Development of a Community-Based Natech Risk Management Framework Through the Lenses of Local Community, First Responders and Government

PARK, Hyejeong

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地域コミュニティ、第一応答者、政府の視点を通したコミュニティベースのNatechリスクマネジメントのフレームワークの開発

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It is the people who matter most,

and without the people we have no disaster.

(WHO/EHA, 2002)

Abstract

Recent disaster trends show disasters become more complex, uncertain, and unpredicted due to global environmental changes. This leads that the concern about Natural hazards triggering Technological disasters (Natech) is also increasing. As a result, local communities, neighboring industrial facilities, affected by Natech, must not only absorb the impact but also face the need to respond and recover to both natural and technological disasters right after or at the same time. The overall aim of this thesis is to propose a community-based Natech risk management framework that enables local stakeholders to manage Natech risks and enhance local community resilience for potential Natech disasters. By looking at empirical three case studies focusing on the activities of various stakeholders, including local community, first responders, and Government, the required elements for developing community-based Natech risk management were investigated.

Various research methods and tools, including a literature review, focus group discussions, in-depth interviews, questionnaires, and field visits, were used for data collection. Two Natech accidents that occurred in 2018 and 2019, in Japan, were selected as case studies. The first case study investigated the roles, activities and perspectives of citizens and members of a community disaster prevention organization in response to floods and an explosion at an aluminum factory in the Shimobara district of Okayama Prefecture in July 2018. The second case study investigated the roles and perspectives of first responders during flooding and an oil spill caused by the flooding at an Ironworks factory in Omachi Town of Saga Prefecture, in August 2019. The third case study investigated government practices for chemical accident risk management through the review of government documents, reports, interviews, questionnaires and field visits. In particular, interviews with chemical accident response team leaders, who are affiliated with the Joint Inter-agency Chemical Emergency Preparedness Centers in Korea, were conducted to explore the current risk management systems for chemical and Natech risks and the government perspectives on the Natech risk management following the introduction of new regulations. Furthermore, other government efforts to manage chemical and Natech accident risks were investigated in the E.U., U.S., and Japan.

The empirical case studies and a broad literature review presented different perspectives of local stakeholders, including the local community, first responders, and Government, on chemical accidents and Natech risk management. The first case study on the local community showed the residents could play six crucial roles in disaster risk management including 1) key actor in community disaster risk management; 2) a bridge for risk communication between local stakeholders; 3) risks and hazards monitoring; 4) decision-making; 5) liaison for coordination and collaboration; and 6) assistance. Also, these roles are supported by identified community resilience, which is 1) a sense of community; 2) trust;

3) and indigenous knowledge. In the second case study concerning first responders' perspectives, it is evidenced that there is a need for consideration of managing Natech risk in existing disaster management strategies. Most responsibilities of first responders focus on general emergency response for natural disasters, including search and rescue and first aid. However, during Natech disasters, there were several challenges, including a lack of risk information and knowledge concerning chemical hazards, lack of Natech risk management systems, and lack of personnel and physical resources. These challenges delayed emergency response. The third case study investigated the perspective of government organizations and their roles in chemical and Natech risk management. The results showed there is still limited consideration of natural hazard triggered chemical accidents disaster prevention and emergency response planning at the prefectural level and at the city level. One of the problems identified in the study was the lack of information provided to local community members and even first responders concerning chemical hazards and chemical accident risks. Thus, this thesis found that there is a need for Natech risk management systems that can be applied at the local level. It was also identified that local efforts, such as the activities of local community disaster management organizations could provide the environment needed for successful Natech risk management with the consideration of some key elements, as suggested below.

This thesis identified four key elements that are needed for Natech risk management. These include the introduction of chemical and Natech risk assessments at the community level, support by local government in the form of expertise, and resources, collaboration in the form of mutual assistance programs, and proactive community engagement and participation. Based on the above, this thesis proposes a community-based Natech risk management framework considering these main elements as follows: 1) a Natech risk management platform centered around the Natech risk assessment process and risk treatment, risk communication, and Natech risk management strategies; 2) active government support through proper regulations and guidelines, resources, regulatory input and supports the platform; 3) mechanisms for mutual assistance between local city officials, NGOs, natural and technological hazard engineers, and industry safety specialists and operators for the Natech risk management platform through assessing Natech risks and potential consequences; and 4) active local community participation which is expected to engage in the Natech risk management processes, explicitly through the hazard and risk identification processes and providing input based on past disaster experiences and local knowledge. In particular, due to the high uncertainty and unexpected occurrence and/or concurrence of Natech disasters, collaboration in the risk management processes among individual experts of natural/chemical accident hazards, and industry specialists, is surely highlighted.

While the framework highlights and confirms the extensive knowledge base from past natural hazards research, the framework also shows the importance of a broader conceptualization of the scope of disaster risk management to include technological accidents. When implemented, the proposed community-based Natech risk management framework will help reduce impacts from chemical accidents triggered by natural hazards while enhancing local stakeholders' coping capacity for potential Natech events. The proposed framework provides the basis for collaboration among all stakeholders and delineates the necessary elements. In addition, the framework can be implemented while maintaining existing disaster management institutions. Nonetheless, strong government support is needed, as well as policies that favor the disclosure and sharing of risk information between stakeholders living near hazardous facilities.

The extensive risk assessment of natural hazards and chemical accidents can contribute to renovate infrastructures, including telecommunication, transportation, river maintenance, and several lifelines against Natech accidents. Furthermore, it offers customized risk management strategies and Natech emergency operation plans at the local level through assessed risks, understanding the occurrence mechanism, and the probability of Natech accidents. Through comprehensive risk management implementation, the framework could fulfill the gaps, which are lack of Natech risk information, collaborative interaction, and flexible risk management system at the local level. Particularly, it is expected to enhance the coping capacity and consolidation of local stakeholders, involving local government, first responders, safety management specialists, and the local community.

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Abbreviation

ADRC	Asian Disaster Reduction Center
AIDMI	All India Disaster Mitigation Institute
APELL	Awareness and Preparedness for Emergencies at Local level
CDP	Center for Disaster Philanthropy
CRED	Centre for Research on the Epidemiology of Disasters
DHS	Department of Homeland Security
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
E.C.	European Commission
EHA	Emergency and Humanitarian Action
EM DAT	Emergency Events Database
E.U.	European Union
EU-JRC	European Union-Joint Research Center
FDMA	Fire and Disaster Management Agency
FEMA	Federal Emergency Management Agency
GEJE	Great East Japan Earthquake
IFRC	International Federation of Red Cross and Red Crescent Societies
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JICEPC	Joint Inter-agency Chemical Emergency Preparedness Center
JMA	Japan Meteorological Agency
KHNP	Korea Hydro & Nuclear Power
LEPC	Local Emergency Planning Committees
NEA	National Environment Agency
OECD	Organisation for Economic Co-operation and Development
STEP	Sequentially Timed Event Plotting
U.N.	United Nations
UN DESA	United Nations Department of Economic and Social Affairs
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNEP DTIE	United Nations Environment Programme-Division of Technology, Industry and Economics
UNISDR	United Nations International Strategy for Disaster Reduction
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Responses
WHO	World Health Organization

Chapter 1 Introduction

1.1 Background

Natech is defined as a Natural hazard triggering Technological Disasters (Cruz et al., 2004; Showalter & Myers, 1994). It has a relatively low probability compared to natural hazards, but severe and unexpected consequences (Masys et al., 2014) and the chained and sequenced impact (Kadri et al., 2014). The effect of Natech disasters often overwhelm the coping capacity of local governments, as well as central governments, and impose hardships in response and recovery (Steinberg et al., 2008). Recent trends present the number of Natech events has been increasing with serious potential impacts on human beings and the environment (Sengul et al., 2012). This increasing trend may be expected to continue, mainly, Natech events caused by hydrometeorological hazards due to climate change (EM-DAT, 2020).

There are some reasons for increasing Natech risks and damages. Remarkable developments in technology and social and environmental infrastructures have improved individual and social comfort and convenience. At the same time, however, risks have increased due to urbanization, industrialization, population growth in the urban areas, and the deterioration of the natural environment (Eziyi, 2011; OECD, 2003; Schultz, 2006; UNISDR, 2019). Increasing risks are often appeared regardless of national boundaries or levels of development (Beck, 1992), coping capacity, and the quality of governance and disaster risk management (DRM) (Shimizu & Clark, 2015). Notably, climate change and the complex environment have led to high uncertainty on disaster consequences and changing disaster patterns, which are more complicated and unexpected (AIDMI, 2018; Amendola, 2004; IPCC, 2012). Recent studies also have shown that the latest disasters have had significant impacts on social and physical infrastructure due to environmental and climate changes (AghaKouchak et al., 2018; Pescaroli, 2018; Pescaroli & Alexander, 2015; Shimizu & Clark, 2015).

According to a report of the Emergency Event Database (EM-DAT), every year, the number of reported natural disasters, including droughts, earthquakes, extreme weather events, hydrometeorological events, landslides, volcanic activity, and wildfires, has been consistently increasing. During the past two decades, there were 7,192 natural disasters (Ritchie & Roser, 2019), with $ 1.3 trillion (USD) of economic losses (CRED, 2019). In this same 20-year period, the number of people who have been affected by natural disasters is about 4.1 billion globally, while disaster fatalities reached 1.33 million people who lost their lives (CRED, 2019). In 2018, the worst year in this period, 315 natural disasters were reported, with about 68 million people affected, 11,905 fatalities, and 131.7 billion USD of economic losses recorded worldwide (CRED, 2019).

Recent disasters tend to trigger additional substantial emergencies concurrently and/or sequentially, and it has high uncertainty, complexity, and interconnection of occurrence and consequences (Ammann, 2012; Cavallo & Ireland, 2014; IPCC, 2012; Shimizu & Clark, 2015). With these characteristics, several studies have recognized these types of disasters, such as cascading disasters, involving Natech events (Girgin et al., 2019), and compound disasters. For example, Pescaroli and Alexander (2015) defined cascading disasters as extreme events that contribute to overall phases of disaster and trigger unexpected and successive consequences generated by the strong primary impact over time. In other words, Cutter (2018), Kawata (2011), and Liu and Huang (2014) considered compound disasters as more simultaneously occurring disasters that lead to interlinked secondary events and amplifies economic and human impact.

In particular, the escalation into a cascading disaster is related to the intensity and extent of the initial impact and may vary depending on the environmental conditions, and the resilience and coping capacity of the affected area. Though recognition might not be new, official concern about and managing risks of cascading disasters is now emerging. Consideration of Natech accidents, as typical cascading disasters, in the current disaster risk management (DRM) is emanated (Cutter, 2018; Pescaroli, 2018; Shimizu & Clark, 2015). The reason is that technological accidents that can be prompted by various natural hazards from industrial facilities can cause significant impacts on explicitly one or more local communities, critical infrastructures, as well as on the interconnected systems (Cutter, 2018). A couple of representative examples of

Natech accidents show impacts on local communities.

- In August 2002, the Spolana chemical plant at a populated small town of the Czech Republic was swept by a catastrophic flood. As a result, 400 kilograms of poisonous chlorine gas was spilled into the air (Cruz et al., 2004) and formed the huge clouds of toxic fumes in the local community (BBC, 2002). There were no immediate fatalities, but this chemical accident threatened a large number of residents for a long time. Even though the chemical facility was built on a flood plain occurring once every 50 years, the probability of chemical accidents that could be triggered by natural hazards was not considered in the surrounding community (Traynor, 2002). As a result, there was not enough information for the local communities who were not aware of and prepared for the potential chemical accidents (CNN/World, 2002).

- Severe flooding was happened by levee breaking and heavy rain during Hurricane Katrina in 2005. It caused 1,836 fatalities, 705 missings, and 15 million people affected in total. In particular, the impact of the hurricane led to the release of hazardous substances (e.g., oil and gas) from fixed industrial facilities and offshore platforms. The hurricane damaged 408 gas platforms and pipelines (Krausmann et al., 2017), and caused a serious of explosion and fires from a damaged gas tank near the town center of the New Orleans (Santella et al., 2010). About 19,500 barrels of crude oil and chemical substances from oil refinery and chemical plants respectively were spilled during the event, and it contaminated a wide residential area (Smith-Hams, 2015), and approximately 1,700 houses were impacted directly (Pine, 2006). However, a lack of accurate information and risk communication for chemical accidents, and planning for evacuation, and unpreparedness for Natech disasters by the government have made that community residents failed to evacuate timely and lost trust government and relevant actors (Miller, 2016; Reible, 2007). These consequences destroyed the ordinary and daily lives of residents, as well as their livelihood with severe environmental contaminations.

- In 2011, the Great East Japan Earthquake (GEJE) and Tsunami swept away a large number of local communities. The disaster caused about 19,868 fatalities and displaced 336,521 people. It also hit several industrial parks leading to chemical material releases, fires, and nuclear accidents (Krausmann & Cruz, 2013). Numerous local communities had to face directly/ indirectly at least three hazards, including earthquakes, tsunami, and chemical accidents (e.g., oil spills, gas leakages, nuclear accidents, fires, and explosions), particularly, in the Sendai industrial parks. However, local communities neighboring the industrial parks were not provided appropriate information timely regarding the circumstances of the chemical accidents, required emergency response actions, evacuation routes by the Government (Yu et al., 2017a). Thus, residents had to rely on their decision based on local knowledge and experiences to survive from the disasters.

Other issues involving the Fukushima nuclear accident are continued to require solutions, and particularly several local communities and many citizens are still suffering from health issues due to acute and chronic radiation exposure (WHO, 2013). There are no detailed information on the accident situation, exposure to local citizens, and specific evacuation and radiation protection procedures. Also, nuclear accident impacts that could be caused by natural hazards were not considered in the local DRM systems. Furthermore, risk communication failure among all stakeholders, including Government and citizens, collapsed public trusts in the Government and their emergency management activities (Funabashi, 2012; Miller, 2016).

- In December 2011, landslides triggered sever oil pipeline explosions and fires at the Ecopetrol oil company near the residential area early in the morning. According to an investigation, the company has noticed the chemical accident risks due to unstable terrain and a lack of maintenance of risk management (Kinosian, 2012). However, the ill-preparedness of chemical accidents that could be triggered by natural hazards in the company (Munoz, 2011) caused 32 fatalities of residents and $19.5 million of economic losses (Kinosian, 2012). Also, some residents could not evacuate on time due to insufficient information, and some people could evacuate due to severe gasoline odor, not appropriate information (Reuters, 2011).

The above examples illustrate the impact of technological disasters that occurred by natural hazards near local communities. The devastating and cascading effects of

Natech could lead to the failure of effective emergency responses due to destroyed social systems and damaged infrastructures. During Natech accidents, the ability to respond immediately or external assistance, including relevant organizations or other nations, would be hampered to a higher degree than natural disasters. Particularly, local communities, neighboring industrial facilities, affected by Natech, must not only absorb the impact but also face the need to respond and recover to both natural and technological disasters right after (Steinberg et al., 2004).

Recently, local communities, thus, are emerging as one of the critical agents to implement and manage multi-hazards and disaster risks within a risk governance framework in DRM that highlights community engagement (Corfee-Morlot et al., 2011; Djalante et al., 2012; Renn, 2008; Tierney, 2012). Through the lessons learned from past disasters, we saw evidence of significant proactive roles of the local community, as one of the first responders (Kapucu & Van Wart, 2006). For example, during the Kobe earthquake in 1995, local community members performed rescue neighborhoods and vulnerable people, supply water and foods, and assist local first responders until the arrival of professional responders and sufficient relief resources (Bajek et al., 2008; Shaw & Goda, 2004). When Hurricane Katrina hit several areas in the U.S., 2005, a small community developed an Emergency Care Contact List for supporting more vulnerable groups and conducted quick and safe evacuation leading by the local community through the decision making with other stakeholders (Patterson et al., 2010). Also, community members independently played other crucial roles, including volunteers, rescuers, assistants for vulnerable people, communicators between external and internal stakeholders during the GEJE in 2011 (NPO Rescue Stock Yard, 2017).

Even though the examples show fragmentary parts of the local community during disasters, community residents have evidenced that they also can fulfill the overall post-DRM activities, in response, recovery, and rehabilitation, as volunteers and active stakeholders rather than as passive victims. Community activities have been recognized that they could be motivated to participate and perform a critical role in improving DRM. The community participation is also demonstrated that the community members could perform a role as community experts with other stakeholders, mainly first responders, and relevant local government officials, within the DRM system.

With the cognitive changes on community participation, several researchers have recommended that the local community must be incorporated in all phases of a DRM system in the context of natural hazards (Bajek et al., 2008; Briones et al., 2019; Mojtahedi & Oo, 2017; Pandey & Okazaki, 2005; Shaw, 2016; Twigg & Mosel, 2017). Through previous studies, following factors were particularly highlighted in order to better DRM at the local community level: 1) building community disaster resilience through understanding local characteristics (e.g., local knowledge, environment, coping capacity, and social demographics) (Briceño, 2015; Kwok et al., 2018; Moreno, 2018); 2) increasing multi-hazard risk perception and awareness (Allen, 2006; Briones et al., 2019; Enshassi et al., 2019; Motoyoshi, 2006; Twigg & Mosel, 2017); 3) effective risk communication (Buckland & Rahman, 1999; Gaillard & Mercer, 2012; Ikeda & Nagasaka, 2011; Owens, 2000; Takeuchi et al., 2012; Tsubokawa et al., 2008); and 4) enhancing coping capacity in DRM (Mercer et al., 2010; Pandey & Okazaki, 2005; Paterson & Charles, 2019; Tozier de la Poterie & Baudoin, 2015). In addition, Collaboration and cooperation based on good risk governance and partnership among multi-local stakeholders, including the local community, local government officials, first responders, and NGOs, are also stressed to build the local DRM cultures (Briones et al., 2019; Djalante, 2012; Kapucu & Van Wart, 2006; Maskrey, 2011; Twigg & Mosel, 2017; UNISDR, 2015).

This plus recognition of the role of the local community in Natech risk management is gradually increasing as well (Suarez-Paba et al., 2020; UNEP DTIE, 2015). However, several studies pointed out that residents living near industrial facilities that have potential to chemical accidents concurrent with natural hazards have little to no information on how to prevent, prepare for, respond, and recover from these types of events (Cruz & Okada, 2008; Funabashi, 2012; Funabashi & Kitazawa, 2012; Miller, 2016; Picou, 2009; Steinberg et al., 2004 & 2008; Steinberg & Cruz, 2004; Yu et al., 2017b). Other studies have highlighted the need for promoting integrated Natech risk management and risk governance and its importance to manage Natech risks at the local level, involving community members, local first responders, and related local government actors in order to deal with uncertainty, increase risk awareness and reduce Natech risks (Cruz & Okada, 2008; Cruz & Suarez-Paba, 2019; Funabashi, 2012; Picou, 2009; Steinberg et al., 2004; Steinberg & Cruz, 2004; Suarez-Paba et al., 2019, 2020). Also, collaborative interaction of multi-local stakeholders, including local community members, local government officials, experts, and industrial safety managers and/or operators, was emerged to manage potential technological accidents triggered by natural hazards (Cruz & Krausmann, 2009; Cruz & Okada, 2008a; Funabashi, 2012; Funabashi & Kitazawa, 2012; Krausmann & Baranzini, 2012; Ozunu et al., 2011; Steinberg et al., 2008).

However, despite the large body of research on the role of local communities in disaster risk reduction (DRR), there is yet no Natech risk management system that could be applied at the community level. Although initial natural hazards may be more localized, the extended type of catastrophe due to uncertainty, complexity, and unpredictability underlines the need to consider risks of Natech and the capacity to protect citizens and minimize the potential impact of the Natech disaster risks in advance.

1.2 Problem Statement

The number of technological disasters (EM-DAT, 2020) and Natech accidents (Sengul et al., 2012) has been on the increase. This trend may be expected to continue, particularly regarding hydrometeorological hazards due to climate change. With regard to this trend, there has been growing national and international support and effort to develop sustainable strategies and policies to improve disaster resilience and governance in order to manage both technological and natural hazard risks, as well as to encourage the participation of local stakeholders, especially local communities, in DRM. Thus, it is not surprising that the United Nations included the consideration of technological and Natech hazards and risks in the Sendai Framework for Disaster Risk Reduction: 2015 – 2030 (UNISDR, 2015).

In this context, several studies show that there is a lack of managing Natech risks at the local level, but the local stakeholders, mainly, local communities are rarely considered in Natech risk management (Cruz & Okada, 2008a; Cruz & Suarez-Paba, 2019; Steinberg et al., 2004; Steinberg & Cruz, 2004; Suarez-Paba et al., 2019). Also, despite the importance of the role of the local community, there is yet no proper

Natech risk management that could be applied to the local community context, considering community characteristics, including knowledge of local history and culture, existing networks, and coping capacity.

The fact is that we need to have good governance that can support Natech risk management at the local level by providing appropriate resources and information and promoting the convergence among multi-stakeholders, including local community members, local government officials, experts, as well as industrial facility managers and/or operators for successful Natech risk management. Hence, a comprehensive Natech risk management framework at the local level is needed to manage both natural and technological hazards more effectively based on understanding the occurrence mechanism of Natech disasters, Natech risk communication, and risk management processes. In this thesis, by looking at three different empirical case studies focusing on DRM activities of local stakeholders, including local community members, first responders (specifically, firefighters), and local government officials, the required elements for developing community-based Natech risk management are investigated.

1.3 Research aim and objectives

The overall aim of this thesis is to propose a community-based Natech risk management framework that enables local stakeholders to manage Natech risks and to enhance the coping capacity for the potential Natech disasters. The specific objectives of this thesis are as follows:

- To propose the initial conceptual framework of Natech risk management at the local level based on a broad literature review;
- To explore the role of the local citizens, first responders and Government through case studies in order to determine the elements of the framework;
- To propose a community-based Natech risk management framework that must be implemented by multi-local stakeholders.

1.4 Research question

Given the above research aim and specific objectives, the research questions in this thesis are formulated as follows:

> *How to the local multi-stakeholders, including the local community, first responders, and the governmental actors, can manage natural hazards and chemical accidents risks and cope with Natech events at the local level?*

Notably, two Natech accidents that occurred in 2018 and 2019, in Japan, and governmental activities were selected as case studies. The first case that is an explosion at an aluminum factory that occurred in 2018, Japan, has been chosen to identify the role, DRM activities, and perspectives of residents. The second case, which is an oil spill and floods that occurred in 2019, Japan, has been chosen to investigate the roles and perspectives of first responders, specifically local firefighters. The third case investigated government practices for chemical accident risk management in Japan and Korea (see chapter 2.5 for further details of the purposes for this selection).

1.5 Thesis structure

This thesis consists of seven chapters.

Chapter 1 (Introduction) addresses the disaster environment changes, emerging Natech risks, and the importance of community participants in risk management. Based on the research gap and need, this chapter presents the problem statement, research aim, and objectives, research questions, as well as thesis outline.

Chapter 2 (Literature review) is devoted to the review of the relevant literature on natural disasters, focusing on compound and cascading disasters, and Natech disasters and its characteristics. In the next part, DRM and Natech risk management, as well as community resilience for disasters and community participation in DRM, are introduced. It describes the understanding of the evolution of DRM. Also, this chapter will provide an example of a community-based DRM overview in the context of Japan.

Chapter 3 (Conceptual framework) proposes the initial conceptual framework for

Natech risk management based on the concept of the Japanese disaster risk governance and a broad literature. It describes the components involving public support, mutual assistance, self-help sectors, and Natech risk management. Through three case studies of the local community, first responders, and Government, this framework will be developed as a community-based Natech risk management framework.

Chapter 4 (The theoretical approaches in methodology) introduces used major research methodology theoretically in this thesis. They are case study, thematic analysis, and the Sequentially Timed Events Plotting (STEP) as one of the accident modeling methods. Also, it explains the advantages and limitations of the methodology applied and the processes in general. It gives a theoretical background to apply the methods in the thesis.

Chapter 5 (Research methodology) addresses the methodology and method procedures adopted in this thesis. First of all, various data collection methods and tools are introduced, including in-depth interviews, focus group discussions with ethical considerations, field notes, and questionnaire surveys. Also, this chapter presents an overview regarding geo-demographic information of case study areas in the Shimobara district of Okayama Prefecture and Omachi town of Saga Prefecture in Japan, where experienced Natech accidents, and the Korean government agency, as the government stakeholder.

Chapter 6 (Results) discusses the overall findings through three case studies. The first case study focused on the local community activities and perspectives, particularly the Jishu-Bosai-Soshiki, in the context of DRM for natural disasters and Natech risk management. In the second case study, activities of local first responders, particularly the fire department and local DRM system, were investigated in Takeo City and Soja City, Japan. The third case study investigated government efforts on chemical accidents and Natech risk management in the E.U., U.S, Japan, and Korea, mainly focusing on the Joint Inert-agency Chemical Preparedness Emergency Centers, as the government agency. Various data analysis delineates required elements of developing a community-based Natech risk management framework considering practical community capacity and lessons learned from past disasters.

Chapter 7 (Discussion) provides discussion about different perspectives of the local community, first responders and Government from the case studies and the details of the proposed community-based Natech risk management, as well as the way of the framework implementation. It also discusses framework limitations, contributions and limitations of this thesis.

Chapter 8 (Conclusion) presents a general conclusion and summarizes the main contributions of this research. Also, this chapter suggests the need for further extensions of this research and some recommendations for improvements and implementation of the developed community-based Natech risk management.

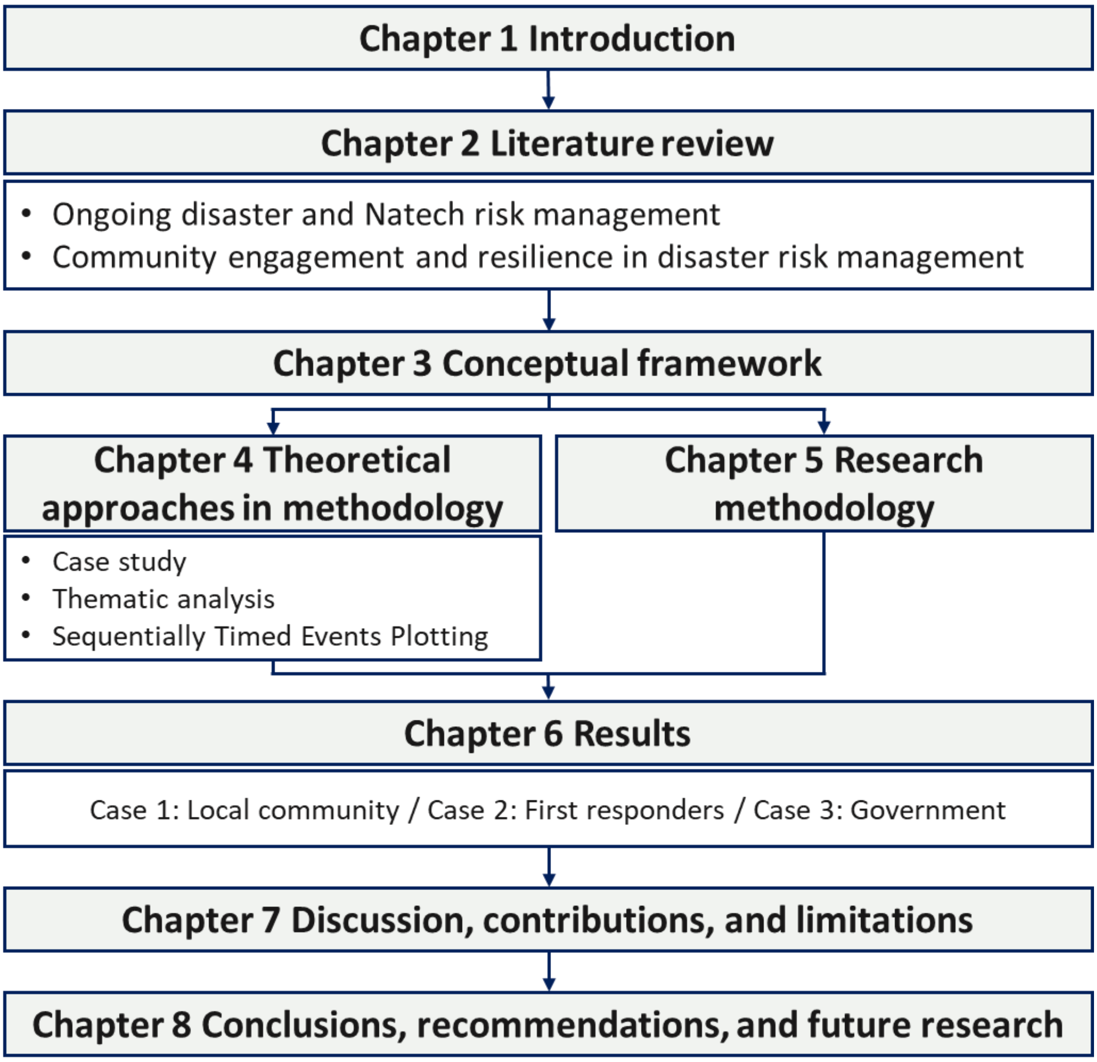

Figure 1. Thesis structure

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Chapter 2 Literature review

This chapter presents a broad review of the literature on 1) a different recent concept of disasters, which are compound and cascading disasters, and technological accidents triggered by natural hazards; 2) DRM and Natech risk management in the context of community engagement; 4) and the concept of community resilience and community engagement in DRM at the local level, and an example of Japanese community-based DRM. Through the review, the initial elements of the conceptual framework are investigated.

2.1 From natural disaster to Natech disaster

2.1.1 Natural and technological disasters

Disaster is a severe and destructive event that affects communities and societies and overwhelms the coping capacity of societal institutions to respond to disasters (IFRC, n.d.; UNDRR, 2015; UNISDR & CRED, 2018; WHO/EHA, 2002). It can be categorized into three generic groups, which are natural and technological disasters (Below et al., 2009) and Natech (technological accidents triggered by natural hazards) (Cruz et al., 2004), as shown in Table 1. Natural hazards involve biological (e.g., Cholera, Ebola, and Avian influenza), geophysical (e.g., earthquake, tsunami, and landslides), water-related (e.g., floods, heavy rainfall, and wildfires) hazards. As technological hazards, there are mainly industrial accidents, explosions, chemical material releases, and infrastructure failures. These cause disasters that may include exposure to certain compounds of natural and technological hazards that have an impact on people, society, or community and severely challenge the capacities of society to anticipate, manage, and resist such disasters (ADRC, 2005; UNISDR, 2015a).

Table 1. Disaster classification

Disaster type			Specific hazards	
Natural	Biological		☐ Epidemic	☐Insect infestation
			☐ Animal stampede	
	Geophysical		☐ Earthquake	☐ Volcano
			☐ Tsunami	☐ Mass movement (dry)
	Weather-related	Hydrological	☐ Flood	☐ Mass movement
		Meteorological	☐ Storm	
		Climatological	☐ Extreme temperature	
			☐ Drought	☐ Wildfire
		Hydro-meteorological	☐ Water and wind causing disasters	
Technological			☐ Industrial accidents (mechanical and chemical)	
			☐ Destruction of infrastructures	
Natech			☐ Natural hazards + Industrial accidents or destruction of infrastructures	

(reorganized from Below et al., 2009)

Natural disasters are recognized as singular disasters caused by simple successive and identifiable mechanisms of a singular hazard following subsequent impacts, propagating over time (Kelman, 2018), as shown in Figure 2. This general process is addressed sequentially in limited areas. As a pivotal event, natural and technological disasters can be generated by technological and environmental developments that might lead to a change in the disaster environment. Recently, rapid and unplanned urbanization, the concentration of population, and degradation of the natural environment might contribute to climate change and increasing disaster risks (Ikeda & Nagasaka, 2011; Pescaroli & Alexander, 2015; Schultz & Elliott, 2013; UNISDR, 2017). Thus, international research communities, numerous governments, and relevant organizations, as well as local communities have expended considerable effort to deal with climate change and disaster risks through developing international frameworks, investing in the improvement of DRM systems as well as enhancing the coping capacity to respond to disasters.

