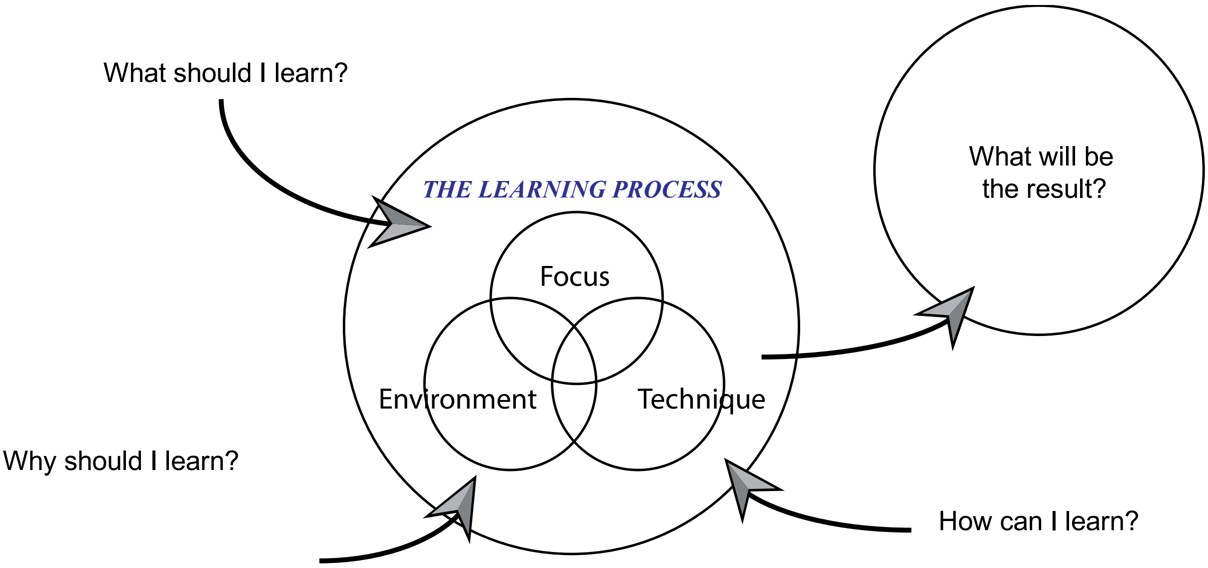


Figure 4-3: Three Constituents of Learning process

Note: the success of the learning process can refer to four sub-processes of Bandura (1969)

Source: Buckler, 1996

To ensure the effectiveness of social learning related to urban resilience, the essentials of physical environment is necessary for cities to encourage the risk communication. This role of physical environment is available in an article on the social learning theory of identification processes by Bandura (1969). The modeling process developed in this article provides more understanding why not all observed behaviors are learnt effectively. Factors both the learning model and the learner governing in the success of social learning can be identified through four sub-processes, which are (1) Attentional processes, (2) Incentive or motivational processes, (3) Retention processes, and (4) Motoric reproduction processes.

In order to learn, the social cognitive theory implies that a learner needs to pay attention to what he or she should learn (Attentional processes). Anything that distracts the learner's attention will contribute a negative effect on the learning process. Due to negative sanctions or inadequate positive attention, the learning performance is rarely activated in an obvious way. Hence, motivational environment and the presence of incentive-oriented sets (Incentive or motivational processes) are likely to make the learner dedicate closer attention to learning. When favorable places and incentives are provided, the learning is likely to promptly begin. Another basic component involved in the learning is the long-term retention of coded modeling events (Retention processes). There are a variety of variables, options, and techniques in reinforcing retention.

> "Among the numerous variables governing retention processes, rehearsal operations effectively stabilize and strengthen acquired responses. The level of observational learning can be considerably enhanced through overt practice or rehearsal of modeled response… Covert rehearsal, which can be readily engaged in when overt participation is either impeded or impracticable, may likewise enhance retention of acquired matching responses (Bandura, 1969, p. 222)."

Similarly, the suitable place and space for conducting a disaster drill is necessary for improving the retention of disaster risks and emergency responses to them and raising the risk awareness of the public.

To motivate the learner to perform individual disaster mitigation measures, a special technique is needed. The covert role-practice models, which govern behaviors: so-called "disaster imagination game (DIG) and urban gaming simulation (UGS)", have the influential function in allowing leaners (named participants in this case) to learn, anticipate, and covertly rehearse responses to disaster risk. In addition to the increased frequency and familiarity of social interactions, DIG and UGS would be little incentive to persuade participants to prepare and perform desirable mitigation measures in the reality, especially when punishment and reward system do not exist. Apart from the rehearsals, it is assumed that the utilization of symbolic representations in the form of signs and verbal contents may be more efficacious in facilitating the recognition (Retention processes), and in guiding overt performances (Motoric reproduction processes).These representational schemes are a basis of self-instruction of the disaster response and recovery. Furthermore, this leads to the new patterns of behavior as part of innovative transformation. “In many instances, modeled responses have been acquired and retained in representational forms but they cannot be enacted behaviorally because of physical limitations (Bandura, 1969, p. 224)”. The learner’s reactions to representational guidance are as essential as the reactions based on the lesson learnt from rehearsals. The mere difference is that, by following the representational guidance, a delay in the behavioral reproduction replies on the symbolic counterparts of absent stimuli, whereas, in the latter cases, the performance is influenced by external cues. For example, in the case of an emergency event caused by tsunami, residents and local authorities may successfully reach the remarkable performance of disaster responses and recovery due to the availability of evacuation places and emergency resources.

Like other cities in Japan, some schools and public parks in Kochi City are designed as the dual space in both daily life activates and in a disaster event. The disaster drills are normally held in the schools, where residents and children assemble and perform a collective disaster drill of each sub-district at least once a year. Whereas some public parks are defined as an evacuation place, in which the shuttle-in-place will be located for the disaster-affected people. Nevertheless, the harmony between those dual spaces’ locations and the urban form has not been studied; even some of them are designated officially. This suggests that the further study shall be related to the interaction between the urban form and urban vulnerability. Table 4-7 shows the selected quantitative variables and their descriptions for urban form analysis.

Most of the variables are similar to those developed by Allen (INDEX: Software for community indicators, 2001) and Song & Knaap (Measuring Urban Form: Is Portland Winning the War on Sprawl?, 2004).

Table 4-7: Quantitative Variables of Urban Forms

Aspects	Variables	Descriptions
Connectivity	Int_Connectivity	Number of street intersections divided by sum of the number of intersections and the number of cul-de-sacs; the higher the ratio, the greater the internal connectivity
	Blocks_Peri	Median perimeter of blocks; the smaller perimeter contributes to the greater the internal connectivity
	Blocks	Number of blocks divided by number of housing units; the fewer the blocks the greater the internal connectivity
	Ext_Connectivity	Median distance between Ingress/ Egress (access) in meter; the shorter the distance, the greater the external connectivity
Density	Lot_Size	Median lot size of housing building units in the neighborhood; the smaller the lot size, the higher the density
	Density	Dwelling units divided by the residential area of the neighborhood; the higher the ratio, the higher the density
	Floor_Space	Median floor space of dwelling units in the neighborhood; the smaller the floor space, the higher the density
Land Use Mix	Mix_Actual	Area (sq. km) of commercial, industrial and public land uses in the neighborhood divided by the number of housing units; the higher the ratio, the greater the land use mix
	Mix_Zoned	Land area zoned for central commercial, general commercial, neighborhood commercial, office commercial, industrial and mixed land uses in the neighborhood divided by the number of housing units; the higher the ratio, the greater the mix
Accessibility	Com_Dis	Median distance to the nearest commercial
	Park_Dis	Median distance to the nearest park; the shorter the distance, the greater the accessibility
	School_Dis*	Median distance to the nearest park; the shorter the distance, the greater the accessibility

Source: Song & Knaap, 2004 (*The variable added by author)

4.3.3 An identification of urban resilience against tsunami

Policy makers have to use a set of information about past trends, current realities, and future directions to aid decision making, just as urban planners use indicators for the data analysis and synthesis to provide a development proposal or a solution to influence changes. Each indicator-development process needs to be linked to the study's goals or to a vision taken as a basis of defining the characteristic of interest (Birkmann, 2006, p. 58). To develop scientifically sound indicators, enhancing tsunami resilience in terms of urban planning is formulated as a goal, and the identification of relevant indicators is taken as a starting point.In practice, there are two types of indicators: system indicators and performance indicators.

First, system indicators focus on summarizing individual measurements that provide a vital picture of the current state, or the trend, or the direction that a development is taking. This type of indicator is often based on technical analysis and scientific research allowing one to assess the vulnerability, the quality, the risk, etc. For example, an increasing or decreasing quality of social structure indicates a higher or lower vulnerability. However, there are some limitations to system indicators. As the inherent uncertainties of natural systems make a set of indicators ineffective, the analysis turns to be impractical. The scientific criteria or benchmarks used to define indicator could; therefore, partially determined the reality when the scientific accuracy is compromised with the needs of decision making and research goals. This limitation becomes quite clear in the social dimension where many of the variables, such as political stability, cultural aspirations, and equity, are hardly quantifiable and cannot even be defined in physical terms (Hardi, Barg, Hodge, & Pinter, 1997, p. 9). The accuracy of defined criteria and indicators may remain unclear, but the assessment based on those indicators could be reasonable if it is a goal-oriented assessment, in a comparable manner and a spatiotemporal aspect. In urban planning sciences, the defined unit of the study is not a closed system. Therefore, a variety of external factors can influence the system and system indicators, which are undeniably regarded as non-controllable factors. In addition, many factors contributing to urban resilience to disaster is not easily quantified, and this makes system indicator difficult to construct (Phillips, 2003).

Second, performance indicator deals with a specific goal that shows whether or not the state of the unit of analysis has reached a defined value (Birkmann, 2006, p. 60). Similar to the system indicator, the performance indicator is also descriptive. It includes a reference value or policy target that allows comparisons with local, national, or international goals, targets, and objectives (Phillips, 2003, p. 12). Thus, this kind of indicator is characterized as the determiner whether a specific value indicates resilience or not. Often, the performance indicator is used when the context of resilience is precisely set. An indicator establishing certain institutional capability for the city – for example, the increasing number of critical facilities located outside of the hazard area or those built to be resistant to the known hazard impacts – are a performance indicator. Since this requires precise goals, it is difficult to design the indicators that can reflect the targeted goals or the complexity of the real world. Besides, the definition of a single value to estimate urban resilience to disaster needs additional interpretations. On the other hand, setting specific goals may be viewed as a too narrow limiting from the perspective of those who have to achieve the goal (Phillips, 2003, p. 12). As an alternative, we can view urban resilience to disaster as both a profile and a set of characteristics rather than a single value.

Back to the research questions highlighting "How resilience in terms of urban planning against tsunami is Kochi City (Number 3.1)?" and "How to enhance resilience of Kochi City through urban planning measures (Number 3.2)?", the literature review points out that there is somewhat uncertainty on how best to address these question. Numbers of research exists on factors associated with key performance index of resilience, but few of them address how to enhance resilience associated with urban planning measures. The study realizes that the best option to reflect tsunami resilience in urban planning is by integrating resilience key performance with the spatial policy formulation and implementation. In addition, external factors, especially in terms of technical and financial assistances should be taken into consideration. Focusing on this tsunami resilience in more practical rather than rhetorical, the constructed criteria are set up as a set of fundamental issues of interview questions. Consequently, issues related to resilience in land use planning are obtained from a book titled "How Resilient Is Your Coastal Community?: A Guide for Evaluating Coastal Community Resilience to Tsunamis and Other Hazards" (U.S. Indian Ocean Tsunami Warning System Program, 2007). Those specific issues are integrated with three crucial elements of resilience (Key Performance Indicators: KPI) as shown in Table 4-8.

The structured interview and questions of the structured interview can be found in Appendix 4. To explore the respondents' opinions on the statements shown in Table 4-8, the structure interview uses a rating scale that comprises of five levels: strongly disagree, disagree, on opinion, agree, strongly agree. The use of rating scale is not only to identify respondents' options, but also to encourage the respondents to discuss about the provided issues in order to get the implicit information that may not tangibly exist in writing document. According to the respondents in the structured interview, six respondents have been working on the field of urban planning, disaster risk management, and engineering infrastructure. Those respondents are government officers and experts. Therefore, the variety of their professional offers interdisciplinary perspectives on spatial planning for tsunami resilience.

Table 4-8: Considerations for resilience scheme and key performance indicators

Resilience element / Key performance	Land use policy and planning	Physical conditions	Technical and financial availability
Robustness/ Stability (Resistance and Availability of Learning Opportunity)	- There are policies that can significantly limit investment in vulnerable areas (Ex. No-build zone). - Knowledgeable people on coastal resources and hazard management have been involved in building setting and urban design.	- Critical facilities, such as water and electric power plants, have been located outside of the hazard area or built to be resistant to the known hazard impacts. - A coastal engineering structure (such as Seawall, Evacuation Tower and Building, etc.) has enough capacities to reduce vulnerability to coastal hazards and minimize impacts to coastal habitats.	- The public can easily access to information and data on physical and structural development activities. - Hazard-resistant building practices have been taught at the secondary and technical schools.
Adaptability/ Reactivity and Bouncing Back (Resourcefulness, Flexibility, Learning Capacity)	- Responsible institutions have enough capacity to implement land use plans and its ordinances.	- Building safety together with hazard reduction standards and codes are supported and enforced by law.	- An assessment of existing critical infrastructure has been conducted to determine vulnerability to tsunami and earthquake. - Builders and architects in the area are knowledgeable and able to apply the building codes and good practices.
Transformability (Diversity and Creativity)	- There are enough incentives or penalties in place to encourage compliance with land use policies and building standards and codes.		- The essence of resilience in national/ regional policies and laws have been present. - Communications and outreach programs are produced to educate the public in hazard-resilient building practices and designs.

Source: adopt from U.S. Indian Ocean Tsunami Warning System Program (2007)

4.4 Data collection

The methodologies and data collection for both primary and secondary data comprise of the interview with local government officers, the observation survey, the questionnaire survey and the collection of statistical data. The periods of data collection vary by the type of data as shown in Table 4-9.

Table 4-9: Methodologies and periods of data collection

Type of data collection	Periods of data collection
The interview with local government officers	December 2013
The observation survey	December 2013 and January 2014
The questionnaire survey	December till March 2014
The collection of statistical data	All along the study's timeframe

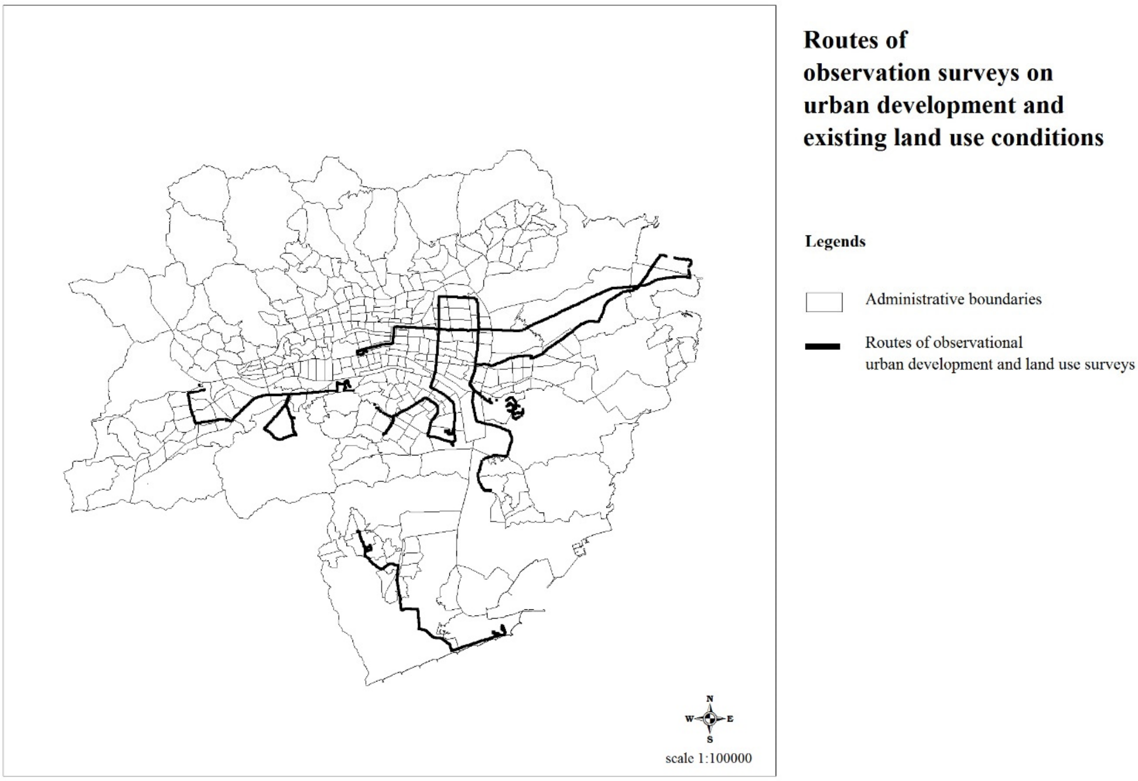


Figure 4-4: Routes of the observation survey based on GPS records (December 2013 to January 2014)

Source: By author

Chapter 5 :
Urban Vulnerability of Kochi City

In this chapter, the research questions and their assumptions are answered and tested. The vulnerability assessment here is conducted in order to achieve the second set of research objectives focusing on how vulnerable characteristics of the coastal city i.e. Kochi City can be analyzed as a case study. This main concern comprises of three sub-objectives as follows: to identify crucial elements of the urban vulnerability to tsunami, to evaluate the urban vulnerability to tsunami, and to compare vulnerability levels of each sub-districts within Kochi City's boundary. Through the vulnerability assessment, crucial characteristics of Kochi City that make the city more vulnerable to tsunami are identified. This chapter intends to test the assumption that "critical social infrastructure, such as the availability of evacuation places and public spaces, is a major determiner of vulnerability level".

5.1 An operational framework of vulnerability assessment

The research methodologies that described in the previous chapter are going to be proceeded. This chapter aims to assess urban vulnerability in terms of the physical infrastructure and demographic structures. In this vulnerability assessment, the broad area of qualitative and quantitative assessment of vulnerability and index construction was set as a reference point. Through the index construction, many indicators were constituted and weighted either equally (a linear aggregation) or differently subject to their hierarchical significance (a weighting aggregation). The study concerned that different indicators should not have the same significant value because the value of each indicator could be varied by its influence on the urban vulnerability. For example, the population density might have higher or lower influence on the evacuation process compared to the building density.

In the assessment, the weighting factors are applied. The weighting techniques consist of Analytical Hierarchical Process (AHP), SMARTER, and equally weighting. According to AHP, the weighting technique is based on a combination of expert judgment and the statistical analysis for determining the relative weighting system. The questionnaire on tsunami vulnerability of Kochi City is devised to seek for the logical aspects about the hierarchical significance of each indicator. The questionaire is drawn based on the different viewpoints of the local government officers, practitioners, and experts who have involved in urban planning, community planning, disaster risk management and emergency response. With the AHP technique, the priorities of criteria are simplified by using pair wise comparisons. This allows descriptive judgment and enhance the precision of the results.

Based on the ration scale of AHP, the weighting results of the comparative importance between each-factor pair are described in term of integer values from 1 (equal important) to 9 (extremely important) (See Table 5-1). The higher numbers means the selected factor is "considered more important in greater degree than other factor being compared with (Bunruamkaew, 2012)". The value in between such as 2, 4, 6, 8 are used to determine shades of judgment between five basic assessment (Syamsuddin & Hwang, 2009).

To seek for the logical aspects and opinions related to vulnerability elements of a city in terms of land use, building use and demography, a questionnaire was sent to over 100 professionals and practitioners having been involved in urban planning, disaster management and emergency response in Japan. Nevertheless, the response rate was 20 percent. Namely, the participants are 20, 7 chose to respond by direct interviews and 13 respond through the electronic mail (e-mail). Before this questionnaire survey, there was a long preparation and testing phase during which the vulnerable elements and objectives were chosen. A series of structured interviews with regional and local government officers was conducted during September and December 2013. These interviews enlightened better understanding about the overall problems of Kochi City and Kochi Prefecture and this supported the articulation and weighting factors of tsunami vulnerability assessment. One essential part of the interviews was to ask the participants about resilient characteristics of Kochi City in their own expectations compared to the experiences in the reality. To generate and analyze the AHP model, a free applet based software named "Web-HIPRE" is used. This software also helps in analyzing the other weighting technique that is applied in this study, which is named "SMARTER (SMART Exploiting Ranks)".

SMARTER is a weighting method based on ordinal criteria. SMARTER is applied to some factors that can be grouped, and then prioritized in relation to their importance in the increase/decrease vulnerability. For example, based on the literature, urban facilities can be divided into three types regarding their importance to the urban activities. The facility essential for urban activities is defined as the most vulnerable use, while another facility can be named as either highly vulnerable use or less vulnerable use. With this premise, the facility falling into a category of the most vulnerable use is placed as the first rank (F1), and the other two are second (F2) and third rank (F3), respectively. (F1 >F2 > F3). SMARTER subsequently assigns surrogate weights in accordance with the rank distribution method.

In this study, a total indicator of 22 is categorized into six groups of exposure elements: 1) Urban density, 2) Facilities, 3) Building condition, 4) Demography, 5) Cultural heritage, and 6) Economy. These six groups are equally weighted (about 16.65 percent of a total score per group). Whereas, the sub-indicators (dependent factors) that represent them are weighted differently depending on the certainty of their straight influence on the urban vulnerability (independent factors). If the influence of dependent factors is ambiguous, the AHP will be applied. The results of weighting scores and the weighting techniques of each dependent factor can be represented as a tree structure of urban vulnerability, as shown in Figure 5-1.

Table 5-1: AHP Pairwise comparison values of a nine-point intensity scale

How important is A relative to B?	Comparison value
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely/ Absolutely more important	9
Intermediate value	2,4,6,8

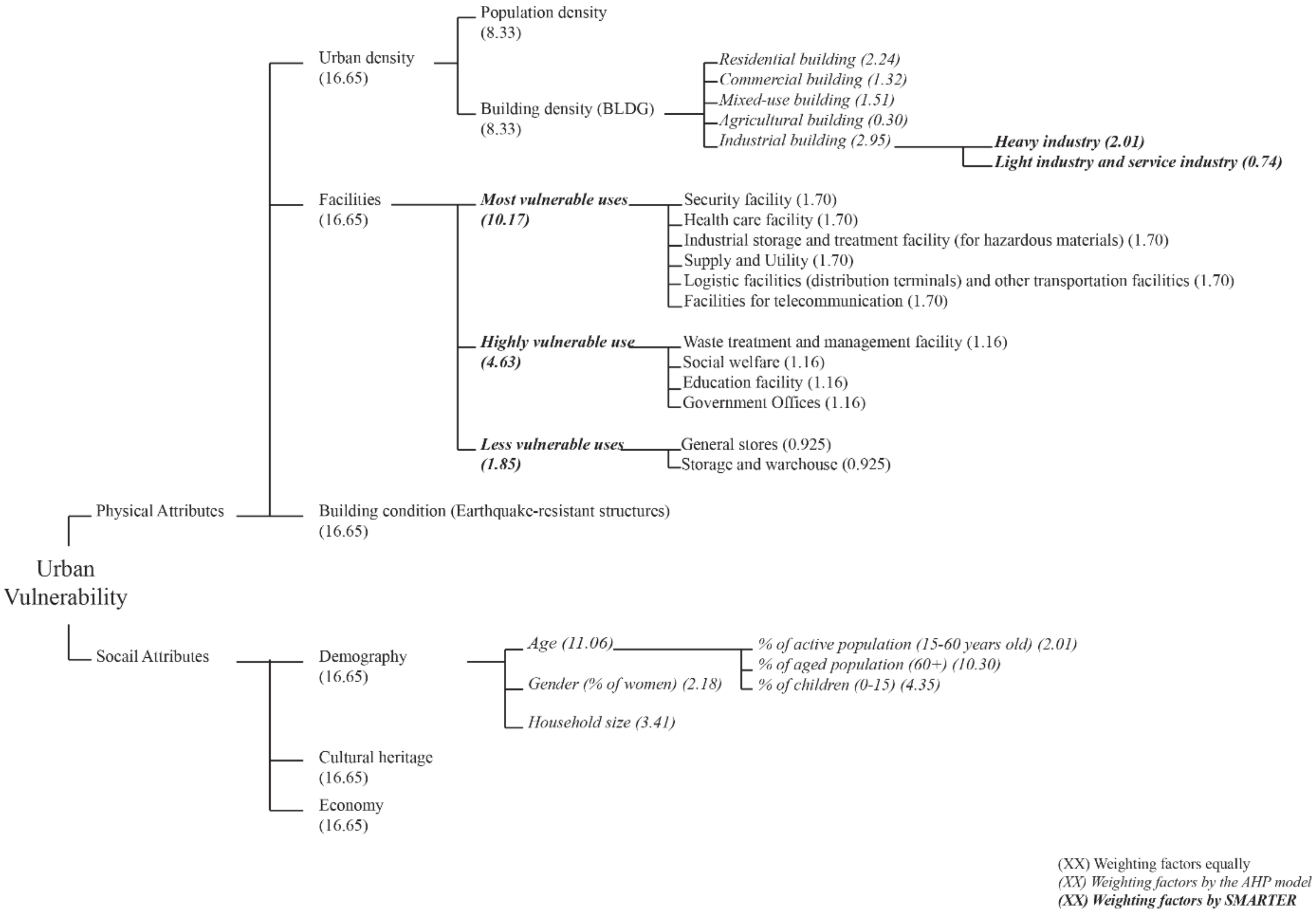


Figure 5-1: An integration of three weighting techniques

Source: By author

According to the analysis unit, the study selected an urban planning area of Kochi City as a case study. Meanwhile this urban planning area of Kochi City covers beyond the administrative area, some non-urbanized areas of Kochi City are out of the plan. The analysis unit of this study; therefore, focuses on the overlapped areas between the administrative boundary of Kochi City and the urban planning area. Then, some sub-districts of Kochi City – most of them are not located in a tsunami-prone area – will not be taken into account. As a result, 357 sub-districts out of 416 sub-districts of Kochi City (as of 2014) are preciously selected as the unit of analysis.

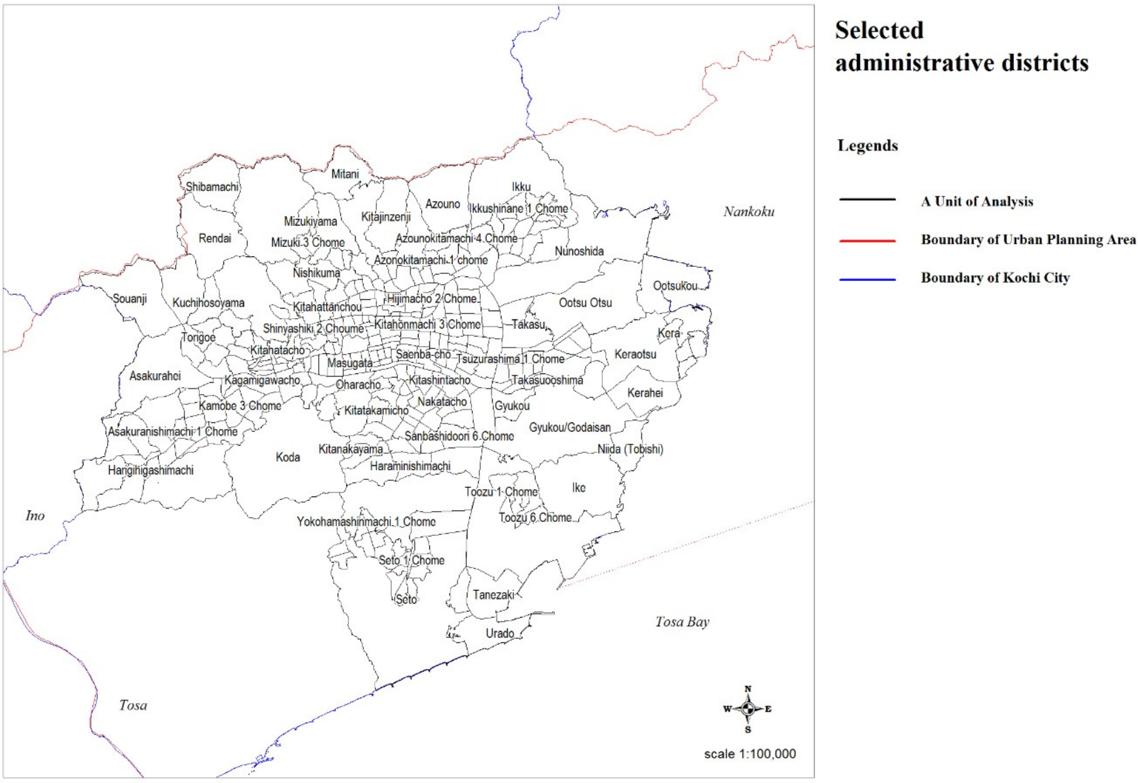


Figure 5-2: 357 sub-administrative districts (Cho) taken as a unit of analysis

5.2 Urban vulnerability assessment (in terms of urban fabrics)

5.2.1 Urban density

(1) Population density

A population and housing census of January 2014 is used for analyzing the population density of the selected 220 sub-districts (See the appendix 1). The administrative area is used to provide an information identifying a place people live in and the population density in that area. Situated in a coastal zone which are enriched by rich natural environment, Kochi City accommodates 338,909 residents within its 309.22 square kilometers. The density of population is 1,096 per square kilometer. This is comparable to other mid-size coastal cities of Japan. Nevertheless, some sub-districts are less dense than the average, because they are not completely flat area, which means there are some unsuitable hills and mountainside for humans to settle. Most of residents of Kochi City prefer to reside in areas of relatively flat land, which make some districts become a densely populated area.

The unit of analysis covers 126.32 square kilometers where 341,865 people live. The average population density is about 11,139 per square kilometer. The most densely populated district is Kitahonmachi 2 Chome (北本町２丁目): 50,458 people per square kilometer; however, the number of residents is merely 182 in an area of 0.001155 square kilometer. Whereas, the less densely populated district is Haramihigashimachi (孕東町): 11 people per square kilometer. The population density is shown in Figure 5-3. Compared to the western transition zone, it is clear that coastal zone of Kochi City is not as densely populated as the intercity, . The residents largely reside in the west and central areas. Besides, some densely populated areas; for example, Yokohamishinmachi 1, 2, and 3 Chome within Yokohama district, are significantly different from their neighborhood due to a new town policy within the Urban Promotion Area (UPA).

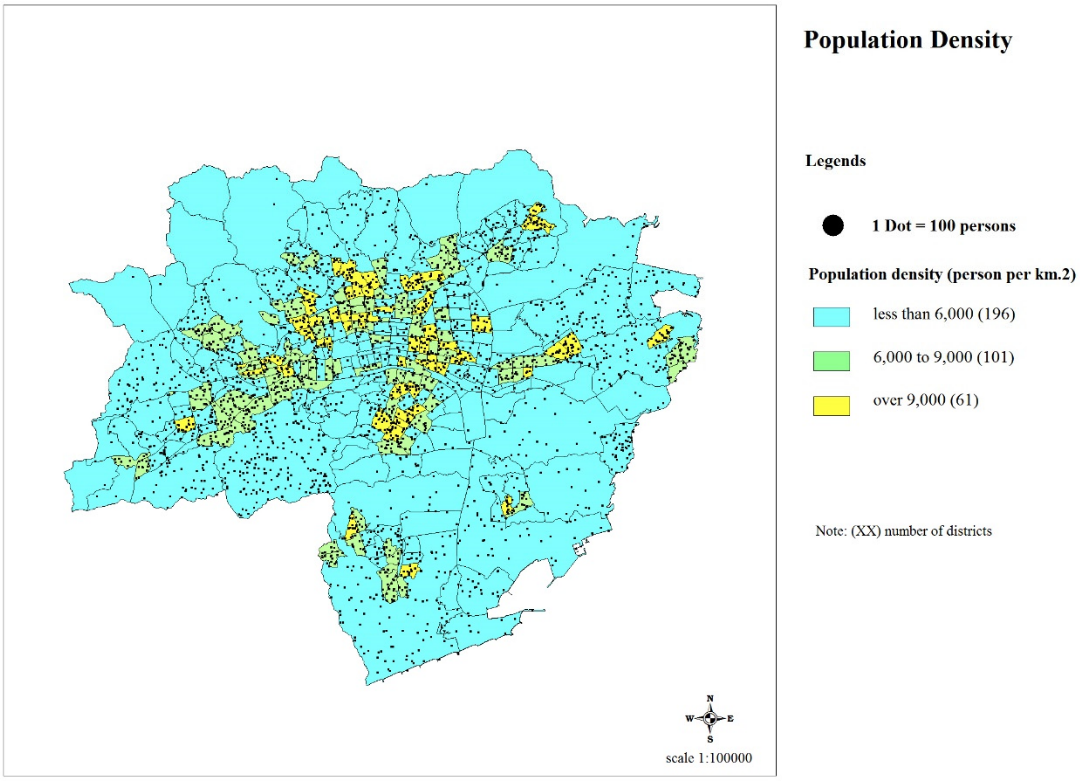


Figure 5-3: Population Density (as of January 2014)

Note: Resident censuses of Sakaedacho 2 Chome (栄田町二丁目), Mizukiyama (みづき山) are not available.

(2) Building density

Building density is measured based on the GIS data of March 2012, provided by the Kochi Prefecture. In this database, the building use is divided into 46 categories. For example, only a building use related to residential purposes and the relevance can be defined as single housing, housing with store, housing integrated with a small factory, and complex housing. Therefore, the study rearranges the building use categories for the vulnerability assessment. The final types of building use comprise of 20 different uses according to their main functions as shown in Table 5-2. Nevertheless, the building density in this section concerns merely first six categories: residential, commercial, mixed-use, heavy industrial, light industrial and agricultural buildings. In order to analysis the building density, the study considers a total floor area of buildings, as it reflects the exact conditions of urban density rather than a building coverage area. The results of this analysis can be illustrated through as a series of figures.

Table 5-2: Types of the building use categorized for the vulnerability assessment

Types of vulnerability Building uses	Building (BLDG) use	BLDG code	Buildings (Units)	Total floor area (m2)
1) Residential building	Single housing	11	101,900	14,765,899.80
	Complex housing	12		
	Facility attached with housing	16		
	Facilities for accommodation	41		
2) Commercial building	Business facility (offices)	21	3,721	1,759,940.20
	Facilities for mass-media	22		
	Facilities for complex selling	31		
	Facilities that attached with store	34		
	Facilities for entertainment	42		
	Game facility (paid)	43		
	Complex facilities for commercial use	44		
3) Mixed-use building	Housing with store	13	7,322	1,673,657.50
	Housing complex with stores	14		
	Housing with small factory	15		
4) Heavy industry	Heavy industry facilities	81	434	214,814.10
5) Light industry and service industry	Facilities for light industry	82	4,026	970,518.80
	service industry facility	83		
	Facilities for cottage industry	84		
	Facilities for forest industry	102		
	Facilities for fishery	103		
	Other facility	200		
6) Agricultural building	Facilities for agriculture	101	532	29,596.90
7) Security facility	Facilities for keeping security	53	108	76,560.10
8) Health care facility	Facilities for medical care	71	655	916,143.80
	Health care facilities	72		
9) Industrial storage and treatment facility of hazardous materials	Storage and treatment facility of hazardous materials	85	177	16,194.90
10) Supply and Utility	Service facility	33	808	131,884.20
11) Cultural heritage	Facilities for culture	64	1,344	304,334.10
	Facilities for religion	65		
	Facilities for monument	66		
12) Supply and Utility	Facilities that attached with factories	86	808	131,884.20
	Supply and Utility	94		
13) Public Sport Complex	Sports facilities (public)	67	47	156,111.90
14) Logistic facilities (distribution terminals) and other transport facilities	Transportation facilities	91	200	95,690.70
	Logistic facilities (distribution terminals)	92		
15) Facilities of telecommunication	Facilities for telecommunication	54	82	110,914.00
16) Waste treatment and management facility	Facility for treatment and garbage	95	294	166,220.20
17) Social welfare	Facilities for social welfare	73	336	194,771.90
18) Education facility	Facilities for school education	61	1,404	1,128,274.40
	Facilities for education	62		
	Facilities for research	63		
19) Government Offices	National facilities	51	231	203,560.20
	Facilities of municipality	52		
20) General stores	General store facility	32	2,792	1,181,527.80
21) Storage and warehouse	Storage and warehouse	93	8,733	922,836.10
Counting out/ unidentifiable	Attached building	201	19,962	87,954.20
	Small building	202		

In order to identify building density, the total floor area (usage space) of the specific building use is taken into consideration rather than the building coverage area. This total floor area will be compared with its administrative land area. The building density is expressed as a ratio of the total floor area of the specific building use to the administrative land area. The formulation of building density can be found in Equation 5-1.

$$\text{A building density ratio} = \frac{\text{The total floor area (usage space)of the specific building use(sq.m)}}{\text{The administrative land area (sq.m) that the building belongs to}}$$

Equation 5-1: A formulation of building density

- Residential building density

An average ratio of the residential building density is about 0.2747 times of the total land area (Max= 8.7281, Min= 0, SD. = 0.5686). The area that has the highest ratio is Kitahonmachi 2 Chome, with the usage space of residential buildings around 6.3546 times of the administrative area. Other areas of dense residential buildings, which have more residential usage space than their actual footprint (land area), are Hijimacho 2 Chome (3.9556), Sakuraicho 2 Chome (2.2814), Chiyoricho 2 Chome (1.1340) and Tamamizucho (1.1340). On the contrary, Wakakusa Minamimachi, Sakaedacho 2 Chome and Mizukiyama are the areas that have no building specifically characterized as a dwelling unit.

Considering housing quality, the average room occupancy per person (excluded mix-use building) is about 45.32 sq. m, and the average room occupancy per household is 94.36 sq.m. A greater rate of the room occupancy per household can be found in Honmachi 4 Chome (1052.74 sq. m), with the average usage space of 1052.74 sq. m. On the contrary, households in Tooricho tend to have the smallest room occupancy than others. The usage space per household in this sub-district is about 2.40 sq. m. One of the reasons of having incredibly small room occupancy per household is that mix-use buildings are excluded in this estimation. If the mix-use building is included in the analysis, the average room occupancy per household of two sub-disaster is five times greater than the previous estimation based on mere residential buildings. The average room occupancy per household of Obiyamachi 2 Chome and Minamikubo varies from 22.97 to 117.45 and 18.63 to 93.93, respectively.

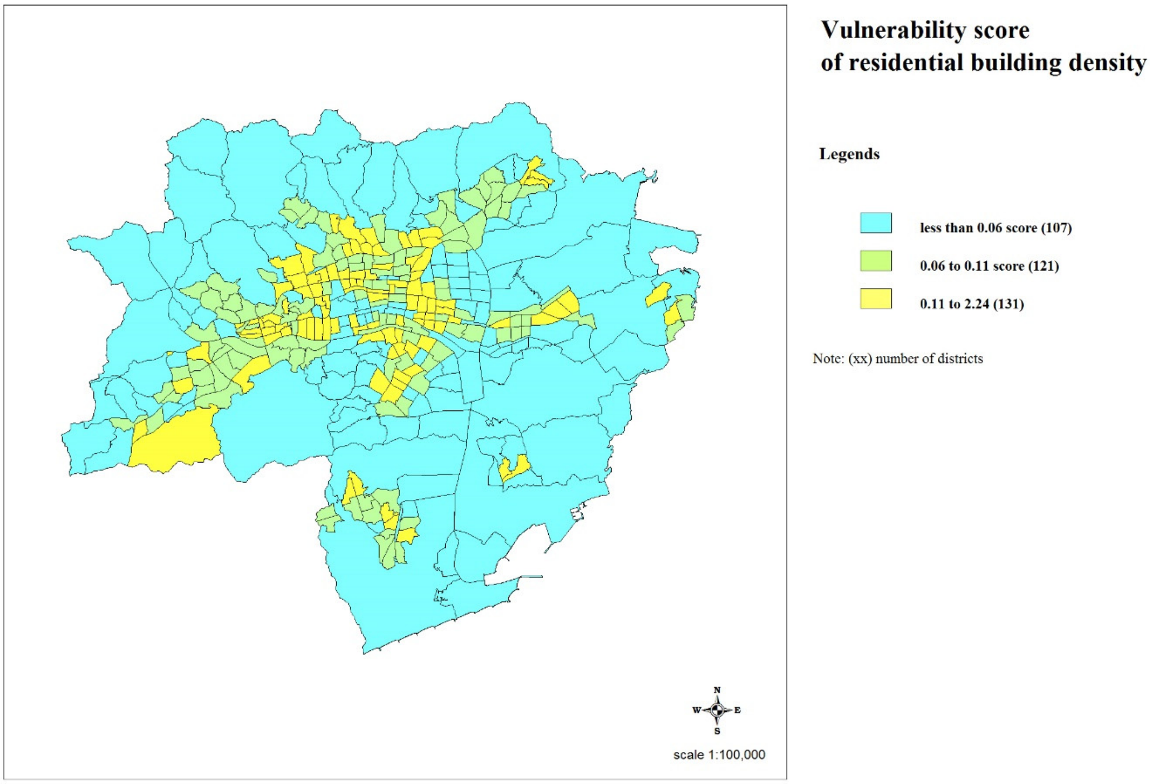


Figure 5-4: Vulnerability score of Residential building density

- Commercial building density

An average ratio of the commercial building density is about 0.0481. Honmachi 4 Chome and Ekimaecho are characterized as a highly commercial district, because the ratio of the commercial building density is higher than the administrative land areas. In those districts, the ratios of the commercial building density to the administrative land areas are 1.3225 and 1.2878, respectively. Besides, those ratio is higher that the ratio of their residential building density (0.4680 and 0.3856 respectively). On the contrary, 43 of 357 sub districts do not have any building that serves for specifically commercial activity: they have mixed-use buildings instead. These mixed-use buildings function as dwelling units combined with other economic activities such as the commercial or small industrial purposes. However, the ratio of the commercial building density to their administrative land areas is lower than one time in other area.

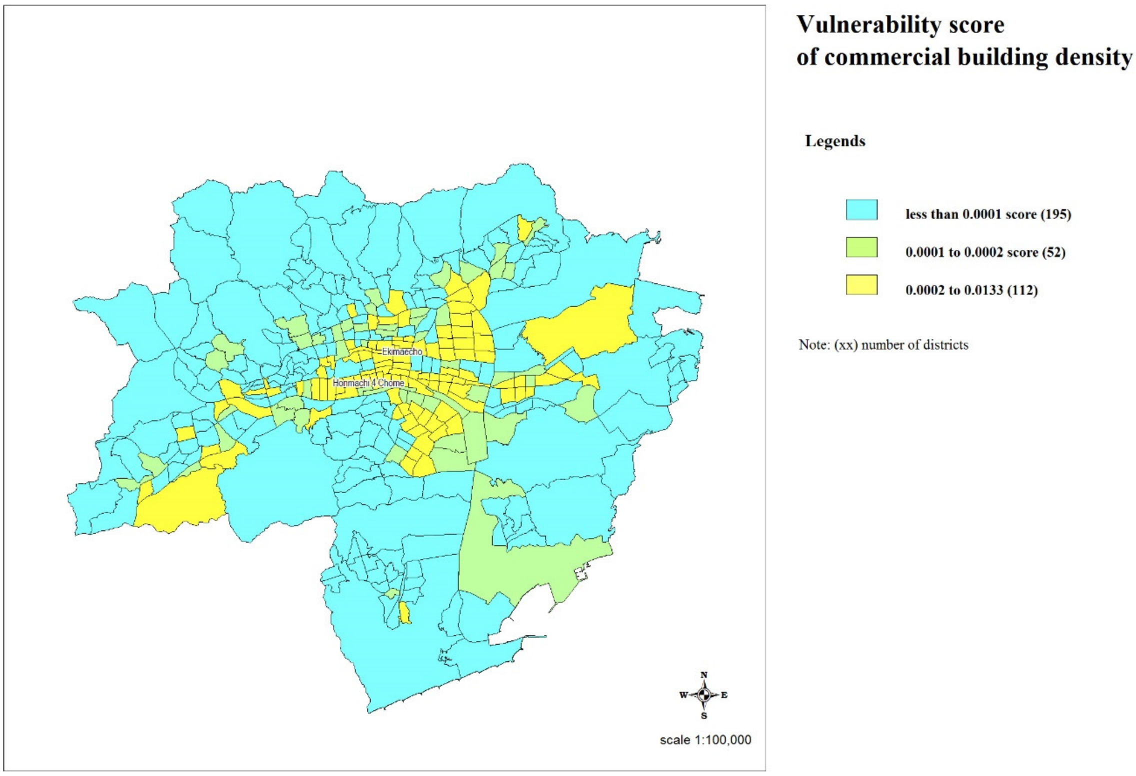


Figure 5-5: Commercial building density

- Mixed-use building density

With the average ratio of the mixed-use building density at 0.0543, the mixed-use building density is just one fifth of the residential building density. More than 60 % of 7,322 mixed-use buildings are located extensively in the city center, while the residual spreads out to the surrounding area of the center. The most densely populated area in terms of the mixed-use building is Kitahonmachi 2 Chome. The mixed-use building density ratio of Kitahonmachi 2 Chome is about 1.3679, while other districts' density ratios are lower than 0.5. Moreover, 20 out of 357 districts do not have any mixed-use building, and eight of 20 have no commercial building as well.

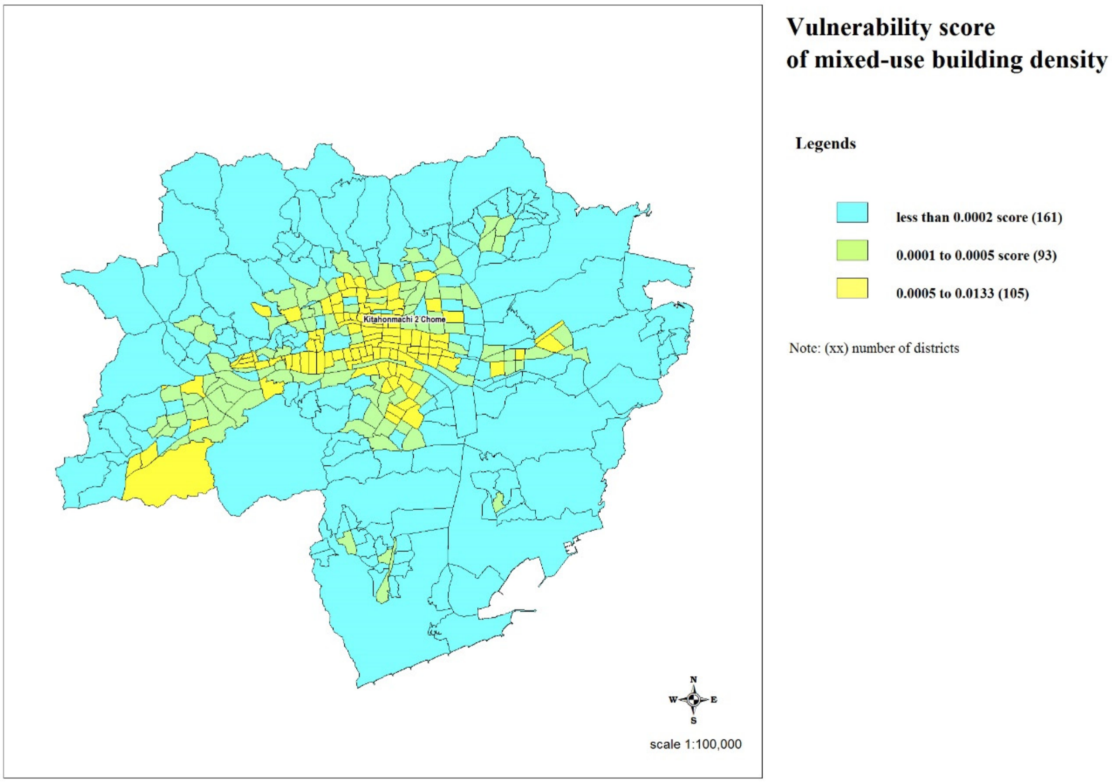


Figure 5-6: Mixed-use building density

- Density of heavy industry

The heavy industry area in Kochi City is well zoned by the city's master plan. It is designated as a category number 12 with the dark blue land use code, which means no residential building construction is allowed. The limit of residential building construction is set for preventing indecent living in polluted environment caused by heavy industries. In Kochi master plan, the heavy industry is permitted to be operated in the southern part of the city, which connects to Urado Bay and Pacific Ocean. Merely 26 of 357 districts are privileged for the heavy industrialization.

Among these 26 districts, Hagimachi 2 Chome is the area having the highest ratio of heavy industrial density (the ratio of 0.2085). Only five residents live in this district, which results in a low population density of 18 persons per sq. km. With on doubt, this district truly serves as industrialization. The second highest ratio is of Haramihigashimachi (0.0841). This district has only eight residents with an area of 0.7665 sq. km, which makes a population density as low as 10 persons per sq. km. Those two areas consist of several large industries producing alloy materials such as Polymer Kochi Factory and TOYO DENKA KOGYO CO. Ltd.. As those industrial activities, which process raw materials, require plant facilities with a large area and usually have a low ratio of employees per acre, they are called “labor-extensive industries” (Kyle, 1999, p. 398)

- Density of light industry

Unlike heavy industry, light industries are allowed to be built more extensively than the heavy industry. For example, an extremely small facility – using the certain amount of hazardous materials – with the total floor area less than 1,500 sq. m. can be built in the fourth land-use category (second type of middle high-rise residential area). This category of land use is designated for middle high-rise residential buildings and other buildings of minor-use that are under 1,500 sq. m. such as hospitals, educational buildings, shops, and offices.

Out of 357 districts, several light industries have been located in 312 districts. Within this list, Iguchicho has a highest ratio of light industrial density of 1.6388. There is no heavy industry in this district, even though it is designed as an industrial promotion area of a category number 11. Minaminomarucho is placed as the second highest light industrial density with a ratio of 0.1741. Even if this area is regulated by the same land use ordinance of category number 11 applied in Iguchicho, some heavy industries are still located there. It implies that Minaminomarucho is now in transition from an industrial promotion area to an industrial complex. Such a transition will make this district having a characteristic similarly to the land use category number 12: a heavy industry zone.

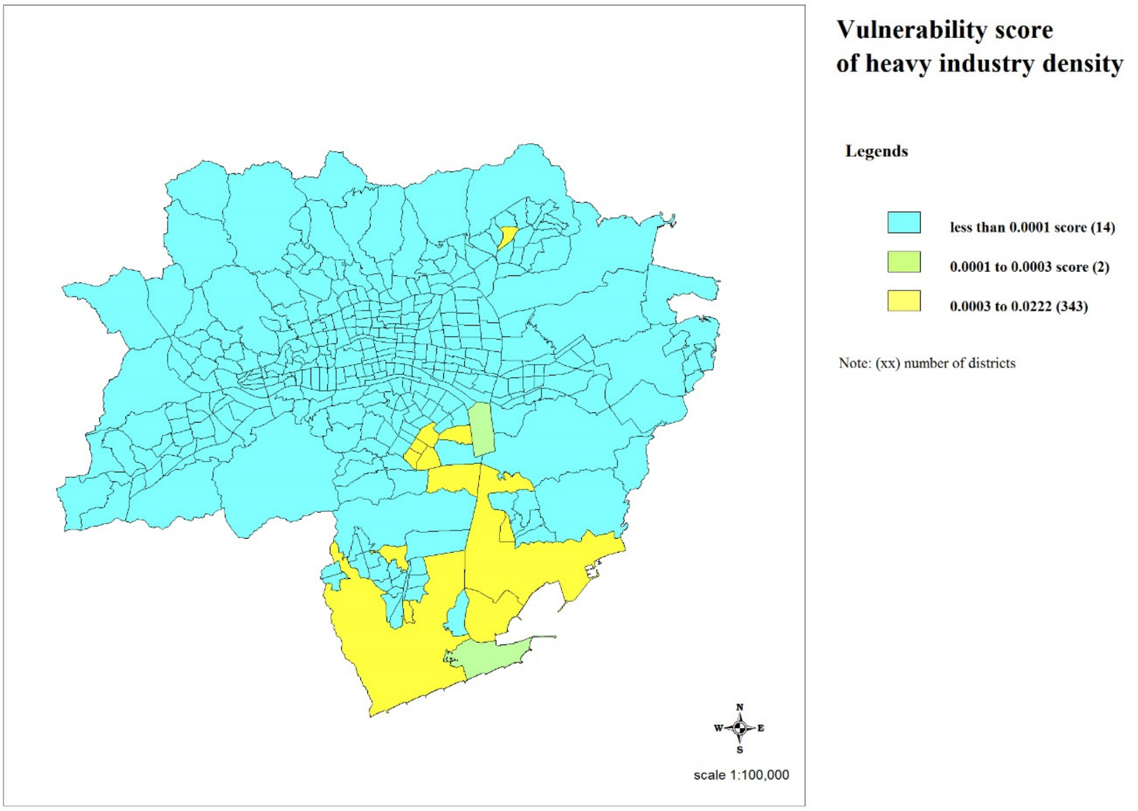


Figure 5-7: Density of heavy industry

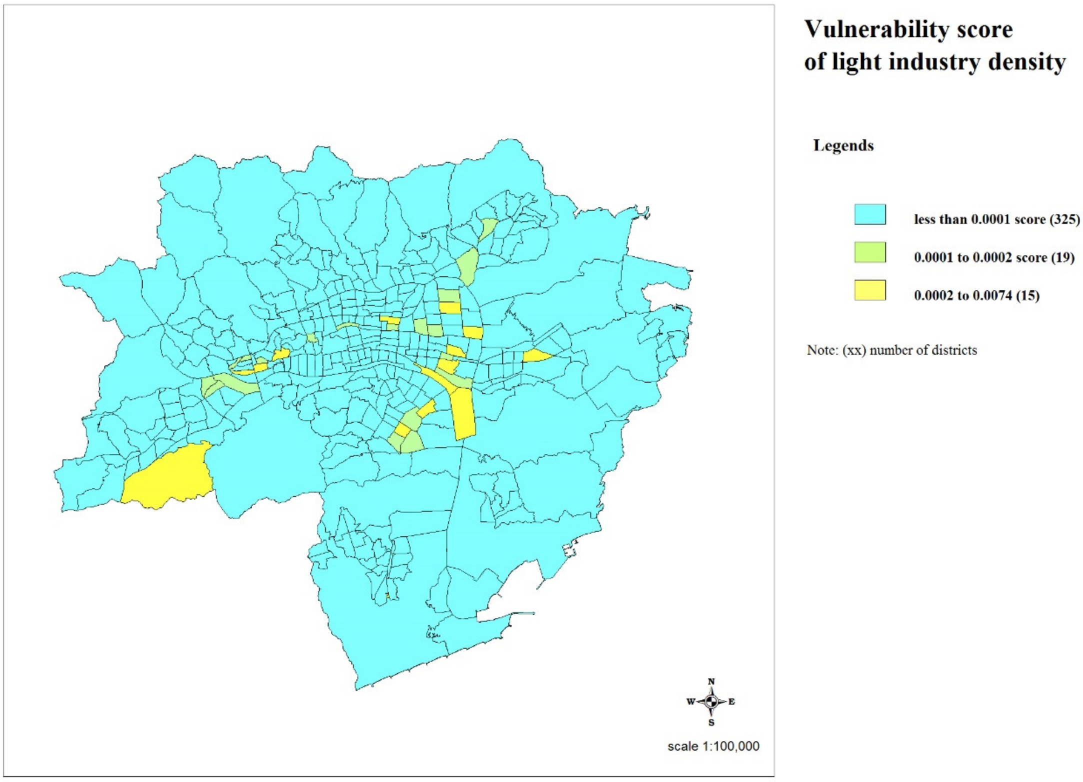


Figure 5-8: Density of light industry

- Agricultural building density

Merely 74 of 357 districts have buildings for the agricultural purpose. Nevertheless, the ratio of agricultural buildings is relatively low (less than 0.015). In terms of a ratio of building space to the land area, the most densely agricultural area is Takasuooshima (0.0114) with a total agricultural building space of 1,209.4 sq. m. However, the district that has the highest agricultural building space is Nagahama with a usage space of 5,809.2 sq.m.

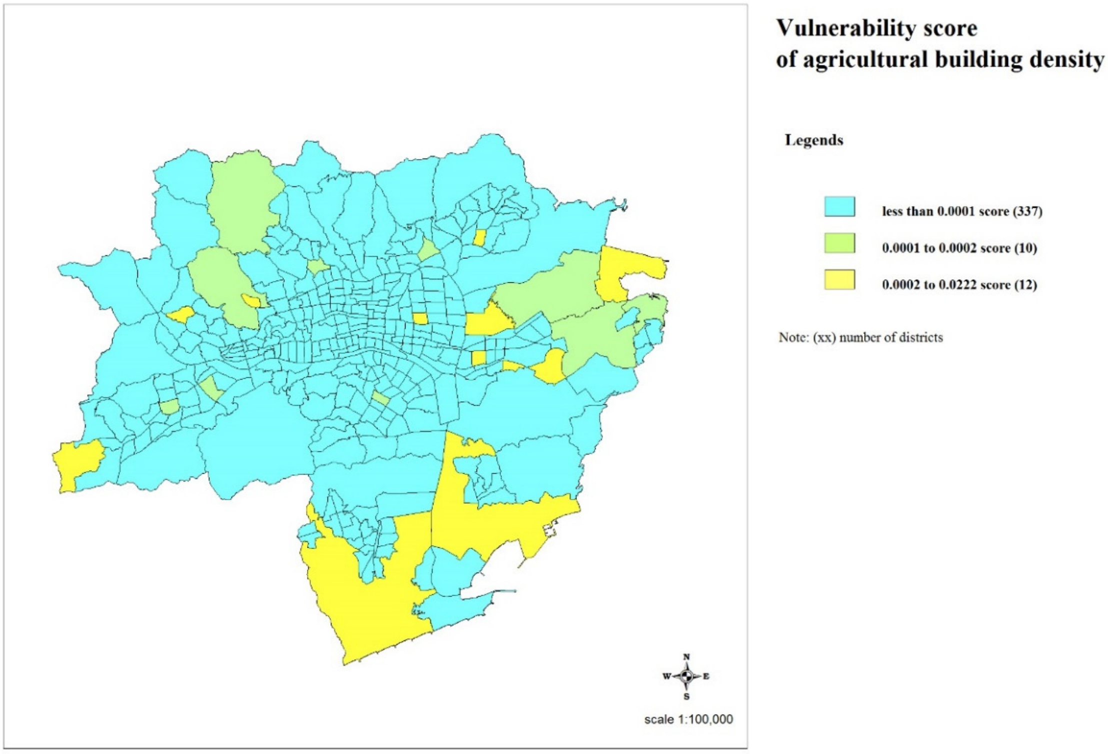


Figure 5-9: Agricultural building density

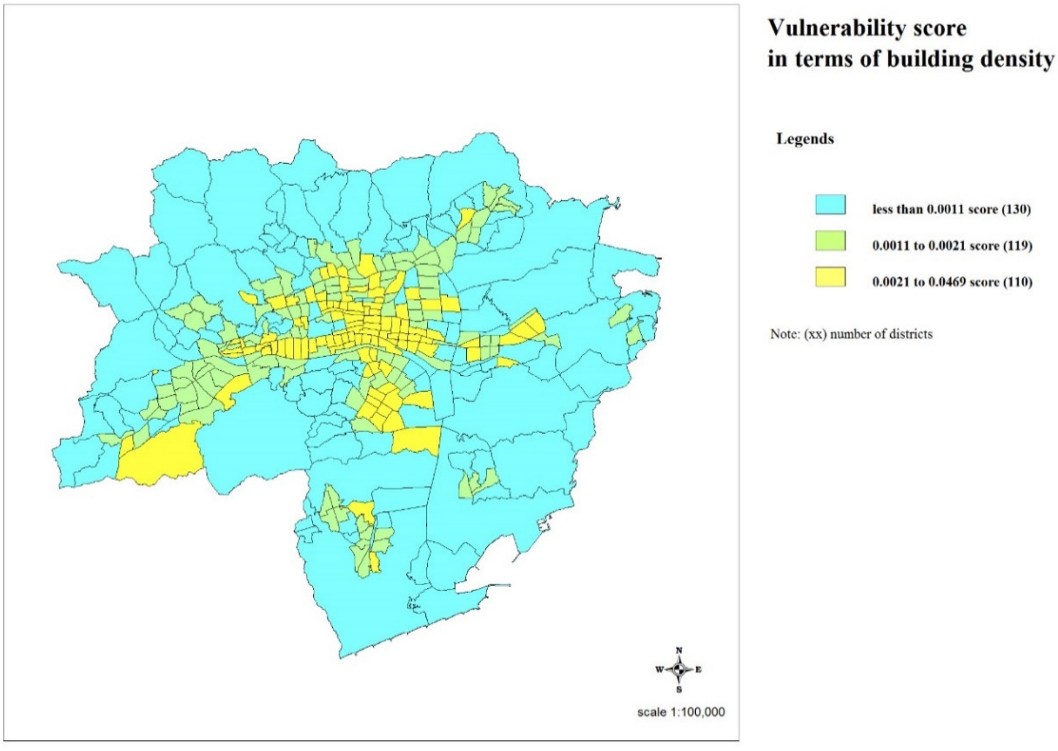


Figure 5-10: Vulnerability map in terms of building density

The most vulnerable district caused by high building density is Kitahonmachi 2 Chome (0.0469 score of a maximum score of 0.0833); whereas the less vulnerable one is Ikku (0.00002 score). Apart from calculating building density using the ratio of building space to the administrative area, we can alternatively use FAR (Floor Area Ratio) and OSR (Open Space Ratio) to represent the density in terms of building agglomeration. FAR is set to limit the building density of each zone. This term represents the ratio of a building's total floor area (Gross Floor Area) to the area of the plot (a land lot area). A formula to calculate FAR is shown in Equation 5-2. For example, a zone with FAR of 3.00 would indicate that the total floor area of a building is three times of the horizontal area on which it is constructed.

Rather than checking the ratio of FAR imposed by the land use ordinance of the master plan, the study analyzes FAR by monitoring the existing condition of building density. This also includes all government offices and other facility buildings. The analysis of FAR shows that Hijimacho 2 Chome with FAR of 4.03 is again placed as the highest building density area among 357 districts. The second rank of building density is Honmachi 4 Chome, which has the FAR of 2.57. Since the FAR of second rank (Honmachi 4 Chome) are half of the first rank (Hijimacho 2 Chome), the predominant FAR of Hijimacho 2 Chome offers more urban spaces. This could imply that the urban activities and services are dominantly more concentrated in Honmachi 2 Chome than in Hijimacho 4 Chome.

$$\text{FAR} = \frac{\text{Gross Floor Area}}{\text{A land lot area}}$$

Equation 5-2: A formula of FAR

Another factor that can imply the density of urban development is OSR. This term represents the proportion of the development required to be left in open space. It can be determined by dividing the open space (uncovered by the building) by the total floor area of the site (see Equation 5-3). In the case of Hijimacho 2 Chome, its OSR of 18.43 is the lowest OSR among the unit of analysis. Honmachi 4 Chome with the OSR of 21.36 is in the second rank of the lowest OSR.

$$\text{OSR} = \frac{\text{Uncovered open space} * 100}{\text{Gross Floor Area}}$$

Equation 5-3: A formula of OSR

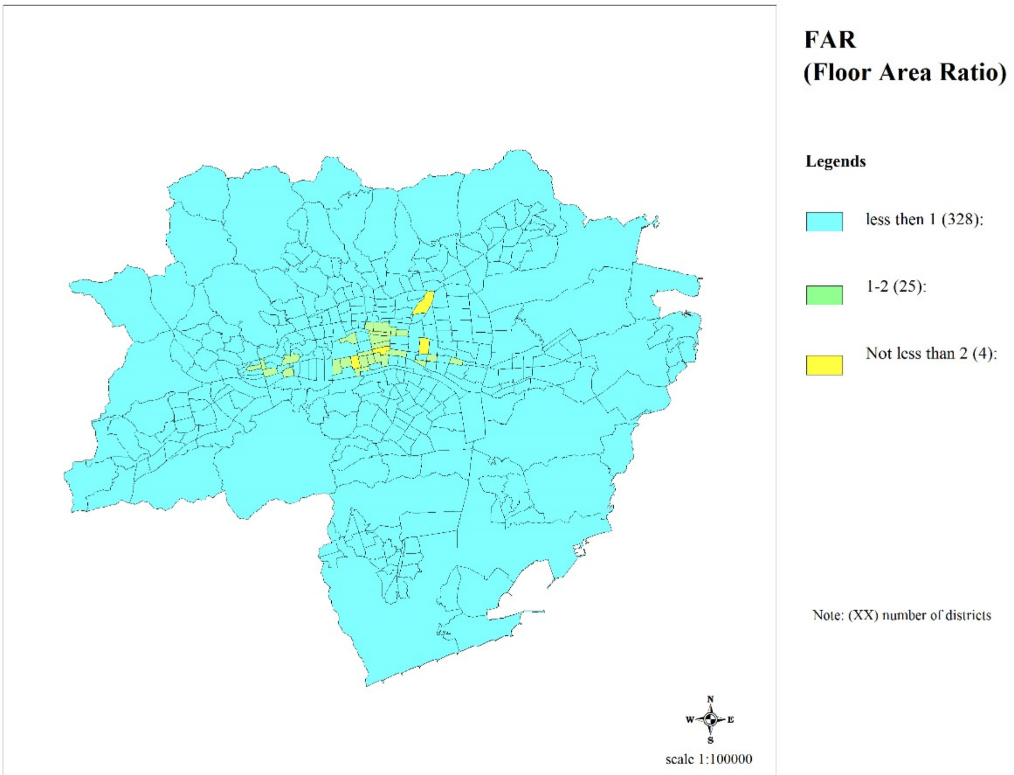


Figure 5-11: FAR (Floor Area Ratio) of each district

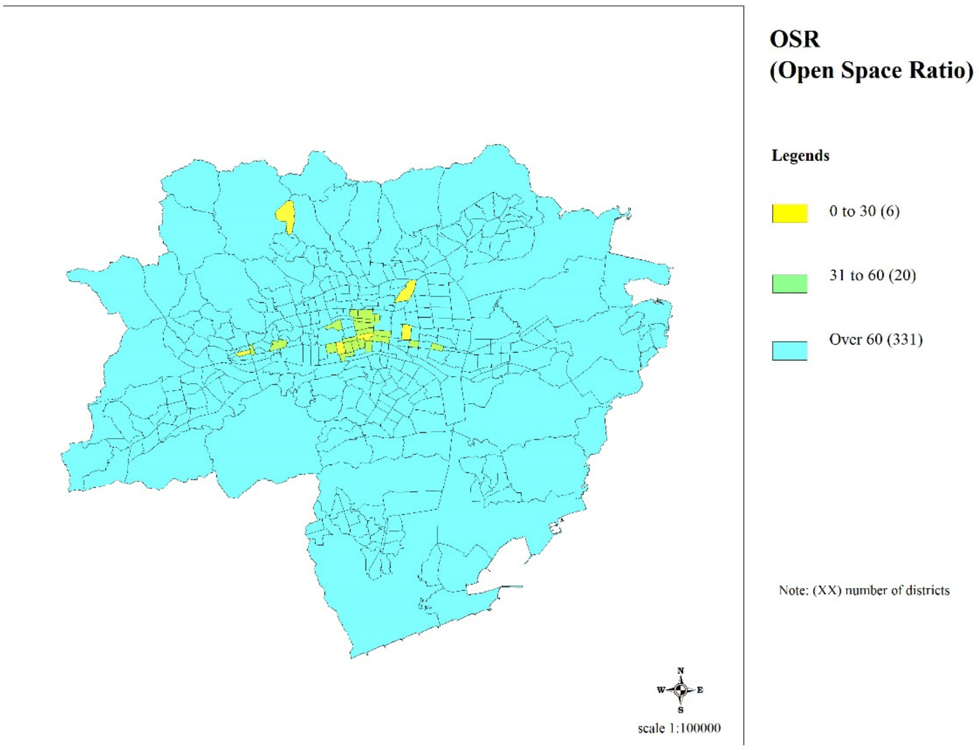


Figure 5-12: OSR (Open Space Ratio) of each district

5.2.2 Facilities

Another indicator influencing the urban vulnerability is facilities. Different types of facilities can contribute to vulnerability in a different way. The study captures crucial differences guided by SEPA *(2012)*. This guidance divided facilities into three groups: most vulnerable use, highly vulnerable use, and less vulnerable use. The components of each group are shown in Figure 5-1. Based on this assessment, the average score of facility vulnerability is 0.0034. The most vulnerable district is Kitahonmachi 2 Chome (0.0431 score), whereas the less vulnerable district are Mizukiyama, Wakakusa Minamimachi, and Mizuki 2 Chome with the facility vulnerability score less than 0.0001. Table 5-3 presents the rank and facility vulnerability score in terms of potential facility to be affected by disaster. Noticeably, for the most vulner district like Kitahonmachi 2 Chome, its major vulnerability scores (almost 50 % of its total scores) come from the existence of less vulnerable facility in the district, instead of the availability of most critical urban facility. Namely, Kitahonmachi 2 Chome is more vulnerable to tsunami due to the diversity of existing facilities, not the importance of functions of the facilities.

Table 5-3: A summary of vulnerability score in terms of potential facilities to be affected by disaster

Categories of Vulnerability score	Top-3 districts (score)	Bottom-3 districts (score)
Most vulnerable facility (Max = 0.1017)	- Obiyamachi 2 Chome (0.0269) - Honmachi 3 Chome (0.0233) - Honmachi 4 Chome (0.0204)	- 49 districts earn zero score
Highly vulnerable facility (Max = 0.0463)	- Seto 1 Chome (0.0132) - Honmachi 5 Chome (0.01183) - Wakakusacho (0.0116)	- 112 districts earn zero score.
Less vulnerable facility (Max = 0.0185)	- Kitahonmachi 2 Chome (0.0185) - Obiyamachi 1 Chome (0.0060) - Minamimotomachi (0.0047)	- Five districts earn zero score.
Overall vulnerability (Max = 0.1665)	- Kitahonmachi 2 Chome (0.0431) - Honmachi 5 Chome (0.0321) - Obiyamachi 2 Chome (0.0286)	- Mizuki 2 Chome (1.74E-06) - Shiomidai 2 Chome (1.0791E-05) - Shibamachi (1.1007E-05) (Excluding Mizukiyama and Wakakusa Minamimachi that get zero score)

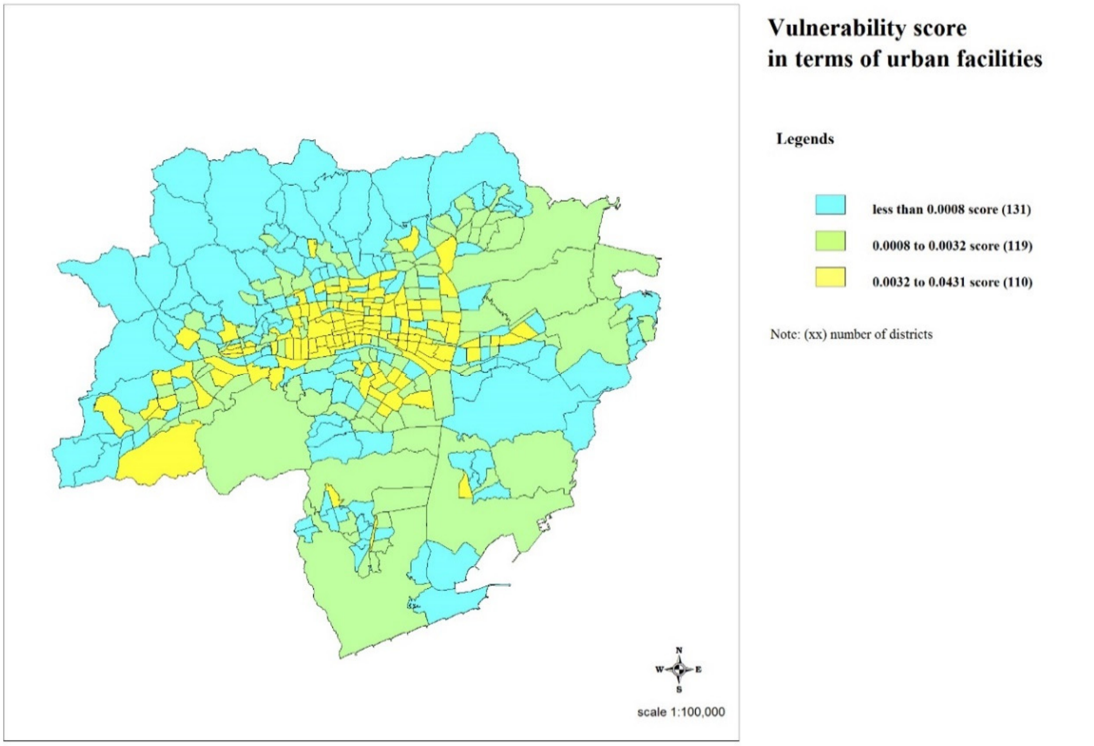


Figure 5-13: Vulnerability map in terms of potential facilities to be affected by disaster

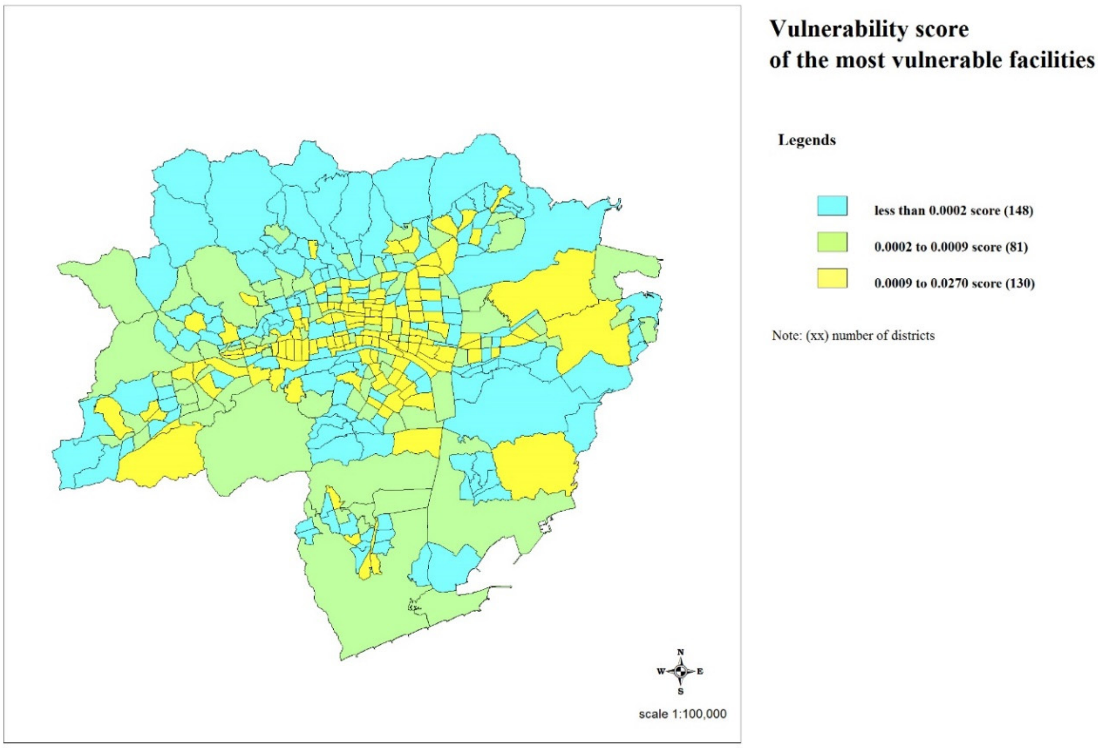


Figure 5-14: Vulnerability score of most vulnerable facilities

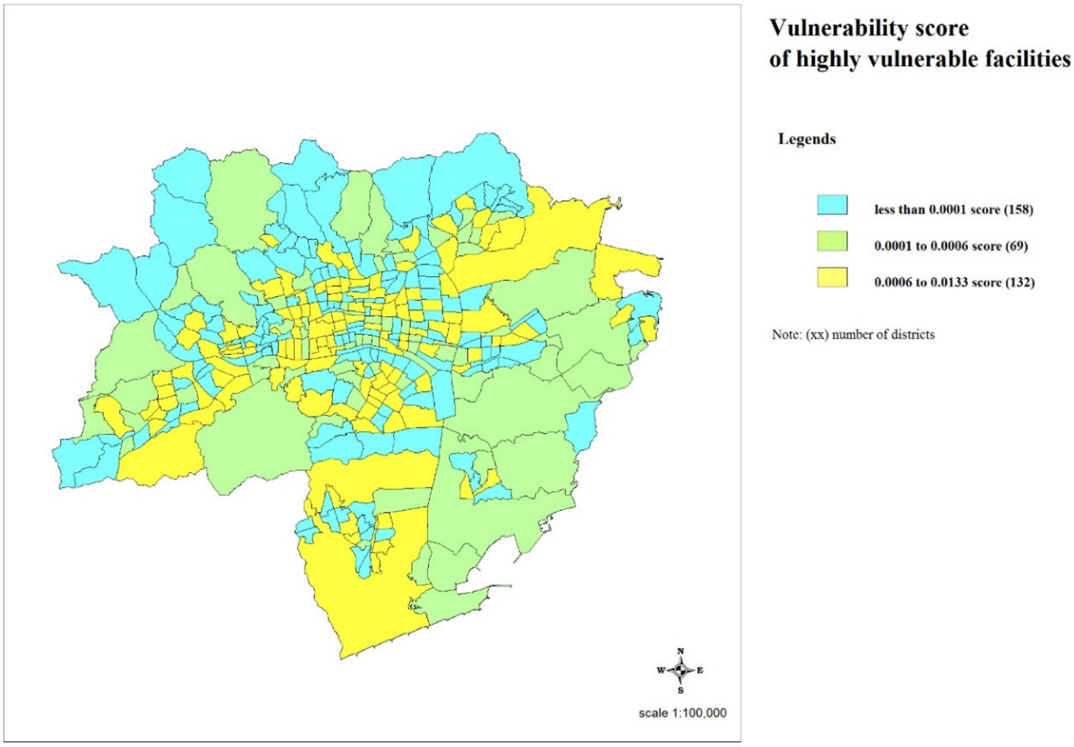


Figure 5-15: Vulnerability score of highly vulnerable facilities

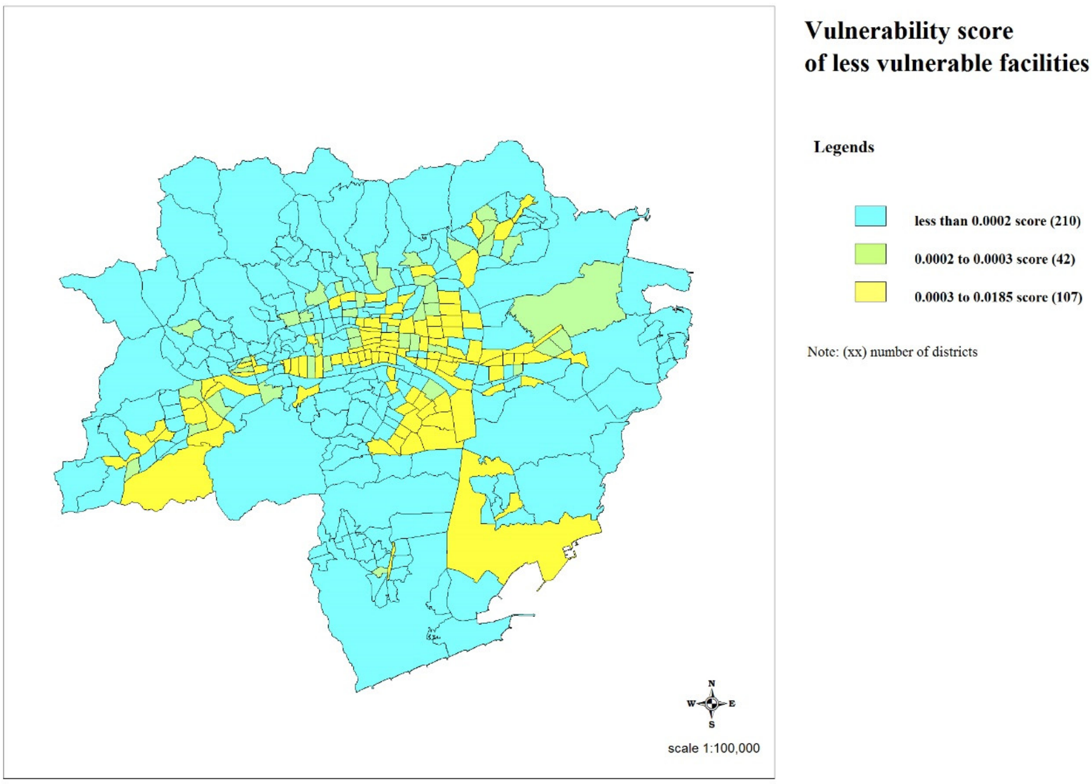


Figure 5-16: Vulnerability score of less vulnerable facilities

5.2.3 Building condition

Building condition related to the earthquake-resistant attributes is also one of the indicators of vulnerability assessment. The structures built prior to the earthquake-resistant construction regulations introduced in 1981 are assumed as the cases having an unsafe condition. Nevertheless, there are cases that a building constructed before 1981 may be just as resistant as one constructed under this regulation enforcement. On the other hand, a building completed in 1982 may not necessarily be built according to the new building code, if the construction began many year prior (Japan Property Central K.K., 2014).

The building Standard Act of Japan has been strictly monitored and developed over time, especially when a large earthquake occurred. The transition of building regulations and earthquake-resistant standard can be divided roughly into four generations as shown in Table 5-1: before 1971, 1971 to 1980, after 1981 to 1999, after 2000 (Plaza Homes, 2012). In 2000, new houses are regulated to have a 10-year warranty against defects, and after 2006 building certificates and inspections became stricter as a result of "the forged earthquake-resistant data scandal by Aneha in 2005" (Japan Property Central K.K., 2014). Nowadays, without rigorous compliance to earthquake proof, one can never get an approval of construction from the public administration office at locality (Plaza Homes, 2012).