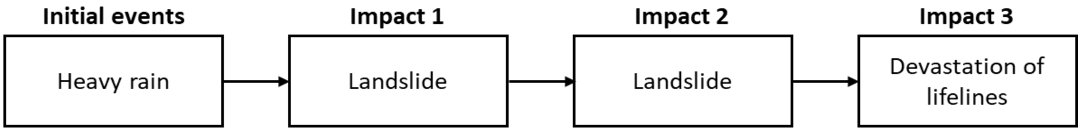


Figure 2. A singular disaster mechanism: an example of heavy rain

As shown in Figure 3, the number of weather-related natural disasters such as typhoons, floods, heavy rain, and wildfires is growing every year. These disaster patterns have increased in severity and frequency (US DHS, 2019). For example, the 2018 California wildfires were more massive and widespread; the 2019 - 2020 Australian bushfires caused huge damage to the natural ecosystem (CDP, 2020); and the 2017 - 2019 Japan heavy rains, floods, and the typhoon Jebi and Hagibis affected multiple Prefectures. Infrastructure destruction, chemical accidents, subsequent floods, and landslides caused severe strains on national and regional disaster management. These disasters brought drastic economic losses and damages as well.

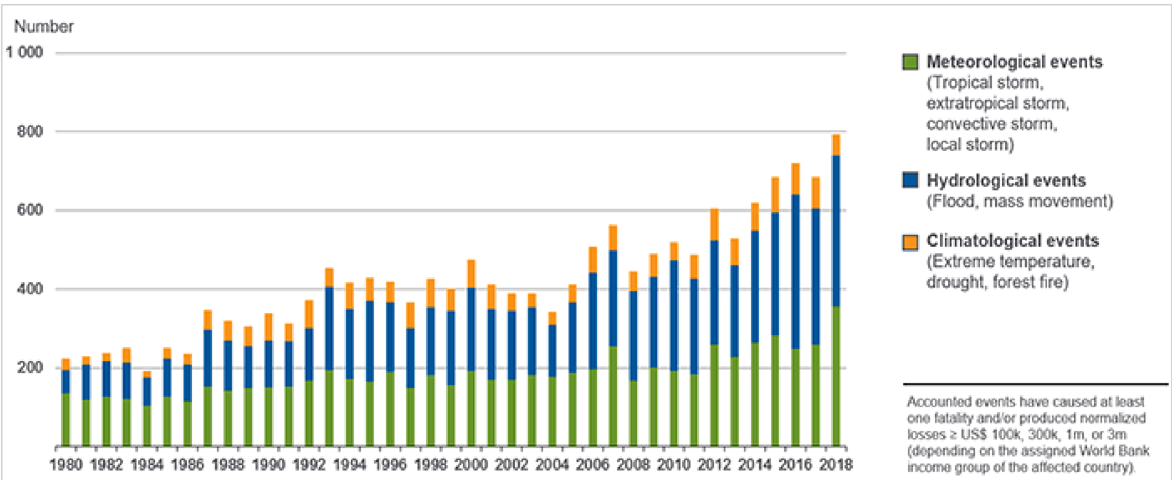


Figure 3. Trends of weather-related natural disasters, 1980-2018[1]

In particular, the number of flood disasters has been increasing every year. In 2018, 108 flood disasters were reported from South-eastern countries, Africa, and Japan (CRED, 2019). Since 1982, Japan has recorded two worst floods triggered by heavy rain. One of the floods is that has led to a technological disaster, which is an aluminum factory explosion in West Japan, 2018. In the past, with developing technologies and

[1] Reprinting from http:// www.iii.org/graph-archive/218092, by Peril, 2019. Copyright 2019 Munich Re, Geo Risks Research, Nat-Cat SERVICE. As of March 2019.

measures for managing floods, the impact and occurrence of floods were distinguished relatively low-risk disasters than other natural disasters because hydrological hazards are generally predicted (Motoyoshi, 2006). However, the trends of natural disasters show the world environment could face higher risks of hydrological hazards, including floods due to climate change and environmental changes (Graaf, 2008; Jongman et al., 2014).

The consequences of flood disasters are different depending on the environmental conditions, regulations, preventive facilities, and several infrastructures, including dams and levees, and it tends to lead to significant uncertainty. In recent, floods cause economically and socially significant tangible and intangible damages, and the impact is gradually increasing in time (Paprotny et al., 2018). Thus, many countries, explicitly, south-eastern countries, the European Unions, and Japan have prepared flood risk management and mitigation strategies in order to reduce the frequencies of floods and flood risks (Graaf, 2008; Motoyoshi, 2006; Paprotny et al., 2018).

In terms of technological disasters, it is well-known as man-made disasters, which are occurred by technological malfunction and/or human error in industrial facilities, infrastructures, and technology-related (Lindsey et al., 2011). A technological disaster is regarded as an event triggered by a distinguishable cause that can be handled and preventive by humans and other technologies (EEA, 2010; Lindsey et al., 2011). However, managing technological disasters is challenging due to unexpected consequences, producing social conflicts, prolonged recovery, and miscommunication regarding disasters (Funabashi, 2012; Lindsey et al., 2011). Over the last few years, there are some significant examples of technological disasters: the B.P. Deepwater Horizon oil spill in the U.S. caused by technological failures in 2010 that affected several maritime industries and communities for a long time (Morris et al., 2013); 2015 Tianjin explosion at a chemical warehouse in China caused by overheated dry nitrocellulose following safety management failures that generated 173 casualties and serious environmental pollution (Aitao & Lingpeng, 2017); over 20,000 tons of diesel oil spills in 2020, Russia caused by the support collapse of oil storage tank on the melted permafrost that occurred dreadful soil and water contaminations (Tidey, 2020).

Compared to past disasters, new risks are more uncertain, complex, and ambiguous to society (Van Asselt & Renn, 2011). Recent studies have demonstrated that disaster environment changes and various enhanced risks have influenced disaster patterns making them more severe, complicated, extensive, extended, and able to generate cascading effects due to interactions of these phenomena with diverse environmental and social factors (Ammann, 2012; Shimizu & Clark, 2015). These phenomena have produced not only compound and cascading disasters but devastated technological accidents that could be triggered by natural hazards. Thus, the need for managing 'compound' and 'cascading' disasters and reducing their risks with vulnerabilities have been noted by several researchers (Alexander, 2018; Eisner, 2015; Ikeda & Nagasaka, 2011; Kappes et al., 2012; Kawata, 2011; Kelman, 2018; Leonard et al., 2014; Shimizu & Clark, 2015).

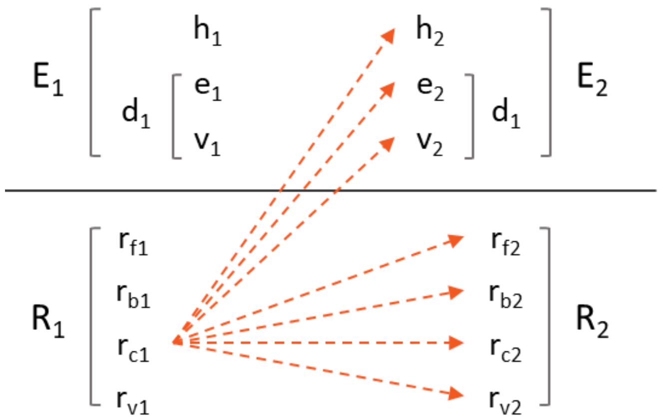
2.1.2 From compound disasters to cascading disasters

The term 'compound disaster' was first utilized to describe disasters resulting from armed conflict in Africa in the late 1980s (Mitra & Vivekananda, 2015; Wachira, 1997). Even though disaster management systems have evolved, managing compound disasters presented challenges due to the causes of conflict and its duration, social features, and cultural diversity (Wachira, 1997). These conflicts had significant impacts on the infrastructure, culture, economies, and environments of the nations in which they occurred. In this context, the cascading damages and impacts caused by these conflicts are regarded as compound disasters.

One of the more recent definitions of a compound disaster is "double- or triple punch disasters" introduced by Kawata (2011) in which a compound disaster triggers more severe consequences than independently occurring disasters, but expected. With this definition, the author estimated damages caused by compound disasters in a metropolitan area. Three features of compound disasters were addressed as follows: 1) combined disasters triggered by an initial event individually; 2) extensive damage in broad areas due to interconnections, and 3) prolonged recovery following chain disaster occurrences. This study also highlighted the importance of preparedness for uncertain failures (e.g., information sharing, collaboration, and resource allocation), for a prompt response, relief support, and appropriate disaster management, including sharing information between each affected local community. Kawata's (2011) main contribution to understanding compound disaster is the focus on sequential phenomena following the occurrence of an initial disaster.

Eisner (2015) and Liu and Huang (2014) have adapted the meaning of the compound disaster as defined by Kawata (2011) in their research. They addressed the compound disaster as a type of disaster that affects local-, regional-, and national levels as well as globally, and overwhelms the coping capacity of the existing disaster management system more than singular disasters. Also, the authors underlined the need for treatment of compound disaster risks and improving DRM systems to minimize the probability of compound disasters.

In the 2015 global assessment report for DRM, Liu and Huang (2014) illustrated the probability of compound disasters, and their interconnections, that is, how a single event unfolds to form multiple disasters. Figure 4 shows the general format of compound disasters having multiple connections between the first event and the following events. E_1 and E_2 indicate the pre-event stage in each event, possible entire disasters (d_1 and d_2) caused by an interaction between hazard (h_1 and h_2), exposure (e_1 and e_2), and vulnerability (v_1 and v_2). These factors lead to the second stage as the post-event (R1 and R2). The post-event stage includes all response activities such as rescue and relief (rf_1 and rf_2), rebuilding (rb_1 and rb_2), reconstruction (rc_1 and rc_2), and recovery (rv_1 and rv_2). During the response in the first post-event (R1), damaged social and environmental systems, as well as the activities themselves, can create other hazards (h_2), exposure (e_2), and vulnerability (v_1) with interconnections of all the indicators. The report highlighted all the probabilities of compound disasters in DRR and DRM considering any initial impact, identifying risk factors, and referring to past experiences and knowledge to prepare for compound disasters. Also, the authors mentioned that some researchers identified the need for coping with uncertainly in interconnected disasters, which has remained a challenge.



(adapted from Liu and Huang, 2014)

Figure 4. Compound disaster process

Eisner (2015) described a compound disaster as progressive and successive failures, in which the first event leads directly to second, third, and fourth events with uncertainty following the initial event. The author applied a typology to interpret the seven features of compound disasters, as shown in Table 2. Likewise, compound disasters lead to catastrophic damages simultaneously and successively, regardless of time, space, and initial hazards (Eisner, 2015; IPCC, 2012). Due to the potential for boundless expansion of impacts, enhancing the coping capacities at all levels, including the neighborhood level and implementation of proper compound DRM, are critical in reducing compound disaster risks.

Table 2. Seven features of compound disasters

Event type	Features
multiple, coincidental simultaneous	Disasters coinciding and in the same space
sequential progressive	Chained hazards
random related	Interacted consequences
random unrelated	Accumulation of unlinked hazards
sequential progressive infrastructure dependent	Regional destructive damage
regional mass casualty	Massive and catastrophic multiple impacts and overwhelms international disaster response
information systems	Collapse infrastructure system

(adapted and reorganized from Eisner, 2015)

Furthermore, Leonard et al. (2014) addressed compound events as "an extreme impact that depends on multiple, statistically dependent variables or events (p. 115)" based on the definitions from IPCC (2012). This concept of compound events has facilitated an explanation of the interaction between the natural and physical environment, human factors, time and space, and dependencies of event processes under any contribution of uncertainty and unpredictability (Cutter, 2018; Leonard et al., 2014). Also, managing compound disaster variables are becoming more critical to reduce risks. Therefore, Leonard et al. (2014) suggested several critical needs: understanding risk variables, potential impacts, hazard combinations, accepting information from stakeholders, multiple analysis, and multi-disciplinary collaboration.

In a different way, such type of disasters is recognized as cascading disasters according to the occurrence mechanism, which has cascading effects. The concept of cascading disasters or cascading effects that can spread disasters are studied by Buzna and Helbing (2008) and Franchina et al. (2011) to identify the impact of cascading events. The 2011 GEJE and Tsunami and the 2005 Hurricane Katrina showed the major concept of cascading disaster, including the uncertainty, complexity, and high interconnectivity (Alexander, 2018; Shimizu & Clark, 2015; UNISDR, 2017; Vahedifard & AghaKouchak, 2018; Vespignani, 2010).

Cutter (2018) differentiates between compound and cascading disasters. She described compound disasters (time and space-specific) as direct and indirect events that occurred in the limited space and time over a relatively short period. Due to the concept, compound disasters are tended to be biased, focusing on the actual event occurrence time rather than the consequences when the priorities are settled to manage the compound disaster. The author also explained that cascading disasters are more hazard-specific (phenomena) and may escalate risks and impact by unexpected interdependent systemic or mechanical failures rather than actual occurrence time, order, and space. Also, risk management strategies for dealing with cascading disasters must be different from those focusing on un-interrelated singular natural disasters. The significant examples are the GEJE and Tsunami in 2011 that resulted in nuclear power plant accident and global supply chain disruption in manufacturing businesses in 2011 and the 2010 Eyjafjallajökull volcanic eruption in Iceland that led to air transportation interruption in European countries. At the same time, these are recognized as technological disasters triggered by natural hazards. This concept of cascading disasters implies the risk management must different from singular natural disasters to reduce unexpected cascading effects and the risks.

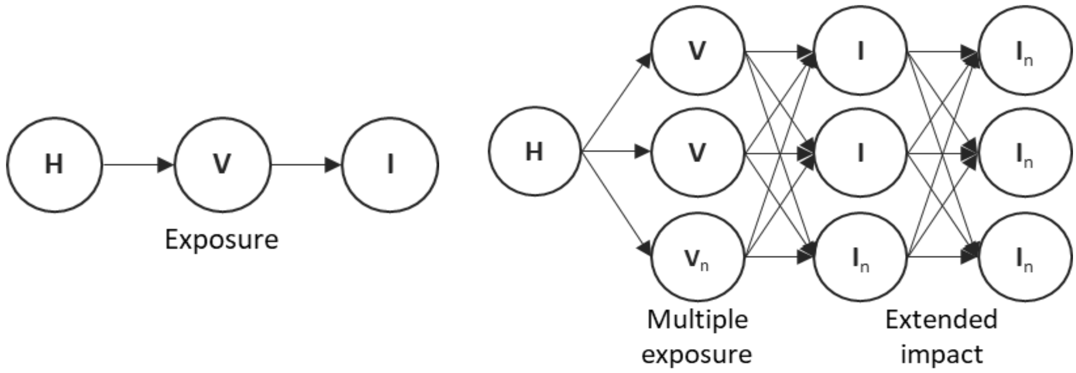
For example, Kelman (2018) clarifies the concept of cascading disasters, calling them “multiple, complex, intertwined causal chains (p. 172).” In addition, FEMA (2006) addressed cascading events as “events that occur as a direct or indirect result of an initial event (p. 3.17)” in the material of independent study course, which is titled as Principles of Emergency Management provided by Emergency Management Institute (EMI). This material mentioned that natural hazards and chemical accidents, as initial disasters, might trigger other subsequent events, for example, electrical failure, chemical accidents, and environmental contamination. Also, the initial events might cause severe environmental damage causing evacuations and harsh long-term impacts on communities affected.

Pescaroli and Alexander (2015) introduced a new definition of cascading events and disasters differentiating these events from singular disasters, drawing on several types of literature. They described the process of cascading disaster as a non-linear impact that is affected by interconnected and interdependent systems as well as initial hazards and human and social factors. Through several case analyses, including the 2001 Howard street tunnel fire in Baltimore, the 2010 eruptions of Eyjafjallajökull, the 2011 GEJE and Tsunami, and the 2012 Hurricane Sandy, they revealed three characteristics of cascading disasters: interdependency; interconnection; and complexity. These cases indicated dynamic system changes, chain events, and consequences of the connections of events. According to the article, cascading disasters are defined as “extreme events, in which cascading effects increase in progression over time and generate unexpected secondary events of strong impact (p. 65).” The study suggested that there is a need for managing different failures and multi-dimensional factors overtime in the cascading process to limit the probability that a disaster will become cascading as reflected in DRM.

More recent work by Pescaroli and Alexander (2018) highlights different concepts of risk, which are compound, interconnected, interacting, and cascading. With cascading disasters, the focus, they advocate the implementation of the Sendai

Framework for Disaster Risk Reduction and support for disaster management due to the uncertainty and complexity of cascading events. Also, cascading risks are associated with "uncontrolled chain losses" that can cause any potential failures in the social infrastructure systems. These integrated interpretations of different meanings of risks give rise to a new approach to improve existing DRM concepts.

As shown in Figure 5, while a single disaster unfolds and has a small effect (Figure 5-a), the cascading disaster is a combination of hazard events, with varying vulnerability, and multiple exposures (Figure 5-b) (Alexander, 2018). Because of the characteristics of cascading disasters, including uncertainty, complexity, and multiple failures of critical infrastructure, coping with cascading risks in terms of risk preparedness and management that focuses on singular disasters is exceptionally problematic. Thus, Alexander (2018) suggested that a magnitude scale for cascading disasters has to be created, which is composed of six levels to better understand and prepare for cascading disasters, as shown in Table 3.



Single disaster =
Hazard X Vulnerability X Exposure

Cascading disaster =
Hazard X (Vulnerability X ○○○ X Vulnerability) X
Multiple exposures

(a) Single disaster

(b) Cascading disaster
(Reorganized from Alexander, 2018)

Figure 5. Conceptual diagram of single and cascading disasters

Table 3. The magnitude of cascading disaster

Scale		Contents
0	Simple incident or major incident	No evidence and progressing or cascading effects
1	Major incident, of limited complexity	The short and straightforward cascading impact Showing secondary effects
2	Major incident or small disaster, with some complex consequences	Limited propagation of second and tertiary events
3	Disaster, with complex consequences	Detecting cascading linkages and progress
4	Disaster, with substantially complex consequences	Identification of chain effects of a cascading disaster
5	Catastrophe, with overwhelmingly complex consequences	Long-term catastrophic impact with interaction destructions

Even though there are multiple efforts to manage the cascading disaster risk and understand the process, these disasters are rarely discussed due to their statistically low frequency compared to natural disasters in general. Kumasaki et al. (2016) investigated inter-relations between cascading natural disasters in an effort to contribute to improving DRM in Japan, which is prone to multiple hazards. Kumasaki research team identified four cascading disaster modes, which are: striking (energy propagation), undermining (system destruction), compounding (system weakness), and blocking modes (the obstruction of normal event flow). In particular, the study highlights understanding the cascading disaster linkage, and these modes can contribute to managing cascading disasters effectively in DRM.

2.1.3 Natech disasters and their characteristics

As Natech was defined in the Introduction, Natechs refer to technological accidents that are caused by natural hazard events. Natech accidents command attention due to the subsequent impacts following natural hazards as the initial events. The trend in the occurrence of Natech disasters is on the rise due to global industrialization, population growth in areas with developed social infrastructures, various facilities crowding, as well as climate change (Krausmann et al., 2019). Such chemical accidents that are caused by natural hazards can be observed in any industrial facility regardless of national or technological development levels (Girgin et al., 2019;

Krausmann et al., 2017). Also, it brings wide-area impacts (Krausmann & Cruz, 2013; Kumasaki et al., 2016).

The impact of Natech has some significant characteristics. These are large-scale and long-term consequences in social, environmental, and economic aspects, unrevealed damage, successive effects, and other burdens on response (Cruz, 2013; Krausmann et al., 2017; Krausmann & Cruz, 2013; Yasui et al., 2017). Masys et al. (2014) defined the Natech disaster as a 'high impact/low-frequency extreme event.' As such, it is capable of unpredicted and extensive occurrences with 'hyper-connectivity' and 'hyper-risks' at the local, regional, and global levels. Due to its inherent uncertainty, unexpected damage, low probability but high consequences, and widespread impacts, Natech disasters require enhanced resilience in both preparedness and response.

Steinberg et al. (2008) stressed that Natech events might simultaneously occur along with natural disasters rather than necessarily following them. When predictable slow-onset natural disasters, such as hydro-meteorological or weather-related disasters, including hurricanes, typhoons, or floods, occur in a Natech risk area, it is economically feasible to prepare for potential Natech accidents. However, it is difficult to respond to Natech when the hazardous area does not have an appropriate evacuation area, or evacuation must be planned after Natech has happened.

There are some examples of Natech disasters showcasing these specific features. The 1999 Kocaeli Turkey earthquake (Mw 7.4) occurred in one of the most populated and advanced industrialized regions. It led to secondary effects, including tsunami, slumping, compaction, and liquefaction, as well as USD 16 billion in economic damage and officially 18,058 human fatalities (D'Ayala et al., 2003). The earthquake triggered cascading impacts, including over 350 industrial facilities damaged; hazardous materials releases, including toxic gases; multiple fires at a tank farm; the intentional atmospheric releases of hazardous gases; environmental contamination (water, soil, and air) affecting several communities; and mass evacuations to prevent casualties and damage from possible explosions of oil tanks (Steinberg & Cruz, 2004).

Hurricane Katrina in August 2005 made landfall in Florida, along the northern Gulf Coast, Louisiana, Mississippi, Georgia, and Alabama (Knabb et al., 2005). The next month, Hurricane Rita hit southwestern Louisiana, bringing destructive winds and storm surge across the region. Several levees and floodwalls failed in Lake Pontchartrain and New Orleans (Knabb et al., 2005), resulting in USD 108 billion in economic losses, 1,833 fatalities, and destruction of social infrastructure, including communication, transportation, and electricity directly to the region and indirectly, across the U.S. (Knabb et al., 2005). There were also significant emergency response failures (Picou, 2009). After these two hurricanes, devastating chemical accidents, including fire and explosions in oil refineries and gas storage facilities onshore and offshore, were triggered, and a total of 611 chemical facilities and pipelines were affected (Cruz & Krausmann, 2009). Notably, the volume of oil spills was about 30 million liters (Guidry, 2006). This cascading disaster led to severe environmental pollution and a long-term impact on human life and the ecosystem (Pine, 2006).

The 2011 GEJE (Mw 9.0) and Tsunami was Japan's worst disaster of this century with unexpected cascading impacts. Almost 906,000 buildings were damaged or destroyed, and it generated several fires (AON BENFIELD, 2011), as well as about 19,000 fatalities and over 3,000 were reported missing (Ishigaki et al., 2013). The earthquake led to a calamitous tsunami, more than 1200 aftershocks, over 380 fires, and significant areas of liquefaction. These cascading effects caused a series of failures of social infrastructures and lifelines, including electricity, water, information delivery, evacuation, telecommunication, transportations, and hampering immediate disaster response (Krausmann & Cruz, 2013). Loss of electricity brought about fires and multiple explosions at the Fukushima Daiichi nuclear power plant, causing radiation and radioactive material releases and global environmental issues (AON BENFIELD, 2011). Also, the earthquake and tsunami impacted industrial facilities, which triggered toxic and flammable substance releases, explosions and fires in oil refineries and LPG storage tanks, and several chemical facilities (Krausmann & Cruz, 2013). Those chemical accidents, including hazardous material releases, induced environmental contamination and both physical and mental health impacts. Suicide and cancer rates have increased in the affected area after the GEJE and Tsunami (Kumagai & Tanigawa, 2018).

Those technological disasters caused by natural hazards are accompanied by uncertainty, complexity, unpredictability, interconnection, and extensive damage. They also create serious short- and long-term issues socially and physically and generate grave concerns and consistent impacts beyond local, regional, and national boundaries. Since the localized impacts are prolonged and more profound on the communities nearby industrial facilities, potential Natech accidents must be managed at the community level (Krausmann & Cruz, 2013; Masys et al., 2014; Steinberg et al., 2004, 2008; Steinberg & Cruz, 2004).

2.2 The evolution of disaster risk management and community participation

Recent global environment and society are more vulnerable and uncertain to risks (Beck, 1992; UN, 2005b), and DRM became one of the current global challenges. Therefore, many countries and international organizations have attempted to reduce the probability of exposure to natural hazards and risks and developed appropriate disaster management systems for their citizens on a multidisciplinary-basis. At the same time, the importance of community participation in DRM has emerged and became an emphasis on international frameworks (Maskrey, 2011).

According to UNDRR (2015), disaster management has been defined as "the organization, planning, and application of measures preparing for, responding to and recovering from disasters (p. 13)." Historically, disaster management has begun as civil protection, defense, and preparedness in the USA, after World War II (Alexander, 2002; Coppola, 2015). At the beginning of the 1970s, disaster management became more focused on natural hazards, particularly meteorological hazards, including storm surge, typhoon, and hurricane, and was initiated to reduce the impact of natural disasters on populations at risk. During this time, the impact of natural disasters on social and economic activity was noted, and disaster management became focused on response and recovery following disasters (Gregory, 2015). Despite the effort to manage hazards, society has become more vulnerable, and the impact of disasters has risen due to changing social and physical environments. International organizations have advocated the development of disaster management plans based on four elements, which are prevention, mitigation, preparedness, and relief. An example is the 'Yokohama Strategy and Plan of Action for a Safer World' prepared in 1994.

The Yokohama Strategy and Plan of Action for a Safer World provided a guideline for disaster management and reduction of natural disaster impacts on communities in 1994. The strategy focused on improving disaster management mechanisms to reduce damages from disasters (Tozier de la Poterie & Baudoin, 2015). This framework was adopted with ten principles: 1) risk assessment for proper disaster risk reduction; 2) disaster prevention and preparedness to reduce disaster relief efforts; 3) integrated policies and plans at all levels including community, regional, national, and international; 4) strengthening coping capacities for effective disaster management; 5) improving early warning systems; 6) prevention through active participation from all levels; 7) vulnerability reduction through adequate education and training; 8) sharing technology for disaster management among international societies; 9) protecting environments for sustainable development; and 10) being responsible for protecting people, social and physical resources. This framework spotlighted cooperation at all levels from the community to the international level, as well as active community participation to more comprehensively understand local perceptions regarding disaster management and improve its scope.

During the active period of the Yokohama Strategy and Plan (1994 – 2004), several studies (Alexander, 2002; Coppola, 2015; Gregory, 2015) were conducted that underlined the importance of comprehensive disaster management, as a capability of the local community, the necessity of prevention, response to complex situations, and participation of all stakeholders including the citizens within the framework of the Yokohama Strategy and Plan. The focus of this research built integrated disaster management systems and resilience at the community level. Through case studies of community engagement in the Philippines, Victoria (2003) argues that community participation is a legitimate part of the natural disaster management system to reduce vulnerabilities and damage. The study revealed that community-based disaster management facilitates building a resilient society, enhances interrelationships among stakeholders, provides an integrated disaster management system, and empowers local actors. However, since the community cannot reduce their vulnerabilities by themselves, the activities should be supported by proper disaster management and cooperation among all stakeholders. Pearce (2003) highlights the need for integrating general disaster management and community planning to sustain disaster preparedness and mitigation from the perspective of response and response-focused disaster management through a case study of the earthquake-prone Portola Valley in California. Buckland and Rahman (1999) underlined the importance of cooperation between the government and rural communities based on a flooding disaster that triggered social conflicts due to a lack of cooperation in community-based disaster management. The authors stressed the need for a partnership and effective risk communication among all stakeholders to improve disaster management.

Vermaak and van Niekerk (2004) highlighted the need to consider indigenous knowledge and a community's perspective as crucial factors to reduce disaster risks in the context of African society. The study concluded that a systematic approach, including developing policies and managing risks in disaster management on the government side, is essential, but it is not necessarily adaptable in all communities. Since each community has different environmental risks and characteristics, the impact of a disaster on the community depends on their vulnerabilities and coping capacities. During this period of applying the Yokohama Strategy and plan, research on DRM dealing with various social, economic, environmental, and political risks (Niekerk, 2006; Vermaak & van Niekerk, 2004) and the concept of DRM has emerged through an acknowledgment of the needs for managing these risks.

After the first global framework for focusing on disaster response and recovery, the UN (2005a) provided the 'Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters' to reduce vulnerability to disasters and disaster risks from significant disasters such as the 1995 Kobe earthquake in Japan, the 9/11 terrorist attack of 2001 in the U.S., and the 2004 Indian Ocean Tsunami. Notably, the Indian Ocean tsunami in 2004 increased public awareness about managing natural disasters and the risks that could generate destructive catastrophic impacts (Tozier de la Poterie & Baudoin, 2015). The new framework was developed to addresses some challenges and gaps in the earlier Yokohama Strategy and Plan, among which is risk governance and risk management, including identification, monitoring, disaster risk reduction, and planning for response and recovery. The Hyogo Framework for disaster risk reduction identified the problem of inter-related risks, including economic, social, and demographic factors to reduce vulnerability (Olowu, 2010). The framework also advocated the development of disaster capacity at the local and national levels.

Specifically, the Hyogo Framework offered five priorities for action: 1) making disaster risk reduction a priority at a national and local level based on the framework; 2) knowing the risks and taking actions; 3) building understanding and awareness of the disaster risks; 4) reducing disaster risks; and 5) preparing for effective response at all levels (UN, 2005a). The Hyogo Framework provided detailed guidelines to reduce disaster risks and vulnerability and enhance resilience for different stakeholders and institutional sectors (Tozier de la Poterie & Baudoin, 2015). It underlined the importance of community participation in disaster management based on recognizing local risks, promoting local engagement, regularly updating and improving disaster plans and information, and utilizing local indigenous knowledge. Numerous commitments are emerging to implement DRM among multiple sectors. However, there remain gaps, which are a lack of cooperation between government and community stakeholders, and solutions in regard to different perspectives between theoretical frameworks and practical applications in adopting the frameworks (Briceño, 2004; Djalante et al., 2012; Matsuoka et al., 2013; Olowu, 2010; Stanganelli, 2008).

Based on a review of the Yokohama Strategy and Plan and its accomplishments, several researchers focused on building resilience to disasters and community-based DRM, advocating a combination of top-down, which is government-centered, and bottom-up, which is a community-based approach. Pandey and Okazaki (2005) and Delica-Willison (2003) highlighted the importance of community engagement to sustain development and DRM for natural disasters by enhancing community resilience to prepare for potential hazards through a review of community-based programs and case studies. For successful community-based DRM to emerge, more proactive engagement, such as analyzing environmental risk and understanding local vulnerability and coping capacities, with accompanying community empowerment are required based on a combined approach of top-down and bottom-up approaches. Bajek et al. (2008) studied the 'autonomous organizations for disaster reduction,' which are known as Jishu-bosai-soshiki, and refers to disaster prevention associations of the local community. These local organizations are established based on voluntary community participation in Japan with case studies suggesting that motivation and quality of community engagement are critical in enhancing community resilience.

Motoyoshi (2006) stressed that a sense of responsibility and high risk-perception would lead to appropriate DRM activities, focusing on flood hazards, at the community level. Luna (2007) and Chen et al. (2006) looked at community-based DRM in the context of the Philippines. Luna (2007) revealed that there is a close relationship between developing community solidarity and community-based DRM for sustainable development. The study pointed out the importance of integrated community-based DRM with community development. Disaster education is necessary to build coping capacity encouraging resident participation, developing local resource management, and integrated community-based DRM.

Maskrey (2011), who examined the DRM approach from a community-based perspective, emphasized the formation of strong partnerships and cooperation across-multiple levels of the community. Acknowledging that there are some limitations to DRM by the local community alone, the author highlighted DRM in terms of social and political aspects in the local management system, that is, in reducing disaster risks. More specifically, officials should consider the active engagement of local actors and promote a sense of ownership of the community. Political officials must take into account local risk territories, improving local economies and mutual support governance based on a top-down and bottom-up approach, and developing partnerships between the national and local governments and communities.

With this perspective, Ikeda and Nagasaka (2011) and Tsubokawa et al. (2008) approached community-based DRM more practically by enhancing coping capacity and reducing local vulnerabilities. To deal with some disaster challenges, such as uncertainty and complexity, they suggested disaster risk governance strategies based on risk scenarios incorporating both scientific and indigenous knowledge from a platform that stored risk information. These authors also advocate multilateral linkages among all stakeholders of the internal and external community for more effective disaster risk reduction and enhancing community coping capacities. Through community-based approaches, various studies attempted to show the advantages of community-based DRM and building community capacity and their contribution to improving DRM systems (Mercer et al., 2010; van Aalst et al., 2008).