Table 5-4: Transitions of earthquake-resistant construction regulations

Generation	Year	Influencers
Emergence of Earthquake-resistant construction regulations	**1924**	Regulations about earthquake-resistant construction were introduced. After the 1891 Mino-Owari magnitude 8 earthquake, research, and study into earthquake-resistant construction began. The 1923 Kanto earthquake further hastened the introduction of building regulations. The regulations required a minimum thickness for wooden beams, reinforced concrete to have an earthquake load and braces to be installed. However, these rules only applied in town areas.
1st	**1950**	**The introduction of the Building Standards Act and what is now known as "kyu-taishin".** The change was brought about after the 1948 Fukui earthquake, which had a magnitude of 7.1. This act ordered a new building to be designed to withstand and not collapse in an earthquake of magnitude 5~7 and with a seismic intensity scale (Shindo-scale) of upper 5.
	1971	After the earthquake off the shore of Tokachi in 1968, the standard for tie-hoops of RC structure was tightened.
2nd	**1981**	**The "shin-taishin", or New Earthquake-Resistant Building Standard Amendment.** After experiencing the disaster caused by the earthquake off the shore of Miyagi Prefecture in 1978, the Building Standard Act was revised and the New Anti-seismic Design Code came in to effect. The new standard focuses not only to prevent buildings from collapse caused by earthquakes but also to secure safety of people inside of buildings. All buildings are expected; Old standard: to be capable of resisting an impact of JMA seismic scale 5 New standard: not to collapse in an earthquake of JMA seismic scale upper 6 or higher * The New Anti-seismic Design Standard has been applied to all buildings requesting approval of construction as of June 1st, 1981.
3rd	**1995**	From the experience of the Hanshin-Awaji earthquake in 1995, Act for Promotion of Renovation for Earthquake-Resistant Structures (an regulation that promotes earthquake-resistance structure on existing buildings) came in to effect. It required larger buildings than a certain size as specified in this regulation a duty to strive to assess an earthquake-resistant level and renovate the structure of buildings in order to secure the same of higher earthquake proof performance level as the New Anti-seismic Design Standard required.
4th	**2000**	The Building Standard Act was revised in order to improve safety of wooden buildings and to clarify anti-seismic performance level as well as specifications and forms of building foundation. The ground investigation became virtually mandatory.
Supplement	**2009**	The Licensed Architect Act was revised as a result of the falsification matter of structural calculation discovered in 2005. The new law required all larger buildings than set on the standard to be structurally designed by a constructional design 1st class registered architect.

Source: Plaza Homes (2012) and Japan Property Central K.K. (2014)

The data of building compliant to earthquake proof is based on the building consensus of Kochi Prefecture. This consensus divides the observed area in accordance with the building area, instead of the administrative areas. Therefore, some sub-districts may have a same vulnerability score in this analytical section.

An overview of the building condition can be comprehensively explained through dividing the city into three areas: 1) Urban Planning Area, 2) Urban Promotion Area (UPA), 3) Urban Control Area (UCA). Within the urban planning area, 48.9% of total buildings were built before 1981. Whereas 49.0% and 46.0% of buildings were built before 1981 in UPA and UCA respectively. Focusing on the vulnerability caused by the building condition at the local sub-district level, there are seven districts in this building census. Those seven districts get no score for this assessment. The result of this assessment is; therefore, based on 357 districts as a sample. Among this sample, Mimase with a vulnerability score of 0.1665 is regarded as the most vulnerable district, while Kitakawazoe with a score of 0.0018 is the less vulnerable districts. According to the building census, 86% of buildings in Mimase are decrepit, while the average rate of decrepit buildings is about 45.8%.

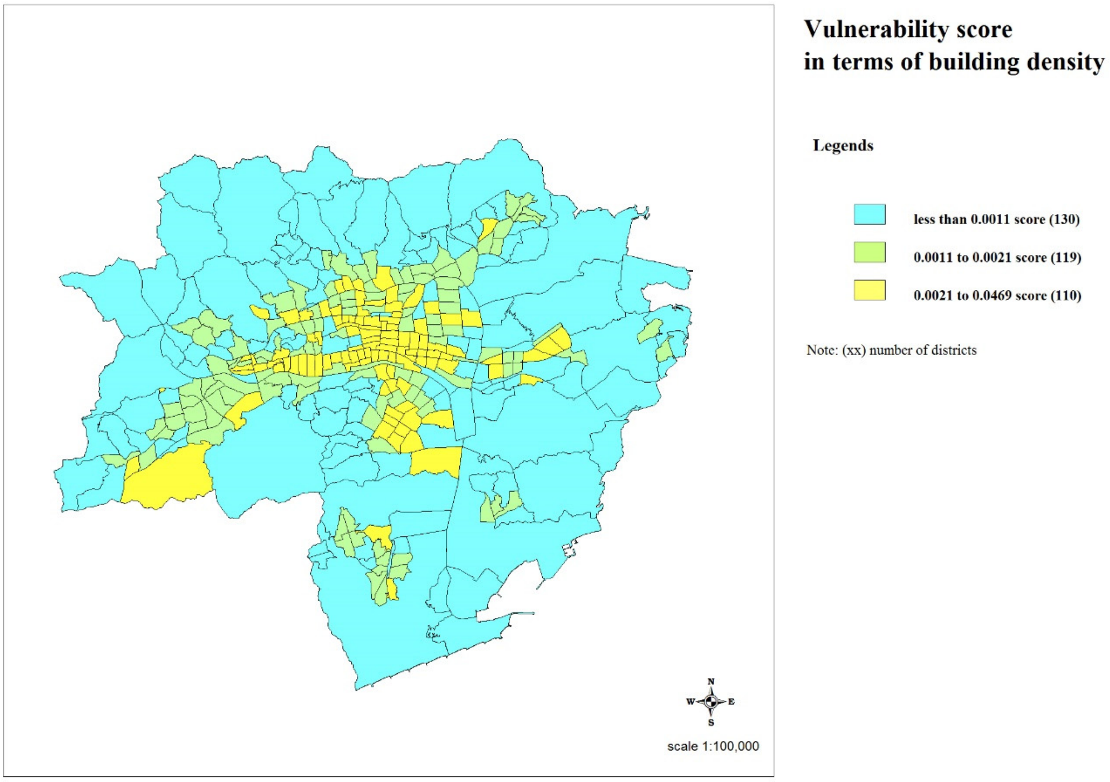


Figure 5-17: Vulnerability map in terms of the building condition

5.2.4 Demography

In this study, a set of indicators related to the demography is different from the population density, as the study focuses on the characteristics of residents themselves rather than territorial space. These indicators are age, gender (percentage of female population), and household size (the bigger family are likely to be more vulnerable to cope with a perturbation). All three indicators are weighted by AHP weighting technique derived from the result of the questionnaire. The maximum score of the demography section is set at 0.1665, divided by age (0.1106), gender (0.0218), and household size (0.0341). The most vulnerable districts in terms of demographic characteristics are Mimase (0.1499 score), Honmachi 4 Chome (0.1405 score), and Seto Nishimachi 2 Chome (0.1398 score), respectively.

- Age

When the significant short warning for the tsunami evacuation is given, a major concern is a group of young children and the elderly. In fact, the mobility-impaired residents should have been taken into the analysis as well, but the availability of data limited the indicator selection. The areas in front of the coastline and in the southern part of the city are more vulnerable to the others as they are homes for the substantial elderly residents. According to independent population of Kochi City, 25.7% of population are the elderly people (over 64 years old), while 13.1% of population are children (under 15 years old). Especially in Mimase, more than 59% of residents are elderly people (over 64 years old). The independent people are assumed to find more difficulty during evacuation process rather than the active age. Therefore, 12 districts tend to have difficulty during evacuation and recovery process, because they have huge independent population with a proportion of active population less than 50% (Table 5-5)

Table 5-5: Districts with less active population (15-60 years old) than 50 percent

District names	Percentage of children (less than15 years old)	Percentage of active population (15-64 years old)	Percentage of elderly population (over 64 years old)
Mimase	3.38	37.40	59.22
Kozaki	18.92	41.89	39.19
Toozu 2 Chome	11.24	45.36	43.39
Seto Nishimachi 2 Chome	10.19	45.60	44.21
Toozu 6 Chome	10.81	45.95	43.24
Takasuootani	6.00	46.00	48.00
Honmachi 4 Chome	6.90	46.55	46.55
Ekimaecho	8.82	47.06	44.12
Obiyamachi 2 Chome	7.26	48.04	44.69
Horagashimacho	8.88	49.42	41.70
Shimojimachou	6.64	49.56	43.81
Nakasukacho	8.38	49.82	41.79
Sakaedacho 1 Chome	5.70	50.00	44.30

Note: Data as of January 2014

Source: Statistic Bureau of Japan (2014)

- Gender

Relationships between gender and the disaster vulnerability in terms of risk management, evacuation, etc. have been a controversial issue among the scholars. Nevertheless, a role of gender is, in this study, related to the individual vulnerability in terms of physical ability and the difficulty of living in evacuation camp. For example, based on the interviews, women may find more difficult during the evacuation process, such as using toilets and bathrooms. Hence, the percentage of female population is taken as a vulnerability factor. There are 327 districts of female majority. Among these, Sakaedacho 1 Chome has highest percentage of female population (66%), and 48% of them are elderly people (over 60 years old).

Table 5-6: Top ten districts of female majority

District names	Name in Japanese (Kanji)	Percentage of female	Age distribution of female population		
			0〜14years old	15〜64 year olds	Over 64 years old
Sakaedacho 1 Chome	栄田町1丁目	65.82	3.85	48.08	48.08
Minamimotomachi	南元町	63.27	9.03	50.32	40.65
Suidocho	水通町	62.50	×	×	×
Akaishicho	赤石町	62.19	4.55	50.57	44.89
Kouyouchou	江陽町	61.88	10.87	59.42	29.71
Otesuji 2 Chome	追手筋2丁目	61.54	7.50	70.00	22.50
Futabacho	二葉町	61.31	10.26	52.62	37.12
Kitahonmachi 2 Chome	北本町2丁目	60.80	3.74	70.09	26.17
Masugata	升形	60.00	8.41	54.05	37.54
Rendai	蓮台	59.74	6.52	56.52	36.96

Note: Data as of January 2014

Source: Statistic Bureau of Japan (2014)

- The matter of household size

It is reasonable to assume that extended households have more burden during the evacuation period and the recovery time, because the extended households tend to have a proportion of independent members rather than active earners. Consequently, they are likely to be unable to cover the unexpected expenses, such as recovery cost after a disaster. As a result, Nagahamamakiedai 1 chome and 2 chome are considered to be more vulnerable due to their household size of four persons. Households in other 355 districts tend to be less vulnerable, as they are households of three persons or less. In any case, the average household size of the unit of analysis is two.

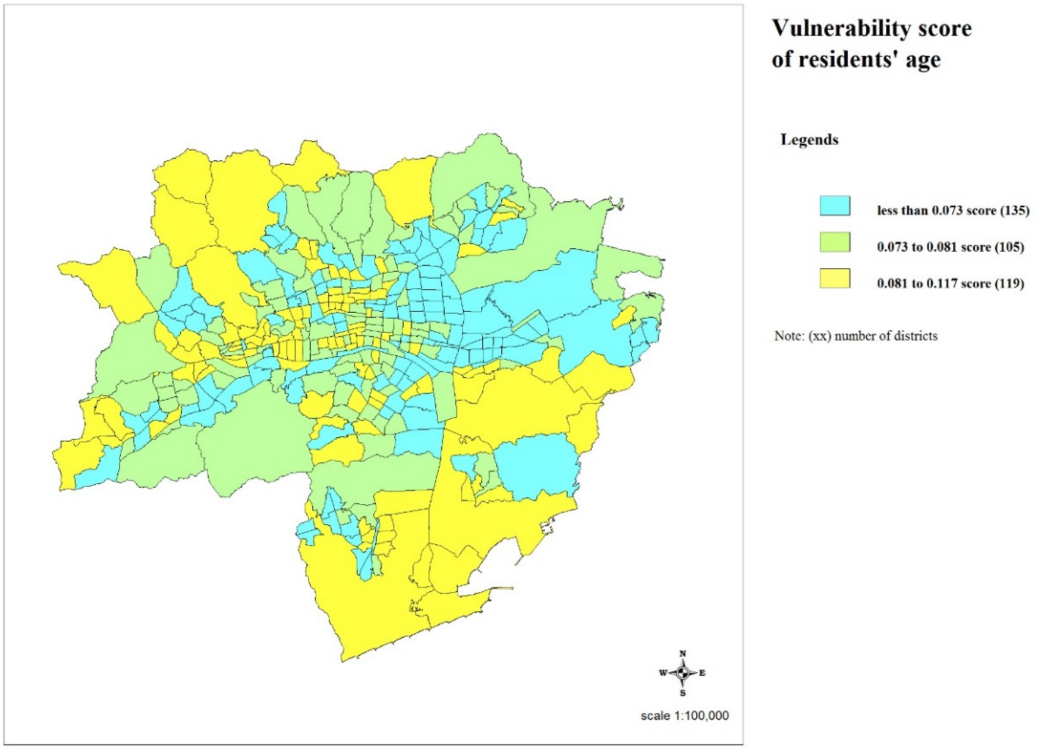


Figure 5-18: Vulnerability score of residents' age

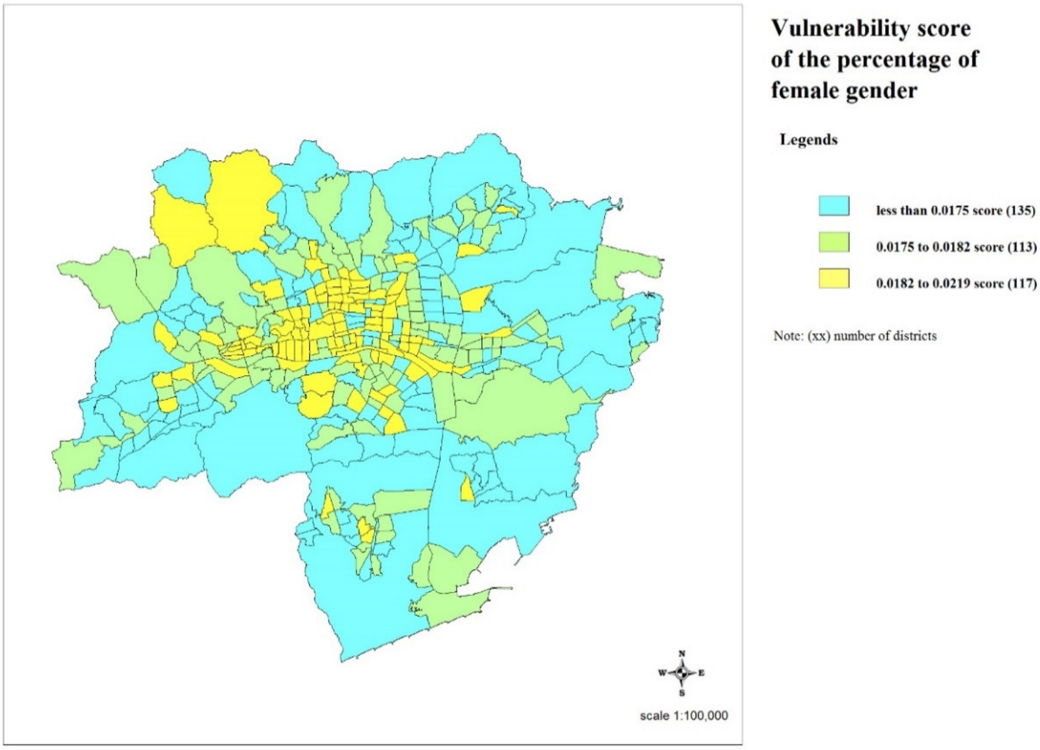


Figure 5-19: Vulnerability score of the percentage of female gender

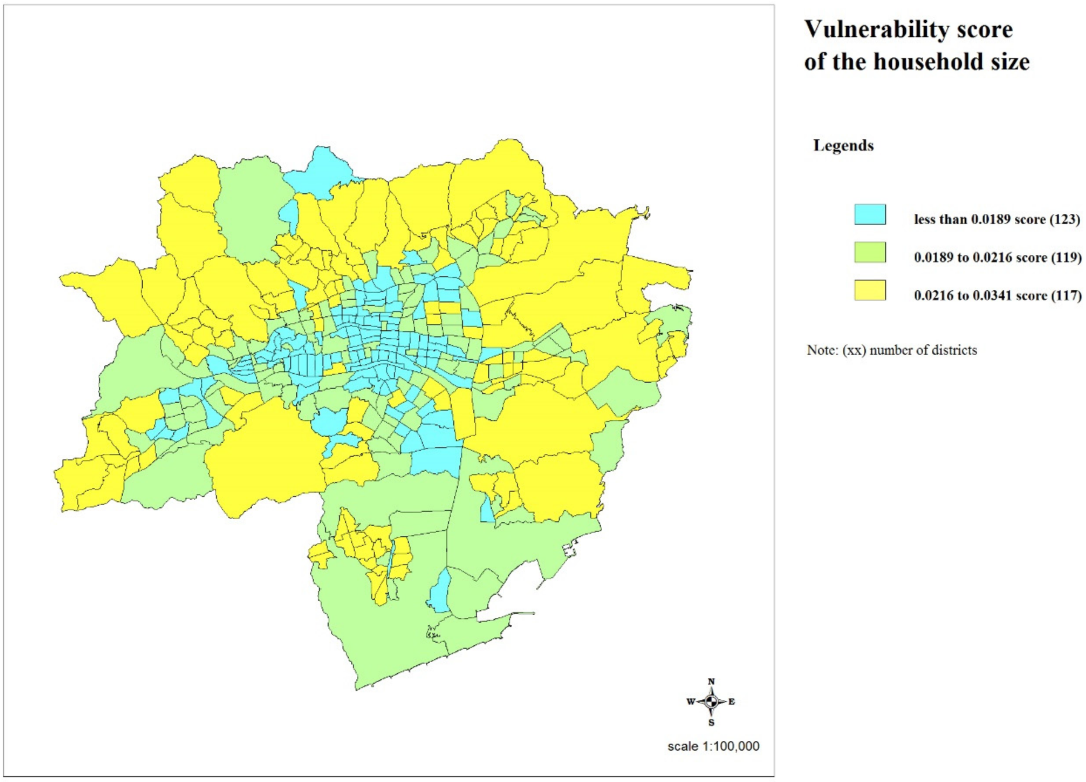


Figure 5-20: Vulnerability score of the household size

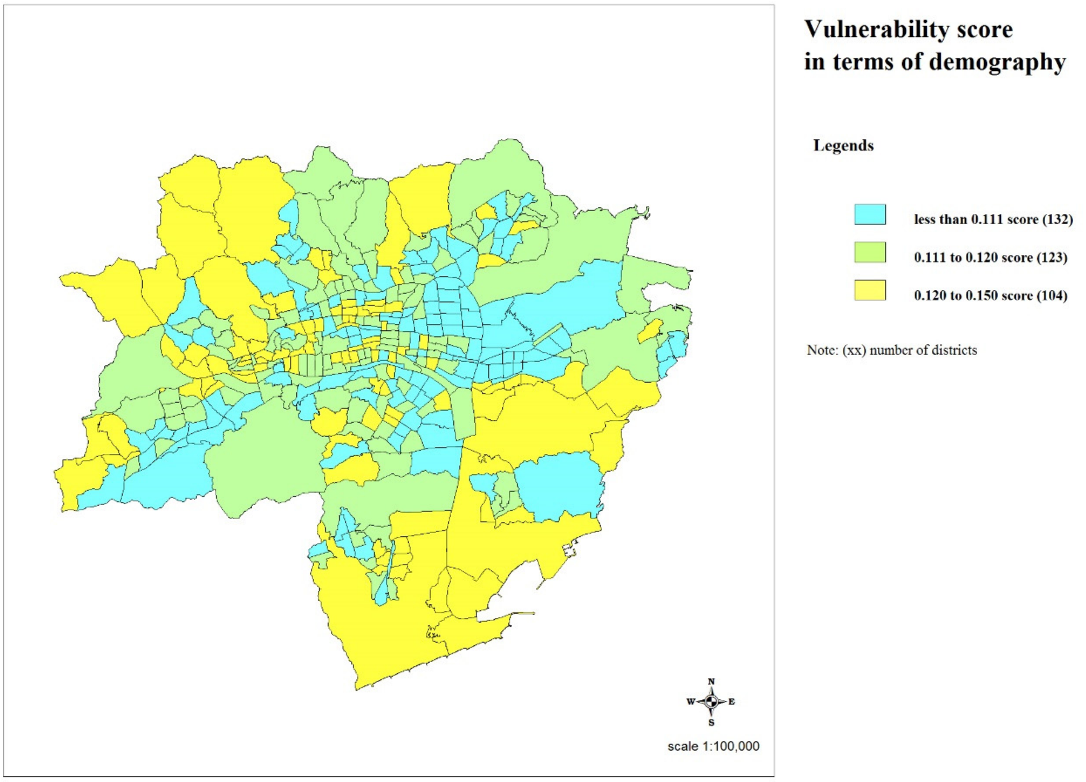


Figure 5-21: Vulnerability map in terms of the demography

5.2.5 Cultural heritage

Kochi Prefecture has Cultural Properties Protection Law to conserve the cultural heritage including both historical monuments and scenic natural monument from the civil construction. Especially in Archaeological area, every construction is required to follow the prescribed procedures under the permit. The list of conservative heritage sites can be found in the official website of Kochi Prefecture (http://bunkazaimap.kochinet.ed.jp/iseki/). There are 267 heritage properties of Kochi City in this list: for example, Asakura Shiroyama ruins, Asakura tumulus, Urado castle ruins and Soanji mark. These heritage properties are irreplaceable, but the tsunami may cause them collapse. The most considerably vulnerable districts that have more heritage properties at risk are Kutanda, Takasu, and Honmachi 4 Chome, respectively.

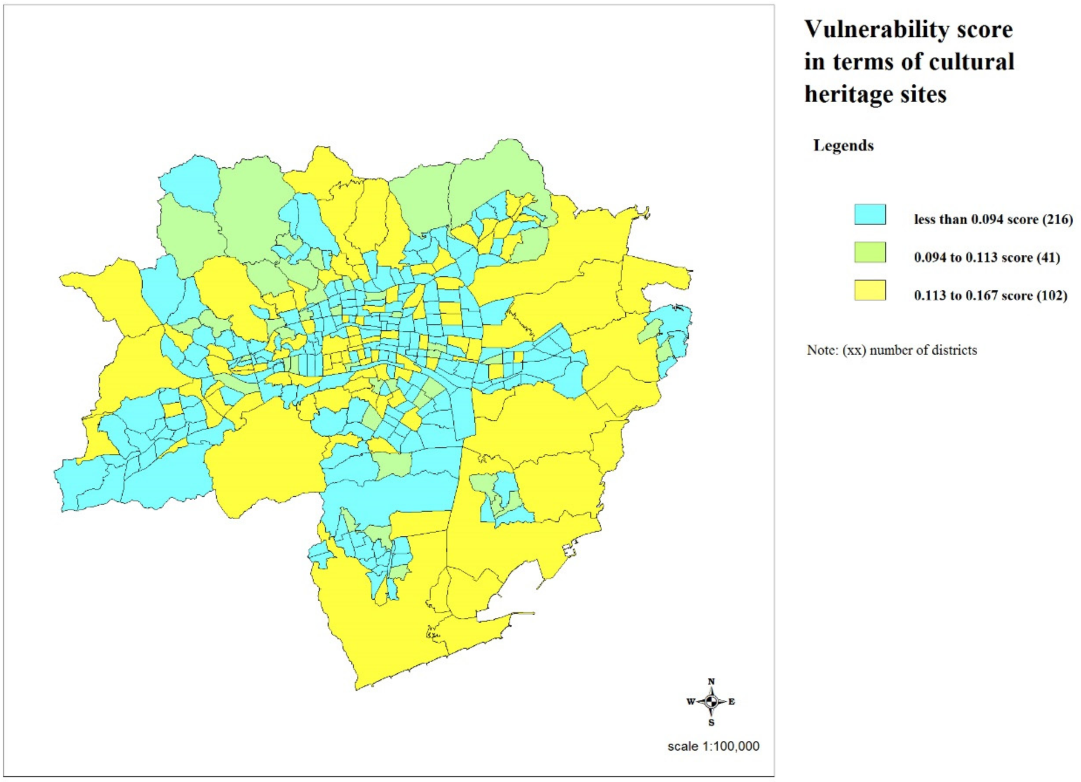


Figure 5-22: Vulnerability map in terms of the cultural heritage sites

5.2.6 Land prices

The analysis is based on the public notice of 2013. Land prices vary from 12,500 Yen to 269,000 Yen per square meter, depending on the location of the land. This land price appraisal is based on the premise that the far distance from the reference of marked land price depreciates land price. The appraisal is performed under the use of Inverse Distance Weighting (IDW) interpolator[1]. Results of the land price distribution is divided into five levels based on its standard deviation (SD): 0-20% (lower 13,000), 21-40% (54,000),41-60% (<64,000), 61-80 (<78,000), and over 80% (>78,000-269,000). The most expensive land (price per square meter) are in Hijimacho 2 Chome (269,000 Yen), Honmachi 4 Chome (264,000 Yen) and Sakuraicho 2 Chome (220,000 Yen). Nevertheless, the price of land within the same neighborhood area also varies upon individual value factors including the site area, shape, and current situation of the facing road (See Land Market Value Publication Act of Japan: Art. 8, 9, and 19).

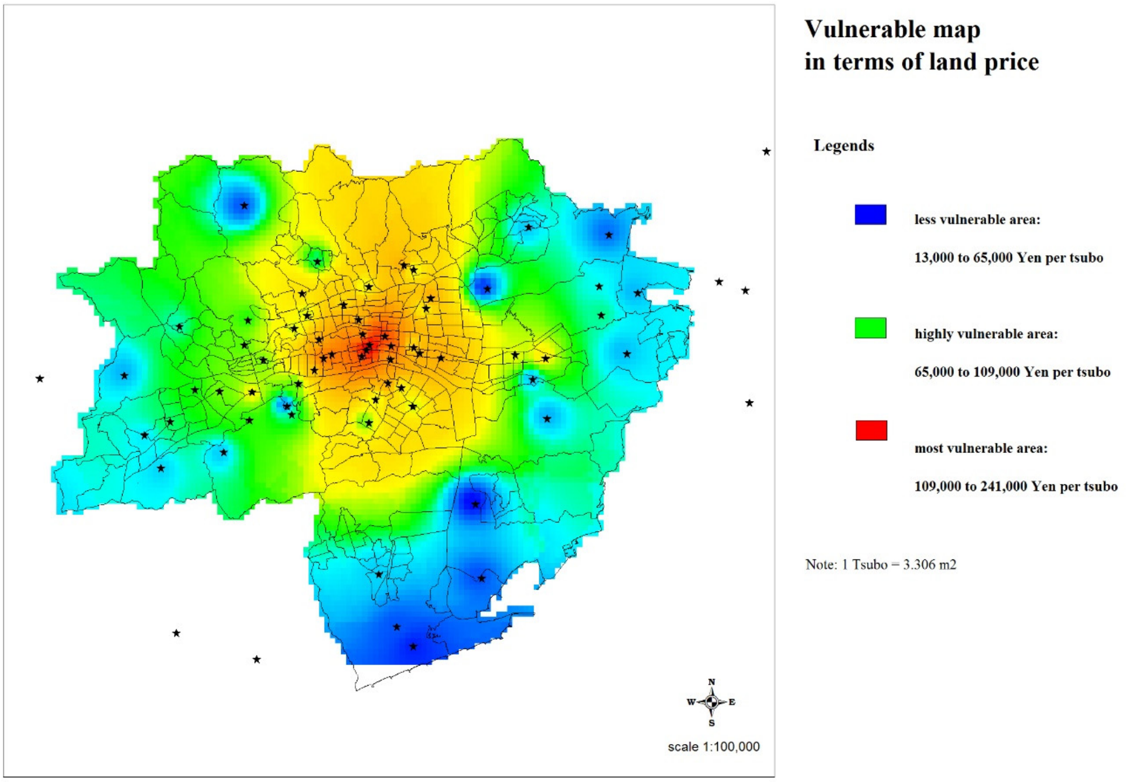


Figure 5-23: Land price distribution by Public Notice (as of 2013)

[1] This option produces raster grid files, which appear as raster layers.

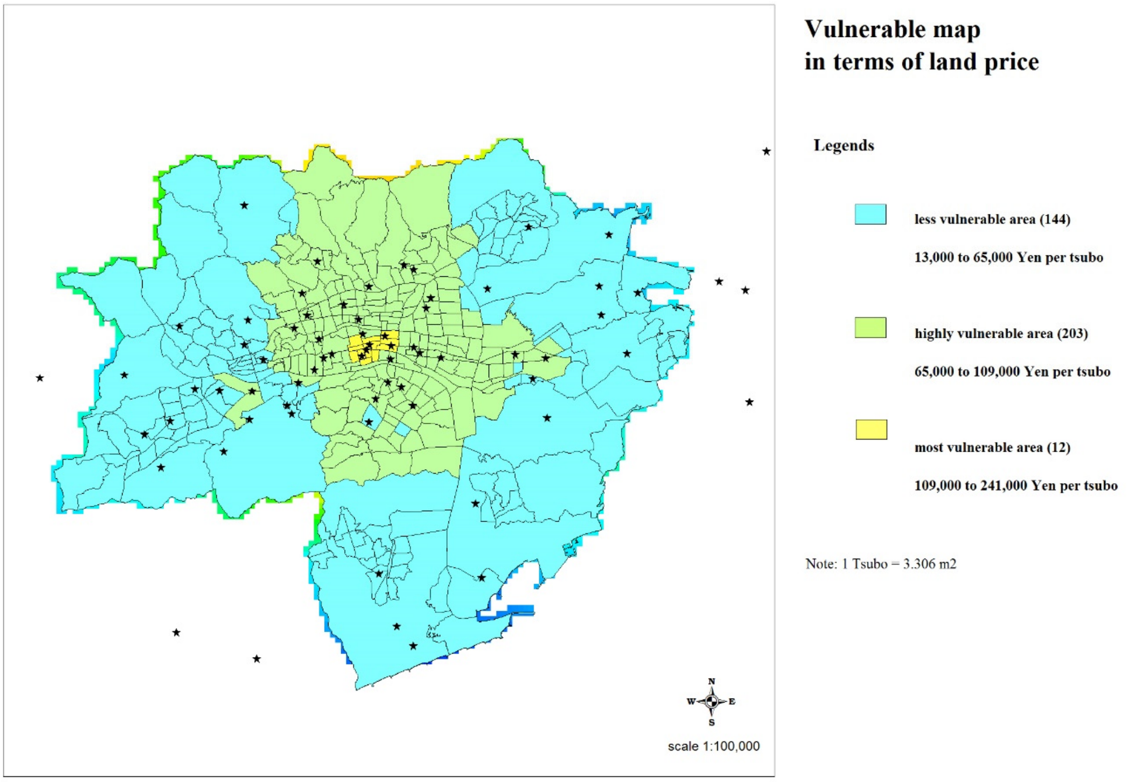


Figure 5-24: Vulnerability map in terms of the land price

5.2.7 A summary of vulnerability assessment

The maximum score of this assessment is 100. However, it is impossible that one can have a maximum score. By assessing vulnerability of sub-districts, the vulnerability can be divided into three levels. Considering the unit of analysis, each district's score is compared with the highest vulnerable district's score. Among 357 sub-districts, Honmachi 4 Chome district is regarded as the highest vulnerable area, with the vulnerability score of 0.5370. Other sub-districts will be classified in accordance with their scores when those are compared with 0.5370. Of 357 sub-districts, 34 sub-districts are considered as highly vulnerable areas, while 308 sub-districts are ranged in the middle between highly and less vulnerable areas. The less vulnerable area in this assessment comprises of 28 sub-districts. The lowest vulnerable one is Seto with a score of 0.0756. The vulnerability score distribution of this assessment can be illustrated as shown in Figure 5-28.

Table 5-7: the number of districts classified by vulnerability level

Vulnerability level	High	Median	Low
Number of sub-districts	34	298	28

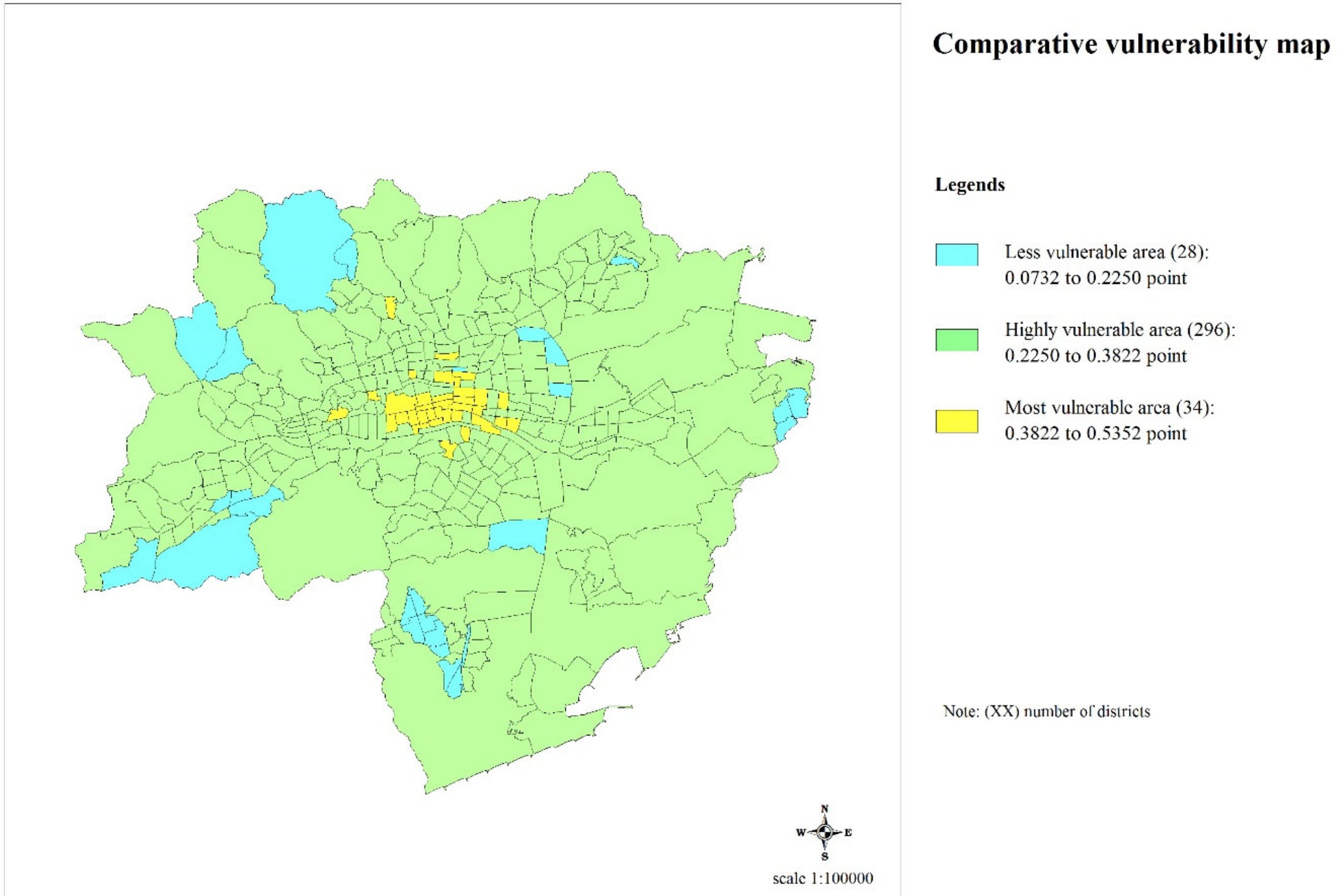


Figure 5-25: Comparative vulnerability map classified by 3-percentiles of highest score

Note: The difference between the top and bottom values in each range is the same. The middle group has a score falling between 33.33 to 66.66 % of the highest score (0.537).

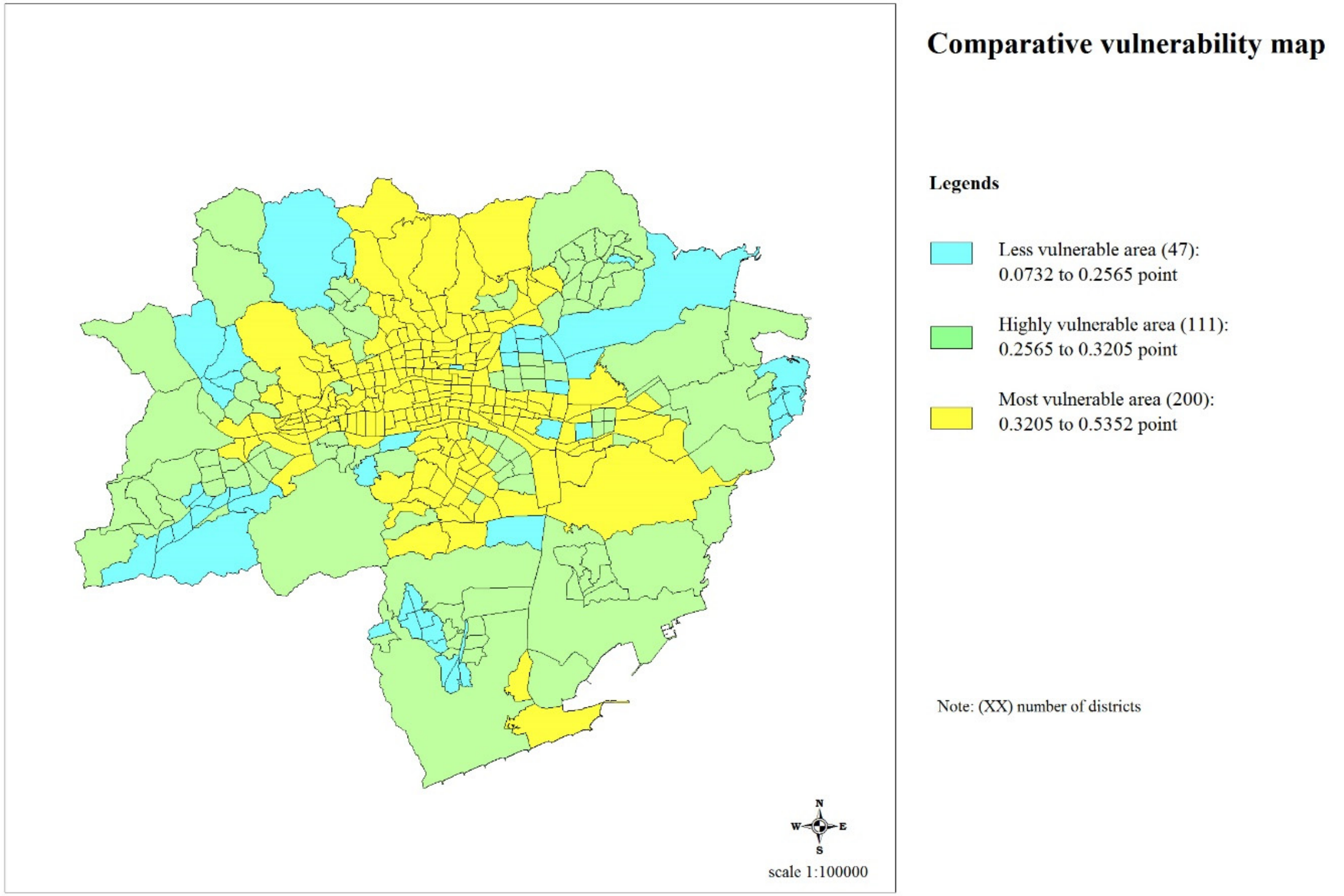


Figure 5-26: Comparative vulnerability map classified by the standard deviation of vulnerability score

Note: The middle range is at the mean of vulnerability score, and the ranges above and below the middle range are one standard deviation above or below the mean.

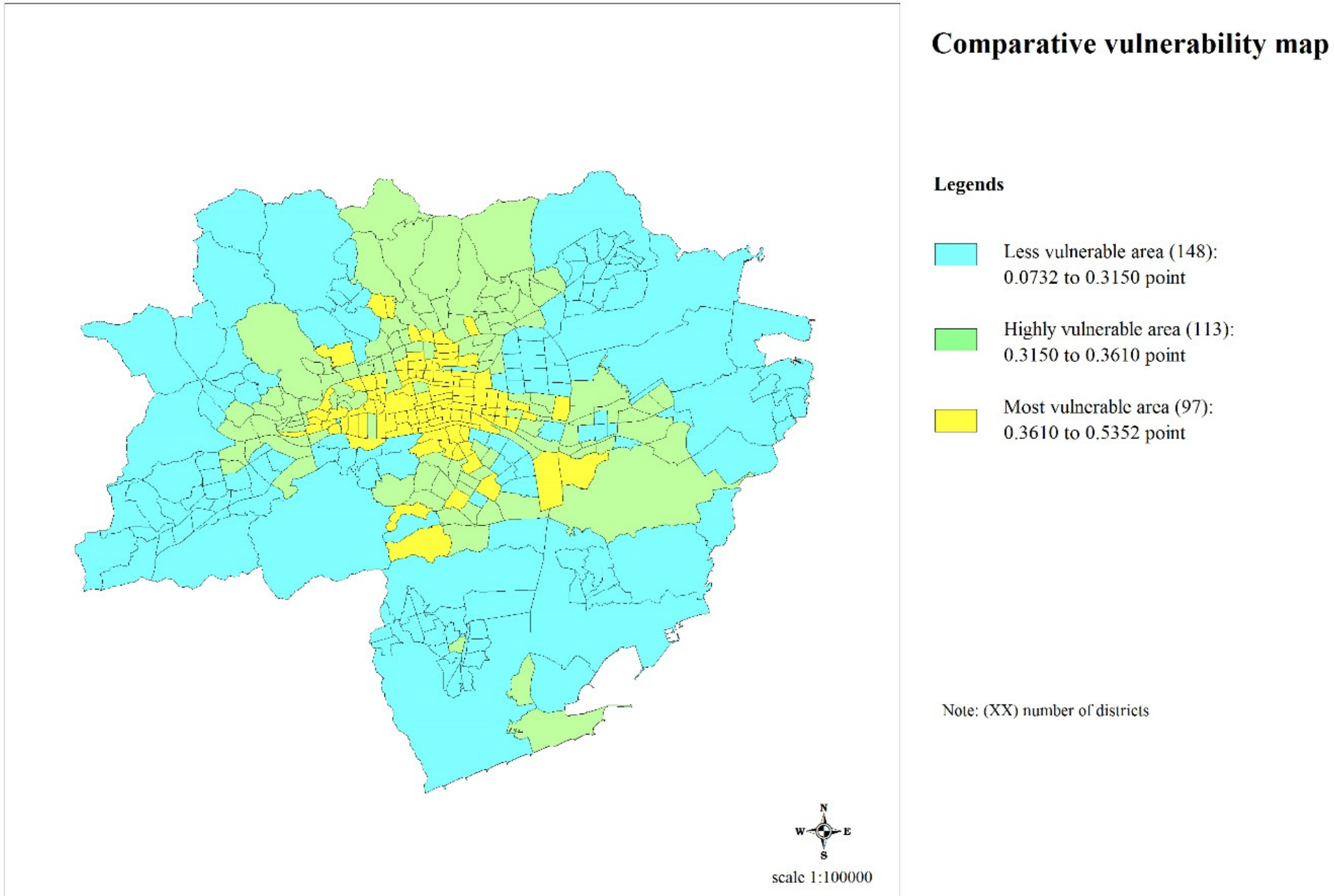


Figure 5-27: Comparative vulnerability map classified by the 3-quantiles of vulnerability score

Note: The 3-quantiles are called tertiles or terciles → T. It determines the distribution of the vulnerability across a segment of vulnerability score.

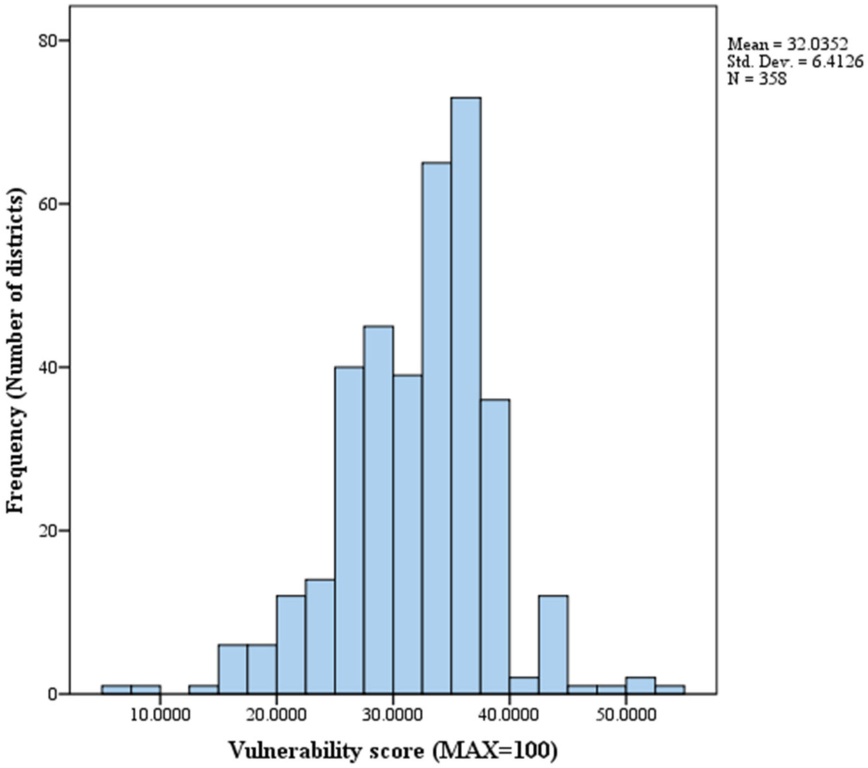


Figure 5-28: The histogram of vulnerability score distribution

Concerning the research question number 2.1 whether "Which vulnerable characteristics make highly vulnerable districts different from the others?", the study assumed that socio-economic characteristics of residents make the highly vulnerable districts different from the others. Therefore, the correlation between the vulnerability groups and those socio-economic factors answers this research question. All districts can be categorized into three groups according to their vulnerability levels (independent variables): highly vulnerable group, middle vulnerable group, and less vulnerable groups. Not only are the socio-economic characteristics in terms of number of residents, population density, the average age, age distribution, household size, average dwelling room per household (or person) included, but also some other physical variables are taken as dependent variables in the correlation analysis, such as building density (FAR), and OSR. A set of 14 factors can be categorized into three different groups as shown in Table 5-8: (1) Urban Density, (2) Demography, and (3) Housing Quality.

To investigate correlations between those variables, the Pearson Correlation coefficient was computed. The test was generated under the hypothesis that the each dependent variable correlates with the vulnerability levels. The statistical hypothesis is illustrated as follows;

$$H_0 : \rho = 0$$

$$H_1 : \rho \neq 0$$

$\rho = 0$ An individual factor is not significantly correlated with the vulnerability level

$\rho \neq 0$ An individual factor is significantly correlated with the vulnerability level

With an alpha level at 0.05 for all statistical tests, the results of the test of Pearson Correlation proved that there were 12 factors (of 14 factors) having an influence on the urban vulnerability. The other two factors – Open Space Ratio (OSR) and the facility of highly vulnerable use – were not significantly correlated with the urban vulnerability (Table 5-8).

The top three factors that positively correlate with the vulnerability levels are a proportion of elderly people ($\rho = 0.382$, $p < 0.001$), a proportion of female residents ($\rho = 0.367$, $< .001$) and an overall facility density ($\rho = 0.338$, $p < 0.001$). These can be interpreted that the more vulnerable the districts are, the richer facility provision and the higher proportion of female and elderly residents are in place. On the other hand, household size and a proportion of children population are the only two factors that have a negative correlation with the vulnerability levels. The districts that have higher vulnerability tend to have smaller household size ($\rho = -0.243^{***}$, $p < 0.001$) and smaller proportion of children ($\rho = -0.129^{**}$, $p < 0.001$). Even though the values of Pearson Correlation (ρ) between those factors and the vulnerability levels are statistically significant, the study found that the correlation levels are relative low ($\rho = 0.30$-0.50) and significantly low ($\rho = 0.00$-0.30).

Table 5-8: The correlation between vulnerability levels (groups) and urban fabrics

Characteristics of urban fabrics	Statistic Values	
1. Urban Density		
1.1 Population density	Pearson Correlation	.130**
	Sig. (2-tailed)	.014
	N	358
1.2 Building density (FAR: Floor area ratio)	Pearson Correlation	.330***
	Sig. (2-tailed)	<.001
	N	358
1.3 Open Space Ratio (OSR)	Pearson Correlation	-.061
	Sig. (2-tailed)	.250
	N	358
1.4 Overall facility density	Correlation Coefficient	.338***
	Sig. (2-tailed)	<.001
	N	358
(1) Most vulnerable uses	Correlation Coefficient	.287***
	Sig. (2-tailed)	<.001
	N	358
(2) Highly vulnerable use	Correlation Coefficient	.087
	Sig. (2-tailed)	.101
	N	358
(3) Less vulnerable uses	Correlation Coefficient	.316***
	Sig. (2-tailed)	.001
	N	358
2. Demography		
2.1 Age distribution	Pearson Correlation	-.129**
(1) Proportion of children (1-14 years old)	Sig. (2-tailed)	.014
	N	358
(2) Proportion of active population (15-65 years old)	Pearson Correlation	.070
	Sig. (2-tailed)	.189
	N	358
(3) Proportion of elderly people (+65 years old)	Pearson Correlation	.382***
	Sig. (2-tailed)	<.001
	N	358
2.2 Household size	Pearson Correlation	-.243***
	Sig. (2-tailed)	<.001
	N	358
2.3 Proportion of female population	Pearson Correlation	.367***
	Sig. (2-tailed)	<.001
	N	358
3. Housing Quality		
3.1 Average dwelling room area per person	Pearson Correlation	.185***
	Sig. (2-tailed)	<.001
	N	358
3.2 Average dwelling room area per household	Pearson Correlation	.112***
	Sig. (2-tailed)	.034
	N	356

Note: - The population data as of January 2014
- *** The correlation of two factors is significant at the 0.01 level, ** Correlation is significant at the 0.05 level, * Correlation is significant at the 0.10 level

In order to identify precisely the different characteristics among the most vulnerable area, the highly vulnerable area, and the less vulnerable area, the study applies an analysis of variance (ANOVA). The test of homogeneity of variances through Levene test is used to check the assumption that the variances of urban characteristics are equal. On the other words, there is no significantly different. Notice that for population density (p=0.255) and open space ratio (p=0.066) the Levene tests are not significant. Thus, the assumption is not violated. In this case, a post hoc test of Scheffe will be used. However, for other factors, the Levene test is essentially significant and, thus, the assumption of equal variances is violated. In the latter case, the similar post hoc test of Tamhane – designed for situations in which the variance are unequal – will be applied. Table 5-11 shows whether the overall Fs for these ANOVAs are significant. The results show that all variables significantly vary by the vulnerability levels, expect the variable in terms of Open Space Ratio. A proportion of elderly people, F (2, 355) = 31.12, p < 0.001 is one of three crucial factors that have highest values of Pearson Correlation coefficient. The mean proportion of elderly people is 34.017 in the most vulnerable districts, 26.099 for the highly vulnerable districts, and 15.183 in the less vulnerable districts. In terms of a proportion of female residents among different vulnerable groups, F (2, 355) = 37.342, p < 0.001, the mean is 56.293 for the most vulnerable districts, 53.505 in the highly vulnerable districts, and 43.477 in the less vulnerable districts. Moreover, the mean of an overall facility density, F (2, 355) = 27.864, p < 0.00, is also different. Remarkably, the overall facility density is 0.428 in the most vulnerable districts, 0.084 for the highly vulnerable districts, and 0.049 for the less vulnerable districts.

Table 5-9: The Test of Homogeneity of Variances

	Levene Statistic	df1	df2	p.
1. Urban Density				
1.1 Population density	1.372	2	355	0.255
1.2 Building density (FAR: Floor area ratio)	9.889	2	355	< 0.001
1.3 Open Space Ratio (OSR)	2.74	2	355	0.066
1.4 Overall facility density	23.463	2	355	< 0.001
(1) Most vulnerable uses	19.256	2	355	< 0.001
(2) Highly vulnerable use	8.892	2	355	< 0.001
(3) Less vulnerable uses	39.121	2	355	< 0.001
2. Demography				
2.1 Age distribution (1) Proportion of children (1-14 years old)	10.825	2	355	< 0.001
(2) Proportion of active population (15-65 years old)	34.942	2	355	< 0.001
(3) Proportion of elderly people (+65 years old)	3.415	2	355	0.034
2.2 Household size	21.048	2	355	< 0.001
2.3 Proportion of female population	79.28	2	355	< 0.001
3. Housing Quality				
3.1 Average dwelling room area per person	15.795	2	355	< 0.001
3.2 Average dwelling room area per household	14.281	2	353	< 0.001

Table 5-10: Means and standard deviations comparing three vulnerable groups

	Three vulnerable groups					
	Less vulnerable area (28 districts)		Highly vulnerable area (295 districts)		Most vulnerable area (35 districts)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
1. Urban Density						
1.1 Population density	4134.929	3419.114	5714.178	4063.754	7008.223	8168.291
1.2 Building density (FAR)	.261	.144	.419	.375	1.073	.539
1.3 Open Space Ratio (OSR)	825.476	1564.789	907.896	3161.854	78.903	45.787
1.4 Overall facility density	.049	.080	.084	.143	.428	.734
(1) Most vulnerable use	.012	.035	.026	.078	.116	.194
(2) Highly vulnerable use	.019	.039	.025	.061	.056	.101
(3) Less vulnerable uses	.019	.034	.033	.090	.257	.575
2. Demography						
2.1 Age distribution (1) Proportion of children (1-14 years old)	10.807	6.926	12.165	4.732	8.266	2.421
(2) Proportion of active population (15-65 years old)	52.582	28.521	59.023	11.554	57.716	6.107
(3) Proportion of elderly people (+65 years old)	15.183	11.047	26.099	9.561	34.017	6.331
2.2 Household size	2.117	.702	2.036	.274	1.751	.168
2.3 Proportion of female population	43.477	18.704	53.505	3.905	56.293	2.986
3. Housing Quality						
3.1 Average dwelling room area per person	39.263	15.701	47.981	32.589	75.031	94.250
3.2 Average dwelling room area per household	94.642	23.211	96.798	65.854	136.643	194.366

Table 5-11: One-way analysis of Variance (ANOVA) summary table comparing vulnerability groups on urban fabric characteristics

			Sum of Squares	df	Mean Square	F	p.
1. Urban Density	1.1 Population density	Between Groups	1.284E8	2	64219464.464	3.065	.048
		Within Groups	7.439E9	355	20955762.522		
		Total	7.568E9	357			
	1.2 Building density (FAR)	Between Groups	14.701	2	7.351	50.333	.000
		Within Groups	51.844	355	.146		
		Total	66.546	357			
	1.3 Open Space Ratio (OSR)	Between Groups	21502740.889	2	10751370.444	1.270	.282
		Within Groups	3.005E9	355	8465899.355		
		Total	3.027E9	357			
	1.4 Overall facility density	Between Groups	3.841	2	1.920	27.864	.000
		Within Groups	24.467	355	.069		
		Total	28.308	357			
	(1) Most vulnerable uses	Between Groups	.268	2	.134	15.467	.000
		Within Groups	3.081	355	.009		
		Total	3.349	357			
	(2) Highly vulnerable use	Between Groups	.032	2	.016	3.832	.023
		Within Groups	1.474	355	.004		
		Total	1.505	357			
	(3) Less vulnerable uses	Between Groups	1.601	2	.800	20.847	.000
		Within Groups	13.629	355	.038		
		Total	15.230	357			
2. Demography	2.1 Age distribution (1) Proportion of children (1-14 years old)	Between Groups	498.743	2	249.371	10.958	.000
		Within Groups	8078.629	355	22.757		
		Total	8577.372	357			
	(2) Proportion of active population (15-65 years old)	Between Groups	1078.897	2	539.449	3.065	.048
		Within Groups	62475.787	355	175.988		
		Total	63554.684	357			
	(3) Proportion of elderly people (+65 years old)	Between Groups	5528.540	2	2764.270	31.121	.000
		Within Groups	31531.845	355	88.822		
		Total	37060.385	357			
	2.2 Household size	Between Groups	2.854	2	1.427	13.916	.000
		Within Groups	36.400	355	.103		
		Total	39.254	357			
	2.3 Proportion of female population	Between Groups	2993.907	2	1496.954	37.342	.000
		Within Groups	14231.297	355	40.088		
		Total	17225.204	357			
3.	3.1 Average dwelling room area per person	Between Groups	26357.836	2	13178.918	7.535	.001
		Within Groups	620918.732	355	1749.067		

			Sum of Squares	df	Mean Square	F	p.
		Total	647276.568	357			
	3.2 Average dwelling room area per household	Between Groups	50655.741	2	25327.870	3.475	.032
		Within Groups	2572938.425	353	7288.777		
		Total	2623594.166	355			

5.3 Natural hazard of Kochi City

Shikoku Island is situated at the convergence of several active plates: Pacific, Philippine and the Amur Plates, in which their annual mean subduction rate is ranked among the highest in the world. This island is located in an active fault zone (Nankai trough) with an average annual rate of movement at 102 mm. Therefore, it is undeniably undeniably a target of future earthquakes and tsunamis.

Located in the eastern shore of Shikoku Island, Kochi City is not only considered as one of the biggest cities but also a vulnerable city to tsunami for two important reasons: the location facing the Pacific Ocean and the high portion of elderly residents. Within the possibility of seismic magnitude 5, the threat of a tsunami is imminent, and the geometry of the larger coastline can act as a magnifier of tsunami wave towards the city. The extent of vertical run-up of wave depends on “near-shore bathymetry, beach profile, land topography and the frequency and velocity of tsunami waves (Cho, Lakshumanan, Choi, Ha: 2008 citied in Rudakevych, Sono, Matsushita, Fong, 2013). Thus, tsunami inundation patterns will vary according to the specific topography of Kochi City.

With the attempt to mitigate and prepare strategies to cope with the coming earthquake, Kochi Prefecture preformed a study on the supplementary assessment for tsunami disaster prevention in 2005. The study, as shown in Figure 5-29, predicted the levels of tsunami inundation and the arrival time of the first tsunami wave after the earthquake. This figure was published in a booklet titled “An information booklet for the international community in Kochi: Preparing for the Nankai Earthquake (Kochi International Association, 2008)”. The booklets were widely distributed to the residents in late 2008. Nevertheless, there had been a controversial debate about the accuracy of a measurement system, which led to a reassessment on May 10, 2012. This revision was based on worst-case earthquake scenarios predicted by the Japanese government in March 2012. Figure 5-30 is used to compare the previous predicted tsunami inundation (the left) and the heights with those in the updated prediction.

Compared with the previous prediction, the potentially inundated areas of the updated prediction cover wider range of area. , Nevertheless, as the inner city is located far from the coastal zone and behind a high ridge of hills, these conditions serve as a natural buffer. Thus, people can buy more time to prepare themselves for the evacuation before a wide river basin between those hills allows a huge wave to get through the city center and surrounding areas. Considering a frontline of the coast that is mainly used for agricultural, industrial, low-rise housing development purposes, there are less densely populated areas than the center. Those areas are potentially exposed to the wave. Besides, when the tsunami occurs, people living there will have no time to evacuation, unless they prepare the evacuation plan beforehand.

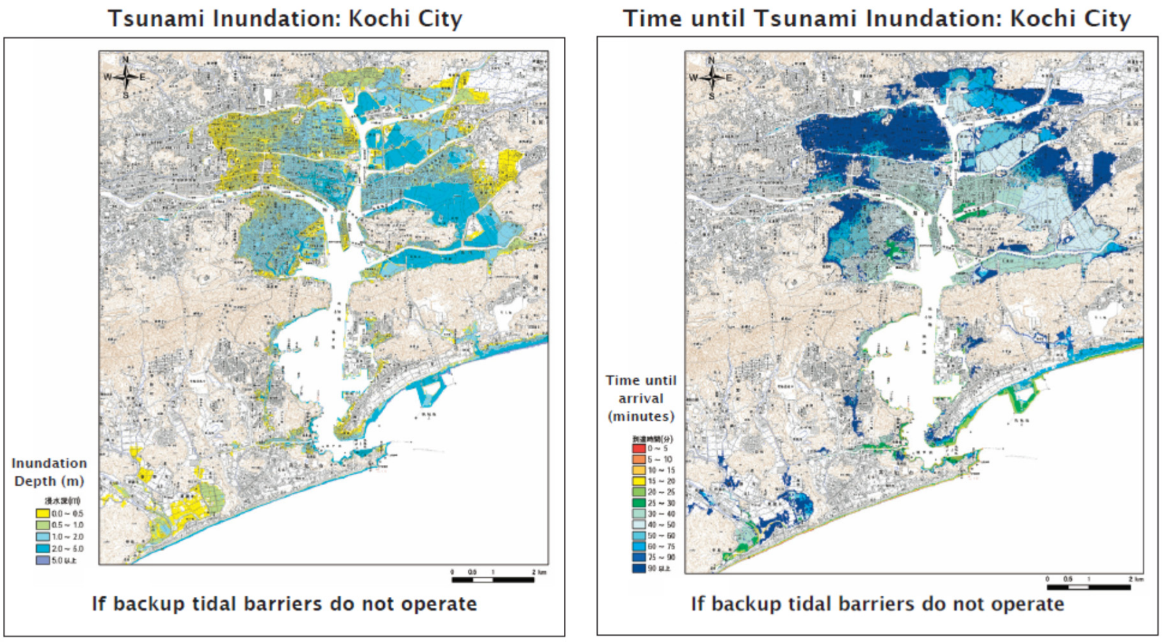


Figure 5-29: An obsoleted prediction of tsunami inundation

Note: - Under the condition of no tide facility operated

- Kochi Prefecture Supplementary Assessment Study for Tsunami Disaster Prevention, May 2005)

Source: Kochi International Association (2008)

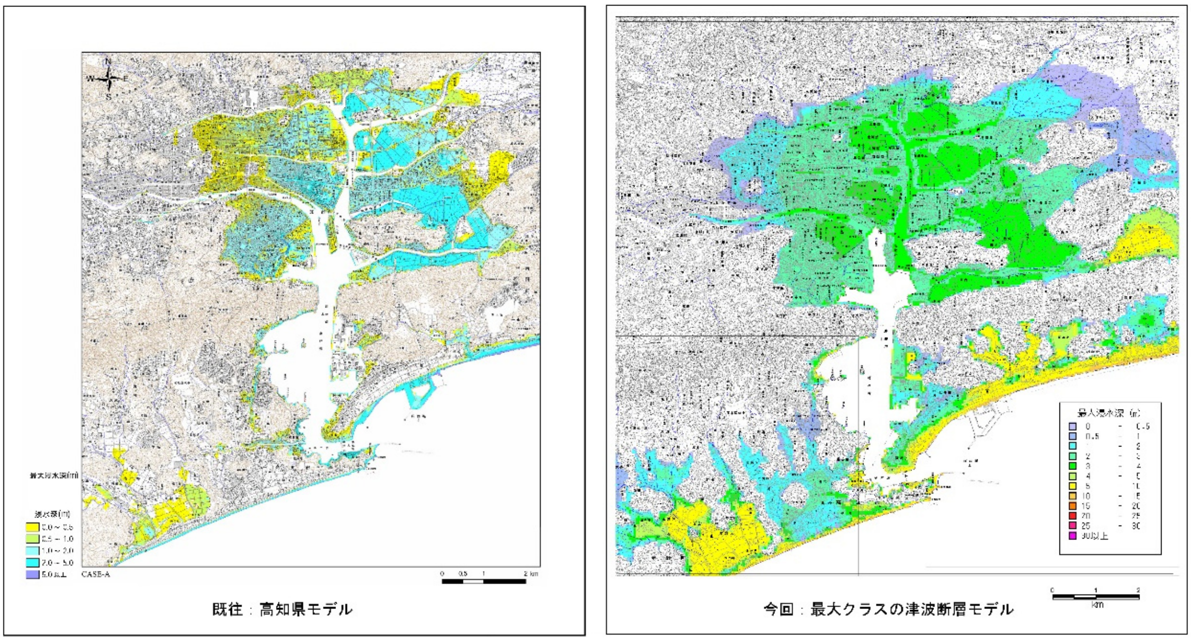


Figure 5-30: A comparison of two predictions on tsunami inundation

Note that the estimation is under the condition of no tide facility operated. The right illustration is an updated estimation as of 2010.

Source:http://www.pref.kochi.lg.jp/soshiki/010201/files/2012051000241/2012051000241_www_pref_kochi_lg_jp_uploaded_attachment_72406.pdf

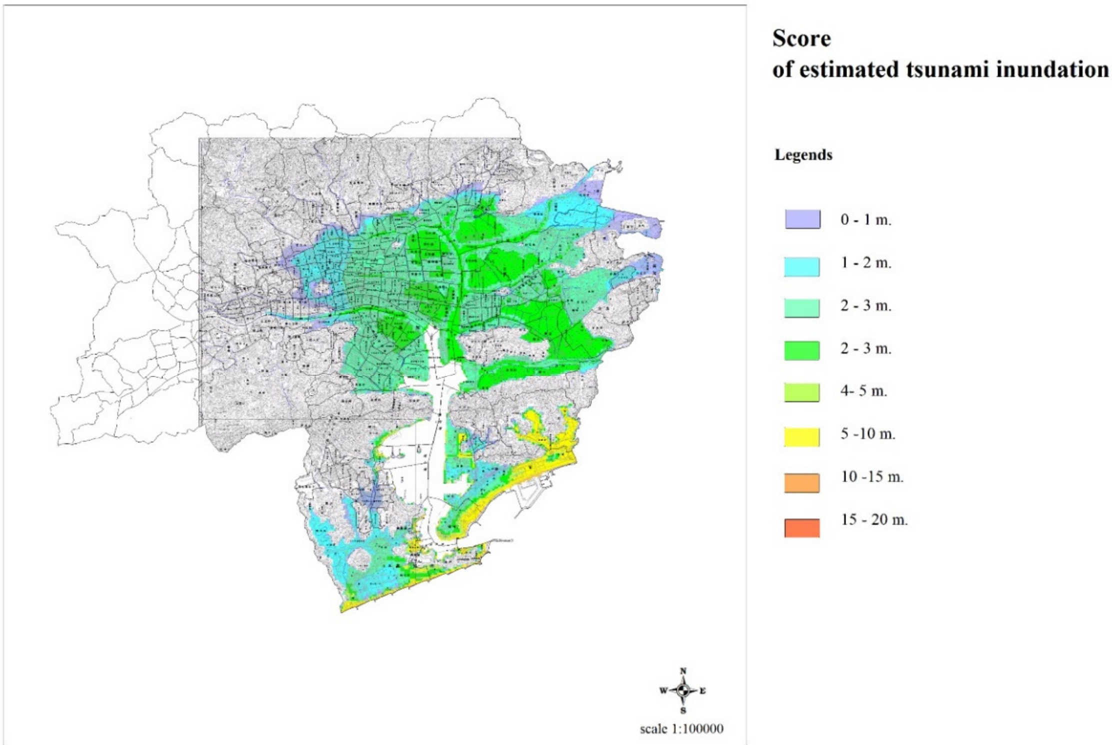


Figure 5-31: Estimated Tsunami inundation

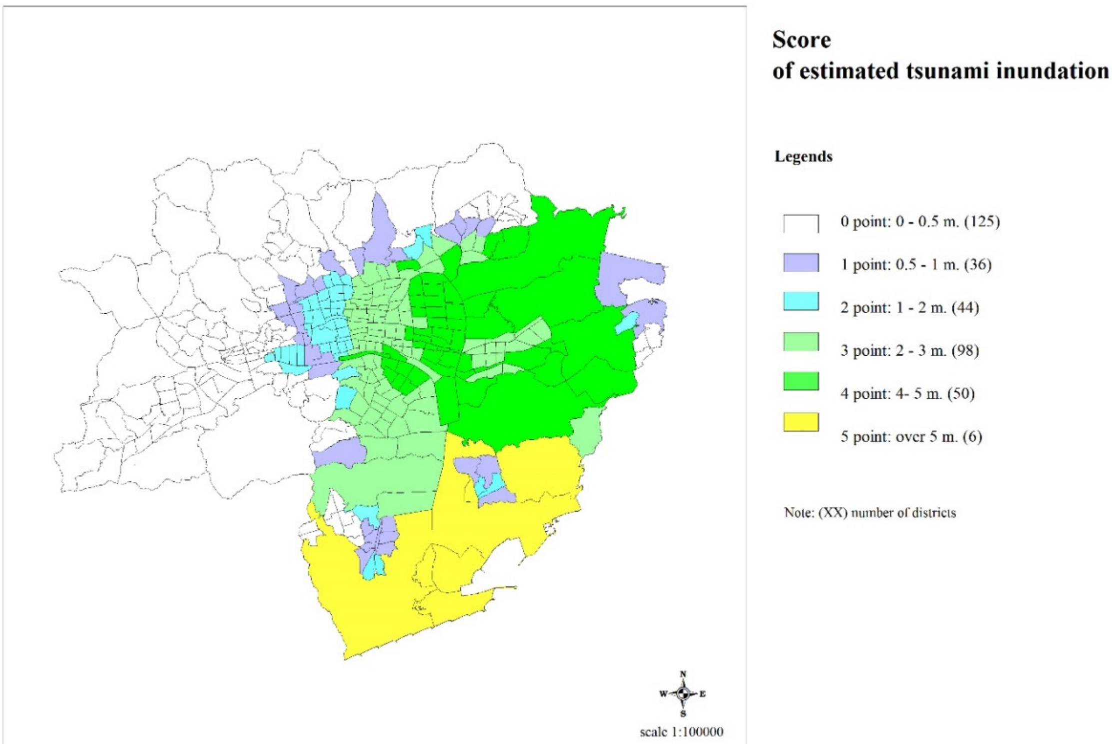


Figure 5-32: Scoring vulnerability levels in terms of tsunami inundation

5.4 Risk evaluation

Vulnerable areas will be classified into nine specific categories based on the vulnerability level and hazard potential level (as shown in Table 5-12). Those nine categories can also be implied to three different divisions of risk level represented the intensity of color (a grey scale). The darker tone represents the higher levels of risk. According to Table 5-12, the selected case studies of 10 districts represent high-vulnerability-and-high-hazard potentials, high-vulnerability-and-low-hazard potentials, and low-vulnerability-and-low-hazard potentials.

Table 5-12: Results of risk evaluation (refer to Table 4-6)

Vulnerability / Hazard potentials	High	Median	Low	Total
High	**2**[*a]	50	**3**[*b]	55
Median	28	111	3	142
Low	**5**[*c]	133	22	160
Total	35	294	28	357

Note: [*a] = Kutanda and Hoei-cho
[*b] = Ebinomaru, Kitakubo, and Kitakawazoe
[*c] = Kaganoi 1 Chome, Echizenmachi 2 Chome, Iguchicho, Masugata, and Kamimachi 1 Chome
Source: By author

Table 5-13: A summary of sub-districts by their tsunami-risk levels

Levels of tsunami risk	Number of sub-districts	Average vulnerability score	Coverage area (Km. 2)
High	2	45.4092865	0.21466037
Median	189	34.4905671	63.62510063
Low	166	29.10136752	64.81980871
Total	357	32.04583407	128.6595697

Table 5-14: Average vulnerability scores of each tsunami risk groups

Vulnerability / Hazard potentials	High	Median	Low	Total
High	0.5092	0.3026	0.1826	0.2999
Median	0.4348	0.3357	0.2164	0.3456
Low	0.4013	0.3057	0.1773	0.2879
Total	0.4367	0.3168	0.1831	

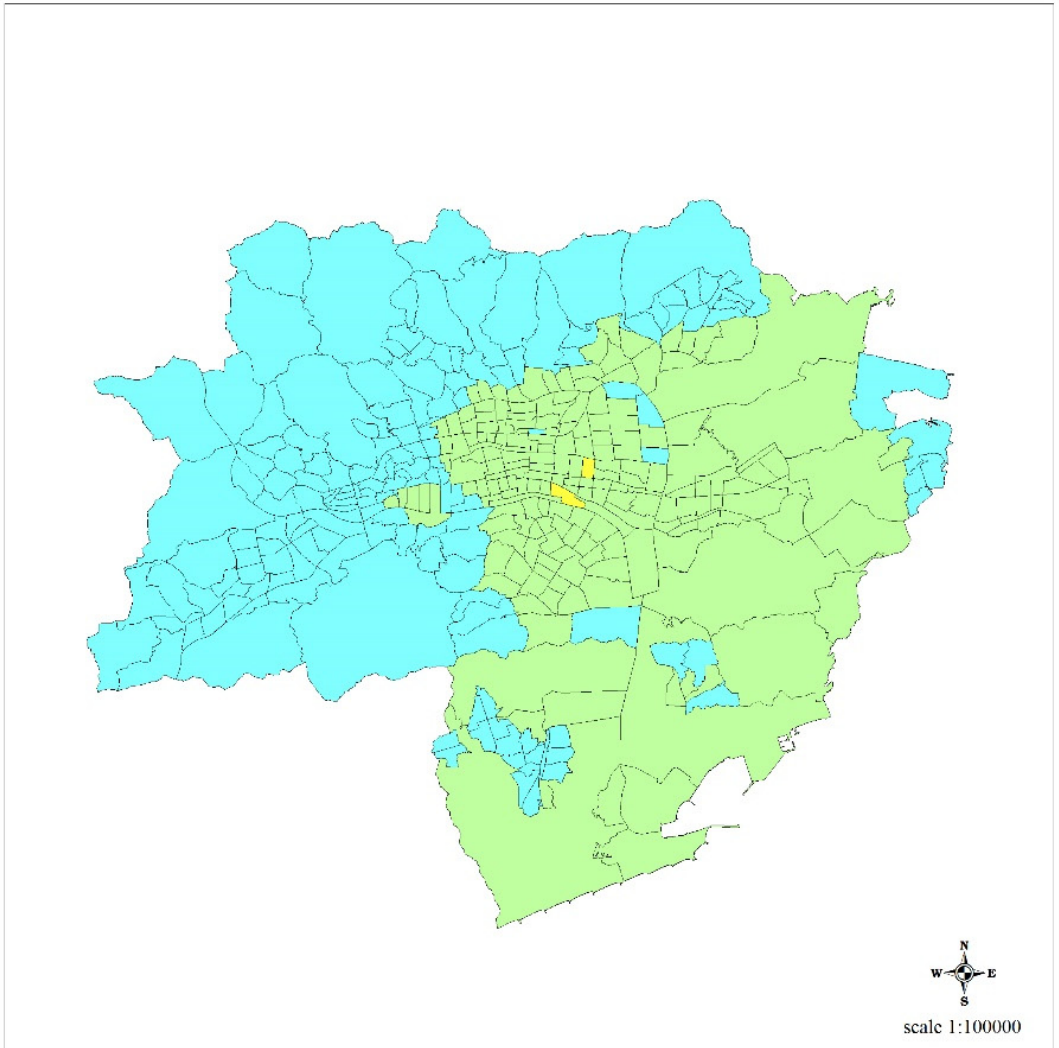


Figure 5-33: Tsunami Risk Map of Kochi City

Chapter 6 :
Tsunami Resilience in Urban Planning and Design

Spatial planning is increasingly realized as one of the important measures in disaster risk management. It facilitates decision makers in visioning the future of urban development and land use strategies and thus changes territorial configurations. Those changes can increase or decrease urban vulnerability to disaster. Disaster events often highlight weaknesses and errors in urban development that fail to consider potential natural hazards. However, a disaster recovery can be viewd as a window of opportunity to build cities that are more resilient to disasters, in part due to the changes of attitude among individual people and government. To identify tsunami resilience in terms of urban planning, this chapter comprises of four main sections. First, the narrative description about tsunami resilience begins with an introduction of integrating disaster risk management in spatial planning. Decisive roles of spatial planning in disaster risk management are emphasized, whereas good governance in the context of spatial information sharing is regarded as an initial step to improve spatial enabled planning. Second, the analysis of spatial planning systems and relevant policies devotes to three elements of policy planning: policy background, policy formulation and institutional structures, and platforms of policy implementation for integrating disaster risk management in spatial planning. Third, to identify Kochi's tsunami resilience in spatial planning, the results of the structured interviews with local authorities are explained based on the facts and the opinions of interviewers. Fourth, the integration of disaster risk management in spatial planning are conceptualized by comparing the advantages and disadvantages of each different spatial planning systems (i.e. Japan, Thailand, and Italy). In conclusion, the chapter illustrates a model of the integration between disaster risk reduction (part of risk management) and spatial planning.

6.1 The concept of integrating disaster risk in spatial planning

6.1.1 Significant elements of spatial planning and roles in disaster management

Spatial planning aims at developing a vision for a long-term land use development, which not only meets with human needs but also ensures the security of human settlement.

Even though spatial planning is not directly responsible for disaster risk management, it plays an essential role in disaster risk mitigation and prevention. This is because when we make decisions on how certain spaces are used; those decisions more or less influence physical vulnerability of the city. Regarding the prevention and mitigation measures, the alternatives in spatial planning to enhance tsunami resilience can be combined with two different ways: structural measures and non-structural measures.

Structural measures against tsunami refer to any physical construction to alleviate vulnerability, reduce risk, or prevent possible impacts of tsunami hazards. Those measures extensively relate to a wide range of engineering techniques to achieve tsunami-resistance and tsunami-resilience in structures or systems. These terms of resistance and resilience refer to just the load-bearing capacity of the strucuture (UNISDR, 2009). Examples of structural measures are coastal dikes against tsunami and other social infrastructure that can be alternated its functions in response with the need during the disaster.

Non-structural measures extensively involve the use of knowledge, practice, or agreement to reduce tsunami risks and vulnerability. In terms of spatial planning, these measures are, in particular, implemented through spatial development policies, land use planning laws, building codes, campaigns of housing design and interior fittings for tsunami resilience, risk awareness raising, and disaster relief assistance.

To be more specific, there are several possible roles of spatial planning in disaster risk mitigation and prevention, as identified by Fleischhauer et al. (2005).

1. Restricting urban development in certain areas: In potential disaster prone areas where disasters occur frequently, the urban development should be restricted or prohibited. These areas can be used as recreation spaces or natural conservation areas (nature reserve and bio-reserve). People can enjoy leisure activities in the regular time, and avoid using those areas when a disaster is likely to occur.

2. Classifying different land use ordinances for disaster prone areas: normally, when the scarcity of land narrows down the choices of spatial location for human settlement, we tend to accept disaster risk based on different land use classification. For example, steep slope that is highly susceptible to landslide would be acceptable for agricultural usages, but not suitable for residential or commercial activities.

3. Regulating land use or zoning plans with legislative enforcement: When urban development exists in areas vulnerable to consequent disasters such as earthquake-and-fire risk, regulations on building density and building materials are essential to reduce damages to physical building and secure human lives. Zoning can be utilized in order to limit undesirable

development in those areas. Although such regulation and zoning are regarded as less tangible measures, they explicitly influence structural development of the public.

4. Structural measures for hazard prevention and mitigation: Unlike non-structural measures that are less tangible, the structural engineering measures are physically tangible produced to prevent or alleviate disaster risks. Spatial planning can play an important role in promoting those structural measures, such as flood embankments.

Table 6-1 offers a broad range of risk mitigation measures that can be taken at different levels of spatial planning. Integrating risk management into spatial planning measures focuses on non-structural mitigation measures. Local spatial planning based on disaster risk mitigation could be more effectively responsive to local demands and necessity, if the local authorities actively respond to an emergency at the very beginning of disasters. Local spatial planning will help enable desirable physical spaces for better local responses.

Table 6-1: Spatial oriented planning and supportive instruments of risk management strategies

Risk management strategy	**A. Regional planning**	**B. Local land-use planning**	**C. Sectorial planning**	**D. Supporting instruments**
1. Prevention oriented mitigation	e.g., Planning settlement and transport structure that cause less greenhouse gas emission	Supporting the use of regenerative energies	Specific strategies for reducing greenhouse and gas emissions (e.g. transport structure)	Kyoto protocol; strategies for reducing greenhouse; gas emissions; tax system
2. Non-structural mitigation (a): reducing hazard impacts	Maintenance of protective features of the natural environment that absorbs or reduces hazard impact (retention areas, sand dunes)	Local rain-water infiltration	Flood protection plans; coastal protection plans; reforestation; adapted land cultivation	Interregional cooperation; economic instruments; information management
3. Non-structural mitigation (b): reducing damage potential	Designations in regional plans; for example, flood in hazard areas	Zoning instruments	Adequate allocation of threatened infrastructure	
4. Structural mitigation	Secure the availability of space for producing infrastructure	Prevention measures as a part of building permissions	Engineering design, Protective infrastructure (shoreline dam)	-
5. Reaction preparedness, response, recovery	-	Rebuilding planning	Emergency plans	Information and training to support public awareness and emergency management

Source: Schmidt-Thomé (2005) cited in Greiving & Fleischhauer (2006)

6.1.2 Good governance in the context of spatial information sharing

As spatial information is essential for spatial planning, it should then be made available and accessible to the public. Fleischhauer, Greiving and Wanczu (2005) defined this concept as Spatially Enabled Government (SEG). SEG refers to the role of government to enhance the accessibility of spatial information by delivering spatial information in a digital form on the website. The concept of SEG raises the level of the government's transparency and accountability. This will potentially enable desirable spatial development in the future. Not only will the government's reputation increase, but also the accessibility of spatial-based information can facilitate productive and effective decision making on spatial development and policies.

6.2 Disaster resilience in spatial policy and planning: a case of Kochi City, Japan

As mentioned in the first chapter, this study uses both system science and social science approach to frame the research analysis. The former approach highlights on an importance of the robustness of physical infrastructure and the characteristics of residents that determine urban vulnerability. Meanwhile, the latter approach focuses on the interactions among the groups of policy makers and the interactions between policy makers and individuals who are imposed by the policies. This chapter then analyzes the integration between disaster risk management and spatial planning in three aspects: the policy background, the policy formulations and institutional structures, and the platforms of policy implementation.