Despite the various efforts to reduce and manage disaster risks, global disaster patterns have become more uncertain, complex, and unpredictable. In response, the

U.S. Federal Emergency Management Agency adopted an 'all-hazards approach' to disaster management following the September 11th terrorist attack in 2001 and Hurricane Katrina 2005 (Gregory, 2015; NEA, 2018). Based on lessons learned from these two disasters, international organizations have recognized that more effective DRM must be implemented to deal with potential cascading hazards and their impacts at the national and local levels (Adini et al., 2012). Even though the Yokohama strategy and Hyogo framework contributed effectively to reducing disaster risks and damage, recent catastrophic disasters continue to generate significant losses, in vulnerable countries (GUHA-SAPIR et al., 2013; Komoo et al., 2011; Nicholson, 2014) as well as developed countries (Krausmann & Cruz, 2013; Okada et al., 2011), and requires international and national action (Zaré & Afrouz, 2012). Thus, the third generation of DRM advocacy was developed as the Sendai Framework for Disaster Risk Reduction 2015-2030 based on the lessons learned and practical gaps from the Hyogo Framework. These gaps have been identified as accountability at all levels, a lack of proper regulation and investment for reducing new disaster risks, risk governance for multiple stakeholders, and balancing DRM systems.

The framework aims to lower disaster risks and reduce damage through an integrated approach to diverse management dimensions and enhance disaster resilience, including preparedness. It has four priorities for actions: 1) understanding disaster risk; 2) strengthening disaster risk governance to manage disaster risk; 3) investing in disaster risk reduction for resilience; and 4) enhancing disaster preparedness for effective response and to ‘Build Back Better’ in recovery, rehabilitation, and reconstruction. It is oriented toward increasing disaster capacity, promoting an all-hazards (or multi-hazards) approach at all levels of government, and among all stakeholders in decreasing various disaster risks and achieving sustainable development. Mainly, this framework highlights proactive engagement by all stakeholders, including government, relevant institutions, and sectors, as well as local actors in the process of disaster risk reduction. The new framework reinforces earlier views affirming the importance of DRM at the community level incorporating indigenous knowledge to enhance coping capacity and resilience.

Despite international investment in the development of strategies for managing multi-hazard disasters and highlighting the importance of community engagement, studies on integrating DRM between government and the community are rarely conducted (Paterson & Charles, 2019; Saja et al., 2020). It remains a challenge as to how the community can contribute to DRM at the government and corporate levels. Some studies have demonstrated that community actors play a vital role in emergency response. For example, Twigg and Mosel (2017) and Briones et al. (2019) illustrated ways in which local actors can serve as first responders and valuable resources immediately after disasters since residents must survive by themselves and assist others until the arrival of professional first responders, such as firefighters, disaster managers, or local officials. Specifically, Twigg and Mosel (2017) identified the role of local actors in disaster as assistants, coordinators, rescuers, responders, organizers, and managers. However, most government and corporate disaster plans do not recognize these roles of local participants despite their demonstrated effectiveness in disaster response. Moreover, Briones et al. (2019), citing the lessons learned from community-level responses, affirms that DRM and disaster resilience could be improved through the linkage between top-down and bottom-up approaches. Also, the authors addressed the need for increased risk awareness to prepare for different types of disasters and the risks they pose.

Through a comparison of the three international frameworks, earlier-mentioned, Tozier de la Poterie & Baudoin (2015) stressed the importance of improving community engagement and coping capacity building in DRM. Although the disaster capacity at the local level has become a more critical factor in compound disasters, community participants are often acknowledged as merely ‘aid recipients,’ based on a top-down approach, rather than a crucial partner group as they are a bottom-up approach to DRM. The reason local capacity is not adequately addressed is that the international frameworks are more focused on technological improvements in DRM strategies and scientific domains. Successful DRM, according to Kapucu and Van Wart (2006), will be achieved by incorporating the different perspectives of various stakeholders and the cooperation of all actors, including community members. It also must consider a community’s unique local characteristics (Enshassi et al., 2019; Gregory, 2015; Ikeda & Nagasaka, 2011; Kapucu & Van Wart, 2006; T. Okada et al., 2018) in all aspect of disaster management including multi-hazard disasters.

2.3 Natech risk management and consideration of community involvement

The evolution of global strategies for disaster and risk management reflects the current needs to manage hazards and risks faced by the international community, including anthropogenic, biological, technological, and Natech. Incorporating technological disasters and Natech in DRM is critical, as Natech disasters have occurred in both developing and developed nations (Chiaia et al., 2019; Girgin et al., 2019). Despite these contributions from international frameworks and adaptations by relevant agencies of governments, cascading disasters like Natech continue to be a challenge in promoting cooperative and participatory DRM by all stakeholders, including the local communities (Hirsch, 2019; Shimizu & Clark, 2015) due to wide-area impacts and severe and long-term consequences (Cruz et al., 2004; Suarez-Paba et al., 2019).

Before looking at how Natech risk management is performed, consider the participation of multi-stakeholders, incredibly, at the local level, there were several efforts and actions to reduce technological disasters and risks. In the U.S., Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA Title III) enacted The Emergency Planning and Community Right to Know Act in order to prepare for catastrophic technological accidents (Lindell, 1994). The SARA Title III has established Local Emergency Planning Committees (LEPC) and relevant legislation in a general approach (Lindell & Perry, 2001) to respond to the emergency of chemical events. The legislation explicitly includes hazardous material information disclosure, effective risk communication with citizens, proper data management, and community vulnerability assessment.

In particular, LEPC facilitates local communities located nearby industrial facilities to identify their vulnerability and build strategies to manage technological accident risks. Several studies underlined multi-stakeholders, including the government officials, safety managers, associated experts, representatives from industries, and community participants, should involve in the emergency planning process at the local level (Lindell, 1994; Lindell & Meier, 1994; Lindell & Perry, 1996b, 2001; Whitney & Lindell, 2000) through enhancing collaboration and coping capacity among all stakeholders (Lindell & Perry, 1996a, 2001). Furthermore, Lindell and Perry (2001) and Lindell and Hwang (2008) emphasized the consideration of the different consequences in chemical accidents depending on the initial hazards and local characteristics to provide appropriate risk communication channels and messages to support the implementation of hazardous material management strategies.

The European Union (EU) regulated the Seveso III Directive on the control of major accident hazards involving dangerous substances in 1982. This directive aims to prevent and manage potential major chemical accidents resulted from industrial facilities and probable consequences for humans and the environment (EU, 2012). In order to reduce chained chemical accident consequences and risks, every chemical business requires providing information regarding hazardous materials, storage, risky area, emergency plan, probable scenarios, and potential issues to the neighbor communities (Renn, 1989). Also, the regulation highlights opinions regarding the public concerned should be reflected in the process of establishing or modifying emergency plans for chemical accidents.

Regarding information management, the regulation highlights that relevant stakeholders must disseminate clear, correct, and high-quality information to the public and scrutinize community participation in the decision-making process to contribute to increasing public risk awareness (EU, 2012). Renn (1989) and Walker et al. (1999), explicitly, stressed the importance of ongoing risk dialogues between the public, industries, government officials, and associated organizations. Also, Renn (1989) pointed out the risk communication activities may facilitate affordable risk management through the widespread participation of citizens.

Moreover, after the 1984 Bhopal gas leak accident in India, United Nations Environment Programme (UNEP), internationally, provided the Awareness and Preparedness for Emergencies at Local Level (APELL) program to minimize technological disaster risks, environmental emergency, natural disasters, as well as Natech disasters at the local community level in 1988 (UNEP DTIE, 2015). The significant aims of this program are to: create a resilient community to multi-hazards, particularly technological hazards; increase risk awareness of technological events; and promote coordinative, integrative, and flexible emergency preparedness strategies based on the existing emergency plans at the local level. Also, APELL affirms three major stakeholder parties, including the government authorities, industry sector, and the public, including the local community, private organizations, and other interest groups. The APELL process consists of five phases, from stakeholder engagement, understanding community hazards and risks, the all-hazards emergency management plan for the community, implementation and validation, and maintenance of the APELL. This process encourages the multi-stakeholders, especially the local community, to active participation in the risk management for technological accidents. In addition, the APELL has been amended according to the Sendai Framework for Disaster Risk Reduction: 2015-2030, and it is expected to enhance the coping capacity of the local stakeholders for technological disasters, as well as all hazards (UNISDR, 2018).

Research on Natech risk management has existed since 1994. Recent systematic reviews of Natech research (Suarez-Paba et al., 2019) have indicated several studies focused on reducing and managing Natech risks, including Natech risk assessment (Antonioni et al., 2014; Cozzani et al., 2014; Cruz & Okada, 2008; Girgin & Krausmann, 2013; Lindell & Perry, 1997), Natech impact analysis (Cruz & Krausmann, 2009; Krausmann & Cruz, 2013; Okada et al., 2011; Ozunu et al., 2011; Steinberg & Cruz, 2004), risk perception and communication (Funabashi, 2012; Lindell & Hwang, 2008; Miller, 2016; Picou, 2009; Salzano et al., 2013; Yasui et al., 2017; Yu et al., 2017; Yu & Hokugo, 2015), and Natech risk management (Cruz, 2013; Cruz & Okada, 2008a; Krausmann & Baranzini, 2012; Steinberg et al., 2008).

In the context of Natech risk assessment and analysis considering the local level, Lindell and Perry (1997) investigated ‘earthquake-initiated hazardous materials releases (EIHRs)’ through a case study of the Northridge earthquake. The authors suggested various hazard assessment and disaster management actions, especially at the mitigation and preparedness stages for potential accidents. They also highlighted the need for improvement in local governance based on enhancing public risk awareness and implementing and sharing information for local emergency managers or officials. Girgin and Krausmann (2013) developed RAPID-N for a comprehensive Natech risk assessment that facilitates the creation of dynamic scenarios, emergency or land use plans, and analysis of Natech impacts at the regional level. Antonioni et al.

(2014) developed a quantitative Natech risk assessment capability adapting equipment vulnerability models based on Natech scenarios triggered by floods, including atmospheric hazards and damage to storage tanks. This assessment assists in decision making related to floods in industrial facilities.

Additionally, Cozzani et al. (2014) introduced a quantitative Natech risk assessment technique to deal with 'high-impact low-probability (HILP)' hazards based on domino effects and Natech accident scenarios. This assessment method can be used in land use planning and decision making. Cruz and Okada (2008b) proposed a 'Rapid Natech Risk Assessment (RNRA)' to reduce Natech risk for 'low frequency/high consequence events.' In the assessment process, various social factors, such as social infrastructures, community vulnerability, environmental conditions, and disaster management systems, are considered. The RNRA enables users to provide proper knowledge and increase risk perception for Natech events at the local level. Also, community participation in Natech risk management is emphasized to enhance the knowledge balance between academies and local stakeholders.

With increasing Natech accidents, several empirical investigations were carried out. Steinberg and Cruz (2004) focused on mitigation and preparedness for Natech accidents through broad surveys and analysis of the impact of hazardous material releases caused by the 1999 Kocaeli Turkey Earthquake at industrial facilities. The study pointed out the need for developing flexible and coordinative Natech risk management, including land-use planning for industrial facilities as well as local authorities and communities. Numerous researchers have analyzed the impact and consequences of the GEJE and Tsunami in 2011. Okada et al. (2011) focused on environmental damage, socio-economic and infrastructure impacts, and the failure of a nuclear power plant as catastrophic consequences. The study addressed the need for improving preparedness for expected and unexpected cascading disasters with multi-hazards, especially for tsunami affecting nuclear powerplants in the coastal area.

Krausmann and Cruz (2013) studied the consequences of earthquake and tsunami on chemical facilities to better understand the causes of Natech, including their social impacts through field surveys of industry damage and failure mechanisms. Among lessons learned, the authors have highlighted improving Natech risk and land-use planning strategies and emergency management plans. Suarez-Paba et al. (2020) suggested a comprehensive framework for Natech risk management that consists of infrastructure, organization and management, risk communication and risk governance, and the interaction among all systems, including community participation in Natech risk management.

In other studies, Cruz and Krausmann (2009) investigated and analyzed over 600 hazardous materials incidents caused by Hurricane Katrina and Rita from platforms and pipelines at offshore facilities. The authors concluded that there was a need to ameliorate risk considering all stakeholders, including public and private sectors, and federal agencies, to reduce Natech risks. In other studies, Ozunu et al. (2011) carried out surveys to scrutinize Natech hazards and the correlation between the vulnerability of the local community and infrastructure in Romania. As a result, they emphasized the need for increasing Natech risk awareness among all stakeholders, creating a detailed Natech risk management strategy, and maintaining risk communication with local communities.

Meanwhile, effective Natech risk communication has also been promoted to deal with a lack of proper information and increasing risk perception (Cruz et al., 2004; Cruz & Okada, 2008b; Cruz & Suarez-Paba, 2019; Krausmann, 2010). Mainly, thus, a number of studies have been carried out to examine risk perception and awareness and highlight their importance in solving issues of risk communication. Yu et al. (2017) and Yu and Hokugo (2015) conducted surveys to understand public evacuation behavior after Natech accidents triggered by the GEJE and Tsunami. They found that risk perception, socio-demographics, and location relative to the hazard influenced judgments on appropriate evacuation behavior. However, residents neighboring industrial facilities/or complexes that have the potential to cause technological disasters triggered by natural hazards to have little information on how to manage these types of disasters and their risks. As a result, citizens should evacuate during Natech events depending on their risk perception and past experiences. The results also implied the need for advancing evacuation strategies and considering Natech events in DRM systems.

Picou (2009) studied the risk awareness of residents regarding air pollution and sediment contamination induced by Hurricane Katrina and Natech incidents in New Orleans. He found that residents and clean-up workers were exposed to toxic and hazardous materials. There was, however, a lack of risk awareness of health and environmental issues, as well as programs for reducing risks. The author suggested that Natech be considered a potential short- and long-term impact on mental and medical health risks within a comprehensive methodology for Natech risks. Miller (2016) analyzed public trust after DRM failures in two Natech accidents, the 2005 Hurricane Katrina and 2011 the GEJE and Tsunami. The findings demonstrated that better quality information could assist in rebuilding individual trust in all government levels, as well as a need for providing communication channels between the government and citizens through community participation in managing the long-term impact of Natech disasters.

Funabashi (2012) and Funabashi and Kitazawa (2012) investigated the causes of the Fukushima nuclear powerplant accident caused by the earthquake and tsunami of 2011. Even though this nuclear disaster could be expected, a lack of communication among all stakeholders, unpreparedness for the accidents, and absence of leadership in the government, inadequate responses influence the occurrence of the most severe Natech. The authors suggested more transparent risk and crisis communication and community involvement in DRM planning to rebuild trust between the public and private sectors and citizens.

With the number of local communities near industrial complexes or facilities increasing, interests in Natech risk management at the local level are consistently rising. Steinberg et al. (2008) pointed out that managing Natech disaster is challenging due to the potential for wide-area impacts, the lack of expertise and resources, the probability of simultaneous effects, and the unlikelihood that Natech has been included in disaster management planning. For these reasons, the authors consider community involvement vital for better Natech risk management, especially at the planning stages of mitigation and response. Cruz and Okada (2008a) analyzed Natech risk management systems in the U.S., Japan, and European countries and enumerated the different types of natural hazards, such as earthquakes, flooding, and strong winds, to establish relevant regulations for reducing and managing Natech risks. They also considered the consequences and cascading effects of potential Natech disasters for employees in the industrial facilities and nearby communities. Krausmann & Baranzini (2012) identified the effectiveness and good practices of Natech risk management through a questionnaire survey to European community members. The findings show that chemical accidents are addressed in policy frameworks, but there is still a lack of proper regulations for Natech risk management, and the existing guidance, which is focused on general chemical accidents, did not include Natech risks and possible accidents. The survey emphasized the need for building effective Natech risk management systems through better risk communication among all governmental stakeholder levels, increasing Natech risk awareness, and better preparedness for regulation and guidelines as well as developing Natech risk assessment.

In the literature above, the severity of damage and its impact on Natech accidents was demonstrated through diverse perspectives and case studies, including the Fukushima nuclear powerplant failure, significant hazardous material releases by Earthquake Kocaeli, and Hurricane Katrina and Rita. While most Natech accidents have had severe direct or indirect impacts on the local communities near industrial facilities, only a few studies, which took a more theoretical approach, have stressed the importance of community involvement or community consideration in Natech risk management (Cruz & Okada, 2008a; Cruz & Suarez-Paba, 2019; Funabashi, 2012; Picou, 2009; Steinberg & Cruz, 2004; Suarez-Paba et al., 2019). Thus, these gaps make local community involvement in Natech risk management is urgent, and policy must be established identifying how they can contribute with other stakeholders, such as experts, officials, and local first responders, to reduce Natech risks and impacts. Furthermore, community engagement would provide a practical perspective from the local level, which is based on community coping capacities, environmental risks, resilience, and inter-relationship with other actors.

2.4 For building resilient communities

2.4.1 Community resilience

The concepts of resilience are addressed as 'resile from' or 'spring back from' disasters (UNISDR, 2009), 'jump back' (Klein et al., 2003), 'bounce back' (Levine et al., 2012; Wisner & Kelman, 2015), and 'bounce forward' (Manyena et al., 2011). Despite the presence of several definitions of resilience, this thesis considers resilience as 'bounce forward.' Considering these origins, resilience is defined as "the capacity of an individual, household, population group or system to anticipate, absorb and recover from hazards and/or effects of climate change and other shocks and stresses without compromising (and potentially enhancing) long-term prospects" (p. 160) (Turnbull et al., 2013). UNISDR (2009) defined resilience as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and function" (p. 24). Through the Hyogo Framework and Sendai Frameworks, 'building resilience' in communities has become a crucial concept to enhance the coping capacity of communities to disasters at all levels (Feleke & Siambabala, 2009; Kruse et al., 2017; Moreno et al., 2019; Wisner & Kelman, 2015). It implies that the resilience capacity could contribute to reducing disaster risks, minimize impacts, and encourage community participation (UN, 2005a; UNISDR, 2015b). In particular, it emphasizes the use of knowledge, innovation, and education (UN, 2005a) to build resilience at all levels (UNISDR, 2015b).

Several researchers have added additional perspectives to the concept of building resilience. Djalante et al. (2012) analyzed building resilience in Indonesia focusing on natural hazards through examining the implementation of the Hyogo Framework for actions. They found that there is still a lack of DRM capacity, systematic learning, and broad consideration in DRM at the local level, even though multilevel participation in the process for improving the DRM system has been extensively implemented. They highlighted the need for integrative risk management at the local level. Zhou et al. (2014) exposed a lack of action for building resilience through examining the implementation of the Hyogo frameworks; the research team highlighted the importance of integration of disaster resilience and disaster education to reduce future disaster risks. Oxley (2013) argued for a 'people-centered principles-based' approach for the post-Hyogo framework. This approach focused on the practical experiences of disasters from the local level and global disaster risk trends, as well as framed principles. In the perspective of resilience as a long-term sustainable system to survive disasters in the community, it requires consideration of the needs, priorities, engagement, and empowerment to enhance resilience at the community level. Also, the analysis highlighted that community resilience, which means a 'people-centered' approach, is a cornerstone toward building national resilience to disasters. Also, Alexander (2013) explained that resilience has multiple-dimensions, namely social, technical, physical, and psychological. Among them, the psychological and social dimensions could contribute to improving the adaptability to disasters within the local social systems, including local culture, activities, and decision-making.

Within this concept of resilience in DRM, community resilience has emerged as a potential capacity of communities. Here, the term 'community' is adapted as a group of tightly networked individuals, live in the same geographical locations or time, and share culture or general perspectives (MacQueen et al., 2001; Oxley, 2013; Wisner & Kelman, 2015). Community resilience is referred to essential state concerning an ability to absorb and deal with all events and its impacts (Cutter et al., 2008). Another definition introduced by Magis (2010) is "existence, development, and engagement of community resources by community members to thrive in an environment characterized by change, uncertainty, unpredictability, and surprise" (p. 402). In the disaster management context, community resilience is emphasized for community survivals (Gonzalez-Muzzio & Sandoval Henriquez, 2015) for at least 72 hours (Lichterman, 2000) until the arrival of aid, including relief supplies (Twigg & Mosel, 2017). Although international and national organizations with experts have consistently made efforts to reduce disaster risks and damage at the local level through developing relevant programs and strategies or regulations, communities are still vulnerable to disaster. Notably, a workshop on disaster resilience (NIST, 2015) underscored the need for community members to engage in DRM by examining and recognizing their-own unique characteristics that would contribute to community-based DRM. Also, Ji (2018) affirmed that community resilience is a crucial aspect of reducing disaster risks.

Norris et al. (2008) addressed community resilience as a mechanism that links the network of adaptive capacities to respond following disruption or adverse effects like disasters. The authors suggested four dimensions of adaptive community resilience including 'economic development,' 'information and communication,' 'community competence,' and 'social capital' as a combination of adaptive capacities. Among them, social capital is highly associated with community resilience theory. It includes ‘network structures and linkages,’ ‘social support,’ ‘community bonds, roots, and commitments,’ that contribute to promoting community engagement to enhance community resilience. At this point, a variety of researchers and their teams examined how community resilience can be applied, and the types of variables that are salient. Kwok et al. (2016) identified community resilience, as social resilience, from different perspectives of stakeholders, including researchers, practitioners, and policymakers. The authors proposed a set of community resilience indicators as follows: ‘community gathering place,’ ‘social support,’ ‘knowledge of risks and consequences,’ ‘collective efficacy,’ and ‘sense of community.’ In addition to these factors, Kwok et al. (2018) highlighted collaboration between the local community and governmental agencies through a bottom-up approach to develop a framework for measuring those resilience indicators. The findings show that the needs and priorities of the community should be considered in DRM. Also, the study emphasized the need to be aware of community resources and their neighbors, as well as to consider uncontrollable cascading disaster impacts.

More practically, Matsuura and Shaw (2015) carried out a study on school-based recovery and community building in a local community affected by the GEJE and Tsunami. The research team has found a resilient community can be built based on active collaboration focusing on child and regional characteristics among local stakeholders. The results show that community and school activities before the disaster were densely interlinked with the coping capacity of the community. Moreno et al. (2019) conducted a case study focused on the responses of a small community in the 2010 Chile earthquake and tsunami. The findings showed that the community resilience factors that led to outstanding DRM were a ‘sense of community’ and ‘social capital’ that characterized the rescue operation; ‘local knowledge’ that promoted self-evacuation; ‘organization’ and ‘cooperation’ despite a lack of external resources; and, support-based ‘trust.’ Alshehri et al. (2013) demonstrated community resilience factors as ‘age,’ ‘education,’ ‘economic,’ ‘risk perception,’ ‘willingness and responsibility,’ and ‘access to sources (information and knowledge)’ through a case study in Saudi Arabia. The ‘willingness and responsibility’ is realized as a fundamental indicator that encourages community members to participate in DRM activities.

With increasing complexity, uncertainty, and unpredictability of multi-hazards like Natech in highly interconnected societies, the concept of community resilience for enhancing the coping capacity for multiple disasters has received attention from various researchers in the context of Natech. Masys et al. (2014) stressed building resilience at government and community levels in order to better prepare for potential Natech disasters and achieve comprehensive risk management and governance for Natech as a paradigm. The study suggested 'reflective response' as a critical component of a resilient community, allowing a systematic approach in a complicated situation, such as cascading disaster, based on improving the present Natech risk management systems. In order to build community resilience to Natech events, Suarez-Paba et al. (2019) noted the importance of risk communication and risk governance for Natech resilience through a proposed comprehensive Natech risk management framework mentioned earlier. The community can best understand its situation and better prepare for potential Natech disasters through pre-event information disclosure by relevant experts. Also, Natech risk governance facilitates community engagement in the Natech risk management process and its decision-making as well as fostering cooperation with all stakeholders.

In general, Natech risk management is carried out by the government with experts as a top-down approach due to time and information limitations. As previously discussed, risk management tends to be a top-down process implemented by relevant experts (Aven, 2016; Renn, 1998). As a part of it, Natech risk management also seems to adhere to this principle. However, during a Natech accident, non-expert local stakeholders, including local communities, may not be recognized as important actors in Natech risk management, including risk communication processes, even if the local community is at the center of events (Burby et al., 2003; Pandey & Okazaki, 2005). Thus, the lack of community-based expertise or community engagement poses an obstacle in which results may vary from limited understanding concerning the application of effective Natech risk management practices to even conflicts between local actors and government agencies.

To build community resilience, the capacity for participation in managing risks regarding technological or Natech accidents is crucial (Lindell & Perry, 2001). Since each community has dynamic aspects, such as cultural, social, and physical diversity;

different levels of information, knowledge and risk perception; and, different disaster experiences, communities will vary in coping capacities and resilience levels. Thus, although several studies contribute to community engagement in Natech risk management to enhance resilience (Cruz & Okada, 2008b; Reniers et al., 2018; Suarez-Paba et al., 2020), strengthening the capacity of the community to build Natech resilience into Natech risk management systems remain challenges.

2.4.2 Community engagement in DRM

The local community responds differently to disasters depending on the types of hazards and regional characteristics in the disaster management system (Paterson & Charles, 2019). The community response activities require proactive and constructive participation of the community members (Mojtahedi & Oo, 2017; Witvorapong et al., 2015). Witvorapong et al. (2015), stressed the importance of the local community as it influences disaster risk reduction at the local level. This social participation can be 'social capital' as the local resources related to community or individual attributes (Chola & Alaba, 2013; Hyyppä & Mäki, 2003). Also, local participation in DRM is a critical component to enhance community resilience (Zubir & Amirrol, 2011).

There are several attempts to understand public participation. Arnstein (1969) suggested the 'ladder of citizen participation' to promote the idea of citizen participation and power generated by the engagement of the community. This theory is recognized as the 'cornerstone of democracy' and focused on the functions of participation. It provides eight grades community involvement with three stages (non-participation, degrees of tokenism, and degrees of citizen power) to explore local community engagement. It is often addressed in research concerning community involvement in decision making (MacAskill, 2019).

Improving this theory, the concept of the 'split ladder of participation' was developed based on the uncertainty of surround circumstances and considering interactive trust by Hurlbert and Gupta (2015). The study addressed the effectiveness of public participation under different conditions in the decision-making process. It suggested that the degree of public involvement will be different depending on the level of determining problems, dividing developed questions, and unidentified problems. The authors explained that a determined problem needs a lower level of participation according to the inherent agreement. Still, the unframed problem is related to a more public problem with uncertainty (Hoppe, 2010), such as climate change. Additionally, the International Association for Public Participation (IAP2) proposed the Spectrum of Public Participation to encourage direct participation in decision-making with a predetermined agreement (IAP2, 2017). It has five levels that inform, consult, involve, collaborate, and empower, offering various approaches to participate in the decision process.

However, there are several challenges for public engagement in DRM. Gaillard and Mercer (2012) and Owens (2000) pointed out that insufficient trust and communication with experts or governmental agencies discourage community participation during the decision-making process. Gaillard and Mercer (2012) argued that 'participation fatigue' induces lower engagement as it limits involvement as interests in participation decline over time. On the other hand, Wells et al. (2013) implied that the local community could build a trusting relationship with the government through active community engagement in DRM. Godschalk et al. (2003) pointed out that insufficient participant's interest also affects community participation in the process of hazard planning.

Community participation is recognized as an essential aspect of successful DRM. Several studies have been done to identify factors that encourage proactive community engagement in DRM, including decision making during emergencies. Mojtahedi and Oo (2012) addressed empowerment, legitimacy, and urgency to promote the involvement of all stakeholders in DRM based on stakeholder and decision-making theory. MacAskill (2019) focused on community participation in disaster recovery, indicating the need for local resources (human and finance), promoting favorable community perception on engagement in DRM, and building trust in government decision-making the right decision. Burnside-Lawry and Carvalho (2015) highlighted the importance of leadership, strategic partnership, a comprehensive initiative for public engagement initiatives, efficient governance to build a system for local-level engagement, and appropriate risk communication among all relevant actors through an analysis of the priorities from Hyogo Framework. Mat Said et al. (2011) emphasized empowerment as a critical element in decision-making to organize and utilize local resources. The present top-down approach must be reassessed to avoid the limitations of the bottom-up approach regarding active participation and expressing opinions, as community-based risk management is conceptualized through comprehensive coordination and cooperation based on ample support from all stakeholders.

Apart from the above, emphasizing the community, McMartin et al. (2018) identified how to do better risk communication and the coping capacity to extreme hazards, and understanding community activities as a priority of community participation to decrease community vulnerability. Zubir and Amirrol (2011) highlighted sharing local expertise, such as community experiences, localized disaster management systems, community-based governance, effective coordination, and sufficient resources. Enshassi et al. (2019) in the Gaza Strip and Valibeigi et al. (2019) in Iran studied community participation components and found that risk awareness, capacities such as knowledge, skills, environment, and local organization status influence public involvement. Ainuddin et al. (2013) and Berkes and Ross (2013) highlighted strengthening coordinative partnerships, building local organizations, developing collaborative risk governance, and considering multidisciplinary perspectives, as well as leadership. The need for consideration of regional and cultural characteristics is stressed in a community-based DRM study by Allen (2006). Since local communities, in a global context, exhibit different social and physical environments, they have different levels of coping capacity and systems, risk perception, local resources, and community engagement. Various literature shows that successful community participation in the risk management must include some major factors, including systemic risk governance at the local level, effective risk communication among all local stakeholders, a sense of community, social networks, and sufficient local resources, which are information, indigenous and advanced knowledge, and experiences.

2.4.3 Community-based DRM: An example from Japan

Based on the literature, an example of Japanese community involvement in DRM shows evidence that leads to practical activities for disaster risk reduction. Japan has been known as one of the most disaster vulnerable countries being earthquake and tsunami-prone and experiencing several typhoons and torrential rain annually.

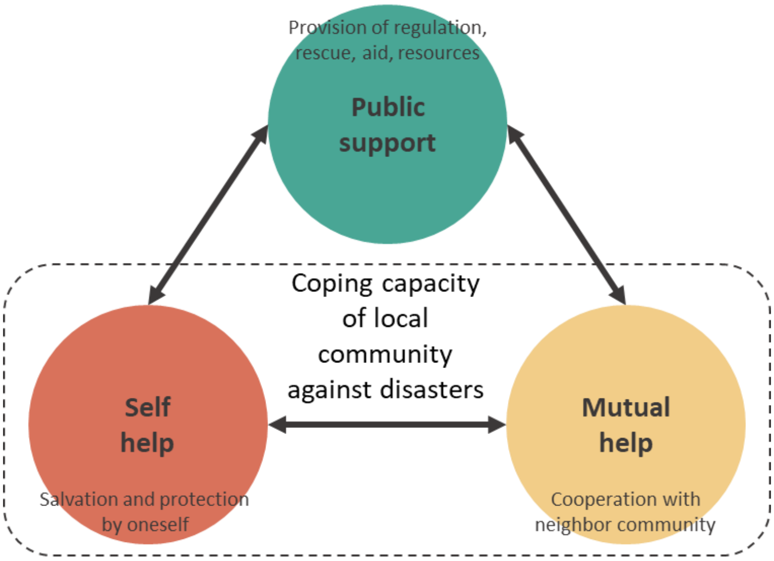
According to a report from the Japan Meteorological Agency (JMA, 2017) and statistic data, the number of typhoons occurring in Japan is approximately 26 per year, and the average number of earthquakes over magnitude 4 per decade (2008-2017) is 1,100.

In the context of high disaster risk in Japan, many cities have industrial facilities, including chemical plants, nuclear power plants, and numerous factories that are located in coastal and seismically vulnerable areas, and many of these vulnerable facilities are interconnected. According to the Japan Fire and Disaster Management Agency (FDMA), there are 75 oil refinery complexes in 82 regions of Japan (FDMA, 2017b). A network of critical infrastructures is forming nation-wide. Whenever disasters have occurred, impacts tend to cascade and affect multiple infrastructural systems (Kobayashi, 2014). For these reasons, Japan has become more vulnerable to cascading disasters, and when disasters occur, the communities and citizens suffer as well as the industries. Considering these vulnerable disaster environments, Japan should have developed a strong history of community-based DRM and community participation under well-structured systems. Such systems do indeed exist and are called 'Jishu-Bosai-Soshiki,' which is the subject of this thesis.

Jishu-Bosai-Soshiki (自主防災組織), or Jishubo in short, mean "autonomous organization for disaster reduction'; this is a community-based association for disaster management focusing on preparedness and response activities. This organization is expected to apply indigenous knowledge, practical experiences, and wisdom from real life to disaster prevention. According to the Japan Fire and Disaster Management Agency (FDMA, 2017a), Jishu-Bosai-Soshiki was initiated under the Basic Disaster Management Plan for the first time in 1961. Since 1973, the government agency has fostered the activities of this organization to prepare for disasters in urban areas. Moreover, though the government and relevant organizations have put efforts to save citizen's lives and enhance community coping capacity for disasters, it is still not realized. However, the Great Hanshin Awaji (Kobe) Earthquake of 1995, provided renewed motivation and fostered community-based DRM, including the Jishu-Bosai-Soshiki, newly-formed NGOs, various volunteer groups, and community activities under the renaissance of disaster volunteerism (Atsumi & Goltz, 2014).