6.2.1 Policy background

After the end of the World War II in 1945, Japan was in need for economic recovery. Japan needs brought a huge public investment that Japan need to support industrialization. Since 1950, the national land policy was made to introduce the construction of public infrastructure, such as roads, railways, airports and seaports, to protect against natural disasters, and to conserve the natural environment (Rimmer, 1998). With regard to public infrastructure policy, prefectural plans included various issues such as industrial development targets, land use, roads, harbors, factory sites, and housing. At that era, Japan was described as a "construction state" since the central government mostly spent on public works in regions (see McCormack, 2001). The effort to foster spatial development and build up the human habitation environment brought about the enactment of Comprehensive National Land Development Act in 1990. This act boosted rapid urbanization and economic growth. On the other hand, the act sadly brought negative effects such as congestion, environmental pollution, and disparities between the urban and rural areas (Kubo, 2012). Since then, the particular-area development plan was firstly adopted so that the special areas were designated to prevent the occurrence of disaster (Kobayashi & Noda, 1987, p. 3).

In general, the National Development Plans of Japan is based on the Comprehensive Land Development Act of 1950. The main objective of these plan was to achieve balanced development in regional areas. As the growth pole strategy was the main strategy, there were fifteen new industrial areas and six provisional areas were designated for industrial reorganization. These new areas were expected to attract investments from the overgrown metropolitans, and then to resolve the imbalance of urban-and-rural development.

According to the Land Development Act, the National Development Plans of Japan entailed measures to deal with the following issues:

1) Utilization of natural resources, involving land and water and so on;
2) Protection from disaster, such as floods, wind hazards, and so on;
3) Adjustment of size and location in urban and rural areas;
4) Appropriate location of industries, and
5) Size and location of public facilities, and preservation of resources, as well as size & location of facilities relating to culture, welfare, and resort activities.

The First Comprehensive National Development Plan of 1962-68 was made in order to improve mentioned problems and promote industrial development along the Japanese coast. In the beginning of the implementation of Comprehensive Land Development Act, it was assumed that logistic network from the capital region to the suburban region would lead to “Balanced Prosperity” across the nation. The railway development was prioritized in order to extend the coverage areas of the services. To link the capital region with the suburban regions via the railway network, high-speed trains such as Bullet Train were operated. With this transportation oriented spatial development, the nationwide logistics network was a key dominant concept till the 5th Comprehensive National Development Plan.

Even though Japan achieved a high economic growth resulting from measures taken in the First Plan, the country faced the concentration of population and the migration problem. Therefore, the Second Plan (1969-76) continuously followed the First Plan of decentralizing industries from the major metropolitan areas. To do so, three types of a large-scale development project were promoted. The first type consisted of the construction of a nationwide transportation network of motor ways and rapid national railways system ('Shinkansen'). The second type was the formation and improvement of a large-scale industrial development project

(Large-scale agriculture and industrial distribution base). The third type is a combination between the first type and the second type. This combination aims at promoting eco-industrial estates. Those large-scaled projects helped to maximize land utilization, and it was expected to distribute the industry development into regional areas and to solve the rural depopulation (Ho, 2003). At the meantime, the government also paid attention to create an affluent environment to ensure the balance between the man-made and natural environments.

Nevertheless, the Second Plan failed to perform as the decision makers' intention. The newly emerging problems regarding excessive concentration, depopulation, and environment pollution proved the failure of the second plan. These problems were then took into consideration in formulating the Third Plan (1977-86). As a result, the Third Plan was designed to control the industrialization in mega cities, to harmonize the urban development with natural environment for human living, and to raise the equal utilization of the whole national land. The migration and depopulation problems were resolved by the campaign promoting permanent residence in the regional areas. With this successfully implemented campaign, the population in Japan rapidly grew to 124 million people by the end of the Third Plan. Nevertheless, more population meant more land to be occupied. It is expected that there would be the new development for a residential purpose about 290-350 thousand ha (2,900-3,500 km^2) in 1976 - 1985, and the land requirement would be about 440-520 ha (4,400-5,200 km^2) in 1976-1990 (Kobayashi & Noda, 1987, pp. 9-10).

The Fourth Plan (1989-2000) aimed at formulating a multi-polar pattern of national land use and establishing an integrated interaction policy. To achieve the first objective, the Fourth Plan aimed at not only developing the National Capital Region (NCR) as a national and international centre of political, economic, and cultural activities, but also decentralizing outer areas and other regional urban centers where natural and man-made environment also received prominent attention (Srinivas, 2006). The NCR Plans draw attention on a number of projects including motor ways, rapid transits, new towns, and water resource development projects (Srinivas, 2006). Furthermore, the Fourth Plan stressed the importance of heavy investment in social infrastructure. The principal tasks in this plan were therefore:

1) To formulate a safe and pleasant national land use;
2) To build vigorous and amenity – rich areas;
3) Development of industry and preparation of living infrastructure for new affluence;
4) Preparation of transportation, information, and communication systems for local settlement and interaction.

After the economic recession in the late 20th century, Japan has faced the demographical problems; for example, the decrease in population, the declining birthrate, and the aging society. This led to the need for new planning concept in the national development plan (Kubo, 2012). Due to these problems, the Fifth Comprehensive National Development Plan of Japan showed major changes in the national consciousness, relating especially to two prominent issues: 1) the population decline and the aging society, and 2) the rising national awareness in safety and security. With the new philosophy attempting to improve the quality of life, “The Grand Design for National Land in the 21st Century” was proposed as a concept of the Fifth Plan. Equal opportunities in education, culture, employment, health, and welfare became new developmental objectives. Thus, the Fifth Plan tries to deal with the agglomeration of 70-80% of the population, GNP, and the quality of cultural and educational facilities (Rimmer, 1998, p. 166).

Considered as the aging society since 2004, Japan is estimated to have the rising ratio of elderly to total population close to 30% in 2020 and 35% by 2050 (Ministry of Land, Infrastructure, Transport and Tourism, Japan, 2006). Therefore, the government intends to promote local revitalization programs targeting the aging population.

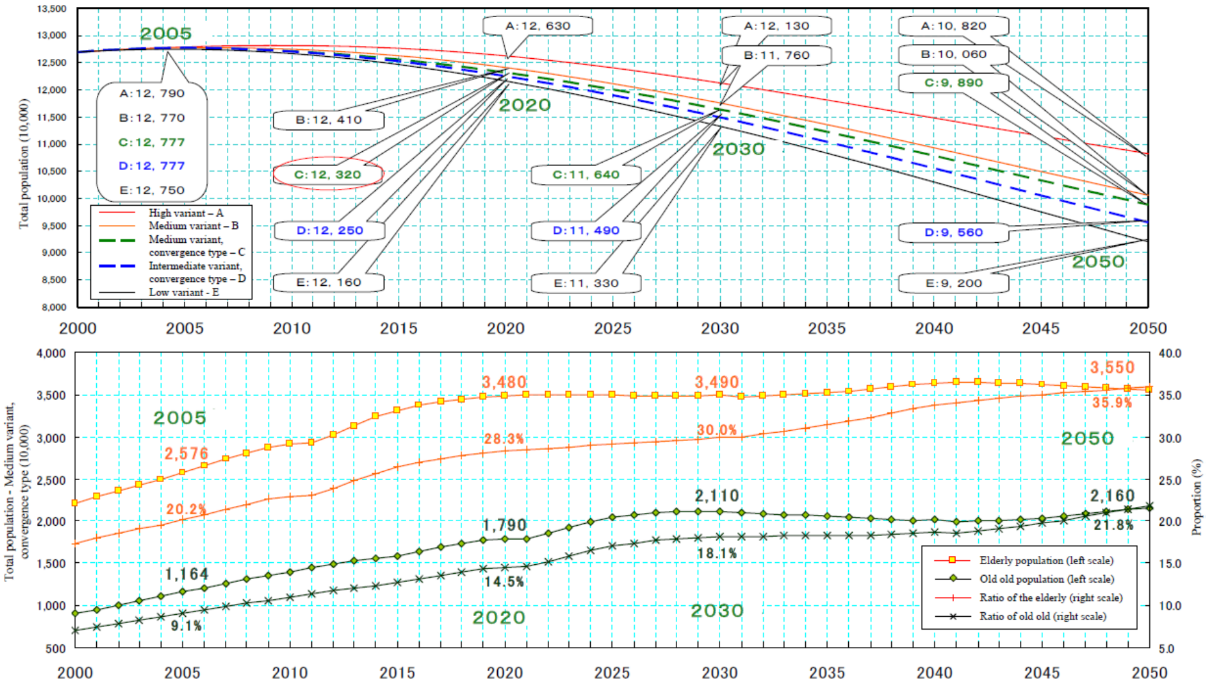


Figure 6-1: Future Population Projection

(Estimated by National and Regional Planning Bureau)

Source: National Institute of Population and Social Security Research, "Future Population Projections for Japan (January 2002)"; Ministry of Internal Affairs and Communications, "National Census Report"; Ministry of Land, Infrastructure and Transport, "Annual Report on Current Population Estimates"

(Note 1): The "medium variant, convergence type" refers to a population estimated on the assumption that the disparity between the total fertility rates used in calculating the medium variant and the latest statistical value will converge in 2030.

(Note 2): The "intermediate variant, convergence type" refers to a population estimated based on the intermediate value between the "medium variant, convergence type" and the "low variant, convergence type." The "low variant, convergence type" refers to the population estimated on the assumption that the disparity between the total fertility rate used in calculating the low variant and the latest statistical value will converge in 2030.

(Note 3): The ratio of the elderly refers to the ratio of the elderly (aged 65 and older) to total population, and the ratio of elderly refers to the ratio of aged people (aged 75 and older) to total population.

The other main concern of the Fifth Plan is the national awareness in safety and security due to the increasing frequency and severity of natural disasters and the climate change. The national land structure of Japan is exceptionally vulnerable to a variety of natural disasters. Japan is one of the largest volcanic countries in the world. Its location is also prone to great inland and marine earthquakes. Those marine earthquakes, such as Tonkai earthquake and Nankai earthquake, are likely to cause tsunamis. The public risk awareness has become serious and led to the increasing load of work to improve existing national spatial planning and infrastructure provision.

The structural and non-structural measures for disaster risk management have been designed to harmonize with landscape creation. The structural measures focus on the efficient development-and-utilization of disaster-prevention facilities, an emergency transportation system, and information-communications networks to ensure the continuity of activites. Mainly, those structural measures are related to disaster mitigation and prevention that can be taken before disasters. Preparation of hazard maps, ensuring evacuation routes and evacuation areas, is a main issue taken before disasters. The disaster preparedness also includes raising awareness of disaster prevention, diffusion of disaster-prevention education, and fostering regional leaders, etc. On the other hand, non-structural ones concern on the responsive actions in accordance with the disaster cycle. During the disaster, the transfer risk information and the announcement of evacuation instruction are regarded as a core of disaster responses. The non-structural measures after disasters comprises of;for example, the provision of disaster and safety information, the disaster victims rescue and transfer, the establishment of medical and home-returning systems, the preparation of equipment and materials, the manpower to implement disaster recovery promptly, etc. (Ministry of Land, Infrastructure, Transport and Tourism, Japan, 2006). Such a combination of both structural and non-structural measures in disaster risk management creates comprehensive visions for disaster-resistant plan and national land development for disaster resilience.

Recently, the central government of Japan has enacted "Basic Act for National Resilience Contributing to Preventing and Mitigating Disasters for Developing Resilience in the Lives of the Citizenry (Act No. 95 of December 11, 2013). This act aims at raising risk awareness related to large-scale destructive earthquake and tsunami that may occur along the Nankai Trough as well as preparing the multi-level collaborations on the provision of preventive measures. Those desirable measures shall contribute to practical disaster prevention and mitigation within reasonable financial resources constraints. Furthermore, those preparations shall be performed in advance, in order to ensure that disaster reliefs and rescue teams shall be allocated intensively to disaster-affected areas within 72 hours. With its ultimate goal of "National Resilience" (Article 1), this act appoints the national government "to establish and implement measures concerning National Resilience in a comprehensive and symmetric manner" (Article 3). Meanwhile, the local government has a responsibility to comply with the above basic principle set by the national government. The act also indicates the involvement of third parties such as business entities and Non-Profit Organizations (NPOs) in developing their understanding of the significance of "National Resilience" and the endeavor to offer cooperative measures implemented by the national and local government. The national resilience measures cover legislative, financial, tax measures, or any other measures that are necessary for the effective implementation (Article 7). Establishing and implementing these measures should consider the following policies (article 9):

1) Implementation cost can be reduced through the use of existing social capital, etc.;

2) Measures should contribute to efficient and effective facility maintenance and management;

3) The measures have a symbiosis with nature and harmony with the environment in accordance with the local characteristics;

4) Private sector funding should be actively utilized;

5) Vulnerability assessment [1]of large-scale natural disasters should be conducted to promote the initiatives of National Resilience;

6) Reasonable use of land should be promoted;

7) Research and development based on scientific knowledge should be promoted and disseminated.

[1] National Resilience Promotion Headquarters established in the Cabinet Office is responsible for setting guidelines for the vulnerability assessment.

Table 6-2: A comparison of the initiative national development plan of Japan and its amendments

	The 1st Plan	The 2nd Plan	The 3rd Plan	The 4th Plan	The 5th Plan
Year of Publication	1962	1969	1977	1987	1998
Term of plan	1960-1985	1965-1985	1975-1985	1987-2000	2010-2015
Target year	1970	1985	1985	2000	2015
Background	a) Toward high economic growth b) Variation of income c) Double the income plan Pacific belt development plan	a) The age of high economic growth b) Concentration of population & industries in big cities c) Variation of income d) Promotion of efficient utilization of resources	a) Stable growth b) Settlement in local areas c) Total variation by region d) Limitation of resource e) change in people's consciousness	a) Vitalization through residence policy & networking activities b) Internationalization & arrangement of world city function c) Arrangement of land and environment with safety & high quality consciousness	a) Global age (Global environmental issues, mega competition, and exchanges with Asian nations) b) Population decline and the aging society c) Information-oriented society
Basic objectives	Balanced regional development	Creation of rich environment	Harmonized environment	Multiple nuclei model dispersed land formation Networking activities among regions	Prepare the basics for a multi-functional structure
Methods	Growth-pole method	Big-project-oriented method	Residence policy	Improvement of transportation & tele-communication among regions	Participation and cooperation
Tasks	a) Dense areas: restriction of factory location b) Arrangement areas: dispersion of factories & development of intermediate local cities c) Development areas: active development	a) Transportation & tele-communication networks b) Large scale project c) Zone of extended living space	a) Preservation of environment b) Stabilization of land & people's life c) Arrangement of comprehensive environments d) Balance of opportunities: education, culture & medical care	a) Prevention from the concentration in Tokyo b) Balanced land formation c) Networking activities among regions d) Safe land	a) Decentralized spatial development from Metropolis and solving problems of sense Tokyo b) Revitalizing Okinawa, and problems related to US military bases

Source: Kaneyasu (1987) and Ministry of Land, Infrastructure and Transport (1998)

6.2.2 Policy formulation and institutional structure

(1) National and regional spatial planning

National Spatial Development Act in 1950 (Act No. 205), City Planning Act in 1968 (Act No. 100) and their amendments thereafter[2] are two main acts that have direct influences on Japanese spatial planning. National Spatial Development Act in general provides spatial development strategies for regional plans and local land use management. This act contributes to the realization of the spatial economic and social development in which "present and future citizens can live with peace of mind" (Ministry of Justice, Japan, 2014). Whereas, City Planning Act designates responsible authorities, regulates institutional structures and identifies essential procedures of spatial decision-making processes from the formulation of plans to the legislative implementation.

The latest revision of National Spatial Planning Act is Act No. 89 in 2005. The disaster risk prevention and mitigation (Article 2) were taken as one of the principles of National Spatial Strategies (NSS). This act designates the National Land Council to be responsible for any studies on NSS as well as the preparation of a draft of NSS. The studies on NSS shall be presented to the Minister of Land, Infrastructure, Transport, and Tourism (LITT). The LITT takes those studies on NSS as guidelines for the provision of ordinance. This ordinance then confers with prefectures and target cities in order to hear their opinions. Under the National Land Use Planning Act, the LITT has to formulate the National Plan as a national land use policy. Then, the National Land Council has to deliberate and express opinion about the National Plan. If the Plan is approved, the LITT shall formulate a draft of NSS for each regions, so-called "Regional District Plans". This draft is taken as a fundamental material to seek public opinions from relevant prefectures and municipalities within the said Regional Plans before the final NSS is announced.

Even though the NSS is formulated based on the top-down approach through the initiative of national government (National Land Council), the procedures of NSS allow regional (prefectures) and local authorities (municipalities) to participate and express their opinions on the Regional Plans, which is at least a part of NSS. The regional and local authorities may also jointly work with the LITT to formulate or change the Regional Plan (Article 11). In addition, they can request the LITT to coordinate affairs of relevant administrative organizations (e.g. Regional Plan Council) (Article 13). These mechanisms, to

[2] such as the National Land Use Planning Act (Act No. 92 of 1974) or the Act on the Exclusive Economic Zone and the Continental Shelf (Act No. 74 of 1996)

some extent, give local authorities an opportunity to involve in a decision-making process on the formulation and the implementation of National Spatial Strategies.

Due to the rising disaster risk awareness in spatial planning, the disaster risk management in terms of prevention and mitigation at the national level has been realized. Nevertheless, an essential role of spatial planning in facilitating the disaster responsive and recovery processes has not yet explicitly mentioned. The national spatial planning merely shows implicit concern about spatial vulnerability reduction through disaster prevention and mitigation, but spatial resilience to disaster is barely defined.

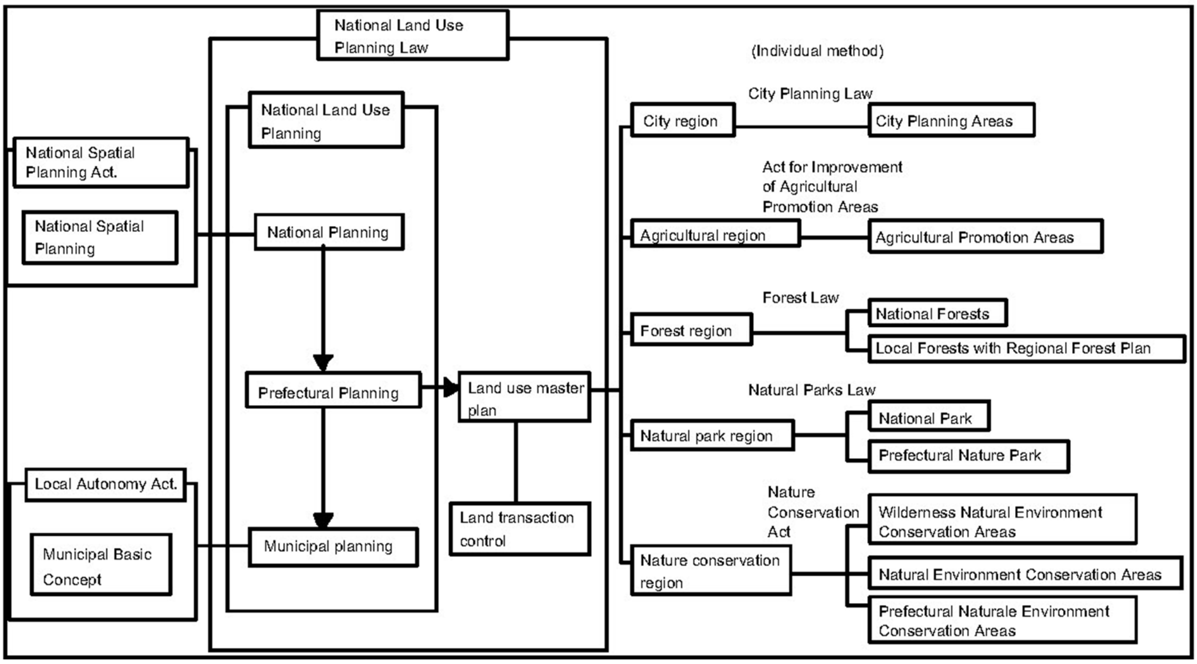


Figure 6-2: The national spatial planning system in Japan

Source: Tominaga, 2011 (Tominaga, 2011)

In sum, the Comprehensive National Development Plan (Act) intended to rectify the negative factors caused by rapid urbanization such as congestion, environmental pollution, and disparities between the urban and rural areas. Meanwhile, the Act also aimed to promote the industrial development along the Japanese coast (Kubo, 2012). With the notion that the improved accessibility would lead to "Balanced Economic Prosperity" across the nation, the provision of transportation network via the inter-city high-speed trains, known as "Bullet Train", became one of the key developmental measures. Nevertheless, the primacy of a few capital regions indicates to what extent economic development has been concentrated in urban development. This implies that the balanced prosperity policy has yet reached its goals. After the establishment of National Spatial Planning Act, the meaning of development in the

Comprehensive National Development Plan has be transformed in terms of maintenance and regeneration to encourage sustainable growth of each region. The concept of transportation-oriented development has been dominated by the new planning concept concerning the natural disaster, the economic recession and the population decline, as well as the aging society.

(2) Local spatial planning and land use management

Another important act related to local spatial and land use planning is City Planning Act of 1968 and its amendments in combination with other relevant laws (Figure 6-4). To decentralize national development and promote public welfare, this act provides a legislative framework of city planning, which consists of the details of city planning and decision-making procedures. One of fundamental principles of this act is to secure functional urban activities and, at the same time, to maintain a healthy balance with the agriculture, forestry, and fishery industries. Thus, the reasonable land use under regulations should be promoted.

Land use system at the local level includes a wide range of measures depending on local circumstances. The structure of City Planning System can be illustrated in Figure 6-3. Contents of the spatial planning at local levels can be generally divided into three main issues: land use regulations, urban facilities, and urban development project.

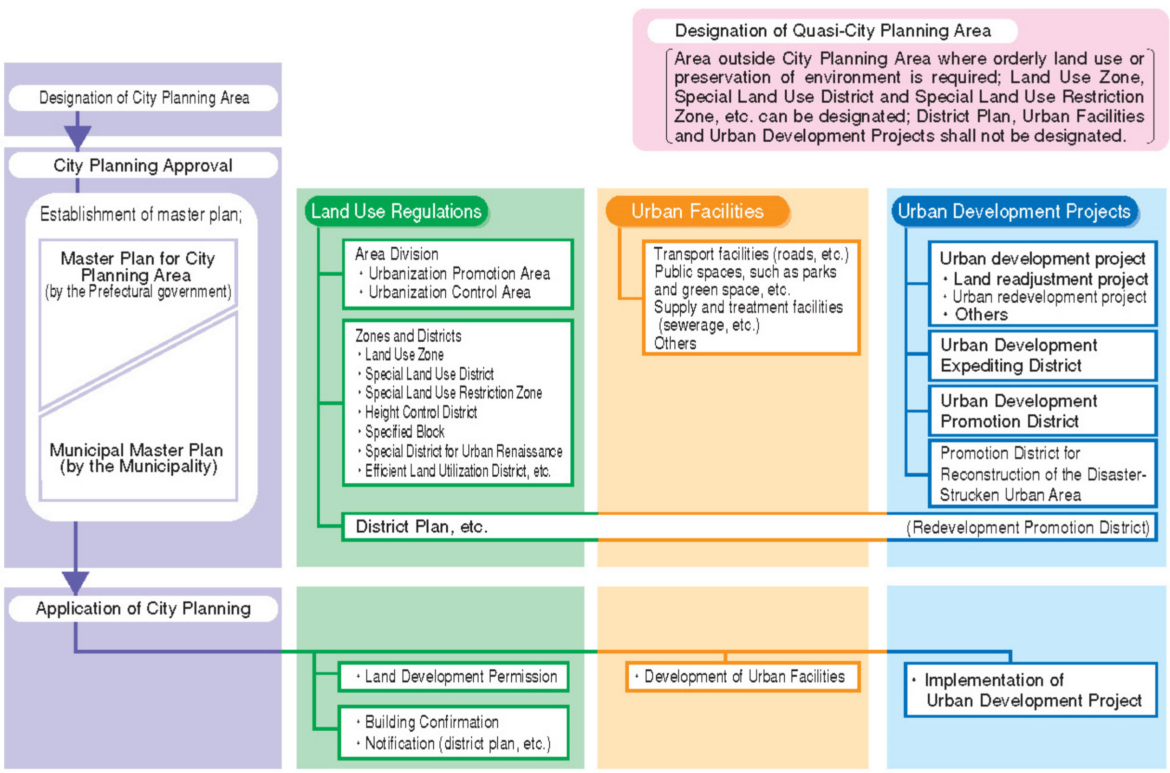


Figure 6-3: The Structure of City Planning System in Japan

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan (MLIT), Introduction of Urban Land Use Planning System in Japan

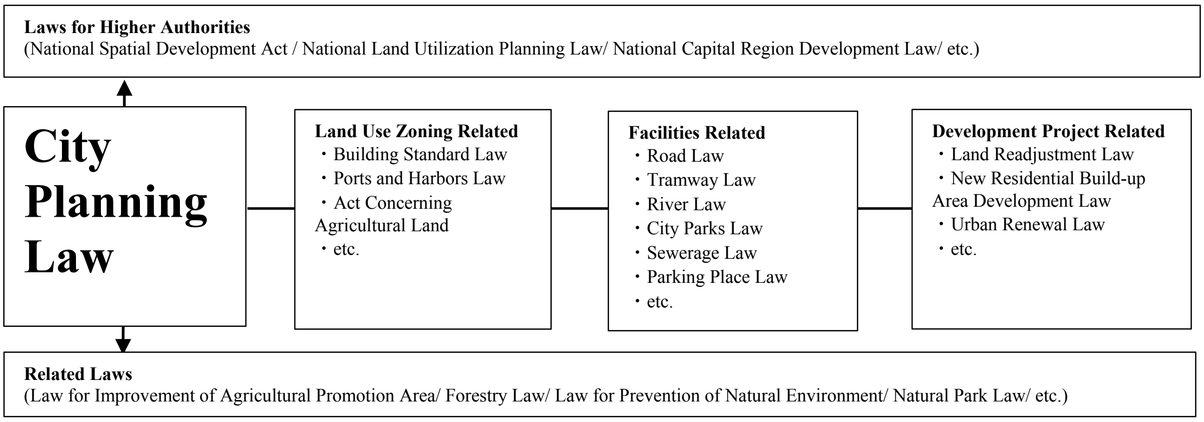


Figure 6-4: City Planning Act and Its relevant legislations

Source: (Ando, 2006)

To define City Planning Areas/ Quasi-City Planning Areas, the land use regulations in combination with land use classification techniques are applied. The land use is then classified into Urban Promotion Area (UPA) and Urbanization Control Area (UCA). UPA shall be either urbanized areas or potential areas to be urbanized within 10 years. Meanwhile, UCA identifies the areas where urbanization should be limited or restricted regarding specific principle, such as for environmental conservation or agricultural promotion area. These classifications will designate desirable land use and building code covering the entire city planning area. City Planning Area highlights the land use classification in disaster-affected areas, and thus gives an opportunity to legislatively create spatial recovery plans. Meanwhile, the specific definitions of (Quasi) City Planning Area refers to densely-urbanized areas rather than rural towns. Those areas should have at least one of the following criteria. First, the population size is not less than 100,000 people. Besides, 50% of the total population works in commercial activities, industry, or other urban business categories. Second, it is expected that the substantial number of population (100,000 people) shall be reached within 10 years. Third, population in the central area is more than 3,000 people. Fourth, there are plenty of potential resources for tourism industry, which can be developed as tourist destinations. The last criterion is that the defined areas were affected by severe disasters and need to be recovered.

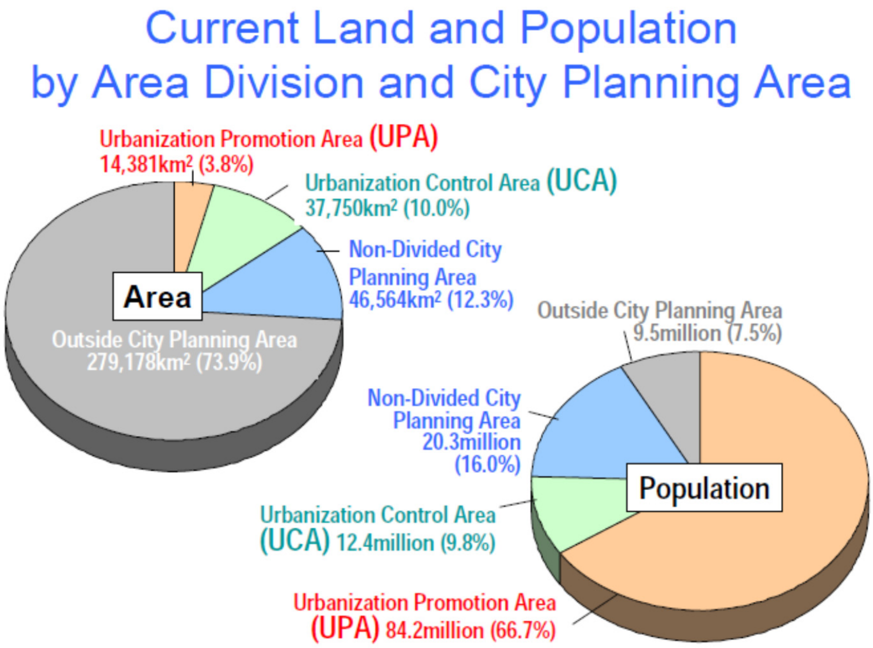


Figure 6-5: Population ratios by Area Division and City Planning Area

Source: (Ando, 2006)

In addition, there are two main types of urban intervention projects: mega urban facilities and urban development projects. Mega urban facilities and utilities will be improved through the development plans of urban facilities (Article 11 of City Planning Act). These facility development plans are interrelated with other acts: for example, Road Law, Tramway Law, City Parks Law, and Parking Place Law (Figure 6-4). Other specific interventions, in accordance with the land use regulations and development plans of urban facilities, will be undertaken by the planning measure named "Urban Development Projects" (Article 12 of City Planning Act). Those urban development projects include, for example, land readjustment, redevelopment promotion, disaster prevention, and reconstruction of the disaster-affected areas.

It is clear that disaster risk management has been integrated into spatial planning of Japan. Unlike the other countries facing difficulties in disaster recovery, the legalized measures for the disaster reconstruction allow Japan to allocate financial and human resources to bring back pre-disaster conditions of physical environment and social economic activities. Moreover, the country's City Planning Law allows the local municipalities to bundle disaster risk mitigation and prevention measures through the disaster prevention districts (Article 7 and 8 of City Planning Act) and the improvement zone of disaster prevention block (Article 12-13 of City Planning Act).

In Japan, national disaster risk perception shapes policy formulation and legislation. This risk perception influences regional and local risk mitigation efforts, which can be regarded as incorporated norms and practices. Nevertheless, the effectiveness of disaster risk management depends on not only the risk perception, but also the coping capability towards institutional and individual awareness. Individual awareness can also be shaped by the way the community or the particular social and cultural milieu performs precautionary measures to handle a certain types of natural disasters.

6.2.3 Kochi's tsunami resilience in terms of spatial policies and regulations

This section aims at answering the research questions 3.1 that are "How resilience in terms of urban planning against tsunami is Kochi City?". In order to seek the answers of the research question number 3.1, resilience schemes and interview questions from a book titled "How Resilient Is Your Coastal Community? are adopted : A Guide for Evaluating Coastal Community Resilience to Tsunamis and Other Hazards" (U.S. Indian Ocean Tsunami Warning System Program, 2007). Whereas, those questions are matched with three key performance indicators (KPI) obtained from the literature (See Table 6-3).

Table 6-3: Questions of urban planning resilience to tsunami (Key performance indicators and schemes)

Resilience element / Key performance	Land use policy and planning (Policy formulation)	Physical conditions (Policy implementation)	Technical and financial availability (Supportive factors))
Robustness/ Stability (Resistance and Availability of Learning Opportunity)	- Have knowledgeable people on coastal resources and hazard management been involved in building setting and urban design?	- Are critical facilities, such as water and electric power plants located outside of the hazard area or built to be resistant to the known hazard impacts? - Is a coastal engineering structure (such as Seawall, Evacuation Tower and Building, etc.) capable enough to reduce vulnerability to coastal hazards and minimize impacts to coastal habitats?	- Have hazard resistant building practices been taught at the secondary and technical schools?
Adaptability/ Reactivity and Bouncing Back (Resourcefulness, Flexibility, Learning Capacity)	- Are there policies that can significantly limit investment in vulnerable areas (Ex. No-build zone)? - Do institutions responsible for policy formulation have enough capacity to implement land use plans and its ordinances?	- Are building safety and hazard reduction standards and codes supported by law and enforced?	- Can the public easily access to information and data on physical and structural development activities? - Has an assessment of existing critical infrastructure been conducted to determine vulnerability to tsunami and earthquake? - Are builders and architects in the area knowledgeable of and able to apply the building codes and good practices?
Transformability (Diversity and Creativity)	- Are there enough incentives or penalties in place to encourage compliance with land use policies and building standards and codes?		- Have communications and outreach programs been produced to educate the public in hazard-resilient building practices and designs?

Source: adopt from U.S. Indian Ocean Tsunami Warning System Program (2007)

Table 6-4: Descriptive statistical explanations of the result of the structured interview questions

Note: I = one respondent's opinion

	Respondents' opinions on the following statements				
	Strongly disagree	Most disagree	Neutral (on opinion)	Most agree	Strongly agree
Land use policies and building standards					
Building safety and hazard reduction standards and codes are effectively supported by law and enforced.		II	IIII		
There are policies that can significantly limit investment in vulnerable land areas (Ex. No-build zone)	IIII	II			
Responsible institutions have enough capacity to implement land use plans and its ordinances.	IIIII		I		
The public can easily access to information and data on physical and structural development activities.		I	IIIII		
Incentives or penalties are in place enough to encourage compliance with land use policies and building standards and codes.		III	III		
Knowledgeable people on coastal resources and hazard management have been involved in building setting and urban design.			II	II	II
Hazard resistant building practices have been taught at the secondary and technical schools.			IIII	II	
Critical infrastructure					
Critical facilities, such as water and electric power plants, have been located outside of the hazard area or built to be resistant to the known hazard impacts.		III	III		
An assessment of existing critical infrastructure has been conducted to determine vulnerability to tsunami and earthquake.			IIII	II	
A coastal engineering structure (such as seawalls, evacuation towers and buildings, etc.) has enough capacities to reduce vulnerability to coastal hazards and minimize impacts to coastal habitats.	II		II	II	
Cooperation of developers and communities in vulnerability reduction					
Builders and architects in the area are knowledgeable of and able to apply the building codes and good practices (Building codes and regulations are understood by the social agents and applicable for them).			I	IIIII	
Communications and outreach programs are produced to educate the public in hazard-resilient building practices and designs.		II	IIII		

Source: the structured interview in December 2013

Figure 6-6: Respondents' opinions on the various statements related to the integrating risk mitigation measures into spatial planning

Note: 5 rational scales = strongly agree (the outer ring)/ Agree/ No opinion/ Disagree / Strongly Disagree (the center of the diagram)

To identify the respondents' opinions on local resilience (Kochi City) in current urban policy and planning systems, the structured interviews are analyzed based on a descriptive statistics. Meanwhile, the secondary data are used as a tangible reference to link the results of interviews with existing phenomenon of Kochi City.

The summaries of the samples (six respondents) are combined with the existing situation to form the comprehensive summaries. These comprehensive summaries form a combination between the initial descriptive statistics and qualitative narrations. This combination enhances sufficient for a particular investigation.

1) The robustness and stability of Kochi City

<u>- Have knowledgeable people on coastal resources and hazard management been involved in building setting and urban design?</u>

Focusing on the robustness and stability of Kochi City, the city plan has been made under the cooperation among Kochi Prefecture, stakeholders, and the knowledgeable people and academic experts. A majority of respondents (four of six) expressed that a group of knowledgeable people mainly from the educational institutions was invited to give advice on the draft of city planning. For example, when the decision-making process on spatial planning takes place, the regulations of Kochi Urban Planning Council show how knowledgeable people take part in the council members. Eight knowledgeable people with relevant knowledge and experience in the area of urban planning and other two residents of the city are regularly required in order to form the council (Article 2 of the regulation of Kochi Urban Planning Council). Additionally, the visiting academic expert advisors can be integrated as part-time committee members (Kochi Prefecture, 2013, p. 12).

<u>- Are critical facilities, such as water and electric power plants, located outside of the hazard area or built to be resistant to the known hazard impacts?</u>

Although the current regulations allows external knowledgeable people to be integrated in the decision-making process, there are still some critical infrastructures are located in highly tsunami-prone areas. One of the respondents pointed out "the area classification of the tsunami-prone coastal zone was changed [3] a while ago. However, old buildings still remain there (This is the case that UPA became UCA)". Besides, the critical facility that provides essential services for urban activities: such as schools and hospitals,

[3] Some areas within UPA became UCA and vice versa.

should have been relocated. Two of the respondents also mentioned about a proposal of relocating schools that are potentially affected by future tsunamis. Nevertheless, this proposal was merely regarded as discussions among government officers taking part in urban planning. This then meant that the campaigns of infrastructure relocation may or may not be implemented.

The results of the interviews could imply that half of respondents (three out of six) realized that a number of existing infrastructures of Kochi City are potentially prone to tsunami risk. GIS data of 2013 showed that most of infrastructures in tsunami prone areas were built after the strike of tsunami in 1946. This could reflect the loss of memories on tsunami impact. The current locations of critical infrastructures show how urban planning measures repeatedly fail to be aware of hazards, as the public risk awareness and norm of policy formulation had not been translated into practice through the policy implementation. Nevertheless, since the Great East Earthquake of Japan and tsunami of 2011 (Tohoku disaster) has risen tsunami awareness across the country, the large-scale and multi-prefecture disaster, disaster awareness as well as the role of the local planning authorities became more and more important.

<u>- Is a coastal engineering structure (such as Seawall, Evacuation Tower and Building, etc.) capable enough to reduce vulnerability to coastal hazards and minimize impacts to coastal habitats?</u>

To protect life and human settlement, coastal engineering structures in terms of tsunami tide embankment, evacuation towers, and tsunami escape buildings were taken into account. “With the estimated cost of one thousand million yen, the tide embankment is costly to be constructed” said one of the respondents. Without the operation of tide embankment, the current capacity of emergency infrastructure became a controversial debate among the respondents. Only two respondent from the risk management section believes that the current emergency infrastructure has enough capacity to facilitate tsunami victims during the disaster. Two respondents from the urban planning department disagree with such statement, and the other two has no opinion about this matter.

Have hazard-resistant building practices been taught at the secondary and technical schools?

There are two major universities in Kochi City and its neighboring towns: Kochi University（高知大学）and Kochi University of Technology (高知工科大学). The latter conducts a variety of courses at different levels: bachelors, masters and doctorate. Most of courses are related to engineering sciences.

At Kochi University of Technology, there are many courses related to hazard-resistant building and infrastructural construction. "Infrastructure Systems Engineering Course"; for example, views facilities as organic systems of the urban built environment. The course then focuses on advanced education and research related to engineering technology for planning and maintaining social infrastructure (such as roads, bridges, water supply, sewer systems, transport systems, etc.). Another example is "Social System Management Course". With the aim to promote infrastructure development through integrated management technology, this course conveys the practical logic and management technology necessary for hard infrastructures, soft infrastructures, and natural infrastructures. The benefit of this course is to product human resources for working in organizations such as provincial construction companies, major construction companies, construction consulting companies, public bodies including the national government and local governments that commission construction, and educational institutions (Kochi University of Technology, 2014).

2) **Responsive and bouncing back capability of Kochi City**

- Are there policies that can significantly limit investment in vulnerable areas (Ex. No-build zone)?

In the National Spatial Planning Act and City Planning Act, almost all of the spatial planning measures for disaster prevention and mitigation focus on the risk of flood, fire, and earthquake rather than tsunami. Nevertheless, the local authorities are allowed to adapt those available measures for tsunami risks. For example, the disaster prevention block can be utilized for limit the investment in highly tsunami-prone areas.

Based on the interview data, most of key informants (four out of six) mostly disagreed that existing policies are capable of limiting investment in vulnerable areas – especially tsunami-prone areas, while the other two informants strongly agree about that. According to the master plan of 2012, none of spatial measures for disaster prevention and mitigation is applied for preventing or mitigating tsunami risk. All of spatial measures for disaster prevention and mitigation were dedicated for fire risk in a form of both fire prevent block and semi-fire prevent block. For example, a fire prevent block was designated along Otsu Bypass Road, near Tosaotsu train station, which is located in the northeastern of Kochi City.

<u>- Do responsible institutions have enough capacity to implement land use plans and its ordinances?</u>

A majority of respondents (five out of six) strongly disagree that responsible institutions have enough capacity to implement land use plans and its ordinances. Only one person mostly disagrees with this issue. It can imply that local government officers do not trust in their institutions' capacity to operate spatial based disaster mitigation measures. Some procedures are assumed to be too complicated and time consuming. As the nature of spatial planning based on the historic data, the legislative processes to enact the spatial plans should be as short as a compact system. The time consuming process will make the plans incapable of dealing the dynamic changes of cities. On the other hand, responsible human resources may be not competent enough to adapt available mitigation measures and implementation channels for tsunami resilience purpose. For example, the local authorities involved in spatial planning are incapable of adapting spatial measures on fire mitigation and prevention for the purpose of tsunami resilience.

<u>- Are building safety and hazard reduction standards and codes supported by law and enforced?</u>

Despite the fact that the building code for earthquake resistance exists at the national level by the legislative enforcement of Building Standard Act in 1950 and its amendments, the interviews report a shocking result. Most of key informants (four out of six respondents) are not sure whether building safety and hazard reduction standards and codes are effectively supported by law and enforced, while two of six disagree about this issue. The reason may be that the regulations of the earthquake resistant construction had not be effectively implemented until its revision in 1981: New Earthquake Resistant Building Standard, so-called "Shin-Taishin".

Especially in the case of Kochi City, nearly 49% of all buildings in City Planning Area were built before the enactment of Shin-Taishin in 1981. Those are suspected to collapse when a severe earthquake occurs (see Chapter 5). Surprisingly, the average rate of decrepit buildings within Urban Promotion Area (UPA) is also higher than that of Urban Control Area (UCA). This means UPA tends to be affected from the quakes more terribly than UCA.

- Are builders and architects in the area knowledgeable of and able to apply the building codes and good practices?

Nearly everyone (five of six people) mostly agree that builders and architects in the area are knowledgeable of and able to apply the building codes and good practices. According to records of construction plans (building permits) and building inspection, "there were few cases that were asked to revise the plans," said one of the respondents. This refers that the architects and responsible persons related to building constructions are able to apply the building codes and other land use regulations. Even though the records of the building permits and construction plans were not available to the public due to the regulations, we could imply that at least the recent constructions are compliant with both Building Standard Act and the local land use regulations.

- Can the public easily access to information and data on physical and structural development activities?

Almost informants (five out of six people) are not sure whether the public can easily access to information and data on physical and structural development activities. Only one informant mostly disagrees about that. Spatial information and statistical data are necessary for planning land use and framing urban development projects. Regarding the concept of spatial information sharing, those information and data should be made available and accessible to public in response to the main idea of "Good Governance". Alternatively, Greiving and Fleischhauer (2006) called this kind of concepts as Spatially Enabled Government (SEG).

Kochi City has implemented this concept by developing a web portal (http://www.city.kochi.kochi.jp/life/1/), which contains 19 main different categories of information related to; for example, consultation on housing and town planning, property taxation, disaster prevention, citizen participation and neighborhood association. The information regarding urban planning matters can be found in a category of urban development. This category is divided into two sections: (1) urban planning and landscape and (2) other urban development projects. The first section provides information about a city master plan and the relevant laws and regulations. Those laws and regulations are Building Standards Law, Kochi landscape ordinance, procedures of building inspection, etc. The other section focuses on urban infrastructure projects, especially recreation areas.

In addition, the information related to urban development activities is also available on a website of Kochi Prefecture (www.pref.kochi.lg.jp/bunya/bosai_anzen_machizukuri). Noticeably, the information on disaster mitigation and safety is integrated. The available information on Kochi City's web portal and that on the Kochi Prefecture's website are, to some extent, different according to the different goals of individual authorities. While Kochi City provides information on specific regulations and activities to enforce the land use master plan and bring the development directions under control, Kochi Prefecture aims to promote the strategic plans, regional disaster risks, and safety campaigns.

<u>- Has an assessment of existing critical infrastructure been conducted to determine vulnerability to tsunami and earthquake?</u>

Most of informants (four out of six people) are not sure whether an assessment of existing infrastructure has been conducted to determine vulnerability to tsunami and earthquake. However, the other two informants mostly agree about the existence of an assessment. Two key informants reveal that there is merely a discussion about the relocation of critical infrastructure. Nevertheless, the plan and assessment have not been produced yet.

3) Transformability (Diversity and Creativity)

<u>- Are there enough incentives or penalties in place to encourage compliance with land use policies and building standards and codes?</u>

Half of key informants (three of six people) are not sure whether there are enough incentives or penalties in place to encourage compliance with land use policies and building standards and codes. While, three of six people mostly disagree about that.

Based on the literature review on official incentive enacted at the local level, there has not been any land use policies and building standards. In practice, encouraging compliance with the legislation should be facilitated by other supportive planning measures; for example, financial motivation, and technical assistance by the government. Even though financial incentives are not legislative, the market mechanism could effectively encourage developers and building contractors to comply with the building standards. Due to the increasing demand for hazard-resistant buildings, only the developers and building contractors that meet such quality will benefit from a higher property price.

<u>- Have communications and outreach programs been produced to educate the public in hazard-resilient building practices and designs?</u>

There are controversies over the availability of communications and outreach programs to educate the public in hazard-resilient building practices and designs. Two of six expressed that there are numerous risk communication programs produced for educating the public about these issues. Another three thought that the available communications and outreach programs on these issues have not much been produced effectively to cultivate public risk awareness. Only one respondent replies that he does not have enough information to give opinion about this issue.

The available risk communication programs are a combination of several neighborhood activities and guidelines for performing disaster precautionary measures. Focusing on guidelines for disaster precautionary measures regarding tsunami and earthquake, important information in both the Japanese and English languages shall be provided in a form of booklet and publicly distributed to the residents.

Kochi city constructed a website providing information related to building guidance and relevant ordinances (http://www.city.kochi.kochi.jp/soshiki/58/kenchiku0301.html). This website consists of; for example, the enforcement of the Building Standards Law, the restrictions on the buildings in the area of the district plan[4], and the procedures related to building agreement. This website facilitates developers and residents to check and make better understanding about the current laws and regulations that shall be imposed on them.

Apart from providing the direct information on regulations, Kochi city makes an effort in promoting hazard-resilient building practices and designs to the residents in a form of booklet. . For example, an information booklet titled "Preparing for the Nankai Earthquake" (Kochi International Association, 2008) aims at providing basic knowledge and information for coping with future earthquake-and-tsunami disasters. Hazard-resistant building inspection and furniture arrangement against the collapse are also included. The local government office motivates owners of traditional wooden dwellings constructed before May 31st, 1981 to have their houses inspected for earthquake resistance, with the cost of 3,000 yen (as of 2007). The earthquake resistance inspection is a comprehensive survey of four phases. The test focuses on the state of the ground and foundations of buildings, how the layout of walls is balanced, how the wall structures are sufficient to support the building's weight, and the structural integrity of the building (Kochi International Association, 2008). The fence of the houses is also taken in account. The walls made of concrete blocks or rocks are regarded as the most vulnerable walls to be collapsed during an earthquake. The collapse of walls may trap people underneath, obstruct the evacuation, and impede the movements of emergency services after the disasters.

[4] Shiomidai, Mizuki slope, Asahi Green Hills Tsurumidai, Kochi South Ryutsudanchi, Makie stand, Nagahama industrial complex, Nagahama sunrise Nominami, Bokai~keoka, Kochi Station East , West Kochi Station, built mansion, Koyodai, Otsu Hinata Town, falconer-cho, Minami New Town, west falconer Town

In addition to the hazard-resilient building practices, Kochi City currently uses two different signs of tsunami evacuation points. The green sign on the left is national standard design, and the blue sign on the right is prefectural design standard. However, the prefectural design is beginning to phase out in order to create uniformity across the nation and to help citizens recognize the sign easily.

	
Tsunami Evacuation Point (Standard national design)	Tsunami Evacuation Point (Standard design throughout the Prefecture

Figure 6-7: Signs related to tsunami evacuation

Source: Kochi International Association, P.16 (2008)

In addition, risk communication programs related to tsunami, earthquake, flood, landslide, and liquefaction have been produced in order to cultivate risk awareness and promote individual's disaster preparedness. Two websites are created by Kochi Prefecture, which are (1) Kochi disaster prevention information (http://bousaimap.pref.kochi.lg.jp/) and (2) Kochi Prefecture's disaster prevention map (http://kouhou.bousai.pref.kochi.lg.jp/). The first website provides basic knowledge covering all local disaster risks. Apart from the narrative description of how to cope and handle with disasters, this website also comprises of disaster risk maps indicating specific risks and evacuation places (including tsunami escape buildings and safe plateaus) in each vulnerable area. This information can educate local residents how risky the areas are, and guide residents how to prepare for the evacuation before the natural catastrophes take place. Nevertheless, due to the fact that all data is in Japanese, this somehow limits the accessibility and readability to the foreigners. The second website available both in Japanese and in English focuses more on the warning system, evacuation processes, and critical evacuation orders. The evacuation alerts and orders are also transferred to the subscribers through social media such as twitter.

Table 6-5: An example of evacuation orders due to heavy rain in August 2014

Towns and villages	Refuge target district	Refuge classification	Recommendation date	Release date	The number of targeted households	The number of objects
Kochi city	Tosayama iris	Evacuation order	2014/08/09 15:00		1	5
Kochi city	Mirror Matobuchi area Oshio apartment complex	Evacuation order	2014/08/07 20:30		12	34

Source: http://honyaku.j-server.com/LUCKBP/ns/tl.cgi/http%3a//kouhou.bousai.pref.kochi.lg.jp/KH722.html?SLANG=ja&TLANG=en&XMODE=0&XCHARSET=utf-8&XJSID=0

Table 6-6: A summary of the interview on Kochi's resilience in urban planning against tsunami risk

	Respondents' opinion on the argument	Remarks
Land use policy and planning		
- Knowledgeable people on coastal resources and hazard management have been involved in building setting and urban design.	There are two respondents who mostly agree about knowledgeable people on coastal resource and hazard management relating to building setting and urban design. Another 2 people strongly agree about that. However, there are two respondents who are not sure about that.	In the process of urban planning, experts are allowed to take part. For example, eight persons with relevant knowledge and experience in urban planning are required in order to form the council (Article 2 of the regulation of Kochi Urban Planning Council)
- There are policies that can significantly limit investment in vulnerable areas (Ex. No-build zone).	All key informants disagreed about this issue.	Urban planning policy and land use ordinance do not clearly state about the limitation of investment in tsunami vulnerable areas. All land use ordinances and regulation are defined in accordance with 12 land use categories rather than a concern on hazard potentials.
- Responsible institutions have enough capacity to implement land use plans and its ordinances.	Nearly everyone (5 of 6 people) strongly disagree that responsible institutions have enough capacity to implement land use plans and its ordinances. Only one person mostly disagrees with this issue.	It reflects that even local government officers do not trust in their institutions' capacity for disaster management. It is a case that some procedures / processes might be too complicated and time consuming so that law enforcement and this makes the substance of spatial plans become obsolete.
- There are enough incentives or penalties in place to encourage compliance with land use policies and building standards and codes.	Half of key informants (3 of 6 people) are not sure whether there are enough incentives or penalties in place to encourage compliance with land use policies and building standards and codes. While, 3 of 6 people mostly disagree about that.	Based on the literature review on official incentive enacted at the local level, there has not been any land use policies and building standards to encourage the compliance with land use policies and building standards and codes. Nevertheless, developers and building contractors gain benefits from market mechanism, since the property price increases when the property meet the higher quality standards.
Physical conditions		
- Critical facilities, such as water and electric power plants, are located outside of the hazard area or built to be resistant to the known hazard impacts?	Half of informants are not sure whether critical facilities are located outside of the hazard area or built to be resistant to the known hazard impacts. Another half of informants mostly disagree about that.	According to an informant, there is the relocation plan of critical infrastructure in Tsunami prone area. Besides, Nankai Earthquake Countermeasure Special Act has been enacted in November 2013. This helps the local admiration bear the cost of the relocation.
- A coastal engineering structure (such as Seawall, Evacuation Tower and Building, etc.) has enough capacities to reduce	- Two informants strongly disagree with this statement. Another two agree. The other two express on point.	-

	Respondents' opinion on the argument	Remarks
vulnerability to coastal hazards and minimize impacts to coastal habitats.		
- Building safety and hazard reduction standards and codes are supported by law and enforced.	According to key informants, most of them (4 of 6 persons) are not sure whether building safety and hazard risk reduction standards and codes are effectively supported by law and enforce, while 2 of 6 persons disagree about this issue.	The building Standard Act of Japan has been strictly monitored and developed over the time. For Kochi City, the local government assumed that structures, which were built prior to the earthquake resistant construction regulations introduced in 1981, are unsafe for earthquake and vulnerable to tsunami. The census of building condition performed by Kochi City reveals that around half of existing buildings are in an unsafe condition to those kinds of risk.
Technical and financial availability		
- Hazard-resistant building practices have been taught at the secondary and technical schools.	Most of people (4 of 6 people) are not sure whether hazard resistant building practices have been taught at the secondary and technical schools. While, other 2 people mostly agree about that.	Courses related to hazard resistant building and infrastructural construction are available at the locality. For example, "Infrastructure Systems Engineering Course" and Social System Management Course that are provided by Kochi University of Technology
- The public can easily access to information and data on physical and structural development activities.	Almost informants (5 of 6 people) are not sure whether the public can easily access to information and data on physical and structural development activities. Only one informant mostly disagrees about that.	One of the reasons is that the public do not pay attention to physical and structural development activities so that the (local) government does not place importance on this issue, even if the government has provided the data. On the contrary, real-estate developers are interested in this information / issue in order to invest in those areas. Hence, the developers collect and monitor this information by themselves For this reason, public sector and private sector do not share information.
- An assessment of existing critical infrastructure has been conducted to determine vulnerability to tsunami and earthquake.	Most of informants (4 of 6 people) are not sure whether an assessment of existing infrastructure has been conducted to determine vulnerability to tsunami and earthquake. However, the other two people mostly agree about an assessment of existing.	Two key informants reveal that there is merely a discussion about the relocation of critical infrastructure. Nevertheless, the plan and assessment have not been produced yet.
- Builders and architects in the area are knowledgeable of and able to apply the building codes and good practices.	Nearly everyone (5 of 6 people) mostly agree that builders and architects in the area are knowledgeable of and able to apply the building codes and good practices.	Without the operation of tide embankment, the current capacity of emergency infrastructure became a controversial debate among the respondents.

	Respondents' opinion on the argument	Remarks
- Communications and outreach programs have been produced to educate the public in hazard-resilient building practices and designs.	There are controversies over the availability of communications and outreach programs to educate the public in hazard-resilient building practices and designs.	Kochi City established a new section - Community-based Disaster Management Section - in order to make people understand and realize disaster risk. To do so, people can make a plan and deal with disaster; flood, fire, tsunami, and earthquake.

Source: interviews with prefectural officers involving in the urban planning and infrastructure management.

6.3 A comparison of spatial planning systems among Japan, Thailand, and Italy

6.3.1 Spatial planning systems in Italy

Since the government decentralization in 1990, duties of territorial planning in Italy have been placed on local authorities without the specific national spatial policy. Nevertheless, the national and international infrastructure development plans still remain as a comprehensive plan leading to urban development. For example, the plans at national scale are limited to mega-infrastructure projects. Those projects are usually relevant to transportation and logistics networks, such as highway and railroad, and correspond with regional policies of European Union (EU). Since 1990s, Italy gains support from EU national fund through the transcending national territory plan and the structural fund. This kind of support is dedicated particularly for areas where Gross Provincial Product (GPP) per capita lower or equal to 75% of the average European GPP. As of 2006, four regions in Italy – Campania, Puglia, Calabria, and Sicilia regions – are qualified with this condition. Another potentials of EU-led urban programs in Italy include, for example, the Urban Renewal Programs in 1995, Neighborhood Contracts in 1998, and PRUSST in 1999 (Rivolin, 2012).

In Italy, the initiative of spatial planning began with the Urban Planning Law legislating in 1942 (No. 1150). This law required local authorities (at provincial and municipal levels) to create their own territorial plans corresponding to the regional spatial policy. However, the regional spatial policy had not been active until 1970. After 1972, the regional government has taken an full responsibility to produce the spatial policy as a guidance for the territorial plans at the local level. Almost three decades later after the constitutional amendment of 2001, the regional government allowed local authorities to formulate their local teams to undertake local territorial plans. Moreover, a new administrative division was formed differently in the metropolitan areas (Citta metropolitan) in comparison with a regular type of municipal territorial plans.

Based on the New Local Autonomy Law subsequent to the government decentralization, the current basic framework of urban planning in Italy is classified into four tiers: (1) regional territorial plans (Piano Territoriale Regionale), (2) provincial territorial coordination plans (Piano Territoriale di Coordinamento Provinciale) and equivalent metropolitan area plans (PRGI), (3) municipal (commune) master plans (PRG), and (4) district plans (PP) (Figure 6-8).

It can imply that spatial planning of Italy varies from region to region. Nevertheless, the regional plans still interrelate with mega-infrastructure plans proposed by the interregional cooperation or the national policy.

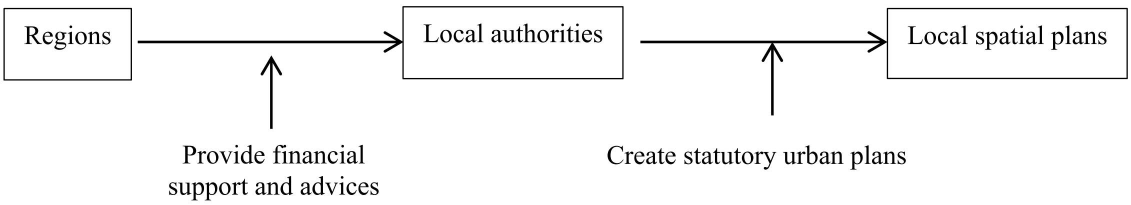


Figure 6-8: Spatial planning tasks of each government hierarchy in Italy

Table 6-7: Significant plans related to spatial and regional development in Italy

Plan	Authority
Regional Territorial Plan (PTR)	Region
Regional Territorial Landscape Plan (PTPR)	Region
Provincial Territorial Coordination Plan (PTCP)	Province or Metropolitan level
Metropolitan Area Plan (PRGI)	Province or Metropolitan level
Municipal Master Plan (PRG)	Municipality

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan (MLIT) (2013)

6.3.2 Spatial planning systems in Thailand

Since the First National Economics and Social Development Plans launched in 1962, Thailand regards this plan and its consecutive plans as a highest national policy framework that serves as strategic guidelines for every developmental aspect including the spatial planning. The initial development plan operated for a six-year period, but successive plans were revised every five years. During the fifth plan till the tenth plan, there had been clear purposes and titles such as “Regional Development” devoting considerably to the topic of spatial development, but after the Ninth Plan, spatial development has received very little consideration (Ministry of Land, Infrastructure, Transport and Tourism, Japan (MLIT), 2013).

The current plan is the 11th Plan covering the period of 2012 to 2016. With the mission of "A happy society with equity, fairness, and resilience", this plan concerns about national security and development through the promotion of participatory process (Office of the national Economic and Social Development Board, 2012). Even though the 11th Plan has not traditionally regarded spatial development policies and the region development plan as a specific topic, the 11th Plan provides an extensive focus on booting local economy to reduce rural-urban migration as well as integrating the spatial development plan with the neighboring countries. According to the issues related to spatial planning, there are five goals toward urban and regional development; (1) promoting ecological cities upon industrial accumulation; (2) promoting creative cities; (3) developing border areas as creative economic zones for commercial, industrial and logistic purposes; (4) revitalizing existing cities in order to improve live and sustenance of low-income group; and (5) concerning about eco-friendly cities together with keeping a balance between economy, social, and cultural aspects. Moreover, based on the lesson-learned from the tsunami in 2005 and the great flood in 2011, this plan highlights the importance of preparedness for confronting with natural disasters based on the regional cooperation (Ministry of Land, Infrastructure, Transport and Tourism, Japan (MLIT), 2013).

In fact, the policy statements on spatial development in Thailand's National Economics and Social Development Plans have recently subsided. The Department of Public Works and Town & Country Planning (DPT), under the direction of the Ministry of Interior, has been in charge of spatial planning as a result of a cabinet resolution of 2002. Under the Town Planning Law and a cabinet resolution of 2002, DPT has been assigned to design the land use master plans and land use ordinances, comprising of land use categories and zonings. The spatial planning is available at the national, wide-area regional, sub-regional, provincial, town and specific area levels. In the master plan, the standard land-use color codes are assigned to represent different types of land use activities and zoning in each area (As shown in Table 6-9).

In compliance with the aforementioned resolution of 2002, DPT has established a national-regional policy for 50-year period (2007 to 2057), which provides a vision on spatial development policies, strategies, and measures and a framework for lower hierarchical plans. Hence, this plan covers all areas throughout Thailand, including special local administration organizations; for example, Bangkok (a capital city) and Pattaya (a city of tourism in Chonburi Province). In addition, urgent strategic plans for 5-year period, 10-year period, and 15-year period are also established as an implementation procedure of the long-term national-regional policy (2007-2057).

Table 6-8: Structure of planning system in Thailand

Subsidiary Planning	Plans	Responsible authorities
National	**Policy Plan** : National Economic and Social Development Plan	National Economic and Social Development Board (NESDB)
	Spatial Plan : National Spatial Development Plan	Department of Public Works and Town & Country Planning, Ministry of Interior (DPT)
Regional	Regional Spatial Development Plan (6 regions)	Department of Public Works and Town & Country Planning, Ministry of Interior (DPT)
Sub-regional	Sub-regional Plan	Department of Public Works and Town & Country Planning, Ministry of Interior (DPT)
Provincial	Comprehensive Plan	Department of Public Works and Town & Country Planning, Ministry of Interior (DPT)
Town	Comprehensive Plan	Department of Public Works and Town & Country Planning, Ministry of Interior (DPT)
Specific area	Specific Plan	Department of Public Works and Town & Country Planning, Ministry of Interior (DPT)

Note: A comprehensive plan usually comprises of Land Use Plan, Open Space Plan, Transportation Plan, and Infrastructure Plan, while specific plan is regularly related to Urban Renewal Plan and Urban Development Plan

Source: Department Public Works and Town & Country Planning, Ministry of Interior, Thailand (DPT) (2013).

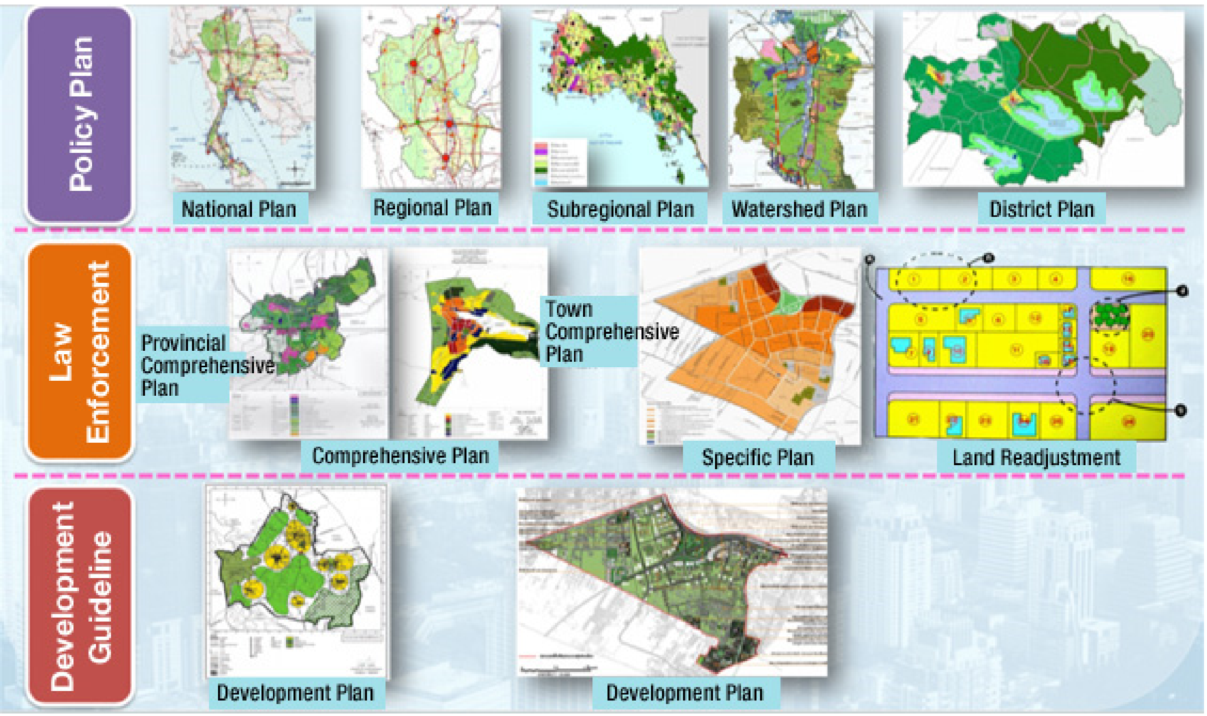


Figure 6-9: Spatial Plan Hierarchy and Characteristics

Source: DPT (2013) cited in Ministry of Land, Infrastructure, Transport and Tourism, Japan (2013)

Table 6-9: The example standard color code of land use in Thailand

Color codes	Color settings	Types of land use
	Yellow	Residential area- low density
	Orange	Residential area- medium density
	Brown	Residential area- high density
	Red	Commercial area
	Purple	Industrial area
	Lavender	Specific Industrial estates
	Violet	Industrial warehouses
	Green	Rural and agricultural area
	White with diagonal green lines	Rural and agricultural conservation area
	Green with diagonal brown lines	Agricultural area for land reform
	Green with white diagonal lines	Land conservation area for tourism
	Light Green	Designated recreation area
	Light green with white diagonal lines	Forest land
	Sky Blue	Open land to maintain the quality of environment and fisheries
	Light Brown	Conservation area to promote cultural identity of Thailand
	Gray	Religious institutions (In some cases, it also refers to educational institutions)
	Blue	Public infrastructure and utilities

Note: the color codes shown in the above table are only the general standard. The master plans may be introduced with varying colors of land-use codes depending on other specific regulations of each urban planning area.

Sources: The Department of Public Works and Town & Country (DPT), Thailand (2014)

6.3.3 Results of the comparison

In conclusion, a comparison of spatial planning systems in Japan, Thailand, and Italy shows that all three countries carry out spatial planning differently. Japanese spatial planning system is regarded as the most comprehensive system among the three systems, although the Japan's legitimate planning system was constructed seven years after the Urban Planning Law of Italy firstly enacted in 1942.On the contrary, with the initiative in 1975, the spatial planning system of Thailand was still in the infant stage.

Regularly, the spatial planning mainly comprises of three tiers: national level, regional or intermediate level, and local level. The national spatial planning is related to strategic plan and development policy rather than any special intervention projects. Those plan and policies are; therefore, regarded as policy guidelines for local implementation. Nevertheless, Italy does not have tangible national spatial planning. Regional, provincial, and municipal governments are responsible to undertake spatial planning.

Commonly, the driving force of the spatial policy development is to boost and balance economic development and social welfare across the nation. In case of Italy, the spatial policy development aims to re-address an inequality of economic development between southern and northern regions. Likewise, an economic goal of spatial planning in Thailand is to distribute the heavily agglomerated economic investment in Bangkok Metropolitan Area into regional hubs across the country: for example, the promotion of industrial development in eastern seaboard or the border trade campaign in the northeast region. In the case of Japan, the spatial planning gives high priority toward the development of public welfare and the natural preservation. Under this aspect, the spatial development of Japan is based on rail oriented spatial development, which differentiates the Urban Promotion Area (UPA) from the Urban Control Area (UCA). In other words, apart from the development in urbanized area, the area outside City Planning Area where the environmental preservation is necessary will be designated as Quasi City Planning Area together with special land use restriction zone. This combined bundle limits any Development Plan of Urban Facilities and Urban Development Projects in Japan.

According to the comprehensive international programs for regional cooperation, the national spatial planning of Thailand and Italy concerns the spatial interrelations with their neighboring countries. The transportation infrastructure of those two countries can be subsidized by the international funds, such as European Union Fund for the case of Italy or Greater Mekong Sub-region (GMS) for the case of Thailand. Unlike those two countries, the spatial planning of Japan is independent from the neighboring countries, as Japan has no land connected to other countries.

Concerning on the disaster risk management in spatial planning system, the flood risk is regarded as a common risk among the three countries. Nevertheless, the study found that there are three different approaches to address the flood risk in spatial planning ; 1) By mandatory hydrogeological risk assessment of the responsible authorities (in Italy), 2) By voluntary effort on disaster risk management of locality (in Thailand), and 3) By special legal planning measures under the City Planning Law (in Japan).

To begin with the case of Italy, Law by decree 180 of 1998 is regarded as the main legislative measures on soil protection. These laws assign River Basin Authorities to establish Hydrogeological Management Plans (PAI)[5]. Moreover, the mapping of disaster prone areas; such as landslides, avalanches and floods, are classified into various risk levels. The different

[5] Piano Stralcio per l'Assetto Idrogeologico (PAI) (In Italian)

levels of risk imply about the restrictions to limit land development and the main protection actions to alleviate hydrological risks across the disaster prone areas. Under those measures, Italian territory is divided into hydrographic basins and classified as being of national, interregional, or regional importance (Organisation for Economic Cooperation and Development (OECD), 2006) .

In addition, the minimum safety requirements for town and land use planning in areas, that potentially face with major hazard accidences, are addressed by the Ministerial Decree of 9 May 2001 related to the Legislative Decree 334/99. This decree regulates the obligation to produce a technical assessment of territorial vulnerability related to both foreseen and unforeseen hazards, especially in industrial areas. By those legislations, the technical document has to be produced under three crucial objectives: 1) to identify the vulnerable elements, 2) to determine the potential damage area, and 3) to evaluate the consequences of the proposed developments. This technical document shall be provided to municipalities as a fundamental component of land use planning (Organisation for Economic Cooperation and Development (OECD), 2006). Nevertheless, technical document stands still operate as an additional technical assistance of risk assessment and risk reduction, without defining certain risk mitigation measures.

According to the policy decision-making process for soil protection in Italy, the Ministry of Environment and Land Protection (MATT) is responsible for determining trends and policies, allocating financial resources and coordinating with River Basin Authorities. Meanwhile, the River Basin Authorities are responsible for producing basin plans and guidelines for flood prevention, mitigation and communication policies in each basin area. Those guidelines will be translated into land-use planning criteria by regulatory acts, under the coordination of MATT and the agreement of the Ministries of Infrastructures and Transport, Agriculture and Forestry Policy, Cultural and Environmental Heritage, the Department of Civil Protection, and of Regions. In the case of Thailand, the burdens on flood risk assessments that are essential for land use planning are not imposed legislatively on spatial planning authorities. In fact, in many cases, the local authorities who get involved with spatial comprehensive planning or specific planning have voluntarily carried out those assessments. In some areas, the guidelines on land use control in floodway areas are undertaken by the experts from DPT. However, least of those guidelines were implemented and few of those were enacted as the legislative decree. Some of the obstacles in implementing those plans are 1) ineffectiveness of land use control and legislative enforcement, 2) conflicts between the reasonable academic suggestions and political interests (Roachanakanan, 2556). Besides, Roachanakanan (2556) pointed out that there is a gap between an academic sector and a policy maker, which makes the extensive knowledge of town planning and watershed management limit to the academic field, instead of putting those into practices. This gap is interrelated to two crucial factors. First, a lack of institutional mechanism that involves the academic sector in policy formulation processes (policy-making processes) makes research findings uncirculated to policy makers. Second, a lack of effort to implement substantial knowledge into practice are caused by the ineffectiveness of law and regulation enforcement and the intentionally changed land use regulations to the contrary to academic reasons.

Unlike the other two countries, Japanese spatial planning system welcomes any opportunities to support efficient disaster risk management. Land use regulations allow municipality to create a district plan, which shows both the future vision of the district development and urban intervention measures related to district improvement. The district plan, in general, consists of the location of public facilities, building control and regulations, and preservation of green areas. In addition, district planning can be formed to prioritize the needs of disaster risk mitigation and prevention. For example, the establishment of Disaster Prevention Block Improvement District Plan extensively aims at reducing fire risk through the promotion of fire-resistant building, widening roads in terms of "building setback", and etc. Equally important to the land use regulations, the planning measures of "Urban Development Projects" can be utilized in order to promotion disaster recovery processes in affected areas. In order to promote disaster recovery after the Great East Japan Earthquake of 2011, the national government enacted the Basic Act for Reconstruction and Basic Guidelines for Reconstruction, based on recommendations from the Reconstruction Design Council (International Recovery Platform (IRP), 2013). As a result, financial resources and technical assistance are easier to be allocated into disaster affected/ prone areas through the spatial planning measures.

In conclusion, it is clear that each country has different ways to put their norm of disaster risk management into policy formulation and implementation. In Japan, the flexibilities of spatial planning system give the locality opportunities to integrate disaster risk management with spatial planning. However, it may be difficult for local authorities involved in spatial planning to perform the disaster risk assessments on their own. Since the risk assessments are obviously needed for the creation of any spatial planning measures relating to risk reduction, the spatial planning system in Italy designates third parties to play an important role in providing technical assistance and comprehensive risk information of local land use planning. Although the local authorities responsible for spatial planning can also acquire the technical assistance through the cooperation with academic and didactical sectors, this kind of cooperation requires institutional mechanism and the effort of decision makers to it possible.

Table 6-10: The comparison of spatial planning systems

Profile	Japan	Thailand	Italy
The initiative of spatial policy	National Spatial Planning Act (Act No. 205 of 1950) in combination with measures by the National Land Use Planning Act (Act No. 92 of 1974)	First Town Planning Law of 1975.	Urban Planning Law legislating in 1942 requires local authorities to create their own master plans under the regional spatial policy and guidance.
Driving forces of the spatial policy development	The land use planning gives priority to the development of public welfare and the preservation of natural environment based on a comprehensive long-term aspect. All natural, social, economic, cultural are taken into account.	-The National Economic and Social Development Plan -The Department of Public Works and Town & Country Planning of the Ministry of the Interior	Since the unification of Italy in 1861, economic aspects are the motivation of territorial planning in order to readdress the disparities between southern and northern Italy. The first long-term economic plan was for the 1965-1970 period.
Levels of Spatial Plans	National Land Use Planning Act is regarded as a foundation of other land use plans and relevant policies. The spatial planning consists of 3 tiers: national, prefectural, and municipal levels.	National land use plan is regarded as a guidance for all spatial policies and planning, There are 4 levels of spatial planning: - National land use plan, - Region plan - Provincial plan (Master plan), - Municipal basic plan (Town planning, Zoning).	The national spatial plan does not exist in Italy. There are 3 levels of spatial policy: - Regions (20): 15 regular + 5 special regions - Provinces (110) - Municipalities (8,101)
Comprehensive International Programs for Regional Cooperation	Since Japan is a country of islands, there is no inland connection with other country. Hence, the land use planning of Japan is independent from the neighboring countries.	The following are examples of comprehensive international programs for regional cooperation with neighboring countries: - Greater Mekong Sub-region (GMS) - Mekong-Ganga Cooperation (MGC) - Mekong River Commission (MRC) - Bangladesh, India, Myanmar, Sri Lanka and Thailand Economic Cooperation (BIMSTEC)	European Union (EU)
Dominant risks	Earthquake, fire, flood and tsunami	Flood and landslide	Earthquake, flood and landslide
Integration between spatial planning and disaster risk management	Urban interventions for disaster mitigation and prevention can be authorized through the measures of "urban development projects" under the City Planning Law.	The municipalities have voluntarily conducted flood risk assessments. In some cases, DPT guided the plans of land use control and floodway, but least of them were implemented, and fews of those were enacted as the legislative decree.	Law by decree 180 of 1998 and amendments thereof establishes Hydrogeological Management Plans (PAI), which impose the burdens of identifying risk zoning and limiting land use for risk mitigation on River Basin Authorities.
Recent tsunami event	Tohoku earthquake of 2011	Indian tsunami of 2004	Messina and Reggio earthquake of 1908

Source: By author

6.4 Modeling spatial planning systems with a concern about disaster risks

The integration of tsunami risk mitigation into spatial planning should consider several aspects from policy formulation, institutional structures, spatial data, and platform for legislation.

In Japan, Disaster Countermeasures Basic Act of 1961 formed the Central Disaster Management Council. This council is regarded as a national body for multi-sectorial coordination and collaboration in order to ensure the effectiveness and comprehensiveness of disaster risk management as well as to enable fruitful disaster risk communication and discussions. In addition, Basic Plan for Disaster Management has been drafted as an ideal fundamental principles of the act.

The sectorial plans related to disaster risk management are initiated according to the need of each development area, and Comprehensive National Development Plan is one of the subjects. The plan identifies "improving the country's safety with regard to large scale earthquakes and other natural disaster" as one of main objectives. With this objective, disaster mitigation measures based on the principle of spatial management is prioritized as the main task for coping with natural hazards. It is obvious that Japanese spatial planning systems have taken disaster mitigation measures into consideration, but it is implicit how disaster risk management and spatial planning can be integrated together. A model of spatial planning for tsunami resilience was; therefore, created to highlight the platforms that those two issues can be integrated. This model can, on the other hand, be titled as "tsunami-risk sensitive land use planning".

The model begin with an assumption that bridging the gap between spatial planning processes and procedures of risk management would enable disaster-resilient spatial planning. Thus, risk communication through a concept of social learning can be one of mechanics to create these linkages. Based on the above assumption, four links between the spatial planning processes and the risk management procedures are proposed. These four links of risk communication are interconnected with different objectives: to collect data, to construct alternative plans, to make a decision, and to mutually implement disaster mitigation measures.

1) Risk assessment as part of the spatial data collection

The first link highlights an essential of risk assessment for spatial analysis. In general, the risk assessment is rarely moved forward into spatial planning, because the spatial planning authority and bodies who are responsible for disaster risk management work separately. The study proposes that the risk assessment should have been utilized since the beginning of the planning processes: a data collection process. At local community level, the groups of community-based disaster protection – who have been active in carrying out the disaster mitigation and protection activities such as disaster drills – can participate in this data collection related to local risk and vulnerability. The transition of indigenous knowledge and wisdom of community members can be expressed through a variety of risk identification and risk assessment activities, for example, risk map mapping. The spatial planning analysis together with local risk assessment will enable planners to understand deeply about a direction of urban development and territorial vulnerability to disasters. This then facilitate them in creating better solutions and planning suitable for the local context.

The proposed public participation process seems to be practical in Japan. It can be integrated into routine disaster mitigation activities of various voluntary associations that are actively involved in community-based disaster risk management. Nevertheless, groups of community-based disaster management are now facing a number of problems mainly related to a decreasing number of members and aging membership (Japanese Government, 2005).

In addition to the participation of community members, academic bodies play a major role in supporting the participation process, along with carrying out scientific and technical research on hazard risk assessment such as earthquakes and impact of tsunami, liquefaction, and lateral flow produced by earthquakes. This role is not mandatory by law, but it is a voluntary activity. The academic research becomes essential, especially in the case of Japan that the analysis on socio economic loss from natural hazard is not carried out by the central government, but by private sectors and local government. Therefore, the academic bodies can supply their expertise to a range of responsible authorities on spatial planning (national, prefectural, and municipal governments) as well as the Central Disaster Management Council. The Central Disaster Management Council can take benefits from the interdisciplinary collaboration in generalizing a set of procedures to enable local authorities to make a practical assessment of their own risk mitigation and crisis-management system. Whereas, in order to enhance community-based activities in disaster risk identification, the Director for Disaster Preparedness, Cabinet Office for Disaster Management shall provide the local authorities with an efficient method to self-evaluate local vulnerability to disasters.

One of Japanese society's strengths – which accommodates the risk assessment to be more precisely and valuable – is the well-maintained records on past disaster events that are usually scarce in another countries. The availability of historical data influences a prediction of the future probability events. The historical data of disasters will be used in producing two basic thematic maps: a hazard risk map and vulnerability map, which are required for the risk assessment in an inaugural spatial planning process.

While each individual hazard map developed using historical data of dynamic disasters is a location-based map, the vulnerability map is subject to different socio-economic characteristics and land use settings that are potentially exposed to a specific hazard. This thematic map of urban vulnerability can be produced by at least three inputs: building, infrastructure, and population and economic activities (See Chapter 2 and Chapter 4). Without the review of existing plans or the sufficient information on the historical natural disasters, the urban vulnerability in the past still remains in the future. On the contrary, understanding the influence of urban planning in risk mitigation is important in preventing a repetition of disasters. However, a major problem in producing an urban vulnerability map is that spatial data and disaster risk information usually come from different sectorial authorities and in different formats. A difference of visualization coding in depicting similar features may lead to inappropriate merging of data, misunderstanding, and misleading decisions. To enable the continuation of data sharing and transferring, the spatial data and disaster risk information should be standardized.

2) Creating alternatives for spatial configuration along with another mitigation measures

It is unavoidable to discuss about the public involvement in spatial planning processes, especially when the decision has to be made. Although the spatial planning has an ideal aim to reconcile different desires among different interest group, its decision-making process usually ends up with a mere political judgment . Undeniably, the political power have had a great deal of influence over the spatial planning and the allocations of human and financial resources since the beginning of spatial policy formulations. Whereas, the City Planning Law states clearly that the public hearing shall be part of procedures of the spatial planning approval before the spatial planning shall be legislatively effective. The unbalanced powers between a group of politics and other stakeholders comes into a question how to increase the public involvement in the decision-making process" .