In more detail, there are manifest limitations to efforts by official agencies in immediate response and minimizing damages during catastrophic disasters. The community activities through community-based DRM become of great importance. Thus, central, regional, and local governments have vigorously cultivating community-based disaster culture through fostering Jishu-Bosai-Soshiki under the slogan 'save our lives by ourselves' and highlighted its significance. Moreover, this perspective focuses on a more bottom-up approach that promotes DRM centered on the local community, not by the central government (Okada et al., 2013).

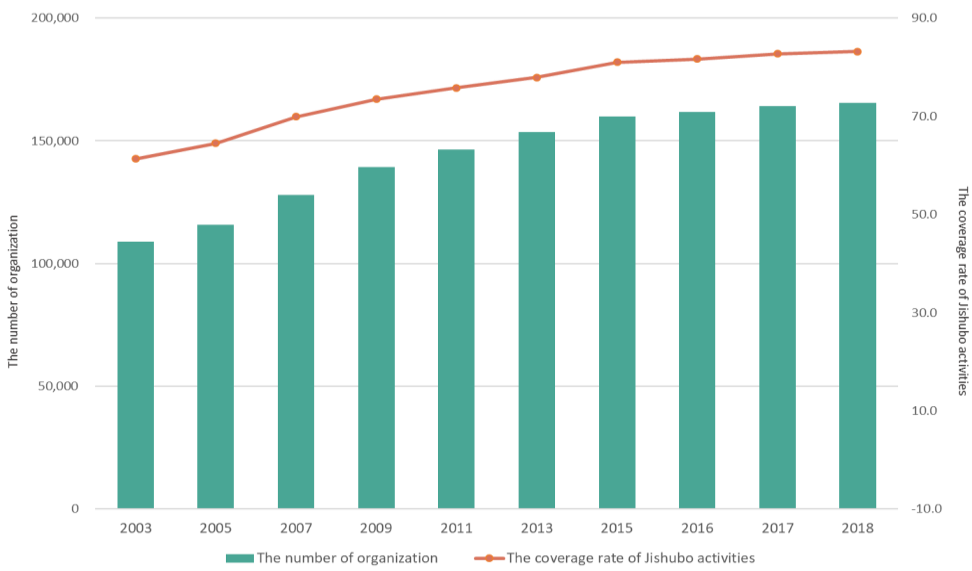
Jishu-Bosai-Soshiki works through a systemic inter-relationship among self-help, mutual help, and public support organizations and associations (Figure 6). Self-help (自助) means to save and protect citizens' lives on their efforts, as earlier mentioned, according to their coping capacity for disasters. Mutual help (共助) is organizational and proactive participation in DRM through building coordinative and collaborative relations with the neighborhood and adjacent community networks. Finally, public support (公助) means that central, regional, and local governments provide proper resources to local communities, and reduce disaster risks by supporting quick local response through legislation or relevant regulations (FDMA, 2017a). The importance of this concept is explicitly highlighted since it makes how associated stakeholders, including local government officials, residents, and first responders, can manage disaster risks within collaborative interactions (Ehrlich & Schneiderbauer, 2006).



(Adapted from FDMA (2017a))

Figure 6. A major concept of DRM in Japan

The fundamental roles of the Jishu-Bosai-Soshiki have mainly entailed activities before and, as necessary, during disasters. In daily life, the organization plans and performs disaster drills and conducts educational workshops, educating local community members, patrolling their residential areas, and maintaining response equipment and facilities. During the emergency, the roles are more focused on responses, such as guiding residents, including elderly or persons with disabilities, to shelters, conducting rescues, providing first aid, and supplying relief goods (e.g., foods, water, or other disaster supplements (Bajek et al., 2008; Cabinet Office, 2018). Jishu-Bosai-Soshiki also works on the maintenance of community activities, development of disaster management plans, or building social networks with other communities in other cities. The average coverage rate[2] of the organization nationwide was about 37 % in 1988 (Cabinet Office, 2005). Subsequent to the Great Hanshin Earthquake in 1995 and more recent catastrophic and cascading disasters, the trend of the rate of Jishu-Bosai-Soshiki, which is shown as the coverage rate of the Jishu-Bosai-Soshiki activity, in 2003 was 61.3 % and in 2018 showed a significant increase with an average rate of 83.2 % (Figure 7).



(Adapted from Cabinet Office, 2019)

Figure 7. The trend of the rate of Jishu-Bosai-Soshiki

Even though community associations, like Jishu-Bosai-Soshiki, are key actors in

[2] The coverage rate of the Jishu-Bosai-Soshiki activity is the percentage of households in the area included in the scope of activities of the Jishu-Bosai-Soshiki, out of all households.

managing multi disaster risks at the local level, they continue to be regarding as recipients in the systems (Cabinet Office, 2018). Further, most formal disaster plans and systems are oriented to single natural hazards and disasters and general disaster management rather than complex and cascading disasters. In consideration of the coping capacity of Jishu-Bosai-Soshiki to multi-disasters, these organizations must contribute to improving the existing DRM, and prepare for potential cascading disasters, especially Natech accidents. In order to better managing Natech risk under conditions of uncertainty and complexity, a new approach, namely a comprehensive community-based Natech risk management, is needed based on active community engagement and localized multiple risk analysis.

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Chapter 3 Conceptual Framework

This chapter addresses a way of involving and ensuring the participation of local multi-stakeholders in Natech risk management to prepare for the potential Natech disasters and reduce Natech risks at the local level. Several studies consistently addressed the topic that how to improve the risk management system for Natech in order to manage Natech accident risks and protect workers in industrial facilities and the resident living near the facilities (Cruz & Okada, 2008; Krausmann & Baranzini, 2012; Reniers et al., 2018). Also, other studies have highlighted a need for Natech risk management and a multi-disciplinary approach through collaboration among multi-stakeholders (Cruz & Suarez-Paba, 2019; Reniers et al., 2018; Suarez-Paba et al., 2020). The present national and regional DRM could provide the cornerstones to develop community-based Natech risk management.

Figure 9 presents the conceptual framework for this thesis based on the literature review and lessons from past Natech accidents. The basic structure of this framework is based on the concept of Japanese disaster risk governance (FDMA, 2017). Here, the reason that the concept has been adopted in this thesis is the possibility of collaborative DRM through building partnerships among all stakeholders, including residents, government officials, and first responders, as well as NGOs (Ehrlich & Schneiderbauer, 2006; UNISDR/ADRC, 2007). Thus, this concept focuses on more initiatives of community-based DRM, including proactive community participation and community resilience through collaboration and soft- and hardware supports by the government and multi-stakeholders. The framework shows the relationship between multi-local stakeholders with three parties, including the local community, mutual aids, and the government, and how they can contribute to improving Natech risk management, explicitly including the local community.

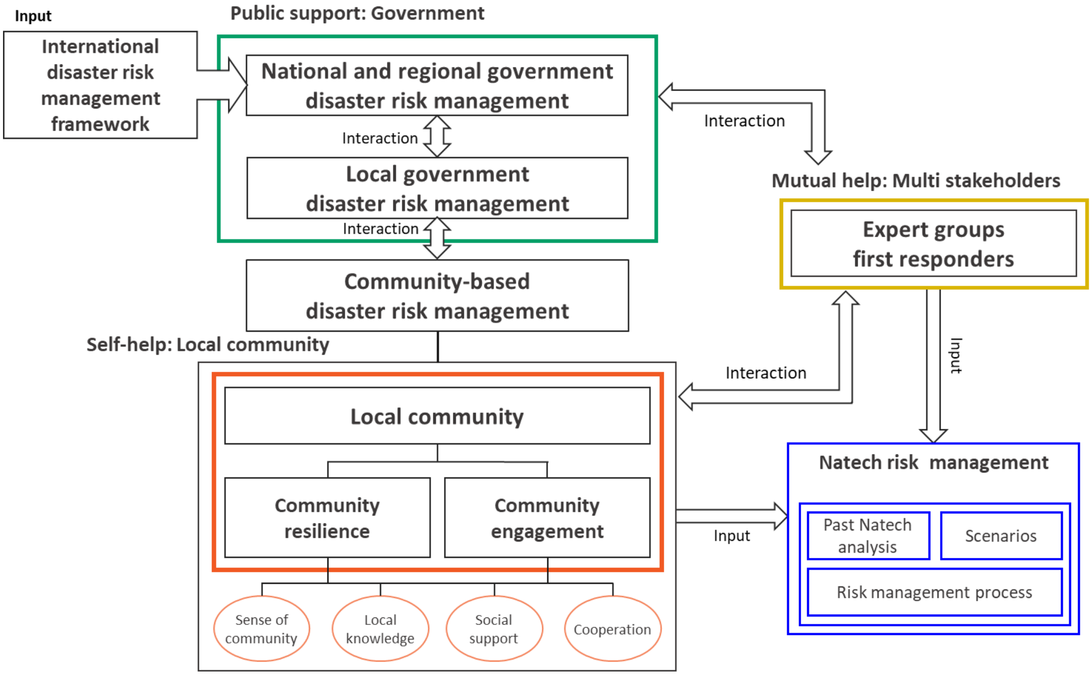

Figure 8. The conceptual framework

Public support: Government

Many countries and the international community have established or improved the national and/or regional DRM strategies and plans based on the international DRM frameworks, such as Sendai Framework for Disaster Risk Reduction, that reflect disaster trends and social and physical environment in each country. The government, particularly local government, considers national DRM strategies, environments, and circumstances when they develop government-centered local DRM and community-based DRM (Cabinet Office, 2018; Maskrey, 2011).

The government is involved in offering systems politically, economically, and culturally that facilitates effective disaster risk reduction (Balamir, 2006; Luna, 2007; Shi, 2012). Specifically, the government leads DRM systems, including relevant policy making, decision making, resource, and finance allocation, providing an educational program to increase public risk awareness, and support knowledge and skills for emergency management to implement DRM in general (Shi, 2012; UNISDR, 2017). The government coordinates the roles of associated stakeholders, including the government, local community, and NGOs, as well as an international society, and promote their engagement in DRM. In order to reduce disaster risks at the local level, the government covers limitations of local or community-based DRM through improving social and political systems to support the local DRM activities as a partner and promoter of local stakeholders (Maskrey, 2011). This approach enables government officials can develop mutual support governance based on both top-down and bottom-up approaches.

In particular, since Natech accidents bring serious and long-term consequences widely, it is important that all levels of government must engage in DRM for managing Natech base on relevant international and national frameworks and collaboration with other stakeholders (Cruz et al., 2004; Hirsch, 2019; Shimizu & Clark, 2015). The government is expected to lead multi-stakeholders, including the government officials, safety and chemical experts, representatives from industries, and local community members, implement proper emergency planning during chemical accidents (Lindell, 1994; Lindell & Meier, 1994; Lindell & Perry, 1996b; Whitney & Lindell, 2000). Furthermore, the government may set a direction for managing both natural and technological disaster risks based on integrative disaster risk assessment for multi-hazard, including technological hazards, encouraging, building stakeholders' and businesses' resilience for maintaining critical infrastructures, and collaborating all levels of government through providing proper risk information and sharing knowledge (UNISDR, 2015).

Mutual help: Multi-stakeholder

Mutual help is originated from initial response activities by neighborhoods, relatives, friends, and community members during disasters until the arrival of professional first responders with appropriate resources (Cabinet Office, 2018). Particularly, it would be difficult for the local or external first responders, as well as municipalities, to perform an extensive disaster response during disasters. Thus, multi-stakeholders, including government officials, associated experts, firefighters, and policies at the local level is spotlighted (Briones et al., 2019; Cabinet Office, 2018; Paterson & Charles, 2019; Twigg & Mosel, 2017).

However, in this framework, a group of mutual help is more widely defined as a supportive agent, including experts of both natural and technological hazards risks and DRM and risk management, relevant local experts, academics, government officials, and local first responders due to a lack of managing Natech risks (Cruz & Suarez-Paba, 2019; Jung & Park, 2016; Steinberg et al., 2004; Steinberg & Cruz, 2004). The roles of mutual help groups are explicitly highlighted in developing risk and emergency management processes (Lindell, 1994; Lindell & Meier, 1994; Lindell & Perry, 1996b; Whitney & Lindell, 2000).

The expert agent group can provide technological support for risk and vulnerability assessment (Lindell & Perry, 2001) as well as developing Natech accident scenarios based on past experiences and risk management processes. Furthermore, the mutual help group conducts to promotes collaboration among multi-stakeholders to manage chemical accidents through correct risk information disclosure and effective risk communication (Feldman, 1993; Lindell & Hwang, 2008; Lindell & Perry, 1996a) in the building Natech risk management strategy and processes.

Self-help: Local community

The concept of self-help means individual citizens and families save and protect their lives by themselves during emergencies (Cabinet Office, 2018). Due to the uncertainty in disasters and expanded damage, self-help, and mutual help within interactions in a multi-stakeholder context are especially emphasized. Thus, the community members must involve in all phases of DRM to mitigate the consequences of all kinds of disasters and sustain disaster resilience at the local level (YEŞĐL, 2009). In order to reduce and manage Natech risks at the local level, contributions of the government (public support) and multi-stakeholders (mutual help) reducing and managing Natech risks should be supported by community engagement in Natech risk management. It might facilitate minimizing a gap of risk information and knowledge through proper risk communication, performing effective collaboration with other stakeholders, and building community-based Natech risk management based on risk management processes. Therefore, we considered community engagement and community resilience, as key elements of self-help sectors in community-based Natech risk management, to enhance coping capacity for the potential Natech risks and contribute to successful Natech risk management at the local level.

Community resilience, as an important factor for successful DRM, can be increased through active community engagement (Mojtahedi & Oo, 2017;

Witvorapong et al., 2015; Zubir & Amirrol, 2011). In order to the community participation in DRM, individual community members should be prepared through building knowledge and understanding environment risks and their vulnerabilities beyond provided national, regional, local DRM strategies, as well as community-based DRM plans. It means that the governments, relevant stakeholders, and the local community shares the responsibility to manage disaster risks (UNISDR, 2004). In this context, as an initiative responder group at the local level, the capacity of the local community should be considered in the community-based Natech risk management.

In this framework, four community resilience, which are a sense of community, local resources, collaboration, and local knowledge, were selected through several literatures (Alexander, 2013; Kwok et al., 2016; Moreno et al., 2019; Twigg & Mosel, 2017; UNISDR, 2015). Community resilience, also, motivates the residents to engage in Natech risk management to preserve their livelihoods and neighbors. In particular, the community can input indigenous knowledge, experiences, and environmental characteristics, including risk factors, to develop Natech risk management strategies and execute a party of local experts in specific risk management processes. The self-help sector can perform as bridges between each community member, multi-stakeholders in the mutual help, and the government level to make appropriate cooperation.

To build community resilience, the capacity for participation in managing risks regarding technological or Natech accidents is crucial (Lindell & Perry, 2001). Since each community has dynamic aspects, such as cultural, social, and physical diversity; different levels of information, knowledge and risk perception; and, different disaster experiences, communities will vary in coping capacities and resilience levels. Thus, although several studies contribute to community engagement in Natech risk management to enhance resilience (Cruz & Okada, 2008b; Reniers et al., 2018; Suarez-Paba et al., 2020), strengthening the capacity of the community to build Natech resilience into Natech risk management systems remain challenges.

Natech risk management

In the conceptual framework in this thesis, risk management for Natech should become together both natural and technological hazards risks. It is important to contemplate what is needed to improve the existing risk management systems to include Natech-focused management. Through a broad literature review, three limitations in the current risk management for chemical and Natech accidents were identified. First, there is a lack of a flexible risk management system for managing chemical and Natech hazard risks in different circumstances (Okada et al., 2011; Steinberg & Cruz, 2004; Yu et al., 2017; Yu & Hokugo, 2015). The flexibility means that risk management systems must be applied in different situations and consider various risk valuables, considering environmental, social, and physical conditions, that may bring uncertainty and unexpected consequences.

Second, even though there are several programs for effective collaborative activities among all stakeholders for effective DRM, local stakeholders are rarely considered as partners in chemical and Natech risk management (Cruz & Okada, 2008a; Funabashi, 2012; Funabashi & Kitazawa, 2012; Krausmann & Baranzini, 2012; Ozunu et al., 2011; Steinberg et al., 2008). The local stakeholders include widely local community members, local government officials, natural and chemical hazard experts, and industrial safety management and/or facility operators. The collaborative interaction is expected to bring benefits to deal with uncertain Natech accident management and decrease gaps of knowledge and awareness of Natech risks among multi-local stakeholders.

Lastly, there is no little risk communication and adequate information disclosure regarding chemical and Natech accidents and their potential impacts (Cruz & Okada, 2008a; Cruz & Suarez-Paba, 2019; Funabashi, 2012; Miller, 2016). Due to the transparency and accuracy of risk communication and risk information disclosure, it needs to be handled strategically in risk management systems. Also, it should consider regional characteristics and risk awareness and literacy level of information recipients that might influence Natech risk management at the local level.

Lindell and Perry (2001) suggested a community toxic-hazardous material management model based on LEPC to manage chemical accidents that could be occurred at the local level. However, there is an awareness that the local stakeholders do not have proper knowledge, skills, and capacity to manage chemical accident risks.

Thus, local stakeholders are rarely considered in emergency planning for chemical accidents, and chemical accident risk management is implemented by chemical experts who are not familiar with local characteristics. Specifically, in order to effective chemical accident risk management, there are some essential considerations: 1) collaboration among local stakeholders to support each other; 2) understand of local stakeholders' capacity to supplement lacking capacity in the case; 3) establishment of chemical accident risk management strategies based on localized characteristics and local stakeholder's capacity; 4) and risk communication for encouraging active participation from local stakeholders, including the local community.

Considering these limitations and highlighted attention to improve chemical accident risk management at the local level, this framework will be the basis to develop a community-based Natech risk management framework by three case studies concerning Natech risk management at the local level.

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Chapter 4 The theoretical approaches in methodology

4.1 Case study

The case study is widely recognized in social science research as a qualitative research methodology (Sandelowski, 1996; Thomas, 2011; Zainal, 2007). This method allows in-depth exploration and investigation into a real-life situation (Crowe et al., 2011; Zainal, 2007) from a scientific perspective (Ridder, 2017). Although this research method was developed and is widely practiced in the social science field, it has been employed in several additional subject areas, including business, education, program evaluation, marketing, nursing, public health, public administration, and social work (Yin, 2014).

The case study is defined depending on the perspective of investigators as follows. One definition introduced by Yin (1981) is "an empirical inquiry that must examine a contemporary phenomenon in its real-life context, especially when" and "the boundaries between phenomenon and context are not evident" (p. 88). Gustafsson (2017) called it an intensive analysis of various subjects, including individuals, humans, groups, seeking to generalize across a range of research units. Stake (1995) addressed the case study as a method of learning concerning the subject case and the outcome of the learning process. Also, Crowe et al. (2011) described the case study as an analysis methodology used to create an in-depth, multi-faceted interpretation of a specific problem in its real-life sense. Simons (2009) identifies the case study as an extensive survey on 'the complexity and uniqueness' of various phenomena in a 'real-life context'. These descriptions show that case study approaches based on real events facilitate in-depth analyses of issues and situations through the lens of multiple disciplines.

According to Creswell (1998) and Yin (1981a), there are three types of case studies, exploratory, descriptive, and explanatory depending on the type of research questions posed. Exploratory case studies aim to identify specified phenomena from varying outcomes or follow up questions of previous studies and developed hypotheses (Mills et al., 2010; Yin, 2014). This approach is more likely to answer the 'what' questions. The exploratory case studies are often considered as preliminary or pilot studies (McDonough & McDonough, 1997; Monteiro et al., 2016; Yin, 2014). An example of an exploratory case study is one conducted by Campbell et al. (2002) on the connections between social capital and HIV infection at the community level in South Africa. Through a questionnaire survey and social capital measurement, the authors established that social capital, such as an economic issue, is positively related to sexual health, which is an HIV infection among some studied groups. In the research, the exploratory method is used to determine what factors of social capital are related to HIV infection among specific groups.

Descriptive case studies set out to describe events, situations, or relationships between cases in real-life contexts (Yin, 2014). Here, 'what'; 'who'; 'where'; or, 'how many' and 'how much' questions are preferred in these studies. According to Mills et al. (2010), the descriptive approach focuses more intensively on study subjects that are highly related to the perspectives of researchers. Also, McDonough and McDonough (1997) suggested a form of case narrative analysis entailing human behavior, skills for guiding actions, and teaching processes in the context of education. An example of a descriptive study is one performed by Morgan et al. (2006), which focused on fatality management after the 2004 Indian Ocean Tsunami. Comparing mortality management in three countries, Thailand, Indonesia, and Sri Lanka, the authors employed the descriptive approach to report how the corpses were handled after the tsunami through semi-structured interviews with checklist and relevant questions.

Lastly, the goal of explanatory case studies is to explore the 'how' and 'why' of any impact, result, cases, and occurrences according to causality (Fisher & Ziviani, 2004; Yin, 2014). Yin (2014) highlighted that the explanatory case study is a proper approach to answer questions regarding a process over time and is characterized by rigorous interpretation, alternative interpretation, and conclusions. Additionally, Eckstein (2009) and Welch et al. (2011) illustrated that explanatory case studies are an appropriate method to explore and validate new theories. The explanatory approach has also been adapted for studies of uncontrollable and complicated social issues such as crises, policy, economy, management, education, and urban planning (Fisher & Ziviani, 2004; Yin, 2014). An example of an explanatory case study is one conducted by Cash-Gibson & Benach (2019), who applied this approach to identify the components of health inequalities through understanding sociohistorical and institutional processes. In the study, the explanatory method is used to determine the potential process and causality using a conceptual model and data triangulation through semi-structured interviews and literature reviews.

The case study approach has diverse advantages. First, case studies are flexible, facilitating various possible research questions such as what, why, and how promoting a thorough understanding of phenomena, events, and issues (Harrison et al., 2017; Heale & Twycross, 2018). This approach also allowed the collection and analysis of data quantitatively and qualitatively depending on the perspective and adopted methodology (Yin, 2014; Zainal, 2007). Researchers who use the case study method can employ data triangulation by combining several methods and multiple sources and theories to deduce outcomes (Creswell, 1998; Dooley, 2002; Stake, 2006). Various types of disasters have been examined using an inductive approach illustrating the utility of the case study as a qualitative approach (Phillips, 2014). Utilizing the case study, researchers can control research questions precisely according to the complexity of the situations and phenomena in real-life environments. The second advantage is concreteness in the context. The case study, as a detailed qualitative research method, facilitates the exploration of answers to questions, interpretation of findings, and an elaboration of the complexity of phenomena (Flyvbjerg, 2006; Phillips, 2014; Zainal, 2007). It helps to illustrate complex issues and rare phenomena through in-depth and integrated understanding as well as to provide a richness of data and information (Harrison et al., 2017; Margevičiūtė, 2012; Noor, 2008; Simons, 2009; Stake, 2006).

Despite the advantages of conducting case studies, there are some limitations to the case study strategy. First, the case study approach has been criticized for its lack of rigor (Lobo et al., 2017; Mills et al., 2010; Yin, 2014; Zainal, 2007), potential investigator biases (Mills et al., 2010), and small data sets (Zainal, 2007). Some scholars have also noted issues regarding the generalization of the findings from case studies (Lobo et al., 2017; Margevičiūtė, 2012; Noor, 2008; Starman, 2013). However, case study proponents respond by saying that the study strategy is more important than the sample size and that deficiencies can be alleviated by the use of supportive theories or model and data triangulation through multiple methods (Harrison et al., 2017; Lobo et al., 2017; Noor, 2008; Yin, 2014). Miles (2015) argued that a case study approach is the best way to understand and analyze the complexities of phenomena. Another limitation of the case study is that it is often challenging to perform and generate data (Heale & Twycross, 2018; Lobo et al., 2017; Yin, 2014). In order to minimize the limitations, Zainal (2007) suggested a systematic approach for managing and arranging the data.

Collecting data in case study research is a necessary process and is usually accomplished through multiple methods (Dooley, 2002; Eisenhardt, 1989; Yin, 2014), including interviews (semi-structured), official or unofficial documents and material, field observations, and relevant publications (Heale & Twycross, 2018; Mills et al., 2010; Yin, 2014). Useful and practical evidence is also obtained from comprehensive databases, which may include field notes, conversation recordings, guidance material, worksheets, or reports (Mills et al., 2010). Yin (2014) has identified six categories of case study data: documentation, archival records, interviews, direct observations, participant observation, and physical artifacts. Documents may include e-mails, diaries, and letters; announcements or plans and reports; governmental documents; previous studies; and articles in the mass media.

Archival records may entail information from public or regulatory agencies, geographical maps or charts, and surveyed data. Interviews include in-depth interviews, focus group interviews, and questionnaire surveys. Using interview methods, the researcher can better understand the participants' views, motivations, and behaviors. Direct observations can provide insights and context into social, environmental, and historical situations. Through participant-observation, investigators may take on roles within the situation to gain insight and better understand the subject. Last, physical artifacts are technological tools or instruments, including machines or computer programs.

Regarding the application of the case study method, there are some examples performed by various researchers. Moreno et al. (2019) conducted a case study of activities of the El Morro community impacted by the 2010 Chilean earthquake. In the study, researchers adopted a single case methodology due to the uniqueness of the local community. This approach was used to explore the resilience capacities of the local community during emergencies and after the earthquake. Also, evidence from the study site was acquired through interviews and conversations with residents, on-site observations at the site, reviews of documents, and social media. The primary method of data collection was semi-structured interviews, including voice records with 32 residents. Burnside-Lawry and Carvalho (2015) adopted a case study method to study the function of local government and suggesting improvements in existing frameworks. Data were collected through community observations, analysis of relevant documents, and interviews. Valibeigi et al. (2019) studied critical indicators for improving public engagement in DRM with a focus on a small city in Iran. The research team used a questionnaire developed based on an international DRM framework; it was administered to 480 citizens in the city. Also, Mat Said et al. (2011) applied a case study method to develop an emergency response plan from the community perspective. In the study, they utilized triangulation of quantitative and qualitative approaches, including focus group discussion, a questionnaire for a cross-sectional technique, observation, using the internet, books, journals and other documents, and a workshop. Last, Cutter et al. (2012) applied a case study method to assess social and environmental vulnerability in George-town, South Carolina, using historical data from the local newspaper, documents, and literature.

In conclusion, the case study method is underlined as an open-type qualitative approach to real-life research, such as disasters, community activities, and human behavior. Unlike quantitative studies that measure or evaluate multiple variables based on sufficient and abundant data, a qualitative approach such as a case study attempts to explore and collect carefully and accurately related evidence from the real-life environment through the inductive perspective. Due to several reasons earlier mentioned, a case study method is frequently adopted in disaster research.

The present thesis employs multiple case studies from a community perspective, including that of first responders and local government. Case studies of the community and first responders were conducted in the Japanese context, and a survey from the government perspective was performed in the Korean setting. In order to identify community resilience contributing to community-based Natech risk management, this study will investigate and identify necessary elements for improving DRM while focusing on natural disasters, and exploring the strengths and limitations of community engagement in the community-based Natech risk management. The concept of the Japanese DRM system and community resilience is taken as an essential structure for data analysis. Different data collection and analysis methods are used, but the outcomes cover the goals of this thesis. The primary purpose of these case studies is to improve Natech risk management at the local level through an in-depth and practical investigation exploring the appropriate considerations from multi-faceted viewpoints.

4.2 Thematic analysis

In this thesis, thematic analysis is considered as the main method for data analysis. Thematic analysis has been widely used in qualitative researches, including interpretative phenomenological analysis (Javadi & Zarea, 2016). Thematic analysis is a systematic process for identification and categorization of data, reorganization of the outcomes, and descriptions of themes (Braun & Clarke, 2006; Given, 2008; Mills et al., 2010). A 'Theme' is recognized as a substantial output, having a pattern and its own meaning, from the analysis of realistic data (Green et al., 2007; Javadi & Zarea, 2016). The result of the examination focuses on the comprehensive messages observed throughout the entire data, such that the researchers can understand the collective data and shared concepts or experiences (Maguire & Delahunt, 2017).

A similar approach, content analysis is often compared or adapted with thematic analysis, but these two methods have not been distinguished due to their apparent similarities. For example, the resemblances are cross-cutting data, theoretical background, data analysis process and approach, interpretation of data analysis, and a manner for searching for themes (Vaismoradi et al., 2016). Content analysis is a systematic coding and categorization process using a quantity of textual data to examine patterns, frequency, and relationship among vital words, and data structures (Grbich, 2007; Mayring, 2000; Pope et al., 2000). Also, the content analysis aims to categorize and describe the data or information based on associated questions (Bowen, 2009). Through a comparison between thematic and content analysis, the significant difference is data quantification in content analysis when measuring the occurrence rate of various categories and themes (Vaismoradi et al., 2016).

On the contrary, the most significant advantage of thematic analysis is that it is simpler, more flexible, and more tangible than other qualitative analysis methods (Braun & Clarke, 2006; Javadi & Zarea, 2016). Also, this method produces understandable and comprehensible outcomes that are accessible by general readers. (Braun & Clarke, 2006, 2012) highlighted thematic analysis as useful in data analysis and qualitative research in terms of 'accessibility' and 'flexibility' in data analysis rather than carrying out qualitative studies, such as participatory research. The thematic analysis provides a way to improve policy or regulations by examining the analyzed data. Unlike other qualitative methods, thematic analysis has the advantage of facilitating the coding and analysis of qualitative data systematically to solve theoretical and conceptual research questions. Thus, the thematic analysis offers an opportunity to analyze data and facilitate outcomes broadly. It is suitable for multiple-research methods, such as a mixed method of context and thematic analysis.

According to Braun and Clarke (2006), there are two approaches, bottom-up, or inductive, and top-down, or deductive. An inductive method is a data-oriented approach. This approach is used to scrutinize qualitative data from an interview or focus group discussion, but there may not be any link between the unique theme from the collected data and induced questions. However, it has some benefits, including comprehensive data collection, close ties between the theme and data, no influence derived from theoretical backgrounds or researcher biases. On the other hand, a deductive method is more researcher perspective-oriented, while outcomes from the analysis depend on the conceptual or analytical preferences of operators. In this approach, specific and featured leading questions are developed to collect proper data.

There are several approaches to the application; this thesis employed a process suggested by Braun and Clarke (2006) to analyze the data from focus group discussions. The method is composed of six phases which are 1) familiarization with the data; 2) generation of initial codes; 3) theme search; 4) review of themes; 5) definition and naming of the themes; and 6) report for the outcome. The detailed procedure is the following, as shown in table 4.

Table 4. Process of thematic analysis

Phase	Detailed process
1. Familiarization with the data	· Transcription · Repeated reading of the data · Writing down any ideas
2. Generation of initial codes	· Creating codes across the entire data in a systematic way
3. Theme search	· Classification of all the relevant data with themes · Aggregation of the data into these themes
4. Review of themes	· Review of the themes in the coded data and the whole data · Generation of a thematic map
5. Definition and naming of the theme	· Analysis and refinement of the details of each theme · Story development · Generation of definitions and names for each theme
6. Writing a report	· The final phase for analysis · Selection of examples · Review of the research question · Report preparation of the analysis

(Adapted from Braun and Clarke, 2006)

4.3 Accident modeling: Sequentially Timed Events Plotting

In this thesis, two Natech accidents are investigated as part of the case studies. Learning from past events is essential to understand the accident mechanism, accident precursors and root causes, accident consequences, and risk management. Learning from past accidents is also important to develop strategies and plans for preventing potential future accidents (Khan & Abbasi, 1999). Generally, chemical accidents may be triggered by various external (e.g., natural hazard loads) and internal (e.g., equipment failure, human error) causes. There are various accident investigation methods proposed in the literature. One such accident investigation method is the Sequentially Timed Event Plotting (STEP) method. STEP was developed by Hendrick and Benner in 1986 as a method to help reconstruct the series of events or action sequences that contribute to the occurrence of accidents. STEP has been used to identify safety issues or develop recommendations for safety management (Kontogiannis et al., 2000). The result of the process is shown in the format of a diagram (Figure 9) arranged logically and comprehensively (Herrera & Woltjer, 2010). The main concept of the STEP diagram is to show the process that led to an accident from the initiation until the end of the event (Nano & Derudi, 2013; Rausand, 2011). Also, it illustrates and interruptive barriers or undesired changes in the mechanism and systems.