According to the City Planning Law, the public participation includes public hearing (Article 16), public notice, and relevant public inspection (Article 17). The public hearing has to be conducted in order to seek for a common consensus and to prioritize the opinions and desire of landowners and landholders (who hold least rights). The agreement among stakeholders had to be made by at least two-third of those members (Article 21-2). This requirement shall be applied to each plan of the integral area of specified size (no less than 5,000 sq. m. in general) as stipulated by the responsible municipality.

In order to achieve those requirements, various risk communication techniques have to be taken into account. Different risk communication techniques enable public involvement in different ways and different levels of participations.

In the earlier chapter (chapter 2), the spectrum of modeling techniques for risk communication can be used at least to set up a suitable tool for a specific purpose, which these can be adapted later to suit a participatory process of alternative creations. Similar to the risk communication for the data collection proposed above, the risk communication techniques can be applied in order to enhance the public participatory in the decision-making process. The mere difference is the objectives in implementing those communication techniques. The techniques, which are applied during the data collection process, aim at gathering the risk information from stakeholders and sharing risk information between local authorities and stakeholders or among stakeholders themselves. Unlike the data collection process, the objectives of engaging participatory based risk communication in the decision-making process are to make a common agreement among the stakeholders on various alternative spatial/urban development plans. Hence, the risk communication techniques in this process would differ from the ones that are applied in the earlier planning phases.

According to the conceptual model of urban resilience to disaster proposed in the chapter 2, the suitable risk communication techniques are regarded as a fundamental principal for driving a social learning process for preparing and coping with natural hazards. Not every communication technique can enhance the social learning in disaster risk management, since the social learning requires a two-way communication technique that not only can convey the expert-let complex risk information, but also make the messages easy to understand for the public. Among various communication techniques available, the gaming simulation can be used as a communication tool for urban planning and design. By this way, a sophisticated simulation that provides a complex context of the reality can be coherently presented in a form of pleasant and playful game, so-called "gaming simulation". The gaming simulation then offers the players to play and make changes to a mock-up of the reality, in order to broaden and deepen understanding of the reality that surrounds them. Besides, the gaming simulation offers the representatives of stakeholders the opportunity to meet each other, discuss, and exchange their different information and opinions on a specific issue. This then enables a fruitful communication which help avoid a risky judgment on wrong terms.

The comparison between the science of urban planning and that of gaming simulation can make better understanding on the differences and the overlapping parts between them. The science of urban design and planning deals with analysis and synthesis on the issues related to infrastructural engineering and social construction of the reality, while the science of urban gaming and simulation mainly emphasizes the importance of building metaphor of the reality under a specific purpose to pursue defined goals (Klabbers, 2006). In a process of producing the urban gaming simulation, the planner can take double vital roles as a designer and a facilitator. Those roles can help the planner to address questions especially in the realm of resolving chronic policy problems and policy implementation, for example, the differences between the public risk awareness and desirable behaviors. On the other hand, designing an urban gaming simulation and facilitating the play allow the planner to use this mechanic and its results for collectively representing tangible solutions to real-world controversial risk management, which often faces the conflict over the different interests as well as tricky interpersonal and institutional social issues.

It is clear that the sophisticated urban risk management strategy requires careful implementation and appropriate risk communication model. Thereby, the efforts of disaster risk communication leads to the emergence of Urban Gaming Simulation (UGS) and Disaster Imagination Game (DIG). To visually illustrate how UGS and DIG can be utilized in urban planning, VADDI (vallo a dire ai dinosaur) designed by Rizzi and et al. (2010) can be taken as one of the best examples.

VADDI, a gaming simulation on urban planning and disaster risk management, shows how UGS and DIG exchange information either between experts and the layman or among experts. This game characterizes as a role-playing game, as it offers players a scenario where they were living ; for example, a coastal region enriched with environment resources such as mountains, forests, rivers, and the suitable land for pastures and cultivations. Players are given four roles as government, planners, developers, and citizens who live in one of three neighboring cities: a metropolis, a seaside town, and a picturesque mountain village. This game simulates the reality where different stakeholders have different concerns on urban development , which possibly bring about the conflict. Additionally, every player has personal objectives and projects to carry out and to make decision under the consensus of community member whom the players lives and works with. During the game, the climate change scenarios - such as urban heat, overwhelming rainfall, summer fires, landslides, and floods will be given as a mark of the seasonal transition. Meanwhile, some areas are subject to prolonged periods of drought. Therefore, the players have to act under the situation where environmental problems are no longer under control. During the last phase of the game, players will be motivated to think about their risk and city vulnerability and to express their ideas and options related to the future of regional development concerning on environmental risk. Remarkably, this game simulation can reach its ultimate usefulness when the decision makers translate the messages from the discussions into risk management projects, strategies and law.

3) Training and risk communication for the policy implementation

The success of tsunami resilience in spatial planning requires the coordination in policy formulation, spatial planning, and implementation. The national government, local institutions and local residents and stakeholders have to take part in this coordination in order to drive the new norm of spatial development for tsunami resilience.

In Japan, the National Spatial Development Act and the City Planning Law offer a variety of channels for local spatial planning authorities to integrate their risk mitigation/recovery measures in their land-use master plans and urban development projects. For example, a designated fire prevent block – a mitigation measure prior disaster time – is implemented in order to keep the densely populated area away from the risk of fire. Alternatively, a promotion district for disaster reconstruction – a disaster recovery measure – is applied to bring the livelihood of affected residents back to their normal states in a timely manner. While, the legislative platforms are available for creating spatial resilient plans against disasters, Kochi residents are also active in performing community-based risk management activities. However, those activities are mainly conducted by existing neighborhood associations; such as chōnaikai (町内会). These can imply that the tsunami resilience exists in the national institution and community associations, but not in local institutions. In the case of Kochi City and Kochi Prefecture, a gap between the national resilient norm and the community aptness in disaster risk management remains because of the inadequate institutional capability to self-organize their own resilient plans and policies.

The results of the interview and literature review show that there is a lack of explicit incentives and penalties in Kochi master plan and land use policies. As a result, such plan and policies fail to encourage local spatial development to comply with national norms of disaster-resilient spatial development, especially for tsunami resilience. These raise a question that why the national resilience has not been transferred to the local authorities. There are several factors involving in these problems. Other possible internal factors may relate to the legislative constraints in implementing national resilient norms at the local level and the lack of human resources in local spatial planning. In the case of Kochi, a dominant factor that influences urban resilience and transformability is a lack of human resources in local spatial planning. This limits the creativity in providing diverse solutions for tsunami resilience.

To create the platforms of spatial planning for tsunami resilience at the local level, disaster mitigation measures shall be integrated with spatial planning measures. This integration requires an appropriate interpretation of each mitigation measure. The different sectorial bodies might interpret the same measure differently due to their technical expertise is dissimilar. Hence, the risk communication plays a role in making the mutual substance of each mitigation measure, which leads to suitable implementations. In additional, human resources in spatial planning should enhance their capacity and creativity in constructing master plans and land use policies that reflect tsunami resilience. At the same time, the national government and academic institutions should provide training programs related to resilient spatial planning for the local officers who involves in spatial planning.

When the technical knowledge of local officers increases, innovative master plans and spatial policies will be created in combination with incentives and penalties to encourage compliance with land use ordinances, building codes and landscape regulations. The next step is to produce communications and outreach programs to educate the public in implementing those policies and plans. In addition, the existing neighborhood associations for disaster risk management should be partially subsidized by the government and by local residents. To sustain these neighborhood associations, the national government shall enable platforms in which these associations can be part of spatial planning process as they are now part of disaster risk management. The engagement of associations can indirectly help the government to reduce the cost of data collections in spatial planning process, enhance the public understanding of spatial based disaster mitigation measures, and improve the effectiveness in implementing disaster resilient policies and plans. On the other hand, the risk communication can improve the public participation, good governance and the government's reputation.

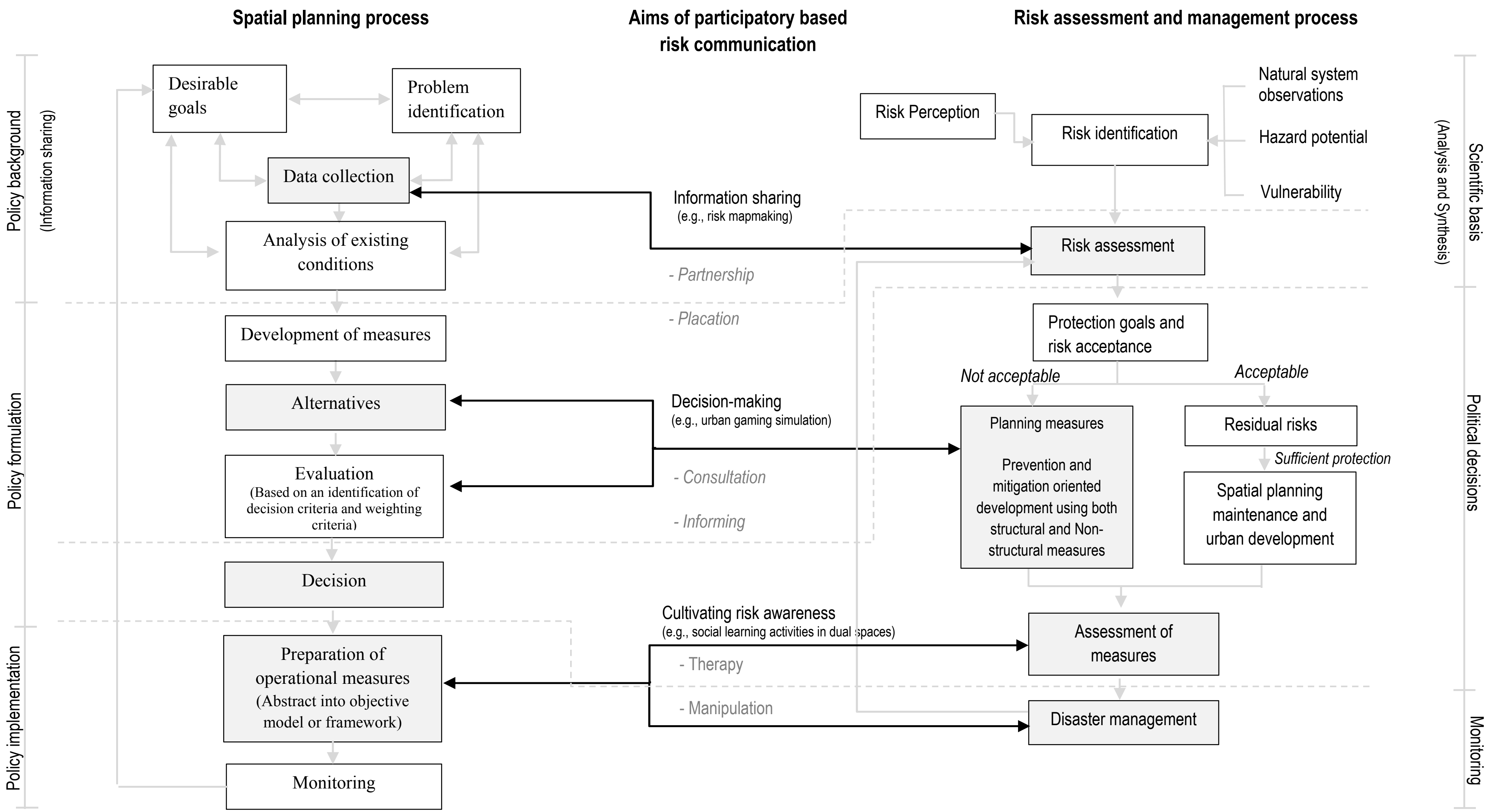


Figure 6-10: A model for spatial planning for tsunami resilience (the integration of risk management in spatial planning)

Note: Sherry Arnstein's 1969 ladder of citizen participation are adapted in this mode

Chapter 7：
Urban analysis and synthesis: a spatial plan for tsunami resilience

With the ultimate goal of the research to improve spatial planning for tsunami resilience, this chapter concludes all results of theoretical and empirical studies. The consideration on the research finding brings about suggestions and recommendations for utilizing the key research findings in spatial planning for tsunami resilience, especially in Kochi City. Recommendations on spatial planning strategies, land use ordinances, and urban development projects for tsunami resilience are defined. These recommendations are described in words.

In the future, natural disasters tend to occur more frequently and more severely, the government and residents, therefore, should closely cooperate on disaster resilience: monitoring hazards, preparing disaster mitigation measures, and planning land use strategies. There are various kinds of natural disasters, but people may not aware of such risks. For example, people normally do not aware of risk caused by heavy rain, while they will pay more attention to severe destructive disasters such as earthquakes and tsunamis.

There are great concerns over risks caused by earthquakes and tsunamis, these two disasters as a combination can occur simultaneously in coastal areas. The concerns are high because there is a high population density in these areas. The possible risk mitigation for earthquakes can be the use of building codes for improving seismic resistance. However, debates on the risk mitigation for tsunami are still controversial, but at the same time, it can be alleviatable to a certain degree. The large-scale construction of tide embankments might help reducing the impacts of tsunami, but this kind of projects is costly and unreliable (due to the nature of uncertainty), causing the implementation seem irrational. The 2011 earthquake in Japan and its consequent tsunami proved that the existing fortifications were inefficient as the height of tsunami run-up was larger than the previous prediction (Kontar, Santiago-Fandino, & Takahashi, 2014, pp. 38-39). Unlike the engineering structural measures such as the tsunami embankment, spatial planning measures can help reducing improper human settlement in disaster prone areas and minimizing monetary investment in a tsunami recovery. Hence, the study proposes a concept of spatial planning for tsunami resilience by integrating risk mitigation measures into urban planning.

7.1 The conclusion of research findings

The study considers both theoretical aspects of urban resilience against disasters and empirical studies based on case studies of Phuket and Kochi. Hence, the conclusion of research findings shall cover all those issues. The research objectives and questions, constituting as a research core, are the key criteria for the conclusion. Hence, all findings are in responsive to these research objectives and questions (Table 7-1).

According to the research findings, the first part is to the better understand the resilience concept and its crucial constituents. This will help transforming the theoretical plausibility of resilience into practice. The conceptual model of urban resilience to disaster emphasizes a dynamic process that can improve disaster vulnerable cities to be more resilient against future disasters. The mechanisms of this dynamic process require social learning, self-organization, and innovative aptness to cope with risk (See Chapter 2).

With the above model, it suggests that increasing disaster resilience does not always mean that disaster vulnerability reduces. To reduce vulnerability and increase resilience, the local authorities need to understand both the characteristics required for disaster resilience and the exposure elements leading to urban vulnerability. Hence, the second part of the research is dedicated to the urban vulnerability assessment in terms of physical and demographical characteristics. The results show that the different demographical characteristics are the key determiners of the vulnerability level. Remarkably, the highly tsunami-risk sub-districts are not the ones that are located in the coastal zone, but those are in the inner city, located 7 kilometers far away from the shoreline.

The third part of the research findings shows that the urban resilience to tsunami depends on the institutional capability of local authorities who involve in spatial planning. The existing situations in Kochi reveal a lack of institutional capability to self-organize and to innovate spatial based tsunami mitigation measures. With the inadequate capability, the national norm on creating disaster resilient cities is rarely exercised by the local spatial planning authorities. The inadequate institutional capability can be defined as a gap between the national norms in building disaster resilience and the tangible efforts of local residents in vulnerability reductions.

Table 7-1: Research Findings in response to research questions

Research Questions	Working Hypotheses	Research Findings
1. How can the theoretical plausibility of resilience be translated into practice?	1. Enhancing resilience is a dynamic process that requires crucial mechanisms to transform city vulnerability to city resilience.	1. The conceptual model of urban resilience to disaster is proposed in Chapter 2. This model shows a non-linear process of how disaster affected cities can turn themselves from vulnerable to more resilient against future disasters. The mechanisms of this dynamic process require social learning, self-organization, and innovative aptness to cope with risk (See Chapter 2).
(The additional research question) Dose increasing resilience to disasters reduce the disaster vulnerability?	No hypothesis is set.	Increasing disaster resilience does not always reduce disaster vulnerability. The results of a preliminary case study in Phuket shows that even the Patong Municipality is resilient in terms of the capability to self-organize in recovery processes after the tsunami of 2004, but this institutional resilience is not transferred to the local stakeholders and integrated into long-term spatial planning measures for tsunami mitigation (See Chapter 3). In sum, increasing resilience is not enough if city want to cope with the tsunami risk, but the urban vulnerability should also be reduced as well. The local authorities need to understand both the characteristics of disaster resilient cities and the exposure elements that cause urban vulnerability.
2. How vulnerable to tsunami Kochi City is? 2.1 What are crucial characteristics of areas that make a city more vulnerable to tsunami (Which vulnerable characteristics make highly vulnerable districts different from the others?) 2.2, Where is the most tsunami-risk area in Kochi City?	2. Socio-economic attributes of Kochi City categorize vulnerability of the urban fabric of this city. 2.1 Divided into two hypotheses (1) Socio-economic characteristics of residents in individual districts make the highly vulnerable districts different from the others. (2) Critical infrastructure is a major determiner of vulnerability level. 2.2 Nearby sub-districts to coastal zone are more at risk to tsunami than inland districts.	2.1. The urban vulnerability level of 357 sub-districts to tsunami varies upon the building and facility densities and demographical characteristics. With a significant level at 0.05, Person Correlation reveals that proportions of the elderly and female population significantly dominate the vulnerability over the influence of the physical elements. The proportions of the elderly and female population are positively correlated with the level of vulnerability, which means a higher proportion of those population triggers the higher vulnerability level. Nevertheless, these results are limited to the research design. The results may change slightly if more variable are added, and weighting techniques are changed (See Chapter 5). 2.2 By considering that the tsunami risk comprises of urban vulnerability and tsunami inundation mapping, the inland sub-districts can be at risk at the same level as the coastal sub-districts. The results of the tsunami risk evaluation show that highly tsunami risk sub-districts are not the ones located on the coastal zones, but in inland areas. The highly tsunami-risk sub-districts are Kutanda and Hoei-cho, which are located in the inner city, which is 7 kilometers far away from the shoreline.

Research Questions	Working Hypotheses	Research Findings
3.1 How to determine or describe tsunami resilience of the case studies? 3.2 How resilient is Kochi City in terms of urban planning against tsunami?	3.1 The resilience is measurable in terms of a narrative assessment by using either Key Performance Index, Benchmark, or a set of indicators. 3.2 No hypothesis is set.	3.1 Based on the literature and the interview, the study confronts with the uncertainty on how best to address this question. Numbers of research exists on factors associated with key performance index of resilience, except for how to enhance resilience associated with urban planning measures. Seemingly, there are no clear indicators to measure the results of resilience programming, and therefore it is impossible to define a good practice of resilience concept. The degree of overall resilience will likely only be measurable in times of crisis or shocks. However, improvements from baselines for each of the components of resilience for individuals, communities and their institutions could provide a useful guide. In order to seek for answers of the research question number 3.1, the interview and secondary data were analyzed. In the interview, resilience schemes and interview questions were adopted from a series of questions. Whereas those questions were matched with three key performance indicators (KPI), which are the stability, capability to bounce back and to self-organize, and transformability (See Chapter 6). 3.2 Based on the Kochi case study in Japan, the national risk awareness is present in both written document (laws and policies) and unwritten commitment (discussion retrieved from the conference report). This risk awareness is regarded as the norm that directs the national development, concerning on disaster risk mitigation. This norm is present explicitly in the national act. For example, The Basic Act for National Resilience Contributing to Preventing and Mitigating Disasters for Developing Resilience in the Lives of the Citizenry (Act No. 95 of December 2013). In addition, the Comprehensive National Development Plan and City Planning Law enable various platforms for local spatial planning authorities to integrate risk mitigation measures, implementing through land-use ordinances, urban infrastructure projects, and urban development projects. For example, in a category of urban development projects, measures to boost the disaster recovery in affected areas can be implemented legislatively as promotion districts for disaster reconstruction. Apart from the national efforts on disaster risk mitigation, local communities and residents are actively in performing disaster preparedness activities. Neighborhood associations for disaster risk management such as “Jichikais” have been established. Such Jichikais play an informative and persuasive role in conducting annual disaster evacuation drills. The informative role of Jichikais rises public knowledge on disaster risks and the mitigation measures, while their persuasive role enhances public risk awareness, leading to the evolving disaster preparedness. On the contrary, local spatial planning authorities have inadequate capability to self-organize and to integrate tsunami mitigation measures into their spatial planning, despite the rules of law and legislative platforms are available. As a result, there is no a land-use ordinance, incentive, or penalties to avoid the investment and development in tsunami-prone areas. This institutional incapability can be defined as a gap of disaster risk mitigation efforts between the national government and communities, acting proactive in disaster risk management.

Source: By author

7.2 Spatial planning for enhancing tsunami resilience

Turning rhetorical urban resilience into practice needs a definite scope and term of resilience. Urban resilience is, in general, a broad concept that is blurred and intangible if this term is used without the definite objectives and goals. For this study, the urban resilience focuses on the importance of integrating tsunami mitigation measures into spatial policy formulation and implementation through urban planning and relevant land use ordinances. This integration is, in short, named "spatial planning for tsunami resilience". The spatial planning for tsunami resilience addresses three crucial characteristics of resilient systems: 1) the stability and the transformability of physical infrastructure, 2) institutional capabilities to self-organize and to bounce back, and 3) social learning capabilities to crease adaptive measures for coping with risk. Addressing tsunami resilience by these three characteristics in spatial planning provides an alternative to frame problems, to respond to uncertainty of tsunami risk and vulnerability of urban fabrics.

In case of Kochi, the literature review on national policy formulation shows that the notions of disaster resilience and resilient development have gained considerable attention in recent decades. This attention is not only paid in relation to a short-term disaster recovery, but also covered in long-term spatial planning. The resilience issue is increasingly prevalent in national written policies and acts. The attention in this research is paid to the issue of how well local authorities consider the national norm in disaster resilience and adopts this to their local urban planning and spatial development policy, in order to deal with the tsunami. The research findings reveal that the notion of resilience in national legal documents does not successfully transfer to Kochi's local authorities even though they are responsible for spatial planning, in relation to the tsunami risk.

The research framework focuses on spatial planning and tsunami resilience by integrating disaster risk management into spatial and urban planning. Reflecting from this framework, cities can be referred as human settlements built by social systems. Based on J. Klabbers' suggestion, the social systems here consist of the interconnected components:

1. Social actors (agents) shaping a social organization
2. Rules of law, legislative procedures, protocols and norms
3. Built environment and other urban resources

The social actors and rules constitute the evolving social infrastructure and normative norms of the spatial development. Protocols are the written and the unwritten rules (guidelines or commitments) that are peculiar to every culture and organization. This peculiarity constructs different normative norms, leading to the direction of spatial development. When a tsunami hits such a social system, both social and physical infrastructures are damaged. The way to respond to and cope with the destructive natural perturbation depends, first of all, on the competent and resilient social infrastructure. It subsequently depends on the physical robustness of urban infrastructure and transformability of spaces. Based on this reflection, the study addresses four recommendations related to the innovative strategic spatial policy, the needs of technical assistance for local planners and developers, the financial incentives together with penalties for land use enforcement, and risk communications (techniques) along with outreach programs. By recommending those, the goal to enhance social learning for tsunami resilient community is likely to be achieved.

7.2.1 The needs of technical assistance for local planners and developers

Even through a concept of spatial resilience to disasters already exists in national policy background, the local planning authorities do not have adequate human resources to implement this concept by themselves. In addition, national guidelines on the spatial planning for tsunami resilience have not been provided by the central government, but by academic bodies. Obviously, the guidelines proposed by academic bodies are somehow inaccessible and incomprehensible to local authorities, and the local urban planning staffs. Hence, the technical assistance in resilient spatial planning is needed for enhancing the capability of local planners and developers.

The central government and academic institutions play an important role as a group of facilitators and trainers in educating local spatial planning authorities to accept the concept of spatial resilience to disaster, which can render local staffs capable of producing their own spatial planning and relevant disaster mitigation measures for disaster resilience. When the human capitals increase, the adaptability to self-organize is likely to improve dramatically. This adaptability to self-organize will expand the institutional learning capacity that leads to maximizing human resourcefulness. This resourcefulness contributes to a creation of innovative strategic spatial policy and disaster resilience planning in response to the local context. In sum, the technical assistance is essential for enabling urban transformability for disaster resilience.

7.2.2 The innovative strategic spatial policy

The knowledgeable local authorities involving in spatial planning are expected to formulate innovative strategic spatial policies, which address urban vulnerability as well as resilience. These policies may be adapted from the official guidelines and academic research. Nevertheless, it is necessary to keep in mind that these guidelines are not ready to implement. The local authorities have to consider the suitability of the guidelines for the local context. The essence of those guidelines should be taken into consideration, while some minor issues that are not applicable to local situation can be diminished or revised for producing a better strategic spatial policy.

According to the above statement, coping with disaster depends primarily on the institutional competency, and subsequently on the robustness of the physical infrastructure and the transformability of the existing spaces. The physical infrastructure and dual spaces that provide critical services (such as urban energy, medical services, etc.) shall be well managed in a way to keep those functioning after the tsunami. The continuity of providing essential services is, to some extent, determined by geographical location and consequently the robustness of physical infrastructure. Focusing on the need of spaces, people who live in tsunami-affected areas may temporarily be not able to go back and use their houses, because the houses might be collapsed, covered by debris, or ruined in the mud after the disastrous event. This situation forces tsunami victims to find another decent shelter that can accommodate them. The concept of dual spaces adopted from Paola Rizzi offer alternatives for public space by creating dual functions in response to the disaster cycle. The provision of dual spaces refers to a way in which spaces, severing for the specific purposes in a pre-disaster state, can shift to emergency spaces and tsunami-evacuation places for the victims. The good urban and architectural design of public spaces will determine the transformability of the spaces.

Apart from the design aspect, integrating disaster mitigation measure into spatial planning and land use management is equally necessary for enhancing urban resilience to tsunami. Decent spatial policies and land use ordinances along with the concern about disaster risk may prevent inappropriate urban development in disaster prone areas. Instead, those policies and ordinances can direct the urban development to more suitable areas where the provision of urban infrastructure is cost-effective. As a result, the innovative strategic spatial policy for tsunami resilience can lead to human settlement in tsunami-proved areas where disaster impacts can be mitigated. Thus, the transformability of spaces and the stability of physical infrastructure can facilitate the social systems (human settlements) to handle disaster risk.

7.2.3 The financial incentives and penalties for land use enforcement

The lesson learned by Phuket case study proves that residents and developers would not comply with the guidelines and even the rules, despite the guidelines and institutional capability to enforce exist. To ensure compliance, motivational incentives to exercise the guidelines and mechanisms to prevent undesirable behaviors should be emphasized. This includes reasonable incentives related to monetary and non-monetary measures. The financial incentives along with penalties can be regarded as tangible measures for the residents and the developers who usually consider the cost-benefit advantages. Those incentives and penalties are, for example:

- Calling for higher property taxes for the development in disaster prone areas
- Tax deductions, tax credits and subsidies for the relocation
- Individual development right transfer

(This common measure exists in Japan spatial systems for land readjustment projects, urban development plans, and conservation programs)

- Indirect taxes on disaster emergency facilities
- Payments for contribution to disaster mitigation measures by tsunami-protected areas
- Technological advances in architecture and design

The above measures could enhance self-reliance capability among individual of each tsunami prone area, while keeping incapable developers who cannot cope with tsunami risk out of the tsunami prone areas.

7.2.4 Risk communications (techniques) along with outreach programs

Public collaboration in implementing spatial policy can be conducted in many forms. The financial incentives along with penalties aim at preventing development projects in tsunami prone areas, while risk communication and outreach programs aim at cultivating risk perception and awareness that lead to individuals' disaster preparedness. The aim of risk communication is to build mutual commitments among stakeholders as well the expert-led technical cooperation. Risk mapping techniques, urban gaming simulation, community mind mapping can be used for enhancing participatory risk communication are: the use of risk mapping techniques, urban gaming simulation, community mind mapping What unites these forms is the quality of participatory risk communication, which reflects a model for spatial planning for tsunami resilience outlined at the end of Chapter 6.

- a deliberate attempt to involve stakeholders, with different interests, in articulating risk information and implementing spatial based disaster mitigation measures

- a recognition of communication techniques and their interpretation to risk and vulnerability, mutual understanding development, theoretical policies, and strategic plans in ways that enhance consensual agreements and commitments rather than exaggerate conflicts.

- a recognition of the established agreement

- an awareness of vulnerability and resilience in terms of social structures and physical infrastructure.

- an appreciation of the institutional capability to innovate social structures and physical infrastructure that result in spatial planning for tsunami resilience.

In this context, spatial planning gains its importance in building urban resilience. Comprehensive and collaborative strategy-marking increases the capability to adapt, react, and bounce back from the disaster through a set of social learning processes. These processes become an interactive process in which mutual strategies and ideas are articulated, whereas commitments, legislative practices, and supportive tools are invented to carry strategies forwards. Hence, the political legitimacy is required in order to encourage a participatory process in risk communication for spatial planning. The risk communication, interactions and dialogues lead to participants' understanding and feeling of ownership of the discussed issues and ideas. The latter improve the level of participation. This contributes to coordination and policy implementation. Despite the process of risk communication maybe costly and time consuming, but it is valuable for the public.

In this context, spatial planning gains its importance in building urban resilience. Comprehensive and collaborative strategy-marking increases the capability to adapt, react, and bounce back from the disaster through a set of social learning processes. These processes become an interactive process in which mutual strategies and ideas are articulated, whereas commitments, legislative practices, and supportive tools are invented to carry strategies forwards. Hence, the political legitimacy is required in order to encourage a participatory process in risk communication for spatial planning. Through the risk commutation, interactions and dialogues develop participants' understanding and ownership of the discussed issues and ideas. The latter improve the level of participation. This contributes to coordination and stability of policy implementation. Despite the process of risk communication has its own cost and time consumption, but even so, there are worthwhile for the public interest.

7.3 Further studies

Urban resilience to disasters is a board concept, covering a wide range of elements. In this research, the concept of spatial planning for tsunami resilience focuses mainly on the essence of social learning and self-organization, which constituting the evolving institutional resilience of spatial planning authorities. However, the urban resilience to disasters consists of both physical infrastructure and social structures. Therefore, the further study on urban resilience should investigate the robustness of physical infrastructure and the transformability of spaces, which can increase comprehensiveness of this research.

References

Agardy, T., Alder, J., Dayton, P., Curran, S., Kitchingman, A., Wilson, M., . . . Vorosmarry, C. (2005). Coastal System. In R. Hassan, R. Scholes, & N. Ash, *Ecosystems and Human Well-being: Current State and Trends* (Vol. 1, pp. 513-543). Washington, Washington, the United States: Island Press.

Allen, E. (2001). INDEX: Software for community indicators. In R. Brail, & R. Klosterman, *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools* (pp. 229-261). California: ESRI.

Armas, I., & Gavris, A. (2013). Social vulnerability assessment using spatial multi-criteria analysis (SEVI model) and the Social Vulnerability Index (SoVI model) - a case study for Bucharest, Romania. (A. Steinführer, Ed.) *Natural Hazards and Earth System Sciences*, 1481–1499. Retrieved from http://www.nat-hazards-earth-syst-sci.net/13/1481/2013/nhess-13-1481-2013.pdf

Armstong, W., & McGee, T. (1985). *Theatres of Accumulation: Studies in Asian and Latin American Urbanization* (Routledge Library Editions ed.). London: Methuen.

Bandura, A. (1969). Social-Learning Theory of Identificatory Processes. In A. G. David, *Handbook of Socialization Theory and Research* (pp. 213-262). Rand McNally & Company.

Bandura, A., & Walters, R. H. (1963). *Social learning and personality development.* New York: Holt, Rinehart and Winston.

BBC News. (2005, December 22). *BBC News*. Retrieved March 20, 2012, from http://news.bbc.co.uk/2/hi/4126019.stm

Bendimerad, F. (2008). *State of the Practice in Disaster Risk Management: Urban Risk. Earthquake Megacities Initiative.* Retrieved November 10, 2012, from PreventionWeb: http://www.preventionweb.net/english/hyogo/gar/background-papers/documents/Chap5/thematic-progress-reviews/urban-risk/EMI-Urban-DRM-Practice.doc

Berry, B. (1964). Cities as sytems within systems of cities. *Regional Science, 13*(1), 147-163.

Berry, P., Rounsevell, M., Harrison, P., & Audsley, E. (2006). Assessing the vulnerability of agricultural land use and species to climate change and the role of policy in facilitating adaptation. *Environmental science and Policy*(9), 189-204.

Birkmann, J. (2005). *Danger Need Not Spell Disaster - But How Vulnerable Are We?* Tokyo: United Nations University.

Birkmann, J. (2006). *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies.* Tokyo, Japan: United Nations University.

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

Bogunovich, D. (2009). From Planning sustainable cities to designing resilient urban regions. *Sustainable Development and Planning IV, 1*. doi:10.2495/SDP090091

Bohle, H.-G. (2001, February). *Vulnerability and criticality: Perspectives from social geography. International Human Dimensions Programme on Global Environmental Change (IHDP).* Retrieved from Managing the risks of extreme events and disasters to advance climate chance adatation (SREX): http://ipcc-wg2.gov/njlite_download.php?id=6390

Bramwell, B., & Rawding, L. (1996). Tourism marketing images of industrial cities. *Annals of Tourism Research, 23*(1), 201-221. Retrieved from http://www.sciencedirect.com/science/article/pii/0160738395000615

Buckler, B. (1996). A learning process model to achieve continuous improvement and innovation. *The Learning Organization, 3*(3), 31 - 39.

Cannon, T. (2008). *Reducing People's Vulnerability to Natural Hazarrds: Community and Resilience.* Retrieved from United nations University: http://www.wider.unu.edu/publications/working-papers/research-papers/2008/en_GB/rp2008-34/

Cannon, T., Twigg, J., & Rowell, J. (2005). *Social vulnerability, sustainable livelihoods and disasters, Report to DFID conflict and humanitarian assistance department (CHAD).* Retrieved March 15, 2013, from http://nirapad.org/admin/soft_archive/1308222298_Social%20Vulnerability-%20Sustainable%20Livelihoods%20and%20Disasters.pdf

Cardona, O. (2004). The Need for Rethinking the Concepts of Vulnerability and Risk from a Holistic Perspective: A Necessary Review and Criticism for Effective Risk Management. In G. Bankoff, G. Frerks, & D. Hilhorst, *Mapping Vulnerability: Disasters, Development and People* (p. Chapter 3). London: Earthscan.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *GlobalEnvironmentalChange*(18), 598–606. Retrieved April 03, 2012, from http://www.sciencedirect.com/science/article/pii/S0959378008000666

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change: Local evidence on vulnerabilities and adaptations to global environmental change, 18*(4), 598–606.

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

Dávila, S., Ayala, J. G., Salazar, F., & Ruiz-Vélez, R. (2014). A Conceptual Framework for Measuring the Exposure to Tsunamis of Puerto Rican Coastal Communities. *Proceedings of the 2014 Industrial and Systems Engineering Research Conference.*

Galderisi, A., Ceudech, A., Ferrara, F. F., & Profice, A. S. (2012). *Del. 2.2: Integration of different vulnerabilities vs. natural and na-tech hazards. ENSURE : Enhancing resilience of communities and territories facing natural and na-tech hazards.* Retrieved from http://www.ensureproject.eu/ENSURE_Del2.1.1.pdf

Holling, C. (1973, September). Resilience and stability of ecological systems. *Annual Review of Ecological System, 4: pp. 1-23*. Retrieved March 29, 2012, from http://www.iiasa.ac.at/Admin/PUB/Documents/RP-73-003.pdf

IPCC. (2007). *Impacts, Adaptation and Vulnerability.* IPCC 4th Assessment Report, IPCC Working Group-II. Retrieved March 25, 2010, from http://www.gtp89.dial.pipex.com/10.pdf

IPCC. (2007). *IPCC Fourth Assessment Report: Climate Change*. (Intergovernmental Panel on Climate Change) Retrieved March 10, 2012, from Intergovernmental Panel on Climate Change: http://www.ipcc.ch/publications_and_data/ar4/syr/en/annexessglossary-r-z.html

Klein, R., Nicholls, R., & Thomalla, F. (2003). Resilience to Natural Hazards: How Useful is this Concept? *Environmental Hazards, 5*, 35-45.

Kobayashi, Y., & Noda, T. (1987). *The Methods and Approaches Used in Development Planning in Japan.* UNESCO. Retrieved from http://unesdoc.unesco.org/images/0007/000721/072126EB.pdf

Kontar, Y., Santiago-Fandino, V., & Takahashi, T. (2014). *Tsunami Events and Lessons Learned: Environmental and Societal Significance.* Springer.

Kritiamphun, A. (2005, January 31). *Impacts of tusnami on Thai's economy (สศช.แจงผลกระทบ สึนามิกับเศรษฐกิจไทย)*. Retrieved March 21, 2012, from Institute of Asian Studies, Chulalongkorn University: http://www.thaiworld.org/th/include/answer_search.php?question_id=96

Lin, P. L. (1996). Urban Resilience: Energetic Principles and a System Ecology Approach. Retrieved from http://www.ntpu.edu.tw/ads/doc/96/6-1.pdf

Maclaren, V. (1996). Urban Sustainability Reporting. *Journal of the American Planning Association*(62), 184-203.

Maguire, B., & Cartwright, S. (2008). *Assessing a Community's Capacity to Manage Change: A Resilience Approach to Social Assessment.* Canberra: Commonwealth.

McGranahan, G., Balk, D., & Anders, B. (2007). The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization, 19(1)*, 17-37. doi:10.1177/0956247807076960

McGranahan, G., Marcotullio, P., Bai, X., Balk, D., Braga, T., Douglas, I., . . . Zlotnik, H. (2005). Urban Systems. In R. Hassan, R. Scholes, & N. Ash (Eds.), *Ecosystems and Human Well-being: Current State and Trends* (pp. 797-821). Washington, DC.: Island Press.

McGranahan, G., Marcotullio, P., Bai, X., Balk, D., Braga, T., Douglas, I., . . . Zlotnik, H. (2005). Urban Systems. In R. Hassan, R. Scholes, & N. Ash (Eds.), *Ecosystems and Human Well-being: Current State and Trends* (pp. 797-821). Washington, DC.: Island Press.

Mitchell, D. (2010, October). *educing Vulnerability to Natural Disasters in the Asia Pacific through Improved Land Administration and Management.* Retrieved April 14, 2012, from FIG: Federation Internationale des Geometres: http://www.fig.net/pub/monthly_articles/october_2010/october_2010_mitchell.html

Morrow, B. (2011). *Risk behavior and risk communication: Synthesis and expert interviews.* Silver Spring: the Food and Drug Administration (FDA).

National Oceanic and Atmospheric Administration. (2013). *Tsunami definition*. Retrieved May 9, 2014, from The National Tsunami Hazard: http://nthmphistory.

Ng, K., & Hamby, D. (1997). Fundamentals for establishing a risk communication program. *Health Physics*(73), 473-482.

Pelling, M. (2003). *The vulenrability of cities: Natural disasters and social resilience.* London: Earthscan Publications.

Phillips, R. (2003). *Community Indicators.* American Planning Association. APA Planning Advisory Service.

Saaty, T. L. (1980). *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation.* (McGraw-Hill, Ed.) The.

Sapountzaki, K., & Dandoulaki, M. (2006). Resilience to Risks: the hidden defense against the limitation of planning. *International Disaster Reduction Conference.* Davos, Switzerland.

Scawthorn, C., & Yanev, P. (1995). Preliminary report 17 January 1995, Hyogo-ken nambu, Japanese earthquake. *Engineering Structures, 17*(3), 146-157.

Schneiderbauer, S., & Ehrlich, D. (2004). *Risk, Hazard and People's Vulnerability to Natural Hazards: a Review of Definitions, Concepts and Data.* Brussels: Office for Official Publication of the European Communities.

SEPA. (2012, July). *Land Use Vulnerability Guidance.* Retrieved from Scottish Environmet Protection Agency: http://www.sepa.org.uk/planning/flood_risk/idoc.ashx?docid=c1d04be4-eec0-4275-b7af-bcd680e80a95&version=-1

Shaw, R., & IEDM Team. (2009, June). Climate Disaster Resilience: Focus on Coastal Urban Cities in Asia. *the Asian Journal of Environment and Disaster Management, 1*.

Song, Y., & Knaap, G.-J. (2004). Measuring Urban Form: Is Portland Winning the War on Sprawl? *Journal of the American Planning Association*, 210-225.

Srinivas, H. (2006). Retrieved from Japan: Overview of Planning: http://www.gdrc.org/uem/observatory/jp-overview.html

Thai Red Cross. (2005, January 25). *Registration for misssing persons from Tsunami in Thailand*. Retrieved March 20, 2012, from the Thai Red Cross, Phuket Province: http://www.missingperson.or.th/index.en.html

Twigg, J. (2007, August). Characteristics of a Disaster-resilient Community: A Guidance Note . *Version 1 (for field testing)*. Retrieved from http://www.childreninachangingclimate.org/database/other/Publications/Twigg_CharacteristicsOfADisasterResilientCommunity_2007.pdf

Twigg, J. (2009, November). Characteristics of a Disaster-resilient Community: A Guidance Note. *2*. Retrieved March 28, 2012, from www.abuhrc.org/research/dsm/Pages/project_view.aspx?project=13

UN/ISDR. (2009). *Terminology*. Retrieved from UNISDR: http://www.unisdr.org/we/inform/terminology

UNISDR. (2007, August 30). *Terminology*. (United Nations International Strategy for Disaster Reduction) Retrieved March 15, 2012, from United Nations International Strategy for Disaster Reduction: http://www.unisdr.org/we/inform/terminology

UNISDR: United Nations Office for Disaster Risk Reduction. (2007). *Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters.* ISRD: International Strategy for Disaster Reduction. Retrieved from http://www.unisdr.org/files/1037_hyogoframeworkforactionenglish.pdf

USAID : the United States Agency for International Development. (2007). *How Resilient Is Your Coastal Community?: A Guide for Evaluating Coastal Community Resilience to Tsunamis* *and Other Hazards.* Retrieved March 2012, 5, from http://www.meted.ucar.edu/communities/hazwarnsys/ccrg/CCR_All_lowres.pdf

Van De Leeuw, S. E., & Aschan-Leygonie. (2000). A long-term perspective on resilience in socio-natural systems. In H. Liljenström, & U. Svedin, *Micro, Meso, Macro: Addressing Complex Systems Couplings* (pp. 227-264). Singapore: World Scientific Publishing.

Vogel, C., & O'Brien, K. (2004, March 13). Vulnerbility and Global ENvironmental Chang: Rhetoric and Reality. *AVISO 13*.

W. Neil, A. (2006). Vulnerability. *Global Environmental Change, 16*(3), 268-281. Retrieved March 17, 2012, from Governance and Social Development Resource Centre: http://www.gsdrc.org/go/display&type=Document&id=3922

World economic forum. (2008). *Building resilience to natural disasters: A framework for private sector engagement.* Geneva: World Economic Forum.

World Health Organization: WHO. (2012, November 13). *Definitions of risk analysis terms related to food safety*. Retrieved from World Health Organization: http://www.who.int/foodsafety/publications/micro/riskanalysis_definitions/en/

World Tourism Organization. (2005). *Tsunami: One Year On - A Summary of the Implementation of the Phuket Action Plan.* Madrid, Spain: World Tourism Organization. Retrieved April 2012, from http://www.preventionweb.net/files/2202_VL323152.pdf

Wyly, E. (2012). Theories of Urban System Development. *Introduction to Urban Geography*.

Yarnal, B. (2014). *Geography 438w: Human Dimensions of Global Warming*. Retrieved May 7, 2014, from Department of Geography, College of Earth and Mineral Sciences, The Pennsylvania State University: https://www.e-education.psu.edu/geog438w/node/327

Appendix 1: AHP weighting technique

		No. respondents																				SUM	Weighting score (Max= 1)	Final weighting scores
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20			
Building density	Residential building	0.515	0.295	0.438	0.479	0.518	0.39	0.174	0.471	0.061	0.068	0.069	0.093	0.473	0.063	0.443	0.074	0.081	0.228	0.214	0.226	5.373	0.269	0.0224
	Commercial building	0.138	0.108	0.081	0.087	0.104	0.078	0.164	0.082	0.224	0.285	0.263	0.258	0.097	0.283	0.051	0.304	0.31	0.105	0.092	0.062	3.176	0.159	0.0132
	Mixed-use building	0.071	0.108	0.349	0.106	0.191	0.351	0.059	0.23	0.135	0.141	0.153	0.152	0.266	0.148	0.339	0.104	0.09	0.228	0.22	0.184	3.625	0.181	0.0151
	Agricultural building	0.028	0.039	0.034	0.04	0.052	0.042	0.036	0.048	0.026	0.041	0.042	0.038	0.031	0.031	0.03	0.047	0.038	0.025	0.031	0.032	0.731	0.037	0.0030
	Industrial building	0.248	0.449	0.098	0.288	0.134	0.139	0.563	0.169	0.554	0.465	0.474	0.458	0.133	0.476	0.137	0.471	0.482	0.413	0.443	0.497	7.091	0.355	0.0295
	CM	0.049	0.034	0	0.084	0.096	0.096	0.056	0.076	0	0.084	0.096	0.07	0.076	0	0.062	0.087	0.049	0.026	0.087	0.043			
Demography	Age	0.701	0.648	0.455	0.784	0.742	0.742	0.435	0.751	0.714	0.097	0.742	0.655	0.751	0.778	0.769	0.659	0.701	0.682	0.705	0.779	13.29	0.664	0.1106
	Gender (percent of female)	0.106	0.122	0.091	0.081	0.075	0.183	0.078	0.178	0.143	0.57	0.183	0.095	0.07	0.111	0.084	0.079	0.106	0.103	0.084	0.079	2.621	0.131	0.0218
	Household size	0.193	0.23	0.455	0.135	0.183	0.075	0.487	0.07	0.143	0.333	0.075	0.25	0.178	0.111	0.147	0.263	0.193	0.216	0.211	0.143	4.091	0.205	0.0341
	CM	0.278	0.076	0.268	0.17	0.282	0.15	0.183	0.198	0.264	0.133	0.103	0.188	0.192	0.191	0.199	0.17	0.123	0.186	0.157	0.161			
Age	Proportion of active population	0.069	0.078	0.111	0.091	0.067	0.077	0.143	0.067	0.177	0.742	0.073	0.061	0.078	0.095	0.103	0.084	0.07	0.084	0.073	0.075	2.418	0.121	0.0201
	Proportion of the elderly	0.582	0.435	0.778	0.528	0.715	0.615	0.429	0.715	0.614	0.183	0.671	0.606	0.717	0.655	0.682	0.705	0.751	0.705	0.727	0.592	12.405	0.618	0.1030
	Proportion of children	0.348	0.487	0.111	0.381	0.218	0.308	0.429	0.218	0.268	0.075	0.256	0.333	0.205	0.25	0.216	0.211	0.178	0.211	0.2	0.333	5.236	0.261	0.0435
	CM	0.085	0.056	0	0.168	0.196	0	0	0.196	0.152	0.096	0.063	0.043	0.063	0.07	0.026	0.087	0.076	0.087	0.044	0.058			

Note: CM = Consistency measure

Appendix 2: Vulnerability scores by sub-districts

No.	Sub districts (Administrative names)	ID (Admin BLDG)	Area (km.2)	Urban Vulnerability		Hazard Potential (Tsunami)		Tsunami Risk Level
				Scores (Max=1)	Levels (3 lev.)	Scores	Levels (3 lev.)	
1	Aioicho	12405	0.0657	0.3197	2	3	2	2
2	Akaishicho	11204	0.0549	0.3689	2	0	1	1
3	Akebonocho 1 Chome	11404	0.0302	0.3377	2	0	1	1
4	Akebonocho 2 Chome	12705	0.1017	0.2727	2	0	1	1
5	Aoyagicho	12502	0.1978	0.3405	2	2	2	2
6	Asahiekimaecho	12502	0.1423	0.3408	2	4	3	2
7	Asahikamimachi	10702	0.0928	0.3607	2	4	3	2
8	Asahimachi 1 Chome	10203	0.0733	0.3574	2	2	2	2
9	Asahimachi 2 Chome	11607	0.1843	0.3384	2	3	2	2
10	Asahimachi 3 Chome	12401	0.1062	0.2915	2	3	2	2
11	Asahitenjincho	13202	0.0592	0.1359	1	1	1	1
12	Asakura Nishimachi 2 Chome	12501	0.1407	0.3059	2	1	1	1
13	Asakurabo	13203	0.0875	0.3166	2	1	1	1
14	Asakurahei	12707	0.6677	0.3148	2	0	1	1
15	Asakurahigashimachi	12802	0.1988	0.3414	2	0	1	1
16	Asakurahonmachi 1 Chome	11801	0.1128	0.2716	2	3	2	2
17	Asakurahonmachi 2 Chome	10905	0.0610	0.3540	2	3	2	2
18	Asakuraki	11802	0.1707	0.2828	2	3	2	2
19	Asakurakou	11601	0.0915	0.3847	3	3	2	2
20	Asakuraminamimachi	12405	0.0777	0.3067	2	3	2	2
21	Asakuranishimachi 1 Chome	11206	0.0734	0.3653	2	2	2	2
22	Asakuraotsu	10702	0.0805	0.3671	2	4	3	2
23	Asakuratei	12102	0.4320	0.2837	2	0	1	1
24	Asakurayokomachi	12902	0.1097	0.3517	2	0	1	1
25	Asounonakamachi	12501	0.1506	0.3093	2	3	2	2
26	Atagomachi 1 Chome	11602	0.0737	0.3691	2	3	2	2
27	Atagomachi 2 Chome	13602	4.7200	0.3580	2	4	3	2
28	Atagomachi 3 Chome	11102	0.0639	0.3639	2	2	2	2
29	Atagomachi 4 Chome	10303	0.0445	0.3792	2	3	2	2
30	Atagoyama	11204	0.0668	0.3751	2	1	1	1
31	Atagoyamaminamimachi	13304	0.1515	0.2830	2	4	3	2
32	Azonokitamachi 1 chome	11805	0.4951	0.3314	2	3	2	2
33	Azonokitamachi 2 Chome	11701	0.1131	0.3090	2	4	3	2
34	Azonominamimachi	13202	0.1062	0.2308	2	2	2	2
35	Azouno	12502	2.0239	0.3359	2	0	1	1
36	Azounohigashimachi	12501	0.2154	0.2632	2	4	3	2
37	Azounokitamachi 3 Chome	12301	0.3276	0.2836	2	1	1	1
38	Azounokitamachi 4 Chome	12501	0.2348	0.3341	2	1	1	1
39	Azounonishimachi 1 Chome	12601	0.0710	0.3621	2	2	2	2
40	Azounonishimachi 2 Chome	10603	0.0783	0.3899	3	4	3	3

No.	Sub districts (Administrative names)	ID (Admin BLDG)	Area (km.2)	Urban Vulnerability		Hazard Potential (Tsunami)		Tsunami Risk Level
				Scores (Max=1)	Levels (3 lev.)	Scores	Levels (3 lev.)	
41	Azounonishimachi 3 Chome	11601	0.0583	0.3845	3	3	2	2
42	Chiyoricho 1 Chome	12610	0.1618	0.3822	2	0	1	1
43	Chiyoricho 2 Chome	10201	0.0431	0.4355	3	2	2	2
44	Chiyoricho 3 Chome	11806	0.1203	0.3358	2	3	2	2
45	Daizencho	11404	0.0394	0.3500	2	0	1	1
46	Doimachi	10202	0.0586	0.4396	3	3	2	2
47	Ebinomaru	13305	0.1649	0.2423	2	4	3	2
48	Echizenmachi 1 Chome	11103	0.0863	0.3541	2	2	2	2
49	Echizenmachi 2 Chome	11002	0.1010	0.3962	3	3	2	2
50	Eikokujicho	11906	0.2030	0.3418	2	0	1	1
51	Ekimaecho	10103	0.0793	0.4106	3	1	1	1
52	Engyoji	12301	0.2781	0.2993	2	1	1	1
53	Fudaba	14202	0.1923	0.3034	2	2	2	2
54	Fukadanicho	12007	0.7202	0.3729	2	1	1	1
55	Fukuichou	13204	0.1504	0.2955	2	1	1	1
56	Fukuihigashimachi	12501	0.0853	0.2856	2	0	1	1
57	Fukuiogimachi	13801	0.3949	0.2047	1	0	1	1
58	Futabacho	12301	5.3188	0.2773	2	5	3	2
59	Gounosechou	13403	0.1069	0.3267	2	0	1	1
60	Gyukou	12006	0.4971	0.3318	2	3	2	2
61	Gyukou/Godaisan	12605	1.2296	0.3333	2	0	1	1
62	Hadaminamimachi 1 Chome	11302	0.1760	0.3818	2	2	2	2
63	Hadaminamimachi 2 Chome	11401	0.0425	0.3801	2	0	1	1
64	Hagimachi 1 Chome	12805	0.1442	0.2615	2	0	1	1
65	Hagimachi 2 Chome	12405	0.0857	0.2972	2	3	2	2
66	Haramihigashimachi	12501	0.5851	0.2635	2	4	3	2
67	Haraminishimachi	11605	0.1703	0.3787	2	2	2	2
68	Harigihigashimachi	10801	0.0759	0.5070	3	3	2	2
69	Harigihonmachi	13401	0.1207	0.3218	2	0	1	1
70	Harigikita 1 Chome	14201	0.6194	0.2538	2	1	1	1
71	Harigikita 2 Chome	13201	0.8216	0.2596	2	3	2	2
72	Harigiminami	13902	0.5887	0.2631	2	0	1	1
73	Hariginishi	13902	1.0456	0.2579	2	0	1	1
74	Harimayacho 1 Chome	12706	0.2025	0.2625	2	1	1	1
75	Harimayacho 2 Chome	12701	0.0771	0.3360	2	1	1	1
76	Harimayacho 3 Chome	12801	2.6617	0.2640	2	0	1	1
77	Hattanchou 1 Chome	10709	0.0796	0.3892	3	3	2	2
78	Hattanchou 2 Chome	11404	0.0665	0.3402	2	0	1	1
79	Heiwacho	13302	0.0943	0.2750	2	4	3	2
80	Higashiishitatecho	13205	0.1253	0.2179	1	0	1	1
81	Higashijinzenji	12301	0.2955	0.2791	2	1	1	1
82	Higashijouyamacho	13205	0.1604	0.1856	1	0	1	1

No.	Sub districts (Administrative names)	ID (Admin BLDG)	Area (km.2)	Urban Vulnerability		Hazard Potential (Tsunami)		Tsunami Risk Level
				Scores (Max=1)	Levels (3 lev.)	Scores	Levels (3 lev.)	
83	Higashikuma	10706	0.1882	0.2529	2	4	3	2
84	Hiji	11909	1.2247	0.1849	1	0	1	1
85	Hijimacho 1 Chome	11405	0.0875	0.3661	2	0	1	1
86	Hijimacho 2 Chome	10201	0.0390	0.4267	3	3	2	2
87	Hijimacho 3 Chome	13903	0.1344	0.2345	2	0	1	1
88	Hijimacho 4 Chome	10705	0.0493	0.3335	2	4	3	2
89	Hinodechou	12705	3.8234	0.2055	1	0	1	1
90	Hitotsubancho 1 Chome	12709	0.1454	0.3591	2	1	1	1
91	Hitotsubancho 2 Chome	12901	0.0863	0.3042	2	0	1	1
92	Hitsuzancho	12301	2.9754	0.2780	2	5	3	2
93	Hoei-cho	10903	0.1077	0.3806	2	3	2	2
94	Honchosuji	11609	0.0960	0.3545	2	3	2	2
95	Honguucho	12502	0.1668	0.3244	2	3	2	2
96	Honmachi 1 Chome	11103	0.0720	0.3617	2	2	2	2
97	Honmachi 2 Chome	10304	0.0498	0.3791	2	3	2	2
98	Honmachi 3 Chome	13301	0.1656	0.2401	2	4	3	2
99	Honmachi 4 Chome	10202	0.0594	0.4462	3	3	2	2
100	Honmachi 5 Chome	11702	0.0945	0.3529	2	4	3	2
101	Horagashimacho	13801	0.1873	0.2639	2	0	1	1
102	Hyakkokucho 1 Chome	11405	0.0286	0.3563	2	0	1	1
103	Hyakkokucho 2 Chome	10901	0.0362	0.3279	2	3	2	2
104	Hyakkokucho 3 Chome	10402	0.1061	0.3731	2	2	2	2
105	Hyakkokucho 4 Chome	10402	0.0030	0.3056	2	0	1	1
106	Iguchicho	10101	0.0674	0.4463	3	2	2	2
107	Ike	12502	0.2134	0.3342	2	0	1	1
108	Ikku	12501	3.2226	0.2646	2	0	1	1
109	Ikkuhigashimachi 1 Chome	11804	0.2242	0.3398	2	3	2	2
110	Ikkuhigashimachi 2 Chome	13202	0.1490	0.2250	1	2	2	1
111	Ikkuhigashimachi 3 Chome	10903	0.1126	0.3574	2	3	2	2
112	Ikkuhigashimachi 4 Chome	12901	0.1833	0.3028	2	0	1	1
113	Ikkuhigashimachi 5 Chome	10707	0.1444	0.3589	2	4	3	2
114	Ikkuminamimachi 1 Chome	10402	0.0925	0.3687	2	2	2	2
115	Ikkuminamimachi 2 Chome	12008	0.2548	0.3714	2	0	1	1
116	Ikkunakamachi 1 Chome	11205	0.0495	0.3626	2	1	1	1
117	Ikkunakamachi 2 Chome	12402	0.1352	0.3218	2	3	2	2
118	Ikkunakamachi 3 Chome	11203	0.0514	0.3234	2	0	1	1
119	Ikkunishimachi 1 Chome	13202	0.1584	0.2242	1	1	1	1
120	Ikkunishimachi 2 Chome	14203	0.2320	0.1682	1	0	1	1
121	Ikkunishimachi 3 Chome	14203	0.1530	0.1728	1	0	1	1
122	Ikkunishimachi 4 Chome	14203	0.1307	0.1677	1	0	1	1
123	Ikkushinane 1 Chome	13101	0.1233	0.2556	2	0	1	1
124	Ikkushinane 2 Chome	13902	0.1772	0.2624	2	0	1	1

No.	Sub districts (Administrative names)	ID (Admin BLDG)	Area (km.2)	Urban Vulnerability		Hazard Potential (Tsunami)		Tsunami Risk Level
				Scores (Max=1)	Levels (3 lev.)	Scores	Levels (3 lev.)	
125	Ikkutokudani	12501	0.2150	0.2867	2	0	1	1
126	Inaricho	10905	0.1660	0.3460	2	3	2	2
127	Iriakecho	10304	0.0537	0.4409	3	3	2	2
128	Isezakicho	12606	0.0821	0.3692	2	2	2	2
129	Ishitatecho	11702	0.0997	0.3333	2	4	3	2
130	Iwagabuchi	12401	0.3772	0.2306	2	4	3	2
131	Izumicho	12405	0.0567	0.2823	2	3	2	2
132	Johokucho	13904	2.3346	0.1744	1	0	1	1
133	Jouyamacho	11601	0.1114	0.3752	2	3	2	2
134	Kagamigawacho	11805	0.2656	0.2766	2	3	2	2
135	Kaganoi 1 Chome	12710	0.0663	0.3589	2	2	2	2
136	Kaganoi 2 Chome	13204	0.1308	0.3058	2	1	1	1
137	Kamihonguchо 4 Chome	13201	0.2735	0.2918	2	2	2	2
138	Kamimachi 1 Chome	13101	7.5558	0.2967	2	5	3	2
139	Kamimachi 2 Chome	11405	0.0364	0.3674	2	0	1	1
140	Kamimachi 3 Chome	10102	0.0585	0.4612	3	2	2	2
141	Kamimachi 4 Chome	10201	0.0436	0.4352	3	3	2	2
142	Kamimachi 5 Chome	13902	0.2335	0.2745	2	0	1	1
143	Kamobe	13203	0.0611	0.3035	2	1	1	1
144	Kamobe 1 Chome	12602	0.1347	0.3363	2	0	1	1
145	Kamobe 2 chome	11803	0.1975	0.3647	2	3	2	2
146	Kamobe 3 Chome	11402	0.0883	0.3307	2	0	1	1
147	Kamobe Kamimachi	12501	0.0881	0.2231	1	0	1	1
148	Kamobetakamachi	13302	0.1096	0.2697	2	3	2	2
149	Kera	10804	0.1071	0.3373	2	3	2	2
150	Kerahei	13902	0.5153	0.2627	2	0	1	1
151	Kerakou	14001	1.1700	0.3259	2	5	3	2
152	Keraotsu	12501	0.1559	0.3053	2	0	1	1
153	Kitagoza	12404	0.1263	0.2470	2	3	2	2
154	Kitahatacho	13203	0.1078	0.3098	2	1	1	1
155	Kitahattanchou	12401	0.0820	0.3481	2	4	3	2
156	Kitahonmachi 1 Chome	11001	0.0450	0.3819	2	3	2	2
157	Kitahonmachi 2 Chome	12612	0.2316	0.3411	2	3	2	2
158	Kitahonmachi 3 Chome	13903	0.1341	0.2407	2	0	1	1
159	Kitahonmachi 4 Chome	14101	1.4317	0.2817	2	0	1	1
160	Kitajinzenji	13601	0.5498	0.3748	2	4	3	2
161	Kitakanada	13308	0.1953	0.2705	2	4	3	2
162	Kitakawazoe	10708	0.2016	0.3557	2	4	3	2
163	Kitakubo	12501	0.1639	0.3147	2	0	1	1
164	Kitanakayama	13602	0.5103	0.3378	2	4	3	2
165	Kitashintacho	10901	0.0856	0.3628	2	3	2	2
166	Kitatakamicho	12403	0.1553	0.3220	2	4	3	2

No.	Sub districts (Administrative names)	ID (Admin BLDG)	Area (km.2)	Urban Vulnerability		Hazard Potential (Tsunami)		Tsunami Risk Level
				Scores (Max=1)	Levels (3 lev.)	Scores	Levels (3 lev.)	
167	Kitatakeshimacho	11001	0.0305	0.3852	3	2	2	2
168	Koda	13903	0.1464	0.2535	2	0	1	1
169	Koichigikyo	12502	0.1503	0.3192	2	1	1	1
170	Kokadai	13101	0.1286	0.2650	2	0	1	1
171	Kotobukichou	12201	1.1988	0.2753	2	5	3	2
172	Kouyouchou	12708	0.2928	0.3630	2	0	1	1
173	Kozaki	13903	0.6856	0.2060	1	0	1	1
174	Kuchihosoyama	11907	0.1588	0.3273	2	0	1	1
175	Kutanda	12901	0.2076	0.2940	2	0	1	1
176	Maezato	12502	0.1864	0.3399	2	3	2	2
177	Makiyamachou	12803	0.1710	0.3014	2	0	1	1
178	Mama	12502	0.2156	0.3279	2	3	2	2
179	Maruikecho	11403	0.1019	0.3467	2	0	1	1
180	Marunouchi 1 Chome	11608	0.1415	0.3213	2	3	2	2
181	Marunouchi 2 Chome	12901	0.2924	0.3493	2	0	1	1
182	Masugata	12611	0.0845	0.3693	2	3	2	2
183	Mimase	13902	0.8126	0.2784	2	0	1	1
184	Minamigosa	12701	0.0792	0.3324	2	2	2	2
185	Minamigounosecho	13307	0.2050	0.1884	1	4	3	1
186	Minamiharimayacho 1 Chome	12806	0.1551	0.2880	2	0	1	1
187	Minamiharimayacho 2 Chome	13001	5.8324	0.2611	2	0	1	1
188	Minamihoeicho	11202	0.0918	0.3613	2	1	1	1
189	Minamikanada	12612	0.0916	0.3766	2	3	2	2
190	Minamikawazoe	11207	0.1298	0.3550	2	2	2	2
191	Minamikubo	11801	0.1128	0.2787	2	4	3	2
192	Minamikuma	13903	0.1130	0.1560	1	0	1	1
193	Minamimama	10303	0.0581	0.3837	3	3	2	2
194	Minamimotomachi	10203	0.0944	0.3807	2	3	2	2
195	Minaminakayama	12008	0.3971	0.2853	2	0	1	1
196	Minaminomarucho	10602	0.0712	0.4264	3	3	2	2
197	Minamishintacho	13205	0.0896	0.1828	1	0	1	1
198	Minamitakeshimachou	11205	0.0481	0.3866	3	1	1	1
199	Misonocho	12702	0.0979	0.3599	2	2	2	2
200	Mitani	12605	1.2879	0.3306	2	0	1	1
201	Miyamaecho	12501	0.1066	0.2963	2	3	2	2
202	Mizuki 1 Chome	12710	0.0882	0.3503	2	1	1	1
203	Mizuki 2 Chome	13303	0.1340	0.2589	2	4	3	2
204	Mizuki 3 Chome	12703	0.1542	0.3595	2	0	1	1
205	Mizukiyama	0	0.2670	0.0833	1	0	1	1
206	Motomachi	10302	0.1364	0.5183	3	4	3	3
207	Nagahama	12003	0.2550	0.3465	2	2	2	2
208	Nagahamamakiedai 1 chome	12004	0.2312	0.3395	2	3	2	2

No.	Sub districts (Administrative names)	ID (Admin BLDG)	Area (km.2)	Urban Vulnerability		Hazard Potential (Tsunami)		Tsunami Risk Level
				Scores (Max=1)	Levels (3 lev.)	Scores	Levels (3 lev.)	
209	Nagahamamakiedai 2 chome	10704	0.1750	0.3649	2	4	3	2
210	Nagaoyamacho	11501	0.2066	0.3393	2	0	1	1
211	Nakahoeicho	13301	0.1178	0.2559	2	4	3	2
212	Nakajinzenji	12608	1.3352	0.3543	2	0	1	1
213	Nakakuma	11908	0.2983	0.2805	2	0	1	1
214	Nakamama	11101	0.0757	0.3808	2	2	2	2
215	Nakanoshima	11502	0.2739	0.3373	2	0	1	1
216	Nakasuido	11101	0.0595	0.3816	2	3	2	2
217	Nakasukacho	11001	0.0516	0.3645	2	2	2	2
218	Nakatacho	12103	0.2479	0.2483	2	1	1	1
219	Nawatechou	13303	0.1456	0.2814	2	4	3	2
220	Niida	12701	0.0254	0.3204	2	1	1	1
221	Niida (Tobishi)	12301	0.7926	0.2987	2	3	2	2
222	Nijudaimachi	10705	0.0487	0.3718	2	4	3	2
223	Ninjinzenji	12501	0.3425	0.2770	2	4	3	2
224	Ninshikanohara	12502	0.1092	0.3438	2	3	2	2
225	Nishikuma	12105	0.2483	0.2389	2	0	1	1
226	Nishimachi	11401	0.0563	0.3663	2	2	2	2
227	Nouninmachi	11603	0.0960	0.3568	2	3	2	2
228	Nunoshida	13102	0.3825	0.3504	2	5	3	2
229	Obiyamachi 1 Chome	10602	0.0755	0.4433	3	3	2	2
230	Obiyamachi 2 Chome	12604	0.9264	0.3475	2	1	1	1
231	Oguracho	12104	0.1630	0.2676	2	0	1	1
232	Oharacho	12901	0.3985	0.3316	2	0	1	1
233	Okawasuji 1 Chome	10401	0.1092	0.3588	2	2	2	2
234	Okawasuji 2 Chome	10501	0.0738	0.3791	2	2	2	2
235	Ootsu Otsu	12502	0.1632	0.3339	2	2	2	2
236	Ootsukou	12705	0.5054	0.2796	2	0	1	1
237	Otani	13205	0.1899	0.1806	1	0	1	1
238	Otanikouenchou	12401	0.0864	0.3102	2	3	2	2
239	Otesuji 1 Chome	10303	0.0430	0.3794	2	3	2	2
240	Otesuji 2 Chome	10304	0.0603	0.3872	3	3	2	2
241	Ozucho	12401	0.1625	0.3138	2	4	3	2
242	Rendai	13402	2.1842	0.2866	2	0	1	1
243	Rokusenjicho	12502	0.1087	0.3480	2	3	2	2
244	Saenba-cho	11904	0.1824	0.2329	2	0	1	1
245	Sagamicho	12401	0.1869	0.3163	2	3	2	2
246	Saiwaicho	10303	0.0342	0.3748	2	3	2	2
247	Sakaedacho 1 Chome	10703	0.1515	0.3469	2	4	3	2
248	Sakaedacho 2 Chome	13801	0.1116	0.2001	1	0	1	1
249	Sakaedacho 3 Chome	11206	0.0943	0.3636	2	1	1	1
250	Sakaimachi	11205	0.0490	0.3748	2	2	2	2

No.	Sub districts (Administrative names)	ID (Admin BLDG)	Area (km.2)	Urban Vulnerability		Hazard Potential (Tsunami)		Tsunami Risk Level
				Scores (Max=1)	Levels (3 lev.)	Scores	Levels (3 lev.)	
251	Sakurababa	10801	0.0305	0.3854	3	3	2	2
252	Sakuraicho 1 Chome	11301	0.1728	0.3080	2	0	1	1
253	Sakuraicho 2 Chome	10602	0.0877	0.4307	3	3	2	2
254	Sanbashidoori 1 Chome	13402	2.4197	0.3274	2	0	1	1
255	Sanbashidoori 2 Chome	12501	0.1524	0.2791	2	0	1	1
256	Sanbashidoori 3 Chome	11002	0.0488	0.3808	2	3	2	2
257	Sanbashidoori 4 Chome	10801	0.0472	0.3776	2	3	2	2
258	Sanbashidoori 5 Chome	12603	0.1803	0.3573	2	1	1	1
259	Sanbashidoori 6 Chome	10301	0.1926	0.3419	2	3	2	2
260	Sannomaru	11502	0.2704	0.2749	2	0	1	1
261	Sasakicho	13202	0.0064	0.0732	1	0	1	1
262	Seto	12704	0.2027	0.3272	2	1	1	1
263	Seto 1 Chome	11102	0.0808	0.3505	2	2	2	2
264	Seto 2 Chome	11703	0.1318	0.2776	2	4	3	2
265	Seto Higashimachi 1 Chome	11406	0.0903	0.3736	2	0	1	1
266	Seto Higashimachi 2 Chome	10901	0.0281	0.2104	1	3	2	1
267	Seto Higashimachi 3 Chome	10902	0.1033	0.3688	2	3	2	2
268	Seto Minamimachi 1 Chome	13101	0.1389	0.2812	2	1	1	1
269	Seto Minamimachi 2 Chome	10101	0.1186	0.3676	2	1	1	1
270	Seto Nishimachi 1 Chome	12607	0.2590	0.3424	2	1	1	1
271	Seto Nishimachi 2 Chome	10904	0.0676	0.3445	2	3	2	2
272	Seto Nishimachi 3 Chome	12610	0.0879	0.3870	3	0	1	1
273	Shibamachi	12705	1.4631	0.2621	2	0	1	1
274	Shimojimachou	10102	0.0636	0.5352	3	2	2	2
275	Shinhonmachi 1 Chome	11001	0.0289	0.3728	2	2	2	2
276	Shinhonmachi 2 Chome	10402	0.0571	0.3807	2	2	2	2
277	Shinonomechou	10601	0.1045	0.3943	3	3	2	2
278	Shintacho	13306	0.1856	0.2145	1	4	3	1
279	Shinyashiki 1 Choume	10802	0.1227	0.3054	2	3	2	2
280	Shinyashiki 2 Choume	11403	0.0545	0.3766	2	0	1	1
281	Shiomidai 1 Chome	11203	0.0353	0.3327	2	0	1	1
282	Shiomidai 2 Chome	10904	0.0956	0.3351	2	3	2	2
283	Shiomidai 3 Chome	13903	0.1720	0.2487	2	0	1	1
284	Shiotacho	12501	0.1291	0.2821	2	0	1	1
285	Shioyazakimachi 1 Chome	12001	0.1597	0.3716	2	3	2	2
286	Shioyazakimachi 2 Chome	12401	0.1259	0.3328	2	3	2	2
287	Shiromicho	13701	4.6636	0.2428	2	4	3	2
288	Showamachi	11201	0.0918	0.3902	3	0	1	1
289	Souanji	12801	2.2945	0.2701	2	0	1	1
290	Sugiiru	10402	0.0066	0.2869	2	0	1	1
291	Suidocho	12002	0.1994	0.3343	2	3	2	2
292	Suigencho	12301	0.0979	0.3024	2	2	2	2

No.	Sub districts (Administrative names)	ID (Admin BLDG)	Area (km.2)	Urban Vulnerability		Hazard Potential (Tsunami)		Tsunami Risk Level
				Scores (Max=1)	Levels (3 lev.)	Scores	Levels (3 lev.)	
293	Takajomachi 1 Chome	10601	0.0949	0.3717	2	3	2	2
294	Takajomachi 2 Chome	11304	0.1707	0.2979	2	0	1	1
295	Takamicho	12501	0.1376	0.2973	2	1	1	1
296	Takaramachi	10705	0.0600	0.3580	2	4	3	2
297	Takasone	11905	0.1593	0.3191	2	0	1	1
298	Takasu	13201	3.2665	0.3023	2	3	2	2
299	Takasu 1 Chome	14102	3.3295	0.2737	2	4	3	2
300	Takasu 2 Chome	10902	0.0694	0.3859	3	3	2	2
301	Takasu 3 Chome	11603	0.1219	0.3646	2	3	2	2
302	Takasu Nishimachi	12705	0.2037	0.2705	2	0	1	1
303	Takasuhigashimchi	13205	0.1249	0.2166	1	0	1	1
304	Takasuhonmachi	12705	0.1514	0.2677	2	0	1	1
305	Takasuooshima	11901	0.2302	0.3150	2	0	1	1
306	Takasuootani	11202	0.1104	0.3204	2	0	1	1
307	Takasushingi	10402	0.0043	0.2973	2	0	1	1
308	Takasushinmachi 1 Chome	13901	0.0118	0.2901	2	0	1	1
309	Takasushinmachi 2 Chome	11602	0.0641	0.3679	2	3	2	2
310	Takasushinmachi 3 Chome	10201	0.1298	0.3708	2	4	3	2
311	Takasushinmachi 4 Chome	10703	0.0999	0.3289	2	4	3	2
312	Takasusunazi	14201	1.2926	0.2739	2	4	3	2
313	Takasutarumi	12301	0.1589	0.2868	2	4	3	2
314	Takeshimacho	12402	0.0884	0.3372	2	3	2	2
315	Tamamizucho	12401	0.1621	0.3380	2	3	2	2
316	Tanezaki	10901	0.0220	0.3536	2	3	2	2
317	Tenjinmachi	12401	0.1835	0.3376	2	3	2	2
318	Tojinmachi	13404	0.1361	0.3422	2	0	1	1
319	Tooricho	12005	0.2109	0.3609	2	3	2	2
320	Toozu 1 Chome	11909	0.5516	0.1789	1	0	1	1
321	Toozu 2 Chome	11203	0.1455	0.3249	2	0	1	1
322	Toozu 3 Chome	11001	0.0527	0.3665	2	2	2	2
323	Toozu 4 Chome	12401	0.0881	0.3501	2	3	2	2
324	Toozu 5 Chome	10303	0.0506	0.4140	3	3	2	2
325	Toozu 6 Chome	12101	0.4886	0.3342	2	0	1	1
326	Torigoe	10701	0.6303	0.3703	2	4	3	2
327	Tsukanohara	11604	0.1306	0.3682	2	3	2	2
328	Tsuzurashima 1 Chome	11103	0.0766	0.3521	2	2	2	2
329	Tsuzurashima 2 Chome	10202	0.0389	0.4826	3	2	2	2
330	Tsuzurashima 3 Chome	13309	0.1388	0.1593	1	4	3	1
331	Tsuzurashima 4 Chome	11609	0.0704	0.3510	2	3	2	2
332	Ugurusu	13801	0.2140	0.2634	2	0	1	1
333	Umenotsuji	10101	0.0515	0.3938	3	2	2	2
334	Urado	11807	0.7665	0.2199	1	3	2	1

No.	Sub districts (Administrative names)	ID (Admin BLDG)	Area (km.2)	Urban Vulnerability		Hazard Potential (Tsunami)		Tsunami Risk Level
				Scores (Max=1)	Levels (3 lev.)	Scores	Levels (3 lev.)	
335	Ushioshinmachi 1 Chome	11402	0.0635	0.3640	2	0	1	1
336	Ushioshinmachi 2 Chome	10803	0.1331	0.3655	2	3	2	2
337	Utsuno	12501	0.1865	0.3053	2	3	2	2
338	Wakakusa Minamimachi	10401	0.1116	0.3857	3	1	1	1
339	Wakakusacho	11806	0.0925	0.2717	2	3	2	2
340	Wakamatsucho	13205	0.1217	0.2147	1	0	1	1
341	Yagashira	12401	0.1035	0.3278	2	3	2	2
342	Yakuchicho	11404	0.0316	0.3285	2	0	1	1
343	Yamanohanacho	13903	0.0930	0.2515	2	0	1	1
344	Yamatecho	11802	0.1828	0.2707	2	4	3	2
345	Yayoicho	12301	0.1715	0.2998	2	2	2	2
346	Yokohama	12609	0.9473	0.3486	2	0	1	1
347	Yokohamahigashimachi	12401	1.2742	0.3399	2	4	3	2
348	Yokohamaminamimachi	11902	0.2329	0.2453	2	0	1	1
349	Yokohamanishimachi	12804	0.1227	0.3190	2	0	1	1
350	Yokohamashinmachi 1 Chome	11303	0.2074	0.3059	2	0	1	1
351	Yokohamashinmachi 2 Chome	11404	0.0232	0.3370	2	0	1	1
352	Yokohamashinmachi 3 Chome	10501	0.2523	0.4409	3	2	2	2
353	Yokohamashinmachi 4 Chome	11903	0.2272	0.2707	2	0	1	1
354	Yokohamashinmachi 5 Chome	12501	0.1753	0.2951	2	1	1	1
355	Yokouchi	13903	0.1034	0.2918	2	0	1	1
356	Yorikimachi	14201	2.5904	0.2626	2	4	3	2
357	Yoshidacho	10202	0.0850	0.4303	3	2	2	2
Minimum			0.0030	0.0732				
Maximum			7.5558	0.5352				
Average			0.3604	0.3205				
S.D.			0.8301	0.0640				

Note:

- Admin area = administrative areas based on GIS data of 2013 (provided by Kochi Prefecture)
- Vulnerability level are classified into three levels: 1 = less vulnerable area (less than 33.33 % of the maximum score), 2 = high vulnerable area (between 33.33 % to 66.66 % of the maximum score), 3 = mostly high vulnerable area (over 66.66% of the maximum score).
- Scores of hazard potential (tsunami) are 0, 1, 2, 3, 4, 5, regarding the levels of tsunami inundation.
- Tsunami level is referred to hazard potential scores:
  Level 1 = 0, 1 Hazard potential score
  Level 2 = 2, 3 Hazard potential scores
  Level 3 = 4, 5 Hazard potential scores
- Tsunami risk level represents the integration between urban vulnerability level and tsunami level.

Appendix 3: Structured Interview Questions

Professional field			
Date (D/M/Y)			
No.			

Interview Questions

"Tsunami Vulnerability and Resilience of the Coastal City: Kochi City"

PROMSAKA NA SAKRONNAKORN Sarunwit (Researcher)
Diver s City Laboratory
PhD. candidate of Department of Architecture, Design, and Urban Planning
University of Sassari, Italy
Email: sarunwit@hotmail.com

1. Let's begin by taking a little bit about yourself?

a. Can you tell me your job title?

----

b. Can you tell me a little bit about your job responsibilities?

----

2. What factors do you think influence vulnerability?

----

3. What characteristics does Kochi City have which make this city more vulnerable to tsunami? Can you give an example?

----

4. What characteristics does Kochi City have which make this city be able to cope with tsunami impacts? Can you give an example?

----

5. During recent disaster events that you have knowledge of, what factors contributed to increased vulnerability?

----

6. How do the following criterions impact your understanding of vulnerability and the actions that your organization could take?

a. Local regulations --

b. Provincial regulations--

c. National regulations--

d. Access to funding--

e. politics--

f. Law enforcement of land use ordinance and building code------------------------

----

7. What actions does your organization currently take to reduce Kochi's vulnerability to tsunami?

----

8. Can you tell me how your organization attempts to make people more able to cope with, and survive after tsunami hits?

----

9. What action could Kochi City do to make the city able to provide basic functions (public utility and services) after being hit by tsunami?

----

10. Please make a mark with accordance to your opinion which level you agree with the following statements related to <u>the current situation in Kochi City</u>. And please give an example with respect to the statement that you agree with.

	Strongly disagree	disagree	Neutral (Don't know)	agree	Strongly agree	Additional expression in accordance with the opinion
Land use policies and building standards						
Building safety and hazard reduction standards and codes are effectively supported by law and enforced.						
There are policies that can significantly limit investment in vulnerable land areas (Ex. No-build zone)						
Responsible institutions have enough capacity to implement land use plans and its ordinances.						
The public can easily access to information and data on physical and structural development activities.						
Incentives or penalties are in place enough to encourage compliance with land use policies and building standards and codes.						
Knowledgeable people on coastal resources and hazard management have been involved in building setting and urban design.						
Hazard resistant building practices have been taught at the secondary and technical schools.						
Critical infrastructure						
Critical facilities, such as water and electric power plants, have been located outside of the hazard area or built to be resistant to the known hazard impacts.						
An assessment of existing critical infrastructure has been conducted to determine vulnerability to tsunami and earthquake.						
A coastal engineering structure (such as seawalls, evacuation towers and buildings, etc.) has enough capacities to reduce vulnerability to coastal hazards and minimize impacts to coastal habitats.						
Cooperation of developers and communities in vulnerability reduction						
Builders and architects in the area are knowledgeable of and able to apply the building codes and good practices. (Building codes and regulations are understood by the social agents)						
Communications and outreach programs are produced to educate the public in hazard-resilient building practices and designs.						