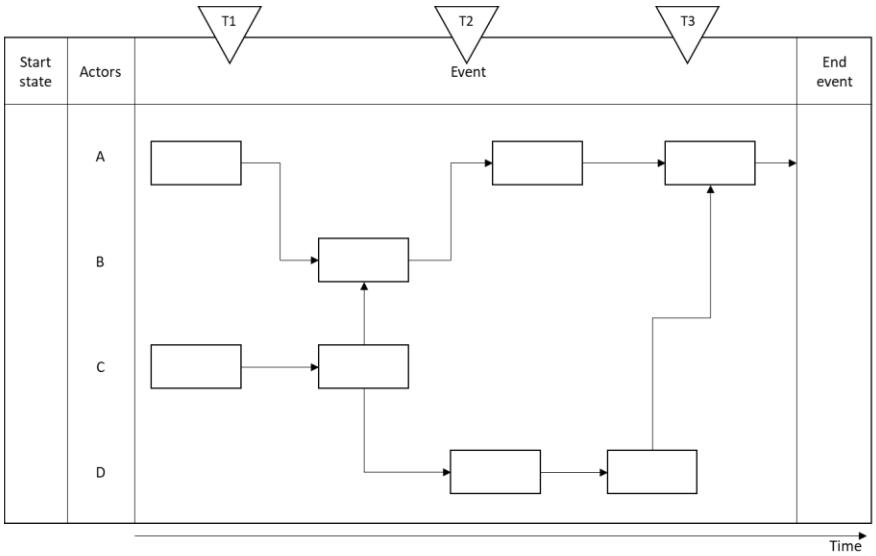

Figure 9. STEP diagram

The STEP diagram, as shown in Figure 8, has seven elements (Rausand, 2011).

1) *Start state*: normal: a normal condition in the system, without events
2) *Initial event*: events that impact on the system and initiating events
3) *Actors*: any factors or actors that changed the system or disturbing normal process (e.g., human errors, technical failures, materials or devices)
4) *Events*: each event that occurred by respective actors (these events are shown as rectangles and connected with arrows, as well as used to develop the logical accident process)
5) *Arrows*: making a multiple-connection between events and showing flows in the accident logic process
6) *Timeline*: indicating the start and endpoint of events to remain sequence of the events (in various ways, for instance, linear)

7) *End event*: displaying the point that shows damage and defines the point of accidents

As a comprehensive and straightforward tool, the advantages and disadvantages of the STEP method are evidenced by several researchers. Herrera and Woltjer (2010) demonstrated that STEP could overcome the limitation of a single linear accident description by representing cascading events from the beginning through a comparison between multi-linear and systemic accident analysis. The authors highlighted that STEP modeling helps provide answers to 'what,' 'when,' and 'why' an accident happened through understanding interactions between actors and events. Nano and Derudi (2013) analyzed an accident that occurred in an electric steelmaking company through a case study with the STEP method.

The STEP allows them to organize the sequences of events systemically and consider multiple events, which are co-occurring. Chakraborty et al. (2018) analyzed the Natech accident in the Cosmo and JX refinery oil refinery during the 2011 GEJE and Tsunami using the STEP method. During the analysis, since there are no rules to order the actors and analysis of interruptions, there are challenges to define the links between the different events and show a cause-effect relationship among the actors and events through the comparison of two different analyses. However, the research team demonstrated that the method is a useful and flexible tool to identify safety issues and show all processes of Natech accidents.

In this context, this thesis employed the STEP model to reconstruct the subjected Natech disaster occurred in Okayama Prefecture, 2018, and Saga Prefecture, 2019, to identify how the accidents propagated over time, and highlight any parts of the process that could have been prevented or handled differently before the accident occurred. Furthermore, the accident analyses are used to develop recommendations for improving proposed community-based Natech risk management.

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Chapter 5 Research methodology

This thesis conducted three case studies to investigate the roles and perspectives of different local stakeholders in local DRM in terms of chemical accidents and Natech disaster risks. This chapter introduces the data collection method, overviews of three case study areas, and main analysis methods of collecting data.

5.1 Data collection methods

This thesis employed a multi-method for data collection and analysis, depending on the survey subject and the characters. The interpretation of method details applied in this research is given in two parts, such as data collection and analysis following the data collection schedule.

5.1.1 Data Collection Schedule and Procedure

Data collection for the three case studies was carried out from February 2019 to February 2020, as shown in Table 5. For the investigation and visits to the Joint Inter-agency Chemical Preparedness Centers (JICEPCs) in Korea, three request letters for permissions were initially sent. Next, the developed interview questions and questionnaires were distributed to each agency in order to conduct the surveys. After that, the persons concerned in the agencies narrowed down the survey data and informed the researcher.

The in-depth interviews and questionnaire surveys were executed on February 25, 27, and 28 in 2019 at the JICEPCs in Ulsan, Yeosu, and Siheung, respectively. Also, in the same year, the research team performed several in-depth interviews with members of the Shimobara district in Okayama Prefecture from March 18-19. During April and the end of May to June 1, 2019, the research team organized several meetings with the community member to consult about evacuation behavior as requested by the community, and the community participation in the discussion was observed to understand their community motivations and willingness for improving DRM systems. After prearrangement with the Shimobara community and the Kito district wide-area fire department headquarters, further data collection activities were implemented by focus group discussions in the Shimobara district on January 23, and in-depth interviews in Omachi town of Saga Prefecture on February 21, 2020.

Table 5. Data collection schedule

No	Activities	Location	Date
1	In-depth interviews and questionnaire surveys	Ulsan, Yeosu, and Siheung-si in Korea	February 25 – February 28, 2019
2	In-depth interview	Shimobara district	March 18 – 19, 2019
3	Field note (observation on the community activity)	Shimobara district	April 24, 2019
4	Field note (participation and observation on the community activity) and in-depth interviews conducted by another research team	Shimobara district	May 31 – June 1, 2019
5	Focus group discussions	Shimobara district	January 23, 2020
6	In-depth interview	Omachi town, Kito-wide district	February 21, 2020

5.1.2 In-depth interviews

For the purpose of this study, in-depth interviews took place face-to-face with previously developed semi-structured questions. An in-depth interview is a multipurpose process across a variety of research subjects and is a suitable method for presenting knowledge and producing understandings. Also, it is enabled to apply to untenable circumstances that hamper collecting extensive data (Guest et al., 2013). Nonetheless, when the interviewee is not honest or does not realize what they know about the potential answer, it is difficult to conduct interviews and obtain appropriate data (Kelly & Bowe, 2011). Also, often in-depth interviews are criticized because responses depend on respondents' experiences and memorization, not real observations, and the researchers have insufficient input to explain the phenomena (Given, 2008). However, the method allows the researchers to acquire valuable data from a wide range of perspectives of participants, as it is more flexible to ask questions and answers, as well as describe the results (Berg, 2001b; Guest et al., 2013).

This in-depth interview, using the semi-structured questions, was carried out in three parts that community members in Shimobara town (see Appendix A), city fire department headquarter in the Shimobara district and Omachi town (see Appendix B), and the chemical accident response teams at the JICEPCs (see Appendix C). In the local community, interviews were conducted to obtain information through free conversation between researchers and community participants. In this part, the interviews aimed at investigating the specific community responses, disaster situations, and the coping capacity of the community organization during the 2018 Natech disaster. Also, participants were not informed of the discussion topics or questions to avoid generating biases. The second part of the in-depth interview in the Shimobara district (Soja City Fire Department) and Omachi town (Takeo City Fire Department) was aimed at collecting detailed data to understand responses to the 2018 and 2019 Natech accident at the local level and the perspective of first responders. The interviewee was provided with preconceived questions by the researchers to focus on the topic and draw more details on the local DRM in Japan.

The goals of the interviews with the JICEPCs in Korea were to investigate the current chemical accident disaster management efforts in Korea, learn from their experiences, and provide recommendations for improving Natech risk management and supporting community-based Natech risk management. Although the questions for three case studies had been prepared as the open-ended type, the interview process and direction were under complete control by researchers (Bernard, 2017; Lisa M. Given, 2008).

5.1.3 Focus group discussion

Focus group discussion was employed as the main method for data collection to investigate the perspectives of Jishu-Bosai-Soshiki and community resilience factors in the Shimobara district on January 23, 2020. This focus group discussion was aimed at understanding the role of Jishu-Bosai-Soshiki and the current community-based DRM, and obtaining a new practical insight and information for community-based Natech risk management.

Focus group discussions are commonly applied to collect qualitative data on human behaviors, opinions and thoughts, experiences, and social demographic or cultural factors (Krueger & Casey, 2000; Teufel-Shone & Williams, 2010) in a small and informal group (Wilkinson, 2004). Usually, performing this discussion takes between 1 and 2 hours (Morgan, 1997), and it consists of 6 to 12 participants (Bernard, 2017; Krueger, 2002). For constructive discussion, Krueger (2000) suggested having a moderator team that facilitates the discussion, encourages participants to speak and be involved, and steer the discussion in the right direction.

According to Anderson and Arsenault (1998), the questions asked during a discussion should be open-ended, qualitative, or quantified, avoiding 'yes' or 'no' answers, adapting indirect questions, and natural progression. Since this method is oriented towards speaking freely and brainstorming, researchers must substitute direct questions, for instance, including 'why' (Dilshad & Latif, 2013). The advantages of the focus group discussion method are that it is more flexible and more comfortable to conduct and allows researchers to investigate specific topics. Concerning the disadvantages, this method faces the challenge of gathering people (Gibbs, 1997), and controlling or analyzing the generated data, and the chief moderator must be well-trained to drive the groups in the right track (Onwuegbuzie et al., 2009). The significant phases of focus group discussion are composed: planning, grouping, conducting, recording the discussion, analyzing data, and reporting the outcome (Dilshad & Latif, 2013). These phases and specific activities are summarized in Table 6.

Table 6. The phases of focus group discussion

Stage	Activity contents
Planning	Clearing the purpose of the focus group discussion, selection of the group, developing questions, assigning time and location
Grouping	Determining group size (6-12 participants), Considering participants socio-demographic, homogeneous or heterogeneous
Conducting	Starting discussion guided by a leader moderator Providing a summary of the discussion
Recording the discussion	Recording the discussion through taking notes or voice recording
Analyzing data	Transcribing the recorded discussion Considering used words or context, reactions, and feelings of participants (Anderson & Arsenault, 1998)
Reporting the outcome	Description and narrative of the findings (Anderson & Arsenault, 1998)

According to the guidance of focus group discussion suggested by Dilshad and Latif (2013) and Krueger (2002), a focus group discussion was undertaken for one and a half hours with core members of Jishu-Bosai-Soshiki in the Shimobara district on January 20, 2020. The community members were asked to participate in the discussion by the leader of the Jishu-Bosai-Soshiki in advance. A total of 11 attendees were involved in the discussion. They were split into two groups of 5 and 6 people, regardless of their gender and age. Two main moderators have led the discussions, and four sub-moderators supported speakers and encouraged participants to answer equally and freely in their language.

The open-ended questions were designed in five sections, namely opening, introductory, transition, and key, and ending questions (see Appendix D: questions for a focus group discussion), and participants' demographic backgrounds were investigated (see Appendix E: Participant demographic survey) to collect baseline data of the persons involved. The questions were associated with how the Jishu-Bosai-Soshiki can contribute to enhancing their coping capacity for disasters and improving DRM in terms of Natech. For instance, the Natech disaster situation that the community has experienced, community activities for disaster risk reduction before and during disasters, and community perspectives for the improvement of the Natech risk management system. After the discussions, the present author, as the chief moderator, summarized the discussions and the whole process and provided small incentives for all attendees. During the event, conversations were fully recorded under a prior agreement. The recordings were transcribed entirely in Japanese and translated into English.

5.1.4 Ethical consideration in Focus group discussion

Several researchers pointed out the ethical consideration to protect participants' rights and personal information during focus group discussions (Smith, 1995). Recently, this moral issue became a concern in qualitative research that involves human beings (Berg, 2001a; Molewijk et al., 2015; Sim & Waterfield, 2019). According to the study on the ethical issues in focus group methodology, all participants in the focus group discussion should be informed about data disclosure, an option of canceling their consent, confidentiality, anonymity, voluntariness, and use of data, as well as a recording of the discussion (Berg, 2001a; Sim & Waterfield, 2019).

All the requirements, regarding specific rules and formats of research participation agreements, for the focus group discussion have been explained before the process, referring to other organizations (The University of Sheffield, 2015; WHO, n.d.). All the participants of the focus group were given explanations for voluntary participation. Also, they were asked to complete signs in the consent form (see Appendix F: consent form).

5.1.5 Field notes

Field notes are recognized as an essential data collection method in qualitative research to support the results of field surveys, including observations, interviews, or focus group discussions (Phillippi & Lauderdale, 2017). Taking field notes in the field surveys is highly recommended by several researchers to take down sufficient information during field surveys and improving the quality of data collection (Creswell & Poth, 2017; Lofland et al., 2006; Mulhall, 2003). Field notes can involve weather conditions, dates, geographical information, socio-demographics, including economic conditions, age, and education, social activities, as well as participant's behaviors during interviews or focus group discussions (Phillippi & Lauderdale, 2017). However, the information context can be flexibly changed depending on the research objectives or the environment of field surveys and conditions, especially in community-based researches. In this research, geographic and environmental information, community activities organized by Jishu-Bosai-Soshiki, socio-demographics were taken during the focus group discussion in the Shimobara district.

5.1.6 Questionnaire survey

The questionnaire survey is a very notorious research method used extensively for efficient data collection in broad contexts, including health issues, industries, social behaviors, policy-related and social characteristics, human behaviors or attitudes, and reasons for human actions under the topic of investigation in social science researches (Bulmer, 2003; Hewitt et al., 2017).

In this thesis, a simple questionnaire survey was carried out to identify Natech risk perception of the employees, as experts and members from different ministries, and current Natech risk management practices, and to use as secondary data to support in-depth interviews conducted at the three JICEPCs. The questionnaire was designed into three sections: 1) Natech risk perception, 2) status of Natech risk management and 3) general information, focusing on the current duties of respondents (See Appendix G). This survey consisted of 19 questions, including closed questions (yes/ no), five-point Likert scale questions, and multiple-choice questions (MCQs). The questions were designed after references from previous surveys implemented in the European Union (Krausmann & Baranzini, 2012) and in Korea (Oh, 2013).

The questionnaire included an explanation of Natech, which are defined as technological disasters, such as hazardous material releases, gas leakages, and explosions triggered by natural hazards, such as heavy rain, typhoon, strong wind, and earthquakes. Also, two typical Natech cases, which are the serious oil spills from the 2005 Hurricane Katrina and the Fukushima nuclear powerplant explosion from the 2011 GEJE and Tsunami, were provided to help describe Natech accidents to responders. Furthermore, the questionnaires were distributed to all employees of three JICEPCs on the same day of conducting in-depth interviews.

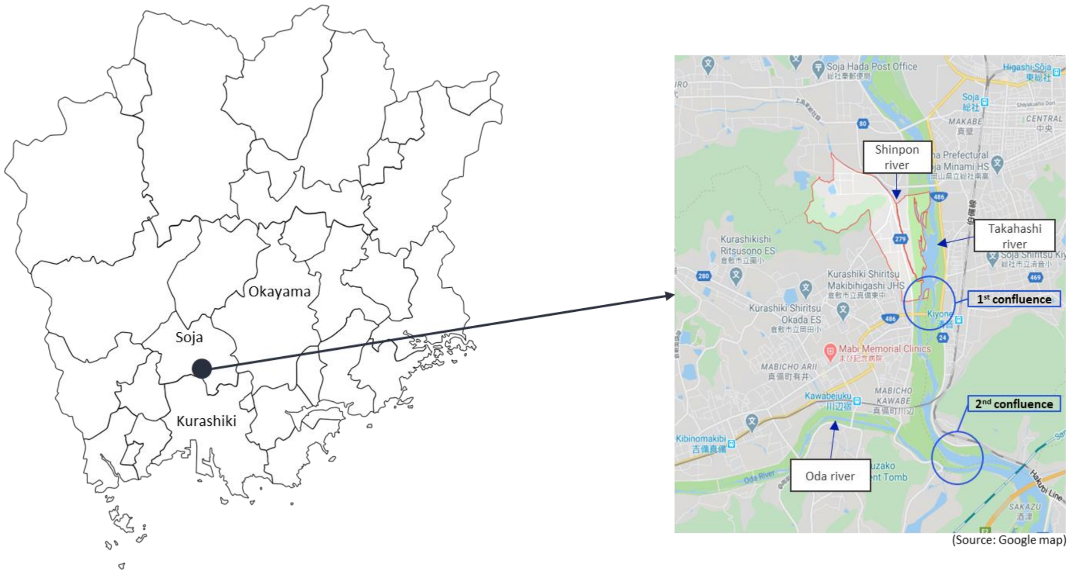
5.2 Overviews of study areas

In this thesis, case studies were conducted in Japan and Korea. In order to understand the context of the case studies, this section presents general information about each case study area, including details on the geographic location, the surrounding environment, and the demographic characteristics. Some relevant historical disaster events are also discussed. The case study in Korea focused mainly on the activities of a government agency that oversees chemical accident risk management of large national industrial parks in the country.

5.2.1 Case study area 1: Shimobara district, Okayama Prefecture, Japan

The Shimobara District is situated in a basin of the southern-middle area of Soja city in Okayama Prefecture, and it is not a highly urbanized area. It is bounded by the Mabi district of Kurashiki city on the west and south sides of the region. The community is surrounded by the Iyobe hill at the height of 105 m.a.s.l. This low mountain area serves as a temporary evacuation site during flooding or disaster drills. There are three rivers, two of which, the Shinpon and the Takahashi, run alongside the Shimobara district from the northern Soja city. The other is Oda River flowing from the West Kurashiki city (Figure 10). These rivers have two points of confluence, where the Shinpon and Takahashi rivers meet, and where they meet their tributary, the Oda River. Thus, agriculture developed as the main economic activity since the past in the area.

Since this area is a small rural town, there are not many social infrastructures, such as public transportation and healthcare. The area has a community center, which is a general-purpose facility for the local community in Japan and offers chances for resident gatherings, event organizations, information sharing, and support management in the community (Shuichiro, 2007). Also, there were two factories. One was an aluminum plant, which was affected by the West Japan heavy rain and floods in July 2018, and the other one is an ironworks company that is still in business.



Soja city in Okayama prefecture

Shimobara district adjacent three rivers

Figure 10. Administrative division of the Shimobara district

According to official statistic records from the city government in October 2018, the total population was 469; 224 men and 245 women. The population aged 60 or older was approximately 46 % (Figure 11). Among them, people who were 90 years old or older made up 18 %. As the number of young and middle age groups is relatively lower than the older groups, this community may be considered as an aging society.

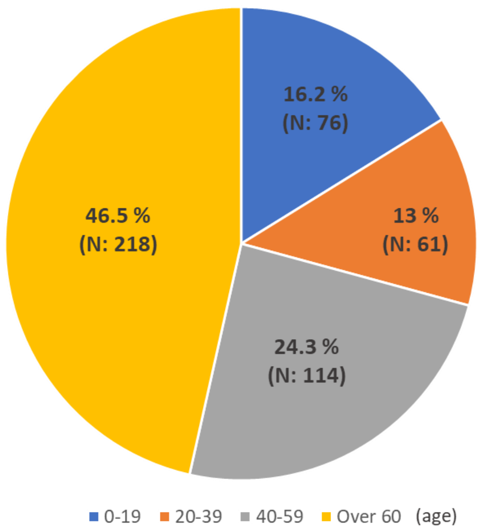


Figure 11. Age distribution in the Shimobara district

Generally, Okayama Prefecture is a geographically stable region due to comparatively fewer risks from disasters, such as earthquakes, tsunamis, and typhoons

(Rikitake & Takeda, 1998). However, sometimes the area is affected by minor hazards like typhoons and heavy rain. As a significant example, a typhoon hit the Kyushu area in 1893 and induced wide-area impacts with numerous casualties. Also, this disaster led to a flood triggered by the failure of an embankment near the three rivers, Shinpon, Takahashi, and Oda (Ohara & Nagumo, 2019) in the Shimobara district. Notably, the community was affected directly by the 1893 floods, where they lost 32 families and neighbors among the 423 casualties and fatalities of Okayama Prefecture.

5.2.2 Case study area 2: Omachi town, Saga Prefecture, Japan

Omachi town is located at the center of Saga Prefecture, Japan. This town is a part of the greater Kito district, which consists of three cities and four towns (Figure 12). The town covers an area of 11.50 km^2. A mountain named Hijiri (416 m.a.s.l.), and a range of hills line up behind the town. Also, these hills have several large and small reservoirs that offer enough water for farming in the Shiroishi plain of the southern zone. A river called the Rokkaku River, which has a total length of 57.2 km, flows across Omachi town and neighboring towns and discharges into the Ariake Sea on the East of this area (Watanabe & Kawahigashi, 2019). The surrounding areas of Omachi town were built on land reclamation. Since the artificial geographical change has put these areas below sea level of the Ariake sea tide (Shimoyama & Nishida, 1999), this region has become more vulnerable to flooding caused by typhoons and heavy rain during the high tide period (Thambas, 2016).

Even though Omachi town is a small town in Saga Prefecture, its location serves as a transportation point with planned national and local roads, as well as local and rapid trains crossing the town. For this reason, it is convenient to access or commute to other cities. Also, several social infrastructures, including schools, hospitals, sports, and cultural facilities, as well as a community hall, have been constructed there. The primary industry is agriculture and stock-raising industries. In the town, four companies are in operation, involving manufacturing related to metals and electronic parts, and ironworks. During the heavy rain and floods in 2019, an oil spill accident occurred at the ironworks company.

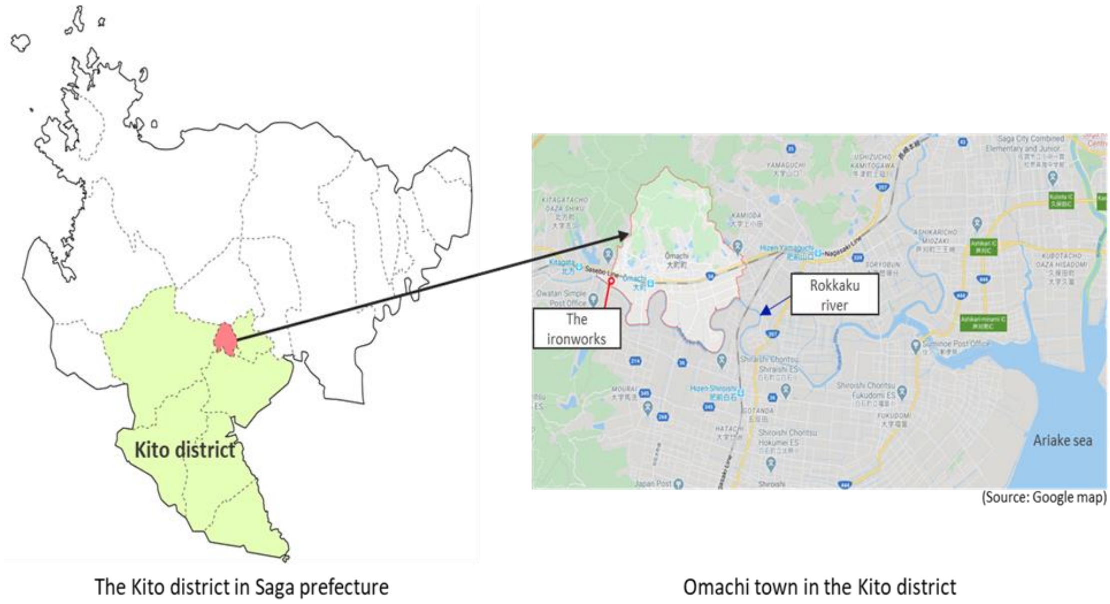


Figure 12. Administrative division of Omachi town

According to a nationwide census conducted by the Ministry of Internal Affairs and Communications in 2015, the total population in Omachi town is 6,777 (Statistics Bureau of Japan, 2017). The number of men and women is 3,077 and 3,700, respectively. About 46% of the population (3,099) is over 60 years old, while 28% are 80 years old or older.

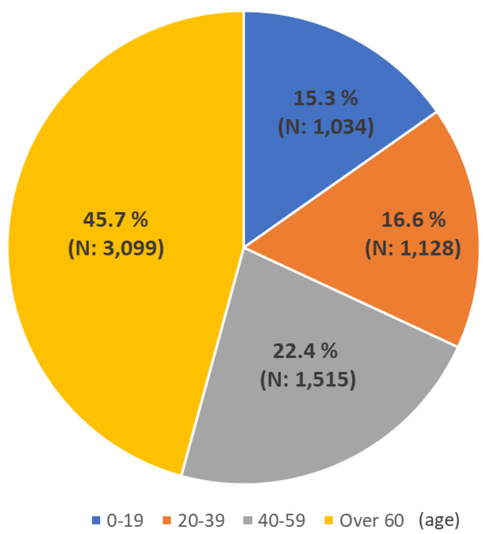


Figure 13. Age distribution in Omachi town

Omachi town has suffered from flood disasters frequently due to its location in a flood-prone area on reclaimed lands. Every summer, from June to September, heavy rainfall and floods occur (Kyushu regional development bureau, 2012). As representative examples, torrential rain for four days struck the entire region in Saga Prefecture in 1953, causing infrastructure destruction, including levee failure and the breakdown of transportation and communication systems, inundation damage to about 14,000 houses, and three fatalities. The 1980 heavy rain, with an average of 253.25 mm a day, induced flooding in a wide area in Saga Prefecture. Also, this event raised river levels triggering a levee break affecting approximately 4,835 houses and inundating about 5,400 ha. Another heavy rainfall incident occurred in 2009, and it resulted in 2,425 ha of inundation and 400 houses underwater. According to a document published by Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in 2012, even though a reservoir was built in 2002 to control flooding, every year, several communities in Saga Prefecture are still under the recurring threat of heavy rain and flooding.

5.2.3 Case study area 3: National industrial park areas in South Korea

The third case study area concerns the location of several national industrial parks in South Korea. After the Korean war (1950 – 1953), national industrial parks started to be developed and since continued to be at the forefront of technological advancement in the country. Following the establishment of the Ulsan industrial park in 1963, 38 total national industrial parks have been set up and are currently operational nationwide. Also, this industrialization scheme has thrived in various fields, such as petrochemistry, metal, steel, mechanics, timber and paper, fabrics and clothes, and food and drink industries, among others.

Among the diverse industries, the petrochemical industrial parks, which are handling hazardous materials, are have been built at the center of regional port areas on the East, South, and West sides of the country. Gyeonggi region, the Ulsan Metropolitan City, and Yeosu city are representative regions that have the largest petrochemical parks, hosting 2,800, 492, and 247 chemical and petrochemical industries, respectively. In addition to this, Korea presently possesses a total of 24 nuclear power plants, 18 of which are in Ulsan and 6 in Jeollanam-do along the coast (KHNP, 2019). Currently, 18 nuclear power plants of the total 24 are in operation.

Moreover, the cities continue to develop, and the population has concentrated around the national industrial parks.

Every year, Korea experiences several natural disasters, including typhoons, localized torrential rain, and floods (Ministry of the Interior and Safety, 2019). In the past, Korea has been comparatively recognized as a safe country from seismic activity, but the recent trend proved that the frequency of earthquakes is gradually increasing even if the intensities are not so severe. According to the Korean Meteorological Administration (KMA) (KMA, 2020), so far, over 3.0 magnitude earthquakes have been observed 182 times. In particular, the number of earthquakes in 2018 was 115, approximately two times higher than the average rate of 67.6 times between 1999 and 2017. Among them, 5.8 and 5.4 magnitude earthquakes occurred in Gyeongju in 2016 and Pohang in 2017, respectively. Since there are nuclear power plants and several industrial facilities and parks near these areas, public and government concerns about chemical accidents that could be occurred by earthquakes were raised.

In these circumstances, the risk of chemical and technological accidents is gradually increasing. Therefore, the Korean government has established seven JICEPCs near the major national industrial parks, including the case study areas of this research study in Ulsan, Yeosu, and Siheung, since 2012 to prevent and respond to the chemical accident as well as natural disasters. Even though there have been no significant reports related to Natech cases yet, minor and major chemical events, for instance, the naphtha cracker explosion in 2020 (Suratman, 2020) and the leakage of styrene monomer in 2019 (hazardex, 2019), have occurred. Those chemical accidents affected neighboring local communities that were exposed to hazardous materials for several days. Thus, the trends show the concern on Natech risk management emerged, and the government invests in improving DRM, including Natech (Oh, 2013).

5.2.4 Purpose of selecting subjects for case studies

In the first and second case study areas in Japan, there were some considerations taken into account to determine these two local communities as study areas. First of all, these two selected local communities have experienced very recently Natech accidents, which are low probability but high consequence events (Lee et al., 2016;

Masys et al., 2014), following heavy rain and flooding in 2018 and 2019. Secondly, these local communities are situated in high-risk zones, prone to flooding, and over half of their populations are over 60 years old. Since most people have lived in the town for more than 20–30 years, they have rich indigenous knowledge and experiences, high perception of environmental risks, and motivation to preserve the local community. Thirdly, the national basic DRM system in Japan does not make any specific reference to the need to consider Natech hazards. Several studies have underlined the need for managing Natech risks at the local level in existing DRM systems as a means to protect the local community from multiple risks.

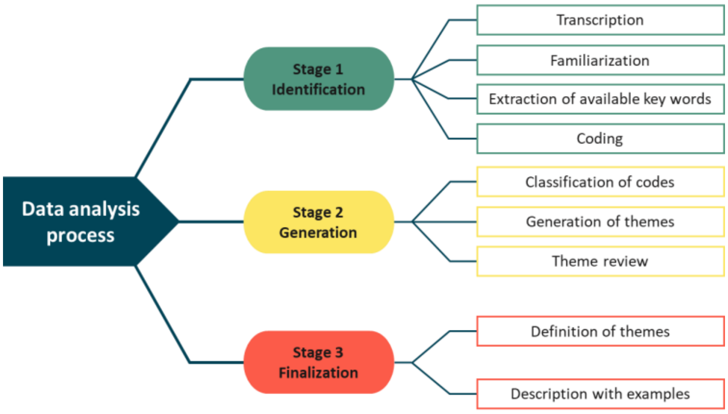
For the third case study area, similarities in social, cultural, and administrative contexts, such as the industrial environments, risk management systems, disaster management systems, and relevant regulations between Korea and Japan, were pondered. Given the difficulty of obtaining interviews with industrial operators and industrial park managers/ operators in Japan, and given the fact that the JICEPCs agreed to our interview requests, the three JICEPCs in Korea were included as part of this study.

5.3 Data analysis

5.3.1 Thematic analysis

In this thesis, thematic analysis was employed as the main analysis method for the focus group discussion. According to the process suggested by Braun and Clarke (2006) mentioned earlier, the data analysis was conducted in three steps, as shown in Figure 14. The first stage was the identification of initial codes for generating themes. The researchers carried out the focus group discussions, divided into two groups of local community members in the Shimobara district, at the same time (Figure 15).

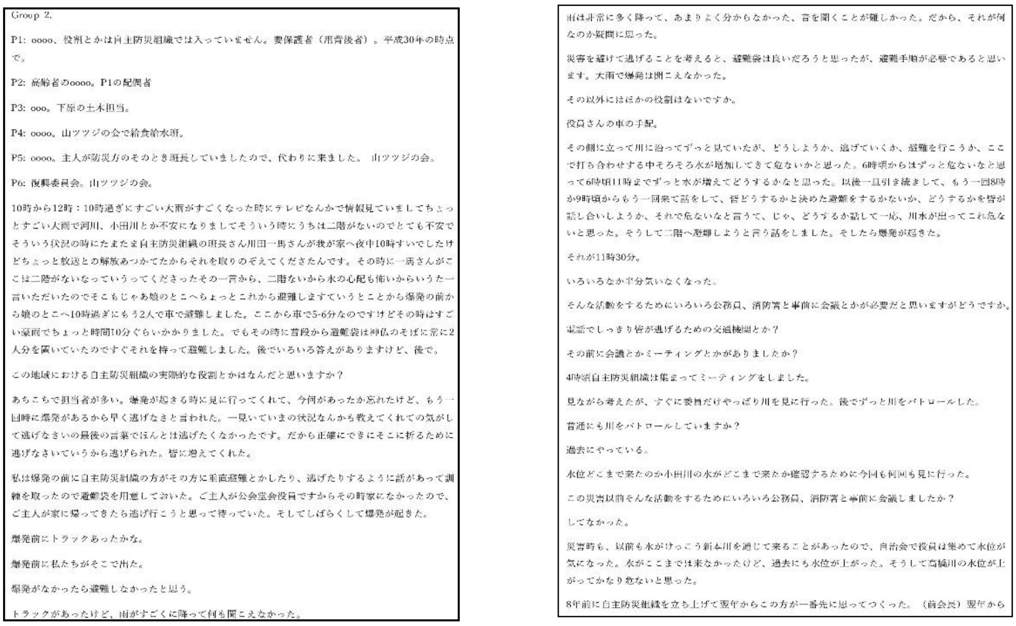
The whole process of discussions was conducted in Japanese and recorded to prevent data loss. Next, the recorded conversations were entirely transcribed as shown in Figure 16, 18,480 words in Japanese. The transcripts were reviewed and affirmed by native Japanese speakers, and it is translated into English.



(reorganized from Braun and Clarke, 2006)

Figure 14. Data analysis process

Figure 15. Focus group discussions in the Shimobara district



Group 2.

P1: oooo、役割とかは自主防災組織では入っていません。要保護者（用背後者）。平成30年の時点で。

P2: 高齢者のoooo。P1の配偶者

P3: ooo。下原の土木担当。

P4: oooo。山ツツジの会で給食給水班。

P5: oooo。主人が防災方のそのとき班長していましたので、代わりに来ました。 山ツツジの会。

P6: 復興委員会。山ツツジの会。

10時から12時：10時過ぎにすごい大雨がすごくなった時にテレビなんかで情報見ていましてちょっとすごい大雨で河川、小田川とか不安になりましてそういう時にうちは二階がないのでとても不安でそういう状況の時にたまたま自主防災組織の班長さん川田一馬さんが我が家へ夜中10時すいでしたけどちょっと放送との解放あつかてたからそれを取りのぞえてくださたんです。その時に一馬さんがここは二階がないなっていうってくださったその一言から、二階ないから水の心配も怖いからいうた一言いただいたのでそこもじゃあ娘のとこへちょっとこれから避難しますていうとことから爆発の前から娘のとこへ10時過ぎにもう2人で車で避難しました。ここから車で5-6分なのですけどその時はすごい豪雨でちょっと時間10分ぐらいかかりました。でもその時に普段から避難袋は神仏のそばに常に2人分を置いていたのですぐそれを持って避難しました。後でいろいろ答えがありますけど、後で。

この地域における自主防災組織の実際的な役割とかはなんだと思いますか？

あちこちで担当者が多い。爆発が起きる時に見に行ってくれて、今何があったか忘れたけど、もう一回時に爆発があるから早く逃げなさと言われた。一見いていまの状況なんかも教えてくれての気がして逃げなさいの最後の言葉でほんとは逃げたくなかったです。だから正確にできにそこに折るために逃げなさいていうから逃げられた。皆に増えてくれた。

私は爆発の前に自主防災組織の方がその方に垂直避難とかしたり、逃げたりするように話があって訓練を取ったので避難袋を用意しておいた。ご主人が公会堂会役員ですからその時家になかったので、ご主人が家に帰ってきたら逃げ行こうと思って待っていた。そしてしばらくして爆発が起きた。

爆発前にトラックあったかな。

爆発前に私たちがそこで出た。

爆発がなかったら避難しなかったと思う。

トラックがあったけど、雨がすごくに降って何も聞こえなかった。

雨は非常に多く降って、あまりよく分からなかった、音を聞くことが難しかった。だから、それが何なのか疑問に思った。

災害を避けて逃げることを考えると、避難袋は良いだろうと思ったが、避難手順が必要であると思います。大雨で爆発は聞こえなかった。

その以外にはほかの役割はないですか。

役員さんの車の手配。

その側に立って川に沿ってずっと見ていたが、どうしようか、逃げていくか、避難を行こうか、ここで打ち合わせする中そろそろ水が増加してきて危ないかと思った。6時頃からはずっと危ないなと思って6時頃11時までずっと水が増えてどうするかなと思った。以後一旦引き続きして、もう一回8時か9時頃からもう一回来て話をして、皆どうするかと決めた避難をするかないか、どうするかを皆が話し合いしようか、それで危ないなと言うて、じゃ、どうするか話して一応、川水が出ってこれ危ないと思った。そうして二階へ避難しようと言う話をしました。そしたら爆発が起きた。

それが11時30分。

いろいろなか半分気いなくなった。

そんな活動をするためにいろいろ公務員、消防署と事前に会議とかが必要だと思いますがどうですか。

電話でしっきり皆が逃げるための交通機関とか？

その前に会議とかミーティングとかがありましたか？

4時頃自主防災組織は集まってミーティングをしました。

見ながら考えたが、すぐに委員だけやっぱり川を見に行った。後でずっと川をパトロールした。

普通にも川をパトロールしていますか？

過去にやっている。

水位どこまで来たのか小田川の水がどこまで来たか確認するために今回も何回も見に行った。

この災害以前そんな活動をするためにいろいろ公務員、消防署と事前に会議しましたか？

してなかった。

災害時も、以前も水がけっこう新本川を通じて来ることがあったので、自治会で役員は集めて水位が気になった。水がここまでは来なかったけど、過去にも水位が上がった。そうして高橋川の水位が上がってかなり危ないと思った。

8年前に自主防災組織を立ち上げて翌年からこの方が一番先に思ってつくった。（前会長）翌年から

Figure 16. Parts of transcriptions from the focus group discussions

The researcher reviewed the transcript several times to become familiar with the data and to extract any keywords. The keywords were then analyzed to identify themes related to the principal roles of the local community, mainly the Jishu-Bosai-Soshiki, and to identify factors of community resilience that can contribute to improving Natech risk management. Also, relevant literature was referred to in order to investigate community resilience factors (such as Alshehri et al., 2013; Kwok et al., 2016; Matsuura & Shaw, 2015; Moreno et al., 2019; Norris et al., 2008).

In the second stage, the data were classified depending on the relevant contents, and this initial organization of the data generated codes where were then analyzed to identify themes. Examples of codes that emerged from the data based on the interviews and focus group discussions include the development of community DRM strategies, efforts to increase risk awareness; consideration of potential disasters; and emergency goods management. See Table 7. A total of 25 initial codes were identified. The codes could be classified into key roles of the local community, and community disaster resilience factors, also shown in Table 7. In total, nine themes were identified. The data analysis showed that the local community plays several critical roles. These are vital agents in the community DRM system; a bridge for risk communication between the local community, first responders and government officials; risk and hazard monitor; a decision-maker, liaison for coordination and collaboration; and assistance provider. The results point out three main community resilience factors that encourage community DRM activities. These include a sense of community and collective behavior, local knowledge, and trust. More details regarding the generated themes and examples from the interviews and focus-group discussions are presented in Chapter 6.

5.3.2 Accidents modeling

An aluminum factory explosion caused by floods in the Shimobara district of Okayama Prefecture and an oil spill caused by floods in Omachi town of Saga Prefecture were analyzed by using the accident modeling method, which is STEP method, following in a time-ordered sequence. The STEP method was employed in this thesis to illustrate the whole process of accidents and understand possible consequences (Chakraborty et al., 2018; Rausand, 2011). Also, we tried to identify proper actions or measures for the next potential events. Various resources, including media, government reports, relevant research articles, and interview contents, were applied to organize the sequenced events and disaster and emergency management activities. Two technological accidents caused by natural hazards were modeled on a timeline, following the sequence of events during the disasters, referring to Rausand, as described in Chapter 4 (2011).

Table 7. Thematic analysis: classified codes and generated themes

	Classified codes	Themes	Description
Six roles of the local community	Developing community DRM strategies	Key actor in DRM	The role of main agents that lead community DRM
	An effort to increase risk awareness (educational program)		
	Considering potential disasters from lessons-learned		
	Maintenance and management for emergency goods		
	The necessity of informing evacuation	A bridge for risk communication	The role of information organizer, deliver, and receiver between the local community and first responders and government officials
	Gathering and delivering risk information		
	Communicating between other stakeholders and residents		
	Participating in disaster prevention workshops and educational programs		
	Inspection and patrol on the surrounding environment risks and hazard	Risk and hazard monitoring	The role of community risk and hazard monitor and environment observer
	Determining evacuation place and time	Decision making	The role of determining community activities on time
	Community DRM activities		
	Collecting risk information		
	Guiding families and neighbors to a shelter	Assistance	The role of support and help families, neighborhoods, and other stakeholders
	Providing emotional support		
	Encouraging local community members to participate in DRM		
	Support and aid neighbor communities and companies		
	Building networks and communicating with other stakeholders	liaison for coordination and collaboration	The role of coordinating the community activities and communicator
	Arranging collaborative disaster educational program and drills		
	Allocating human and physical resources		
Community resilience factors	Collective behavior in response	Sense of community	An element of community capacity
	Having a mind that they are a community family		
	Gathering local community members for community activities		
	Recognizing unreported accidents to the government	Local knowledge	Collective memories from past disasters and experiences
	Sharing learning knowledge from past disasters and experiences		
	Being trust other local stakeholders and community members	Trust	An essential factor for community DRM activities

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Chapter 6 Results

The following sections present the main results of this thesis. All the information presented below is based on the data collected through interviews, focus groups, and field visits unless otherwise stated. In order to protect the identity of the individuals that participated in the study, particularly interviews and focus group discussions of the local community, their names will not be revealed. In some cases, we refer to the participants of interviews and focus group discussions simply with a letter (e.g., A) in the text.

6.1. Local community perspectives

In this thesis, local community perspectives were investigated through a Natech accident which occurred in Okayama Prefecture, Japan, in 2018. The Natech event involved an aluminum factory explosion triggered by floods in the Shimobara district of Okayama Prefecture. Based on the review of government documents, reports, several media articles, and the field visits, interviews and focus groups, the Natech accident and its consequences, and the community's disaster prevention organization, which is the Jishu-Bosai-Soshiki were investigated. The roles of the Jishu-Bosai-Soshiki during the Natech disaster, as well as before the accident, were elucidated. Furthermore, the level of community engagement and critical resilience factors in the local community were identified. The focus group discussions and in-depth interviews with community members were analyzed using an inductive thematic analysis approach.

6.1.1 Natech disaster overview

According to Tokyo Climate Center (2018), from 5th to 8th of July in 2018, unexpected and unprecedented torrential rains occurred, pouring approximately 900-1,500 mm of rain due to a typhoon, humid air streams, the stationary Baiu front activation, and liner rain-bands. The heavy rainfall resulted in an overflow of rivers, several landslides, levee breaks, and large-scale flooding in western areas of Japan, including Saga, Nagasaki, Hiroshima, Tottori, Kobe, and Kyoto Prefectures (Cabinet Office, 2019). There were 237 deaths in 14 Prefectures, and 4,072 people were evacuated to designated shelters, resulting in severe economic damage and social infrastructure collapse, including telecommunications, transportation, and lifelines (Cabinet Office, 2019). During the heavy rain, there was a significant Natech accident, the explosion of a furnace in an aluminum factory due to floodwaters entering the installation. The Natech accident was investigated following the STEP approach. Figure 15 illustrates the resulting STEP diagram, which shows the actors (which include the hazardous events) on the vertical axis, and the timeline on the horizontal axis.

As the diagram in Figure 17 shows, heavy rain started on July 5, 2018, and continued for two days, significantly raising the water levels in the Takahashi, Shinpon, and Oda Rivers. The Shinpon River, which meets the Takahashi River near the aluminum factory, approached the flood stage on the afternoon of July 6. Although workers at the aluminum factory were concerned about possible flooding, they continued to operate facility around the clock due to the use of an aluminum furnace. Repeated flood forecasts and warnings that afternoon prompted the company to remove aluminum from the furnace and evacuated the factory at 22:00, July 6. Due to the increasing water volume in the Takahashi and Oda Rivers, the Shinpon River could not drain into the bigger branches and already flooded around the explosion time.

The aluminum factory in the Shimobara district of the Soja city, Okayama Prefecture, exploded at 23:35 on July 6 due to the reaction between remained aluminum in the furnace and flooded water (Figure 18). The chemical accident triggered by flooding affected the local community with damage (Figure 19), including broken glass, four significant house fires, and a few injuries (Araki, 2018; Hokugo, 2019; Kawata, 2018).

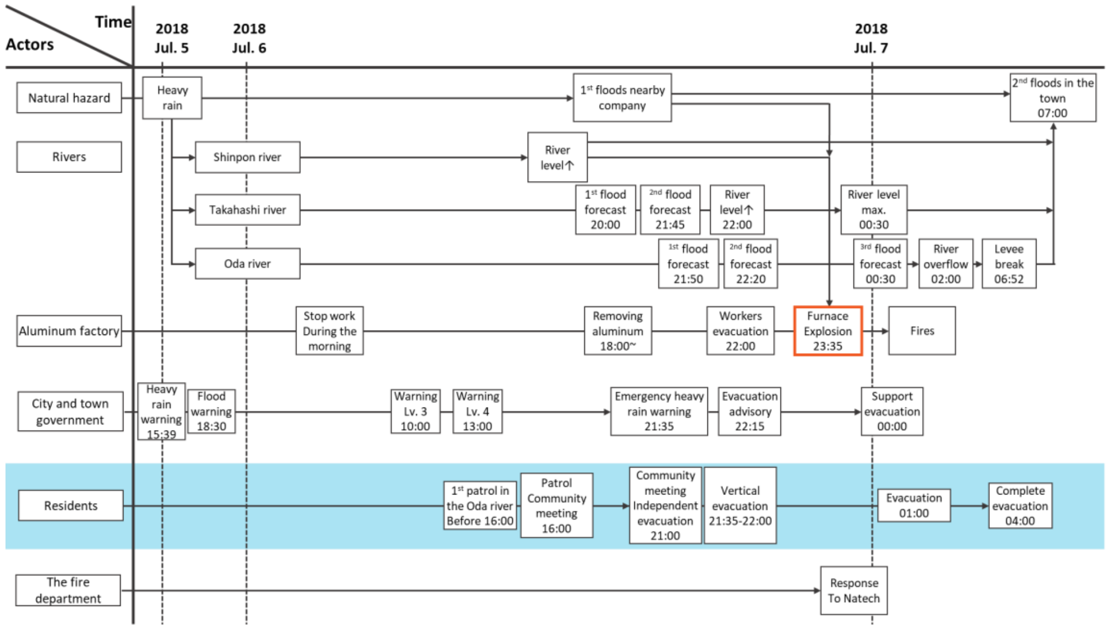


Figure 17. STEP for an aluminum furnace explosion caused by floods in the Shimobara district

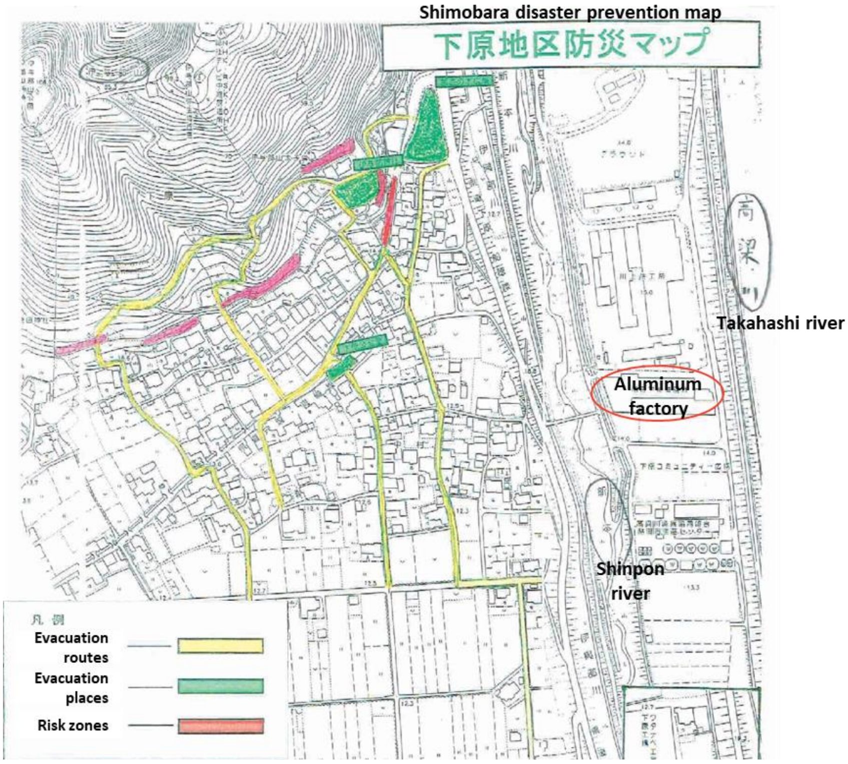
(Source: https://youtu.be/7KbWdQXamsE)

Figure 18. Explosion and damage at the Asahi aluminum factory

(Source: by the author (March 18, 2019)

Figure 19. Damaged house from the aluminum furnace explosion in Shimobara district

Prior to the factory explosion, members of the local community were concerned about floods and a possible accident at the factory. However, there was a lack of information on chemical accidents triggered by heavy rain or floods, even in the hazard map. In fact, the city government released two types of flood hazard maps, involving close shelters and expected inundation zones. According to the city government, the primary hazard map is designed equivalent to approximately a 150-year return period, considering 248 mm of rainfall per 48 hours and shows expected inundation areas. The intensive hazard map assumes the maximized precipitation (674 mm/ 48 hours), which is approximately a 1,000-year return period. Unfortunately, the hazard map shows only expected inundation areas, and it did not give any appropriate information, including evacuation routes nor the impact of a Natech accident on the evacuation to the local community. The Jishu-Bosai-Soshiki members had prepared their own flood hazard map (Figure 20) considering their geographical environments and evacuation routes and referred to it during the emergency.



(Source: the leader of the Jishu-Bosai-Soshiki in the Shimobara district)

Figure 20. Shimobara district hazard map

Members of the Jishu-Bosai-Soshiki discussed a response to the evacuation recommendation from the city government for the flood based on an independent patrol along the three rivers and led to the recommendation that residents vertically evacuate. The community organization gathered critical information by direct observation, media, and warnings from the city government. The explosion (the Natech event) reinforced the community's flood response and prompted a decision to evacuate to the assigned shelter or safe area. The Jishu-Bosai-Soshiki guided and assisted neighbors to evacuate appropriately to safe places and assured that there everyone was safe. After the evacuation was completed, the Shimobara district was completely inundated.

During the heavy rain, the city government issued several warnings for floods. Officials of the crisis management team of the city government shared relevant information directly to the Jishu-Bosai-Soshiki's members and supported timely evacuation by providing transportations to safe areas. The city government, including firefighters, also assisted in the community's recovery in cooperation with stakeholders from outside of the Shimobara district, including volunteers, NGOs, other community members.

6.1.2 Jishu-Bosai-Soshiki in the Shimobara district

The Shimobara district in Okayama Prefecture is located in a flood-prone area, at the confluence point of the Takahashi, Oda, and Shinpon Rivers. Due to these geographies of the area, the community experienced a severe flood of 1893, and members of the community have recognized the necessity of disaster management in preparation for potential future disasters. In 2011, the GEJE and Tsunami, which shocked the world, strongly motivated an organizational unit of the resident's association in the Shimobara district to prepare for future disasters and did so by establishing the Jishu-Bosai-Soshiki in 2012. The basic objectives of this emergent organization are: 1) to implement DRM plans, including hazard mapping in the district, 2) to monitor the community members' safety and security, 3) to arrange for shelters in any emergency, and 4) develop specific evacuation plans.

The organizational structure of the Shimobara Jishu-Bosai-Soshiki consists of seven divisions: 1) initial firefighting, 2) evacuation and guidance, 3) information management, 4) emergency food and water provision, 5) rescue and relief, 6) supporting vulnerable people, and 7) water resource management. This organization is composed of resident volunteers, community-based associations, including women's group, children's group, community fire brigade, and Parent-Teacher Association (PTA). The Jishu-Bosai-Soshiki is typical of community-based DRM in Japan, which is based on self-help, public support, and mutual assistance.

6.1.3 Roles of the local community

As discussed previously, the data collected through the interviews and focus groups were analyzed using a thematic analysis approach. A total of 25 initial codes were identified and classified into six key roles of the local community (Figure 21) and three community resilience factors for disasters. The emergent nine themes were defined and interpreted with the use of some examples. Firstly, as figure 21 shows, the identified roles the local community include: (1) key actor in community DRM; (2) a bridge for risk communication; (3) risk and hazard monitoring; (4) decision making; (5) liaison for coordination and collaboration; and (6) assistance. These will be discussed below.

(1) A key actor in the community-based DRM

Generally, the central and local governments in Japan comprehensively develop DRM plans or strategies, and these are disseminated to the city and community level, essentially a top-down approach. However, regional and local environmental characteristics are rarely considered in such DRM processes (Luna, 2007). As the consequences of disasters are more localized, and the harmful impacts greater (Kawata, 2011), the importance of a community-based DRM system is highlighted (Luna, 2007; Marcia, 2007; Pandey & Okazaki, 2005). This community-centered approach also facilitates reducing gaps between the experts and the local community to make a better society (Höppner et al., 2012; Wisner, 1995).

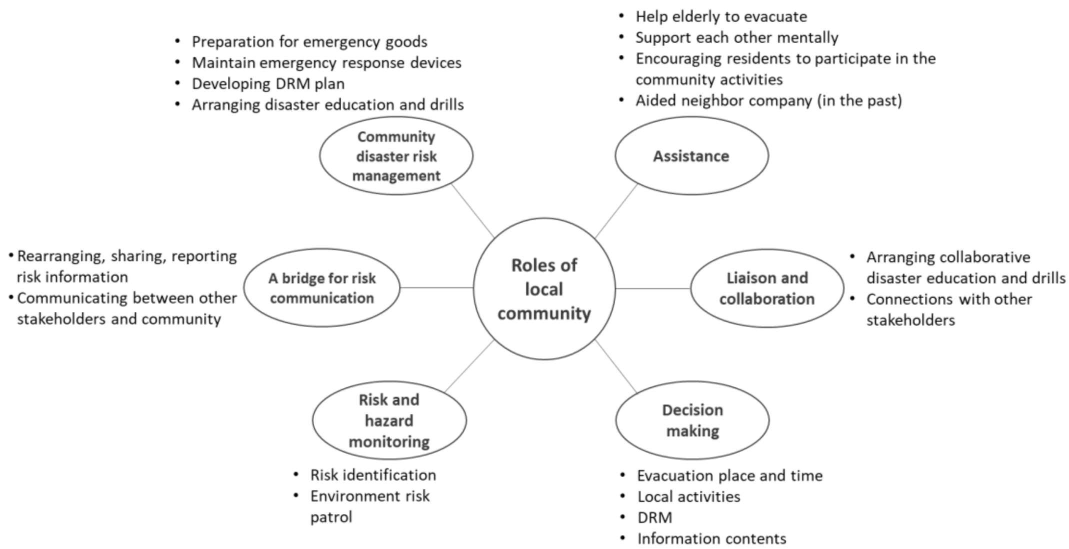


Figure 21. Six roles of the Jishu-Bosai-Soshiki

In this context, the Jishu-bosai-soshiki in Shimobara district carries out its roles as a key DRM actor, and the main members contribute to the community beyond their disaster risk reduction activities. This community organization for disaster prevention and risk reduction develops the community-based DRM plan based on an understanding of localized risks and the community's coping capacity for disasters. This plan has been drafted and is reviewed every three years. Depending on the current community status and governments' plans, the Jishu-Bosai-Soshiki regularly updates the document based on the advice of officials, experts, and practitioners. The plan consists of twelve sections, including distribution of disaster knowledge, community DRM, disaster drills and training, information management, and evacuation instruction. Information regarding Natech risks, however, were not included in the local strategies even though some factories have employed chemical materials in industrial processes for several years.

As part of the risk management activities, the organization encourages young residents to develop expertise and obtain a certificate as a community disaster prevention manager, as local expertise. The young members are then asked to apply the acquired professional knowledge to manage disaster risks to the community. These young leaders are also expected to contribute to supporting the local community and transferring their attained DRM cultures to the next generation. Designated members of the Jishu-Bosai-Soshiki develop flood hazard maps based on examination of the community environment, and thoroughly evaluating hazard maps provided by the local government. This risk management activities offer a chance to prepare for catastrophic disasters.

According to their formulated three-year-plan, the Jishu-Bosai-Soshiki carries out evacuation drills, focusing on flooding and earthquakes every year. The community implements special night evacuation drills under the assumption that disasters do not occur only during the daytime. The community organization considers vulnerable groups in their plan, including children, the elderly, or the people with mobility impairments, and evacuee lists are compiled for counting residents. After the drills, through systematic feedback, the organization updates the current DRM plan incorporating evacuation strategies to be implemented in actual emergencies. During the focus group discussions, one of the focus group participants, whom we will refer to as “A”, said: *"The reason that we could evacuate before the flood at night was that we had conducted strategic disaster prevention drills, including evacuation drills at night. During the process, we could learn how to help and assist our families and neighbors."*

Through the involvement of the Jishu-Bosai-Soshiki in the planning for DRM, community members could accumulate their experiences and apply them to the plan. “A”, who is involved in the women’s association, stated: *"We provide every meal with water to the residents, even to volunteers. I could appreciate how we need to support and provide relief during the Natech disaster."* Another member of the women’s association, “B,” said: *"Because response activities are difficult to work for us, I tried to look for any work that we can do. So, we went to the city hall and learned how we could prepare emergency bags and food. Also, I oversee checking emergency bags and goods of all community members annually."*

For the last eight years, Jishu-Bosai-Soshiki's members acquired disaster prevention certification and assumed responsibility for community disaster prevention and security. The members who have certificates are responsible for disaster education and evacuation drills, having learned about DRM systems and preparedness for evacuation from the crisis management team of the city government. Members improve their skills and knowledge in DRM through comprehensive discussions with officials and other Jishu-Bosai-Soshiki members, and participation in relevant activities. With regard to these activities, "K", a leader of the community, remembered: *"We have made a sister relationship with Soma city in Fukushima Prefecture, so our Jishu-Bosai-Soshiki and community fire brigade team went there to take lessons from their experiences of the Great East Japan Earthquake. These activities have definitely made us increase our risk awareness levels."*

(2) A bridge for risk communication

Risk communication is a two-way interactive process for exchanging information between relevant experts and the community as information recipients (Kikawa, 1999), and is acknowledged as a supportive component for effective DRM (Takeuchi et al., 2012), which enhances disaster risk awareness through various activities, including disaster education, training, and dynamic information distribution and exchanges (Eisenman et al., 2007).

During the 2018 emergencies, members of the Jishu-Bosai-Soshiki attempted to translate risk information regarding the heavy rain and floods for the residents in the district. Due to noise created by the powerful rain, the residents were unable to hear the guidance for evacuation by loudspeakers. Even though the residents had looked for proper and correct information from the media, including TV news, the Internet, and radio, information received was for the general areas, not specific communities. For example, "A", recalled: *"On that day, the rain sound was like a drum beating. So, I could not hear anything related to the emergency announcement. I tried to find information from several media, but I was confused about them. Because there were several different information sources, and I did not know which one I could trust."*

The members of Jishu-Bosai-Soshiki, who are responsible for information management, collected appropriate information, which is suitable for the community, from the crisis management team of the city government, as well as various additional sources. They reorganized the details and disseminated them door to door. Participant "B" in the focus group discussion remembered: *"Several community members asked us what they need to do, and which information is correct or not. I thought it was challenging to understand the suitable information. So, I started to reorganize the collected information to reach a better understanding. And then, I tried to deliver it to each resident."* Participant "C" member mentioned: "*I got a call from the city government, and they asked me to deliver an advisory for evacuation. When I started contacting the neighbors, the explosion at the aluminum factory occurred. I thought there is no time and went to each house to let them know that they should evacuate now.* Participant "D," said: *"I think the greatest effective response was to give notice to the residents to evacuate immediately through visiting each house with our truck and bicycle with a microphone."*

The Jishu-Bosai-Soshiki independently sought information without the assistance of authorities. Since the district is situated at the confluence of three rivers, which are under different jurisdictions, risk information regarding floods was piecemeal, and some were irrelevant to the immediate community. Thus, the members of Jishu-Bosai-Soshiki identified the river conditions and shared information with other community members and stakeholders, including the city government officials and fire department. Participant "B" recalled: *"We did not have enough information on the Oda River,* *because the neighboring city government managed the river. Also, there was no communication or information sharing between the neighboring district and its city government. However, we could not wait for warning information from our city government. So, we went to the river to check the condition ourselves."*

Under normal conditions, the Jishu-Bosai-Soshiki has attempted to raise community risk awareness and enhance the coping capacity through various educational activities that boost disaster and hazard knowledge, as a part of risk communication activities. They also accumulated and shared relevant information such as community history from past emergencies, newspapers, reports, and memories from ancestors or parents.

Additionally, this community organization maintains close relationships with other local communities to support and provide aid for DRM. Their networks distribute practical information, past disaster experiences, and knowledge related to reducing disaster risks by learning from each other. The Shimobara district's Jishu-Bosai-Soshiki believed that the level of risk awareness and DRM is on a higher level than in other local communities. As participant "K", one of the principal members of the Jishu-Bosai-Soshiki said: *"Without all of our efforts within the organization and community, we could not respond to this heavy rain, flood, and the explosion properly. I thank our community members for actively participating in any activities for disaster management."*

(3) Risk and hazard monitoring

To achieve effective DRM, identifying and understanding risks and hazards are essential processes to prepare for disasters and reduce damages (Carreño et al., 2007; Gao & Sang, 2017), given their critical importance in decision-making (Hao et al., 2014). Risk and hazard identification must incorporate risk perception as well as assess risks (Cardona, 2005). According to Cardona (2005), the risk identification process involves several items" cataloging of disaster and damage, hazard mapping with monitoring and evaluation, risk assessment, and community engagement in DRM, and disaster training and education. Moreover, identifying hazards and understanding situated hazard risks helps to minimize disaster losses in hazard zones (Gao & Sang, 2017).

Though some of the Jishu-Bosai-Soshiki members had received certification for disaster risk reduction activities, which focuses on preparedness and response, they do not have adequate tools or processes for risk and hazard identification. Therefore, they organized a patrol team to investigate environmental risks and hazards within their community boundaries. Members of patrol teams, which have three persons in a team, referred to lessons-learned from past experience and local knowledge in the following quote. One participant, “F”, recalled: *"We saw some fires and smokes from the factory several years ago. So, we thought if the factory is inundated, something will have happened. Our team has checked many times surrounding environments near the factory and the adjacent three rivers because we were concerned about any accidents in the factory and flood"*. Another focus group participant, “G,” said: *"Our community has already experienced an increasing river water level before. We do not have in-depth knowledge, but we know the places where it is the highest risk because we have living here for several decades*."

Through frequent reconnaissance, the Jishu-Bosai-Soshiki had sufficient time to discuss flood risks and how to respond to this emergency and was familiar with evacuation timing. “F” also mentioned: *"For us, the biggest objective of this patrol is to save lives and preserve our community. So even though it was dangerous to approach the rivers during heavy rain, we went to see the condition*."

(4) Decision-making

During emergencies and disasters, it is crucial to make good decisions; for instance, how to acquire resources or what kind of response activities the local community should pursue to save and protect themselves. In a community-based DRM approach, the local stakeholders, including leaders and key members of community organizations, must be empowered (Bang, 2013; M.M, 2014). When empowered, participants in DRM are able to make flexible (Bang, 2013), efficient decisions despite time pressures (Young et al., 2012) and practical circumstances. At the community level, decision-making is an essential role of the Jishu-Bosai-Soshiki, determining whether the community can evacuate on time without fatalities or not.

In the situation of the flood and factory explosion, the Jishu-Bosai-Soshiki made an independent decision to evacuate, which was timely, and there were no deaths. The

Jishu-Bosai-Soshiki adapted the concept of an 'evacuation switch', which is a decision-making process for that when the local community should initiate an emergency response, mainly evacuation on time during floods. The evacuation switch process is implemented based on three types of information related disaster and meteorological conditions from the government or relevant agencies; local environmental risks observed by the local community; and indigenous knowledge regarding past disasters (Yamori et al., 2018).

Recently, information advancement and aging in the local community have led to decreasing disaster information literacy, even though residents receive information from various sources. It made citizens hesitate to evacuate on time and rely on government decisions, and many people have lost their lives during 2017 and 2018 heavy rain and flooding in Japan (Kobayashi, 2019; Yamori et al., 2018). This evacuation switch facilitates the local community can determine to initiate response and evacuation timely based on their knowledge from experiences and local environmental details.

Usually, the Shimobara's organization leader assigns tasks to members to monitor flood risks in three rivers and observe the environmental condition. During the heavy rainfalls, the community organization had started monitoring the river conditions carefully, even before receiving warning and advisory from the city government. They discussed whether to evacuate based on their collective decision. Regarding evacuation, participant "H" said: "*Whenever disaster occurs, the government and media disseminate various kinds of information, including early warning, response guidance, and evacuation shelter, but we are often confused when exactly we should evacuate and which directions we should follow*.*"* Concerning the community's collective determination, participant "G" of the patrol team, remarked: *"As we did not have time to wait for the government to announce evacuation, I think our work to look out for the risk of flooding was very important. Finally, all of the residents could evacuate before floods hit our district."* Moreover, participant "I", a member of the organization, said: "*Of course, the explosion of the aluminum factory made us evacuate, but the judgment of leaders of the Jishu-Bosai-Soshiki made us respond appropriately*.*"*

(5) Liaison and collaboration

In the middle of the heavy rain and floods, the Jishu-Bosai-Soshiki and other local stakeholders, including firefighters and city government officials, demonstrated how each party could support their responses and collaborate to reduce damage. When the community organization decided on a full evacuation, there was a general lack of information and resources, including transportation means and drivers, since broad areas of the community were affected by the disaster. The community leader had asked city officials to arrange transportation, and the city government helped them in this regard. The leader of the community organization declared: "*When we established the Jishu-Bosai-Soshiki, we asked for competent consultation from experts and the local stakeholders. So, we had to meet them several times, and we realized that they consistently wanted to help us. The close liaison has continued so far, and the reason is that everything because we had built strong trust with other stakeholders."*

As a support scheme, the city government appointed an official to assist in community-based DRM activities and organizations. When the Jishu-Bosai-Soshiki develops and updates the DRM plan, they discuss it with the person in charge of community support. A leader from the community remembered: *"Usually, it is challenging to discuss community activities and specific documents. However, the officials tried to help and support us to improve our capacity in* DRM*, and we kept a good relationship".* Also, annually the community arranges evacuation drills, including night drills, disaster prevention seminars, and disaster workshops for the residents.

(6) Assistance

According to demographic data, our field notes, approximately 50 % of the Shimobara residents are over 60 years old. Some of them, who have mobility difficulties, required help during the flooding disaster situation. The Jishu-Bosai-Soshiki members knew who needed help, who had mobility challenges, and where they lived in the Shimobara district. Participant "L", an 80-year old woman, explained: *"I heard that we need to go to some safe places. However, because I have a physical problem, I could not move as quickly as ordinary people. One team leader came to my house and asked me to go with him. If they had not come, I could not have survived."* After evacuation activities, the Jishu-Bosai-Soshiki's members went to every house of all vulnerable residents to determine whether anyone was missed in the evacuation.

The successful evacuation reinforced strong community bonds and a sense of community within the context of community-based DRM. One participant, “T,” declared*: “We think our community is like a big unit. So even though we have been affected by disasters, we trust ourselves, and we know our local community can overcome any challenges.”* Also, another member of the Jishu-Bosai-Soshiki, “R,” explained: *“I think there are certain reasons why we responded to the disaster very well compared to other communities. Those reflect our efforts to improve DRM, collective actions, and local power. Our actions made us feel that we are like a family and express our community power.”* Members of the community organization encouraged other residents to participate in community DRM. Their participation promoted a high percentage (93 %) of community engagement and generated a persistent and influential community culture.

In terms of hardware infrastructures, the Jishu-Bosai-Soshiki attempted to improve ability and overcome the environmental limitation of vulnerable people. Since the Shimobara district is a small rural area, most of the houses were built alongside narrow paddy paths, so there are challenges in using cars and other mobility assistive devices for disadvantaged people, such as wheelchairs or handcarts, for the evacuation. Thus, the community organization carried out a project to repair all roads and modify them as emergency routes, so as to be able to reach higher ground in the nearby the hill quickly in case of evacuation.

6.1.4 Key community resilience factors

In the focus group discussions of the Jishu-Bosai-Soshiki's role, three themes of community resilience that facilitated the community-based DRM activities emerged. Those include (1) a sense of community, (2) trust, and (3) indigenous knowledge. They are closely related to the identified Jishu-Bosai-Soshiki's activities, as described in the following sections. Here, the details are provided with each concept of identified factors from several literatures.

(1) Sense of community and collective behavior

The sense of community is a community-specific attitude or a sense of reciprocal trust and belonging with other community members (Perkins et al., 2002) based on mutual concerns and shared values (Norris et al., 2008). Community social solidarity is acknowledged as an element of community capacity and has generated a high level of attention from researchers as it relates to community issues, respect to other members, kindness, support for neighbors, environmental and humanistic bonding, and achievement (Goodman et al., 1998). Environmental conditions can have an impact by increasing the sense of community depending on interdependency and community similarity (Abramowitz, 2005; Edelstein, 2018; Kaniasty & Norris, 2004).

A sense of community in the Shimobara district was profoundly a significant influence in dealing with the disaster in all phases. The participants in the focus group discussion acknowledged that all community members have the belief that their community should be protected and preserved by their own efforts. Some of them mentioned: *"We are all Jishu-Bosai-Soshiki's members, and external people did not force us to participate in community activities."* Furthermore, the other members explained: *"We conduct many local activities all of us together."* In reality, the community has several activities, in addition to disaster management. For instance, the community members clean up the mountain behind the district and water channel for recreation and agricultural use. It provides opportunities to build trust even during daily life activities.

Depending on whether it is the men-, women-, or children-oriented sub-groups, the community offers several activities including collective farming by the men's association; a fitness class and four generations' exchange meetings by the women's association; and cleaning, attending religious events, recreation and tea party by the children's association. A leader of the Jishu-Bosai-Soshiki stated: *"Our community activities definitely made us get together in contrast to decomposed traditional community and society, and this gave us a strong connection among community members that is very important in maintaining our community."* Another participant, "P," declared: *"We have a strong sense of unity. So even though we have suffered from disasters, we could smile because we trust ourselves and support each other. We know our neighbors can overcome any challenges."*

A sense of community was evident in members of the Jishu-Bosai-Soshiki and manifested in the high level of responsibility in carrying out their tasks. One member of the women's association, "L", remembered: *"One leader of a team in the Jishu-Bosai-Soshiki was bleeding while he was guiding other residents to evacuate. Nevertheless, he did not stop helping others to tend to himself."* Another member recalled: *"I am thankful for the Jishu-Bosai-Soshiki's efforts. Without them, I still think we could not have correctly responded to disasters."* The community activities reinforced a sense of community, built-up a strong confidence, and engendered solidarity. Participant "C", recalled: *"I think if we had not done anything from what we could do at the beginning of what we could do, there might have been no advance up to the present."* Also, he mentioned the reason that everything was possible was that there was a key person who established the community organization and encouraged the community members to conduct active disaster risk reduction.

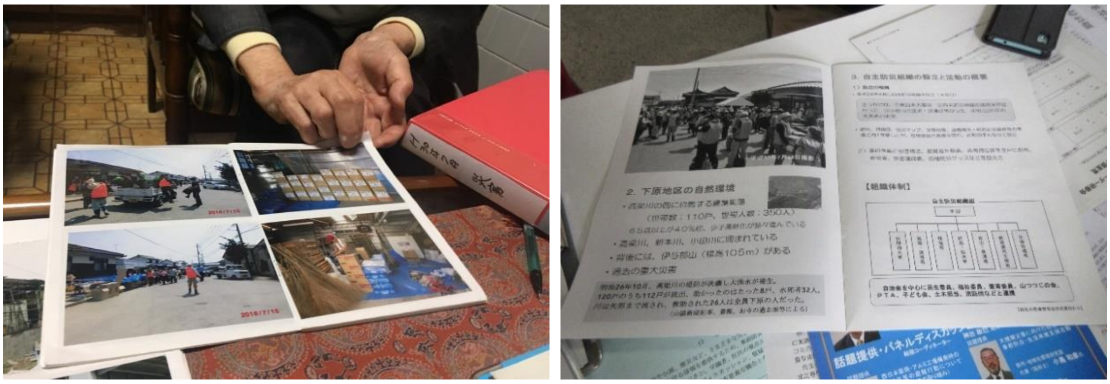
(2) Local knowledge: collective memory from past disasters and experiences

Local knowledge, including community memories, resilience, local resources, must be considered by disaster and emergency managers to better DRM (McEwen et al., 2017). It is what the local community people know and believe that makes the residents do something in a disaster situation (Dekens, 2007). Local knowledge includes local people's experiences, and historical background, and is connected to the coping capacity in good governance structures (Islam et al., 2018).

Since most community members have lived in the Shimobara district for some decades, inhabitants accumulated more indigenous knowledge than 'outside' stakeholders, including city government officials, firefighters, and experts. Participant "D", a 74-year-old member of the community organization, remembered: *"We had recognized the flood risk as I have lived here for over 50 years. When I was a member of a volunteer fire brigade, I saw the neighboring town being inundated during heavy rain. So, I went to the town to provide help and support."* Another participant, "H," said: *"We know very well about our community, personally and environmentally. Our parents' generation who have already passed away, let us know about environmental risks in this region."* The community members used this collective experience to improve the community’s DRM.

For several years, Shimobara residents had recognized the risk of chemical accidents at the aluminum factory. People remembered that there had been fires and smoke, as well as bad odors from the factory. Participant “A”, a Jishu-Bosai-Soshiki member, said: *“Whenever there was heavy rain, we were worried about chemical accidents because 3-4 years ago there was a fire in the factory. The firefighters brought water to extinguish the fire. However, they realized it was aluminum and came to our district to borrow baskets for carrying sand.”* Since this respondent had been worked in a refinery for a long time, he was aware of the risk of chemical accidents. Also, he remembered the fear of chemical accidents since he knew the temperature of the melted aluminum was over 600 degrees, and it could affect the community directly.

During the heavy rains and explosion at the aluminum factory in 2018, the residents did not receive proper information from external sources. Though the Jishu-Bosai-Soshiki could not adequately prepare for chemical accidents, their past experiences and knowledge contributed to community evacuation procedures and decisions. In addition, the community’s knowledge and experiences helped other, previously mentioned stakeholders to accomplish collaborative DRM. Through their local historical knowledge and the organizational embodiment of this disaster experience in the Jishu-Bosai-Soshiki, community DRM was perpetuated in community culture. Throughout the year, the local community has preserved their historical information, local knowledge and relevant cases as a document (Figure 22-a and b). The community members thereby hope that their historical material will be passed on to the next generations and that lessons-learned will be preserved for the benefit of preserving those lessons.



a. Cataloged photos of the disaster during 2018 heavy rain and floods b. Locally generated disaster literature

Figure 22. Disaster data collection by local community members

(3) Trust

Trust is essential in effective community activities and influences collective efficacy (Perkins & Long, 2002). It is defined as a combination of mutual trust and willingness to work for the neighborhood's common benefit (Sampson et al., 1997). Trust in individual and social contexts plays a profound role in making better decisions for risk actions through effective and proper risk communication (Earle, 2010; Jardine et al., 2013). As an essential element of community resilience, trust is expressed emotionally and physically by collaboration and mutual help by all stakeholders in community action (Moreno et al., 2019). If levels of community trust are low, cooperative community action during disasters will be a major challenge (Norris et al., 2008).

Members of the Jishu-Bosai-Soshiki knew how they built trust and a good relationship with other stakeholders, especially the city government officials and local first responders, as well as specialists. A leader of the community organization mentioned that a central factor in trust-building was a face-to-face collaboration with local government officials and the Jishu-Bosai-Soshiki. During their mutual collaboration, including workshops for DRM and evacuation drills, community members became familiar with relevant stakeholders who contributed to better DRM. In addition, since the district was organized hundreds of years ago, trust has been developing over years of contact with local government actors responsible for various everyday life issues, such as agriculture, civil engineering, environment, welfare, and children's education.

6.2 First responders’ perspectives

This section provides first responders’ perspectives from two Natech accidents occurred in Omachi town, Saga Prefecture and in Soja city, Okayama Prefecture that experienced the aluminum factory explosion and floods in 2018 as described earlier In this section, mainly, an oil spill accident triggered by floods in 2019 in Omachi town was analyzed.

6.2.1 Oil spill disaster overview in Omachi town

According to Cabinet Office (2020), from August 26th to 29th, 2019, warm and moist air flows, a stationary Baiu front activation, and liner rain-bands triggered unexpected and unprecedented torrential rains, a record-breaking of 600mm in Kyushu area. In Saga Prefecture, over 100 mm of rain per hour was observed, and precipitation in Shiroishi town (Kishima county of Saga city) experienced twice the average amount of rainfall for August. This extreme event caused three deaths in Saga Prefecture, inundations of 5,049 houses, and 72 landslides. It affected multiple lifelines, including electricity, gas, and water, telecommunications, transportation, and river maintenance systems.

Takeo city in the Kito wide-area district consists of three cities, and four towns, including Omachi town, is one of the high flood-risk areas for flooding. It is located between the Ariake Sea and two major rivers, the Rokkaku and Shioda, as well as several smaller river streams, and at high tide, during this massive rainfall, was heavily impacted by flooding (Watanabe & Kawahigashi, 2019). Even though the government and relevant agencies have initiated mitigation efforts, including the installation of water drainage, pumps to reduce flood risks from several rivers flows at high tide, the heavy rains (*Tidemark data*, 2019) in this extreme event could not be appropriately managed to prevent floods.

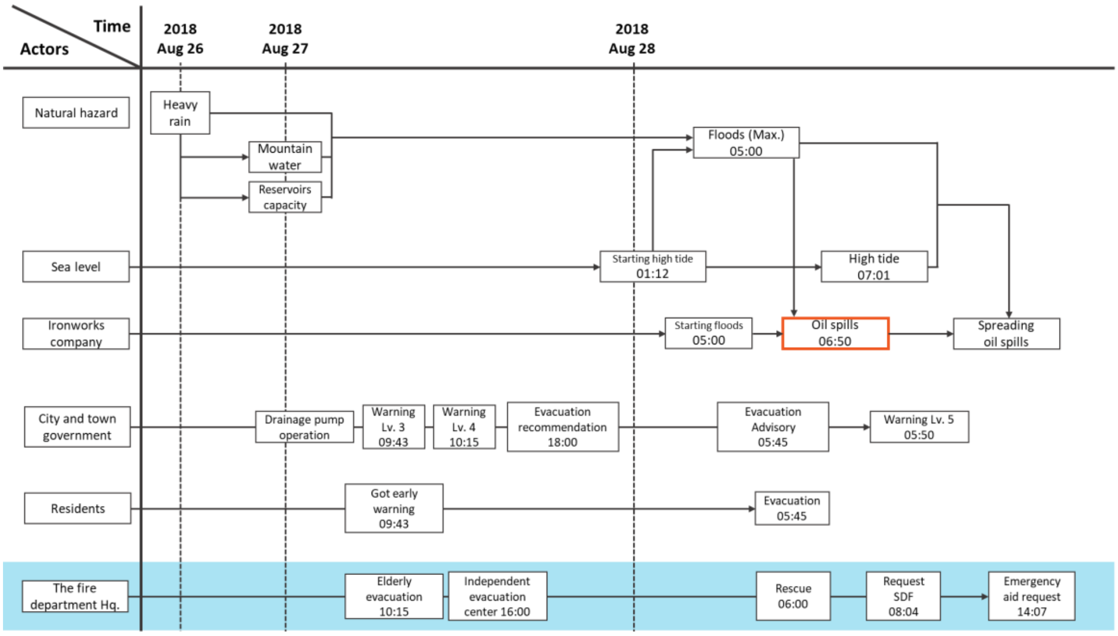


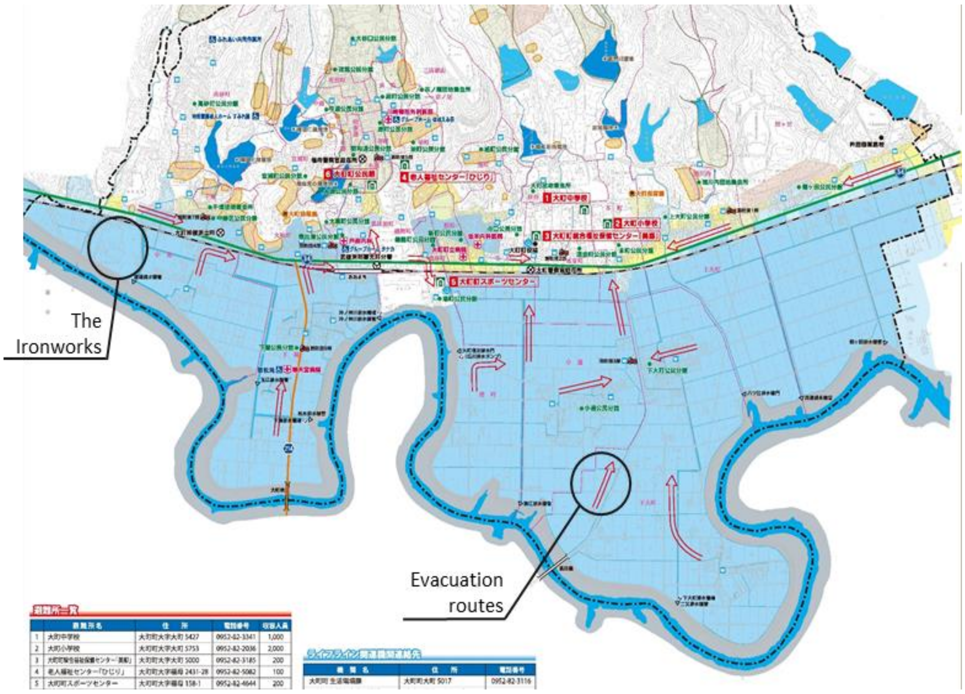
Figure 23. STEP for oil spill accident caused by floods in Omachi town

This disaster is reconstructed using the STEP method. The sequential progress of a Natech accident triggered by the flooding and the stakeholder's actions in Omachi town is documented, as shown in Figure 23. The intense downpour starting on August 26, induced increasing mountain water flows, exceeding reservoir capacity and elevating river water level, and finally, causing flooding in Takeo city, including Omachi town. The heavy rain, arriving at a high-tide period, exacerbated the flooding. The maximum inundation in the city of Takeo (around 5:00 am on August 28) was about 7 km from east to west and 3 km from north to south, covering about 21 km^2 in area. About 200 people, including admitted hospital patients and medical staff in Omachi town, were isolated for two days by the inundation (Asahi Shimbun Digital, 2019).

During the disasters, the city government issued three warnings to the residents (Cabinet Office, 2018). The first was a level 3 warning, which calls for evacuation of vulnerable people and evacuation preparation for others at 09:43 on August 27; a second level 4 warning was issued, which recommended evacuation of everyone in a designated area, at 10:15 on August 27. In level 4 warnings, the evacuation recommendation can be changed to evacuation advisory depending on the emergency status. The final warning was of level 5, which means that the disaster has occurred and that residents must take action to protect themselves in any manner available.

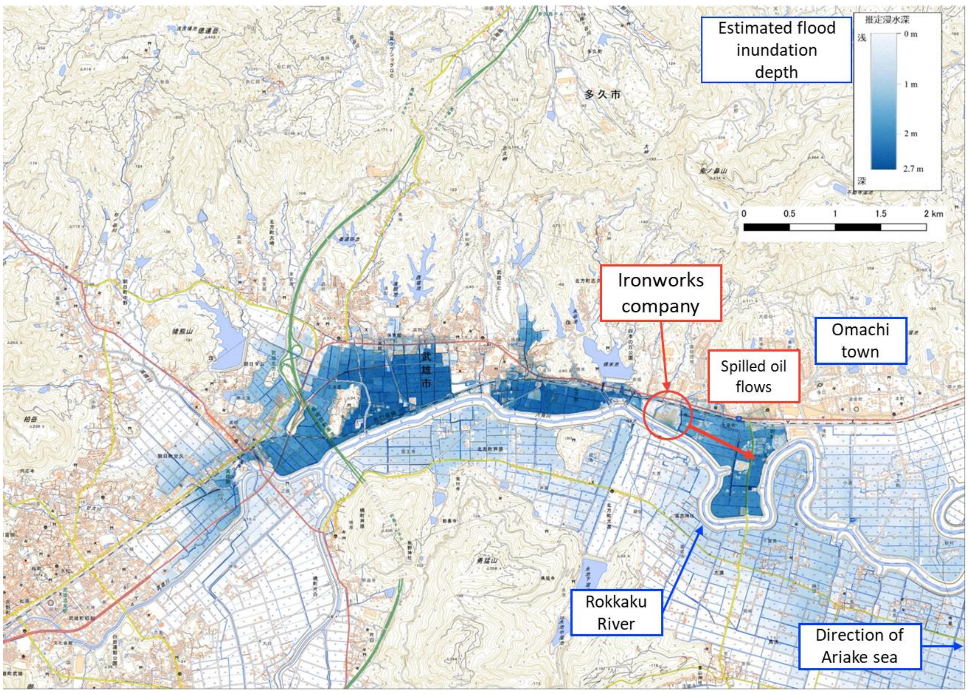
Omachi town developed a flood hazard map in 2009 based on hazard information from the Geospatial Information Authority of Japan, as shown in Figure 24. These hazard maps estimated that the Rokkaku River would overflow due to heavy rain once every 100 years, and it assumed the area in which the ironworks, named Saga ironworks, is located would be inundated by 2 to 5 meters (Yamamoto et al., n.d.). After two chemical accidents that occurred in 1990 and 2009, the company installed equipment including preventive shutters and walls of 2m around oil tanks and a drainage pump to prevent potential oil leakages. However, in the 2019 flooding, the factory was inundated again (Figure 25), and the preventive equipment was not sufficient. Also, a community member also mentioned this kind of unexpected heavy rainfall and past chemical accidents that triggered by floods were considered in flood hazard map, through a news interview (Saga Shimbun Live, 2019b). These show that the hazard maps did not contemplate the other hazards, such as Natech hazards.

The company usually operates on a 24-hour basis and stored oil underground in eight tanks. It was difficult to adequately seal the tanks to prevent oil spills due to their structural conditions (Saga Shimbun Live, 2019c), and at 04:30 on August 28, conditions required termination of operations. According to articles, from the total 113,000 liters that were stored at the ironworks company, the floods triggered an estimated 54,000 liters of oil spills, reaching the local community in Omachi town (Nishimuta et al., 2020; Saga Shimbun Live, 2019b), as shown in Figure 26. Since it is not possible to measure the exact amount of spilled oil, it is supposed that up to 80,000 liters were released during the Natech accident. Merging with flood water, the released oil spread quickly and widely, covering an area of about 980,000 m^2 (Saga Shimbun Live, 2019a), affecting 100 houses in Omachi town (Nishinippon Shimbun, 2019). The oil spill clean-up operations (Figure 27) was carried out by local stakeholders, including residents, firefighters, government officials, NGOs, and external volunteers. The clean-up continued until mid-September 2019 (Japan Nikkei Shimbun, 2019).



(Source: http://www.town.omachi.saga.jp/)

Figure 24. A partial flood hazard map of Omachi town



(Source: Geospatial Information Authority of Japan, 2019)

Figure 25. Estimated flood inundation zones

(Source: Nihonnikkei Shimbun, 2019)

Figure 26. Oil spill in Omachi town during the 2019 heavy rain and floods

(Source: Nihonnikkei Shimbun, 2019)

Figure 27. Cleaning up released oil by stakeholders

6.2.2 DRM at the local level

In order to investigate perspectives of the first responder on Natech hazards and risks and local DRM for both natural and technological disasters risks, intensive interviews using semi-structured questions were carried out with each city fire department of Omachi town beyond the jurisdiction of Takeo city and Shimobara district beyond the jurisdiction of Soja city. Specifically, during the interviews, the local DRM system, risk communication with government officials, other stakeholders, and the local community, collaboration with the local community, and the challenges during the emergencies were asked.

(1) Local DRM and chemical accidents

Omachi town and Takeo city area are historically flood-prone. Heavy rain and flooding in 1990 and 2009 caused chemical accidents, which are oil spills, in the same ironworks company. After this chemical accident event, the company improved its preventive infrastructure according to an estimation of floodwater levels and risk assessment conducted internally by them. Local stakeholders, including the fire department, also made an effort to prevent and prepare for potential technological disasters caused by natural hazards, mainly heavy rain, and floods. However, the 2019 Natech disaster, defied all expectations.

Omachi town, the most affected area by the 2019 Natech accident, had estimated the risk of an oil spill caused by heavy rain and floods. The estimation was based on the assumption of proper operation of the drainage pump in the river, and timely discharge of river water would mitigate the hazard. As it turned out during the heavy rain and flooding of 2019; however, the operational delays in activating the drainage pump and high-tide led to disaster and failure of emergency management in Omachi town.

In order to manage and prepare for the uncertainty in occurrence time and disaster type, the fire department headquarters in the Kito-wide-district considers various scenarios. For example, in the pre-disaster response stage, the fire department checks different places of high flood risks and emergency response devices and facilities to make certain of their capability to operate and respond effectively to disasters, especially at night. Also, the headquarters have updated their DRM plans and strategies, only focusing on natural hazards, considering the changes in the local environment and physical resources.

Several companies, which use chemical materials, are located along the Rokkaku River, the main river that flows through Omachi town. Chemical disasters triggered by natural hazards are rarely considered in their safety management plans despite fire headquarters recommendations to mitigate the risks and damages from potential chemical accidents. Despite that lack of planning by companies that use chemicals, responding government agencies include in their plans the immediate identification of chemical accidents, the leak source and equipment, the substance released, the toxicity of the material, and the extent of likely human impact. Thus, first responders have planned to carry out tailored responses to Natech events based on collaboration with other stakeholders in efforts to minimize the area of damage. The interview in the Kito fire department headquarter stated that these broad and collaborative DRM activities would contribute to the local community's quick response and the evacuation of vulnerable residents to a safe place.

In another case, we conducted interviews with the Soja city fire department that experienced the 2018 aluminum factory explosion and floods. In General, the Soja city fire department informed they are responsible for emergency response, including search and rescue, and regulation compliance inspection of industrial facilities regarding chemical material usage. The fire department supervises chemical material storage facilities and hazardous materials amount in order to prevent fires and chemical accidents and do not exceed the permissible limits. There is no consideration of chemical or Natech accidents in the local DRM. However, the fire department mentioned they are prepared for controlling chemical accidents through their educational programs, including chemical accident response training and hazardous materials training.

(2) Risk communication

In the Kito-wide area municipal district, risk communication is basically divided into three parts, between the fire department headquarters and the government, between the fire department headquarters and other stakeholders, and between the fire department headquarters and the local community.

During disasters, local firefighters from the Kito-wide area fire department headquarters in collaboration with other government agencies communicate with the prefectural government to sharing information, report field conditions, and request resource allocation. This communication between fire units and local government agencies responding to emergencies in their jurisdictions extends to other responding fire departments and governing branches that are assisting. This shared information, including the incident location, the status of physical damage and human losses, the evacuation status, the emergency response progress status, and other necessary information, are exchanged among the fire headquarters, local government agencies, and relevant organizations. Police and Self-Defense Forces, as directly related actors, distribute information from each town through special disaster response headquarters set up in each municipality.

In the case of the Soja city fire department, the disclosure risk information to the resident through several communication channels, including webpage, social network systems, radio, siren, and regular newsletters, is sent from the city government to each resident. Also, the fire department communicates with local community members through collaboration with a community organization, which is Jishu-Bosai-Soshiki. As mentioned earlier, when the region faces disasters, the fire department headquarters focus specifically on disaster response, including rescue, first aid, fire suppression, and support evacuation activities in the local community. During such response activation, particularly chemical or Natech accident emergency, it is a challenge for fire headquarters to share or disseminate information to the residents and the Jishu-Bosai-Soshiki. Thus, risk communication to the local people is handled by each city or town government, or the community council and Jishu-Bosai-Soshiki transmit any relevant information concerning the community circumstances to the city or town government. In addition, communicating a chemical accident and its risk information is emerged as another issue during emergencies due to a lack of proper knowledge, information, and experiences regarding chemical accidents and/or Natech.

(3) Collaborative relation with Jishu-Bosai-Soshiki

Engagement of the Jishu-Bosai-Soshiki in the DRM for Natech is admittedly a big challenge with budgetary issues, age composition, personnel, and social resources in the city or local government. So far, there have been no cooperative activities for managing Natech risks. However, it is required to develop a collaborative system for managing the Natech events, from completing the evacuation process and staying at evacuation centers, to working on reconstruction with limited organizational structures afterward.

During the Natech in 2019, the first responder team was activated as a major component of the greater specialized systems for an emergency operation. The reason is that the Ministry of Land, Infrastructure, Transport and Tourism assumes the responsibility for sites where cases of oil spills affecting rivers occur, while the fire department headquarters of Fire and Disaster Management Agency acts as an assistant organization, supporting the ministry. Also, the fire headquarters worked with other stakeholders, including prefectural and municipal officials, and other fire departments within the prefectural government. Still, the Jishu-Bosai-Soshiki was not considered as a critical actor in DRM for chemical accidents.

(4) Challenges of responding to Natech accidents in 2018 and 2019

During the oil recovery operation, the spilled oil that spread in Omachi town was collected using absorbent paper, transported, and used by multiple stakeholders without any specialized proper protectors. However, specific issues continued, and some others emerged from such practice due to the adhesion of oil to clothing, heat measures in protective clothing, and a wide range of other complications. Also, this aspect tested mentally and physically all participants in the response, recovery, and cleaning up activities. In the event of a chemical accident triggered by a natural hazard, there are some unique difficulties, for instance, the severity of the released hazardous materials, the immediate impact on human life and environment, or the impediment of approaching the scene. In order to reduce human losses and damages from Natech, the fire headquarters should be adequately prepared for the potential Natech and use all available means from the fire department side to strategize and implement the appropriate responses.

In addition, some systemic challenges have emerged in the initial response and support systems. Since the disaster, particularly heavy rain and floods started at night, and the initial response was focused on handling floods. Thus, response to the Natech accident was delayed due to the impediments in the deployment system for human resources and equipment, difficulties in gathering details, sorting the priorities while administering triage, and disseminating disaster information. Regarding the support system, deciding the time to request support proved to be another complicated task, as was prioritizing and dispatching reinforcement units, selecting the method of information sharing, and further establishing and maintaining communication liaison during the response operation.

In the 2018 aluminum factory explosion triggered by floods in the Shimobara district, the Soja city fire department was not prepared for the chemical accident that could be occurred by natural hazards due to a lack of knowledge about Natech accidents. At the same time, there was a lack of personnel and physical resources since two disasters happened sequentially and concurrently as Omachi town disaster. The fire department pointed out risk information disclosure regarding hazardous materials would make the resident concerned and fearful. However, they believe that hazardous material information that is handled near or in the local community should be shared with the resident in order to reduce chemical accident risks and damages.

6.3 Government perspectives

6.3.1 Government' efforts for chemical and Natech risk management

Risk management involves a series of systemic and integrative processes, including identification, analysis, and assessment, and measurement of potential hazards and risks, to eliminate or reduce the negative impact on people, the environment, and property (Rausand, 2011). Also, it aims to make the best decision to deal with uncertainty relying on different hazards and situations (ISO, 2018; Treasury Board of Canada, 2010). The Implementation of risk management can be different in compliance with an organization's internal and external background, such as associated regulations, enacted acts, and social and cultural factors (ISO, 2018). With increasing concern over technological and Natech hazard risks, managing risks are one of the main issues that many countries are confronted with, and some legal frameworks and risk management programs have been established.

In the EU, the Seveso III Directive on the control of major accident hazards (EU, 2012) was introduced to prevent and manage potential chemical accidents in 1996, as mentioned previously in Chapter 2. Correctly, this Directive is applied for the major chemical accident prevention, and humans and environmental protection from accident consequences. Although it is established to manage chemical accidents, it does not cover all risks of chemical accidents, for instance, military facilities, nuclear hazards, transport of hazardous materials, mineral exploitation, waste land-fill, and gas storage. The Seveso III Directive requires the consideration of the domino effects of chemical accidents, as well as consideration of chemical accidents triggered by natural hazards in risk management programs. One crucial part of the Seveso III Directive is that it requires the disclosure of chemical risk information to local responders and the public, and opportunities for participation in the decision-making process related to chemical and environmental risks. In particular, the Directive states the facts that all people, who might be affected by major chemical accidents, must be provided clear risk information, including the possibility and probable impact, and emergency measures that can be taken in case of accidents.

The Environmental Protection Agency (EPA) of the United States established the Risk Management Plan (RMP) rule to prevent chemical accidents and require industrial facilities to identify potential chemical accident effects and prepare for emergency response procedures (US EPA, n.d.). Also, these plans aim to provide adequate risk information to local stakeholders, particularly first responders, to prepare for and respond to potential chemical accidents. It includes the result of risk assessment, preparedness programs, including safety measures, educational programs, and emergency response programs. This RMP rule does not contemplate any types of chemical accidents that could be triggered by natural hazards, although the states implement additional rules.

In order to carry out specific risk management based on the regional characteristics, particularly earthquake hazards, the state of California, United States, set out the California Accidental Release Prevention (CalARP) program rule. It aims to prevent accidental releases of chemical materials that have potential consequences to the public and the environment and to minimize the chemical release possibility during earthquakes. It also fulfills the community's right-to-know act mandate (Cal OES, 2020). This program applies to broad industrial facilities, including oil refineries, chemical manufacturing processes, and water treatment plants, that handles and uses regulated chemical substances. The CalARP states that the public can access risk information based on the results of the RMP reports by individual companies, and provides opportunities for public participation in the decision-making processes for risk reduction activities. It mentions the risk information disclosure leads to reduce chemical accident risks and intensity. Furthermore, the CalARP Program requires the provision of risk information to the public. CalARP also promotes that the Unified Program Agency (UPA) means the local agency, considers public participation in implementing the CalARP Program at the local level.

Japan has been the second-largest country that has chemical industries after the U.S in the world. In Japan, the Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture, Etc. (the Chemical Substances Control Law, CSCL), for managing chemical substances was enacted in 1973. CSCL was enacted as a result of an accident involving accidental exposures due to food contamination caused by released polychlorinated biphenyls (PCBs) that are used as heat medium in deodorization process of rice oil production processes (Yoshimura, 2012) in 1968 that affected people's chronic health and the environment in Western Japan area (Mishima, 2017). Following this event, chemical material management and accident prevention, as well as safety management were regulated by several laws and acts in Japan, including the Act on Confirmation, Etc. of Release Amounts of Specific Chemical Substances in the Environment and Promotion of Improvements to the Management Thereof, the Pollutant Release and Transfer Register (PRTR) System; the Industrial Safety and Health Act; the High-Pressure Gas Safety Law; the Air Pollution Control Act; the Water Pollution Control Law, the Soil Contamination Countermeasures Act; the Basic Environment Law; and, the Act on the Prevention of Disasters in Petroleum Industrial Complexes and Other Petroleum (hereafter, the Petroleum Complex Disaster Prevention Law). In particular, the Petroleum Complex Disaster Prevention Law was updated due to a huge tank fire triggered by the 2003 Tokachi-Oki earthquake (Krausmann et al., 2017).

Particularly, the regulation on Safety of General High-Pressure Gas (revised April 2020) is the only one that requires risk reduction measures of industrial facilities for chemical accidents that could be triggered by earthquakes and tsunami, as potential external hazards (Cruz & Okada, 2008). After the GEJE in 2011, Japan has more improved the seismic code for high-pressure gas storage tanks to minimize the damage to storage gas facilities that can be impacted by long-period seismic events. Also, a new Land Resilience Basic Law[3] was enacted to promote enhancing sustainable and comprehensive national resilience in order to mitigate and recover from large-scale disasters. This law requires comprehensive countermeasures considering potential accidents and damage, including fires, explosions, and disruption and the occurrence of complex disasters in bay areas (Krausmann et al., 2017).

According to these enacted regulations mentioned above, the Japanese government performed multi-disciplinary chemical safety management as enforced by various governmental agencies, including the Environment, Fire, and Disaster Management Agency (FDMA) and the Ministry of Economy, Trade, and Industry (METI).

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[3] The full title of the Land Resilience Basic Law is the Basic Act for National Resilience Contributing to Preventing and Mitigating Disasters for Developing Resilience in the Lives of the Citizenry (強くしなやかな国民生活の実現を図るための防災・減災等に資する国土強靱化基本法). (Act No. 95/enacted in December 11, 2013/lately revised in September 11, 2017)

The government has identified the relevant divisions within the Ministry of Environment to collaborate with local stakeholders, including industry owners, and respond effectively to chemical accidents according to the guidance provided for different types of chemical accidents at the local level. Although Natech has rarely been contemplated in the national DRM system, concern about Natech events is gradually increasing after the nuclear powerplant accident and other chemical incidents triggered by the 2011 GEJE and Tsunami.

Concerning chemical accident management, the Maritime Disaster Prevention Center (MDPC), as a general foundation corporation and Nonprofit Organization (NPO), was established in 1976. The goal of this organization is to prepare for and respond to chemical accidents, not only maritime accidents but land chemical accidents, based on the Law Relating to the Prevention of Marine Pollution and Maritime Disaster (latest revised in 2017) enacted in 1970. The center has established a nationwide maritime disaster management system and provides several services, such as the Maritime Disaster Safety Service (MDSS), Hazardous Material Safety Service (HMSS), Hazardous Materials Emergency Response Service (HMERS), and Land Disaster Safety Service (LDSS). The MDPC, explicitly, designated Tokyo, Osaka, Ise Bay, and the Seto Inland Sea as high-risk zones and has offered intensive preparedness for chemical accident response. However, the MDPC, as a private organization, takes care of the containment and cleanup of accidental oil spills; they are not responsible for protecting neighboring inhabitants from other chemical accidents or Natech events.

There are regional and local government efforts in Japan to reduce chemical accident risks. According to field surveys and interviews with government officials, the government, particularly, Osaka Prefecture government, supervises several industrial parks located nearby ports. Since the industrial parks store large amounts of chemical materials, including fuels, those facilities are assigned as particular disaster prevention areas. The government is responsible for preventing chemical accidents through collaboration with other stakeholders, including companies, fire departments, and local governments. According to the interviews, Osaka prefectural office has established a disaster prevention plan for chemical accidents that is annually reviewed with relevant stakeholders and informs it to other stakeholders, as well as via an official website (Jaelani, 2019). Also, Jaelani (2019) showed that the plan contains much specific information and includes technical words that make it hard for the public, who does not have proper knowledge, to understand the plan. Also, the plan does not include chemical accident emergency instructions for residents, nor does it include information regarding the risk assessment of the industrial facilities. The Osaka prefectural government consistently tries to make efforts to manage and prepare for chemical accidents that could be caused by natural hazards. However, there are no yet exact chemical can Natech risk management systems that contemplate the residents that are neighboring chemical or industrial facilities, and that requires that the public be notified of risk information from the industrial parks and government.

Furthermore, the responsibility to develop disaster prevention plans for chemical accidents at the local level remains with local city officials. The lack of regulations in Japan regarding the disclosure of chemical risk information to the public has meant that residents are not informed about chemical hazards and the risk they pose by local government and industry owners/operators.

South Korea has been ranked as the fifth-largest country in terms of the chemical industry (Kotra, 2017). The Korean regulatory systems for chemical materials and hazardous substances management is similar to those of Japan. The government enforced several significant regulations and laws, including the High-Pressure Gas Safety Control Act; the Occupational Safety and Health Act; the Framework Act on Fire Services; the Nuclear Safety Act; the Marine Environment Management Act; and, the Act on the Safety Control of Hazardous Substances. These laws and acts are designed to manage a variety of hazards and prevent potential chemical accidents caused by different types of hazardous materials (Lee & Choi, 2015).

In September 2012, about eight tons of toxic extremely hydrogen fluoride (HF) gas, which also forms corrosive hydrofluoric acid when mixed with moisture in the air, was released into the atmosphere due to human-error in Gumi Industrial Park in Korea. This accident killed five employees, affected 12,243 inhabitants in the local community, and killed 3,944 animals. Through studies of this chemical accident, Jung and Park (2016) identified issues in the emergency management system, including a lack of i) interactive risk communication between response organizations; ii) well-trained experts; iii) proper information within inter-organizational systems; iv) preparedness of chemical accidents. Also, Han and Park (2018) identified a need for developing a suitable risk management system for chemical accidents that facilitate risk communication with the local community and cooperation among multi-stakeholders to reduce chemical accident risks.

Due to the accident, the Korean government re-enacted the Chemicals Control Act (CCA) in 2014, formerly the Toxic Chemicals Control Act (TCCA) (1990-1996), which was fragmented among different government organizations. The CCA's goal is better chemical substance management and the development of an integrated risk management system for hazardous materials, as well as preventing chemical accidents and promoting timely response to incidents. The Act on Registration, Evaluation, etc. of Chemical Substances involves appropriate risk information concerning the chemical substances of materials and products should be evaluated In order to promote risk communication between all stakeholders, expert groups, including the government agencies. The CCA states that operate the Comprehensive Chemical Information System and industries that handle chemical substances require disclosure risk information and emergency response manual to local communities in Article 42.

Although Japan and Korea have made efforts to manage technological risk, like potential chemical incidents, and securing safety from hazardous materials through regulation, there are still no Natech-specific risk management systems and regulations. Attention in both countries is needed to prepare for potential Natech disaster and reduce Natech risks, which are likely to affect entire regions, including local communities. Through looking at some Natech accident cases in the previous chapter, it was evident that the local community, neighboring industrial facilities or complexes, could be affected by natural disasters as well as chemical accidents. Despite the extensive laws and regulations passed in both Japan and Korea, local communities are still rarely acknowledged as actors in Natech risk management. Thus, under a similar but different regulation for managing chemical accidents and materials, this thesis investigated chemical and Natech risk management practices of the government by investigating the JICEPCs in Korea.

6.3.2 Overview of the JICEPCs

The 2012 chemical accident involving the hydrogen fluoride leakage at the national industrial park in Gumi, Gyeongsanbuk-do, highlighted several issues. Those issues were: 1) the failure of the initial response, 2) the lack of a disaster management system for chemical accidents, 3) insufficient risk communication between all stakeholders, including residents, first responders, and experts, 4) inadequate knowledge, and 5) inefficient duty allocation during the emergency between relevant agencies (Lee, 2015). Thus, the need for a collaborative organization focusing on on-site chemical DRM has emerged in Korea, and the government has begun to strengthen the systems to reduce potential risks of chemical incidents and protect citizens. In 2013, the government improved its related laws and regulations for hazardous material management systematically, involving risk assessment, risk information disclosure, chemical substances safety management, and preparedness and response to chemical accidents (Lee et al., 2016). This challenge allowed the Korean government to integrate relevant regulations and laws for hazardous material safety management into the Chemicals Control Act in 2015 so that related stakeholders could deal with chemical disasters and risks in a cooperative structure and manage hazardous substances.

Furthermore, since 2014, the government established the JICEPCs in the seven national industrial complexes based on the Regulation of the Establishment and Management of the Joint Disaster Collaborative Center for a Chemical Accident. The primary tasks of the organization are to perform risk management, preparedness for efficient response and protecting residents, crisis management during the events as well as natural disasters, and recovery support. This organization is composed of the five collaborative teams from different government departments, including the Ministry of Environment, National Fire Agency, the Ministry of Employment and Labor, the Korea Occupational Safety and Health Agency, the Korea Gas Safety Corporation, and the local or city government.

With increasing concern about chemical accidents, the Korean government established the JICEPCs, which are organized by five ministries in Gumi in December 2013. They were aimed at preparing for all types of chemical accidents, as well as technological disasters. As of 2020, a total number of eight JICEPCs have been set up located around national industrial parks in Seosan, Iksan, Siheung, Ulsan, Yeosu, and Chungju. The responsibilities of these centers have been pertained to fire extinguishing, responding to natural disasters, and assisting in other accidents, such as car crashes or mountain incidents, and working in cooperation with other agencies, as provided for in the present agreements (Lee, 2015).

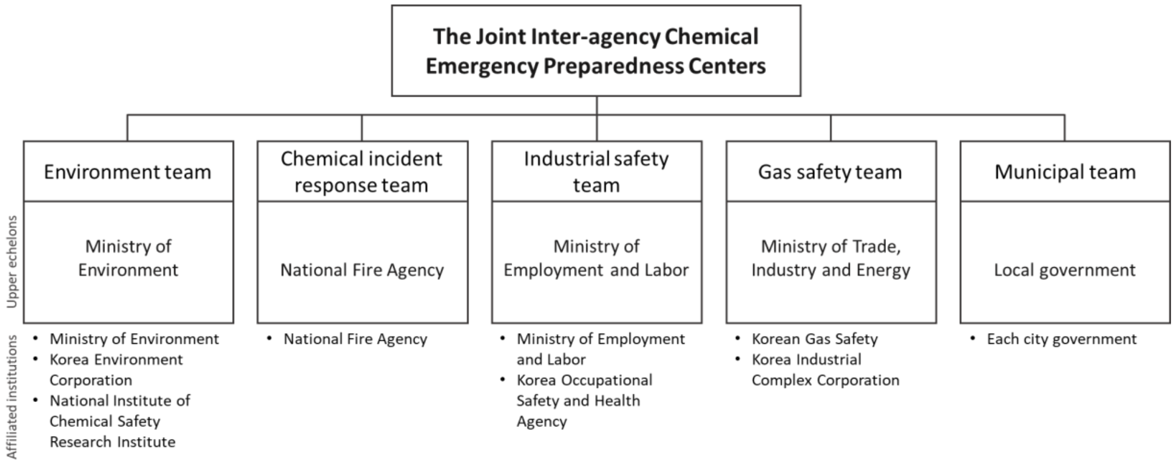


Figure 28. An organizational chart of the JICEPCs

All the centers consist of the same organizational structure, incorporating an environment team, a chemical incident response team, an industrial safety team, a gas safety team, and a municipal team, as shown in Figure 28. The five collaborative teams are under different 'umbrella' organizations depending on the task characteristics. The tasks are divided into ordinary and essential tasks based on the Regulation on the Establishment and Management of the Joint Disaster Collaborative Center for a Chemical Accident (Directive 66), as shown in Table 8 (Lee, 2015; Ministry of the Interior and Safety, 2013). Also, the essential tasks of each team are controlled by concerned regulations of upper administrative tiers.

Furthermore, according to the Korean Directive No. 66 (recent revised 2018), which is the Regulation on Installation and Management of the Joint Inter-Agency Chemical Emergency Preparedness Center (Ministry of the Interior and Safety, 2013), the detailed common assignments of the centers are provided by the regulations according to the disaster management phases, as follows.

- Prevention: risk assessment for the industrial park, maintenance of response devices, and provision of relevant information for chemical accidents
- Preparedness: preparation of early warning and response for emergencies and

joint training education for residents

- Response: crisis assessment, decision-making for the warning, prompt response, protection of citizens and workers, and investigation of damages
- Recovery: incident investigation and follow up, support for damage recovery, and measures to prevent recurrence of accidents.

Table 8. Tasks of JICEPCs' teams

Ordinary tasks	
○ Chemical material information sharing	○ Response training for chemical incidents
○ Building emergency networks	○ Securement of response resources
○ Guidance and inspections on individual workplaces handling hazardous materials	

Essential tasks	
Team	Tasks
Environment Team	· Permission and guidance for business on hazardous chemical substances · Coordination on the scene of chemical accidents · Investigation of health and environment impact
Chemical Incident Response Team	· Response to chemical accident and rescue · Rescue and first aids · Prevention and preparedness for chemical accidents
Industrial Safety Team	· Safety inspection of chemical facilities · Review and verification of process safety management · Technical guidance · Incident inspection
Gas Safety Team	· Investigation of the cause of accidents · Review and verification of process safety management · Technical guidance on workplaces using high-pressure gases · Management and support of industrial complexes
Municipal Team	· Resident evacuation · Securement of human and physical resources · Operation of emergency management headquarters · Support to detoxication and decontamination

6.3.3 Korean Chemical Accident and Risk Management

(1) Relevant regulations and strategies

The JICEPCs operate according to the Regulation on Installation and Management of the Joint Inter-Agency Chemical Emergency Preparedness Center. These centers are tasked with various roles in managing chemical accident risks, better preparing for the events, and responding to chemical accidents based on several relevant laws and regulations. Also, each team of the agency executes their responsibilities under different regulations depending on each team's affiliations, such as the Act on the Safety Control of Hazardous Substances, the High-pressure Gas Safety Control Act, the Safety Control and Business of Liquefied Petroleum Gas Act, the Occupational Safety and Health Act, and the Toxic Chemicals Control Act.

The associated government agencies in the JICEPCs provide a list of designated hazardous chemical materials depending on their specific regulations. For example, the Ministry of Environment has assigned 772 materials, as toxic chemicals, including toxic agents, prohibited materials, restricted matters, and substances requiring preparedness against accidents. Also, the Ministry of Employment and Labor designated 97 toxic agents, the Ministry of Trade, Industry and Energy appointed 69 chemical agents, and the National Fire Agency specified 6,828 hazardous materials offered through the national hazardous material information system.

According to the interview, all the teams in the agency have plans for emergency and chemical accident risk management, but most of them are focused only on hazards and emergency management. The management strategies are rarely shared among stakeholders within the agency. In order to facilitate effective management of risks and hazards, the National Fire Agency and the Ministry of Environment independently formulate their manuals for managing chemical accident risks, and disseminate them to each center. Also, the centers have established a regular disaster management plan, including a chemical accident response, considering the regional characteristics and specific features of industrial parks. In particular, the center in Ulsan has established a specific plan to manage nuclear accidents that could occur in nuclear power plants located around the coastal area of Ulsan.

(2) Chemical accident and Natech risk management

The Korean national industrial parks consist of several companies, which are handling various types of chemical substances. Even though the plan of chemical disaster management does not consider chemical material details, guidelines were developed based on the related laws and authorities that provide specific information about chemical substances responsible for frequent accidents. The developed guidelines include response procedures, considering scenarios involving hazardous materials that can trigger serious chemical accidents. When chemical accidents happen, the response team refers to earlier mentioned regulations and laws, detailed guidelines, and an Emergency Response Guidebook[4] containing diverse chemical material information.

The JICEPCs implement chemical accident risk management based on the Act on the Registration and Evaluation, etc. of Chemical Substances enacted in 2015, and the Chemicals Control Act legislated in 2014. The overall aims of these Acts are to share the appropriate information obtained through chemical material inspection and risk management and to manage and prevent any event involving hazardous substances. Each center has formulated a risk management strategy for chemical accidents and prepared for various types of chemical accidents based on the list of 97 major hazardous substances causing chemical events, as well as shared the list with other stakeholders within the centers. Although plans, guidelines, and strategies do not include specific Natech disaster risks, the stakeholders consider probable chemical accidents caused by natural disasters in these systems.

As far as risk management is concerned, the divisions in each agency have not designed a specific and integrated risk management system as a framework for risk management according to the ISO 31000: 2018 Risk management, yet implement risk management jointly. The interviewees said that even though there are no specific guidelines for the agency to deal with Natech and the risks, they estimated that the current systems or regulations are sufficient to respond to chemical accidents caused by natural disasters or hazards. Also, they said that Natech risk management is considered a critical part of the DRM plan and their risk management systems. However, since severe Natech or chemical accidents have not occurred so far, the participants in

[4] In 2012, the Ministry of Environment translated an Emergency Response Guidebook published in Canada to identify chemical substance information for better responses during chemical accidents. This book is divided into orange pages and green pages. Mainly, orange pages involve an introduction of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS), hazardous substance indexes, e.g., UN, Korean, and Chemical Abstracts System (CAS), emergency response guidelines. Green pages contain initial gap and response distances, and specific materials reacting water. Since 2012, it has been revised three times by the National Institute of Chemical Safety (NICS) under the Ministry of Environment.

the survey supposed that those events can be responded to and managed by the existing regulations and plans sufficiently.

Within the overall system of the JICEPCs, the entire process of chemical or Natech risk management is only partially considered. The agencies carry out a fragmentary process of risk management, which is risk identification, to help to detect risks and support decision-making every month. The actions are observed by the risk management guidelines developed by the centers. Through this action, the agency — and especially the response team dispatched by the National Fire Agency and the environment team from the Ministry of Environment— visit industrial companies handling hazardous materials to identify risk factors, including past events, assess the surrounding environment and any available resources, knowledge, and information, and prepare the analogous accident prevention and response strategies of the company.

Based on the risk identification, the response team develops several scenarios written as scripts and estimates potential accident scenes based on the practical investigation. The scenarios include hazardous chemical materials, task allocation of first responders from the center, the necessary response facilities with equipment, the extent of damage, the route of access and the other possible or cascading accidents or disasters, the time required, and potential obstacles. Moreover, hazard maps were created from this process based on the location of hazardous materials and referring to the facilities' performance in terms of risk management, including any preparedness and response measures.

However, it does not contain any information concerning natural hazards, chemical accidents, or Natech. To enhance the coping capacity for unexpected emergencies and identify probable limitations, these scenarios are used in a blind emergency response training mode, in which employees and officials in the center are not informed about these details in advance. Furthermore, the center often uses the Chemical Accident Response Information System (CARIS) to investigate the release of chemical materials. However, the system is not frequently used in the risk management process, and training or education since the system outcomes vary depending on the different atmospheric and environmental conditions of each specific region.

(3) Risk communication among multiple stakeholders

Risk communication, as a form of two-way information exchange, can be applied in various ways with different messages (Reynolds & Seeger, 2005). When chemical accidents occur, the real-time information is shared with JICEPCs in other regions, relevant government agencies, and local fire departments through hotlines of the local government, wireless communication system, social network system (SNS), and physical documents. Primarily, the response team communicates and shares information about natural and chemical disasters, fires, and accidents with other response teams in other authorities, as well as exchange their perspectives to deal with issues that are coming up from performing their tasks and increasing their knowledge of accident cases.

Regarding inspection and report of accidents, each team in the JCPCEs investigates separately occurred events and report the results to their 'parent' organization. Also, the major accident causes, as derived from the inspection, are shared with other teams, but the details usually are not. Each part of the JCPCEs investigates the causes of chemical accidents through their manuals from their own viewpoint, but there is an apparent lack of collaboration for accident investigation and sharing the outcomes of the accident inspections between the teams. In the case of the response team, they generally report details of accidents such as the company information, the hazardous substance that caused the accident, the amount of leakage, the level of damage in terms of human life and property, and the accident consequences. In the Ulsan center, although teams conduct accident investigations individually, they share the correct data with other teams regarding human damage.

Likewise, the JICEPCs have made an effort to help the neighboring local community better understand chemical and Natech accident risks and increase their risk awareness. Since the principal target of the JCPCEs is companies handling hazardous materials located in the national industrial parks, there are no formal channels for risk communication, including education and training related to chemical accidents for the local community, to increase risk awareness of chemical accidents and listen to the local concerns. The center is not responsible for the education or training of the local community. It is recognized that those are executed by the local government and the local fire department. The center conducts education or training only on the employees in the national industrial parks and communicates with them.

However, the centers offer particular opportunities to the national industrial parks to communicate with experts or government officials through monthly or yearly education and training, as well as a regular campaign on industrial safety and chemical accidents. Also, there are some programs for risk communication regarding chemical substances and risks between a safety council of a large company and the leader group of the local community to reduce concerns on chemical accidents and its impact and increase risk awareness and public trust. During chemical accidents, relevant information regarding evacuation or situation is disseminated or guided by the government level. In the middle of chemical events, most of the JICEPCs' divisions focus on the site, and the centers are not in charge of providing related information to the public and directly recommend evacuation to the safe place. Thus, most information needed is delivered by the local government to the local community by emergency alert messages.

Every month, the agencies offer education and training for companies in the industrial park, using a table-top approach based on the results of the risk identification performance test, and confirm possible access toward the scenes. The contents include fire safety, chemical accident responses, the practice for using response equipment, and a consultant on general security. Mainly, the environment team executes regular programs with approximately representative councils of roughly 2,000 businesses to increase risk awareness and understand challenges on chemical disaster preparedness.

During the process of training, they examine difficulties or limitations, such as access pathways to the accident scene and uncertain situations, to reflect on updating their strategies and structuring risk information databases. Also, full education and training under coordination with other teams is performed six times a year, and on-site training and practices of using response equipment for chemical accidents in the industrial parks are conducted twice a month. Furthermore, the center offers chemical safety education programs eight times a year by visiting companies. The opportunities given by the collaborative agencies are expected to contribute to enhancing the coping capacity for potential chemical accidents and Natech disasters and making better risk management systems. However, this education or training opportunities are only provided to the relevant actor in the business field, not nearby residents or the general public.

(4) Hardware resources for chemical emergency response

There is a total of 7-8 special vehicles owned by the centers. During chemical accidents, using all those vehicles is inevitable. Those vehicles are specialized for the physical response (a destruction vehicle of unmanned water spray, a high-performance chemical vehicle, and a multipurpose excavator), chemical response (a multipurpose decontamination vehicle), support response (a carrying equipment vehicle and prevention and inspection car) and a reformed bus for inspection and detection of chemical materials used by the environment team. 6-7 team members per shift in the response team may be considered suitable for an ordinary day. However, since the response team is operated through three shifts a day, all members must handle each particular vehicle in the case of chemical accidents. In a time of emergency, on-call members are dispatched directly to the on-site response, as well as the centers request support from the local fire departments in case of necessity.

Although the operation of the centers is effective in responding to accidents in corporations within the jurisdictions of the national industrial parks, a simultaneous response is not possible in the event of multiple accidents. For example, there are two different areas, A and B. Two areas are away 100 Km from a center on opposite sides of each other. When a chemical accident occurs in area A, JICEPCs should be dispatched in the scene with all vehicles and equipment. At the same time, if there is another chemical accident in area B, 200 Km far from area A, the response team should now move to area B. In this situation, a quick and proper response to the second accident is not possible. It may occur even when the center is operating in other regions, which effectively increases the potential damage.

6.3.4 The viewpoint from government agency officials on Natech

The questionnaire survey was carried out on February 25, 26, and 28 in each JICEPCs, Ulsan, Yeosu, and Siheung. The questionnaires were distributed along with a brief description of the concept of Natech, including a few previous cases as examples for clarification purposes. These were collected on the same day of the in-depth interviews. The total expected sample size was about 157 respondents, 55 from Ulsan, 46 from Yeosu, and 56 from Siheung JICEPCs. However, only 38 employees responded, providing a total reply rate of 24.2% due to the absence of workers by the specific scope of work in each department. Despite the small sample size, the analysis gives an overall view from government stakeholders on Natech risk management.

(1) Risk awareness and consideration of chemical accidents and Natech

In order to understand respondents' perceptions of a chemical accident and Natech disasters, the first subsection was aimed at understanding the general awareness of Natech and the consideration of Natech in the JICEPCs' tasks. The results (Figure 29) show how the participants consider chemical accidents and Natech risks in their tasks. Half of them believed that they aware of the difference between general chemical accidents and Natech. It must be noted here that their understanding might have been affected by the previously distributed concept description of Natech. Also, the respondents mentioned that they are considering a chemical accident and Natech in their assigned tasks. The centers and each department do not prepare individually for Natech disasters, but the increasing chemical material usage and Natech risks have led to change the viewpoint of the government and stakeholders (Oh, 2013).

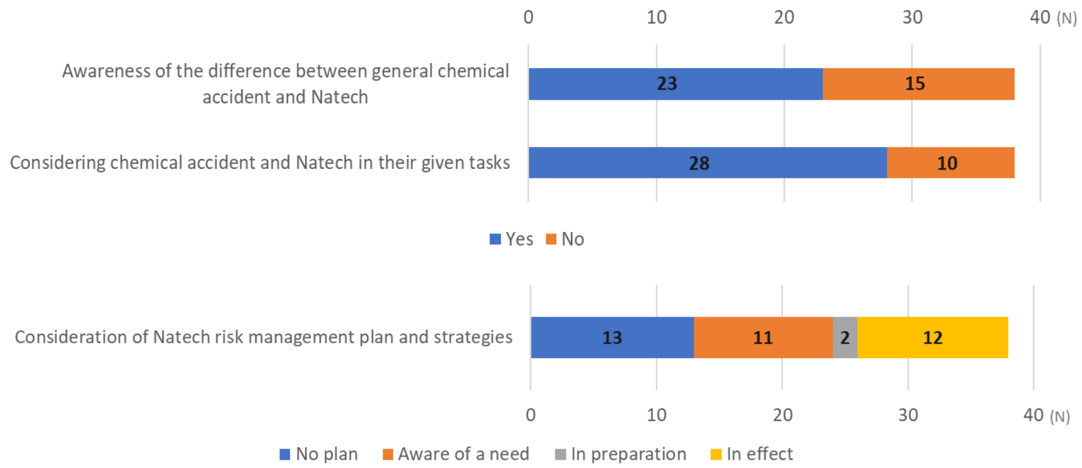


Figure 29. Awareness of Natech and consideration in risk management for chemical accident

Furthermore, while 11 (out of 38) respondents showed there is a need to develop a for managing Natech risks, 13 respondents answered that there is still no plan for Natech management. 12 responses indicated they are in a stage of developing Natech risk management plans or strategies, while 2 already had a risk management plan involving Natech in effect.

(2) Risk management for chemical accidents and Natech

In this sub-section, nine questions were asked to explore the status of risk management for a chemical accident and potential Natech. We asked respondents' opinions concerning the natural hazards that have the potential to trigger a Natech disaster; the answer to this question permitted multiple-choice (Figure 30). The result reflects the most frequent natural hazards in Korea, depending on the geographic location of each center. The two natural hazards, namely earthquake and typhoon, are of the biggest concern for potentially triggering a Natech accident. Although Korea is not in an earthquake-prone area, respondents' perceived risk might have been influenced by a recent increase in the frequency of lower magnitude ground movement and the Fukushima nuclear powerplant accident.

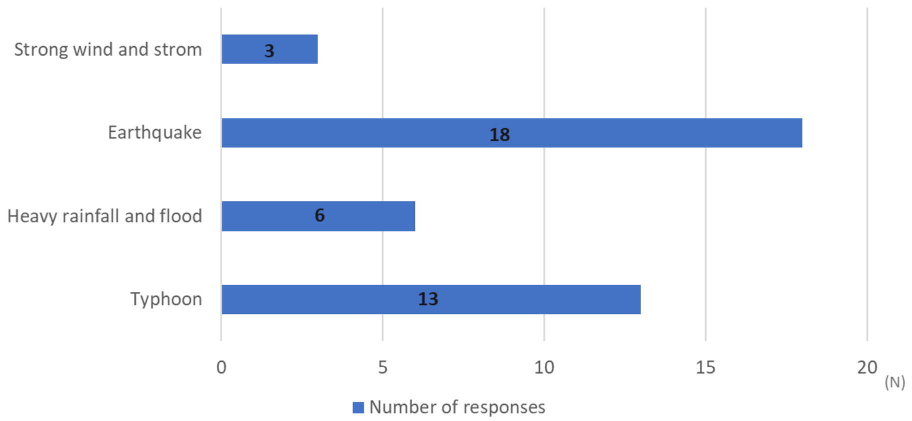


Figure 30. Identified Natural hazards triggering potential Natech accidents

In the next question, we asked the participants about the scope of their responsibilities in respect of their perspective on risk management for chemical accidents and Natech. This question also permitted a double answer. Among the responses, most of the participants answered that their assigned tasks in the JICEPCs are related to risk management (Figure 31). Also, even though they do not have proper tools to implement the risk management process, the respondents mentioned that they believe their currently established DRM system can be adapted to cover chemical accident events and Natech if the government provides appropriate regulations for handling hazardous materials.

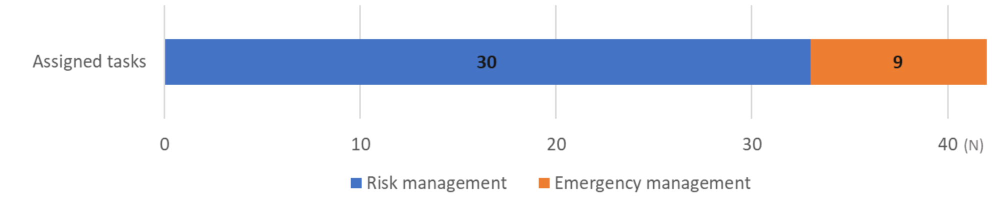


Figure 31. Assigned tasks of the participants in the JICEPCs

With respect to the perspective on the priorities of risk management dealing with chemical accident and Natech risks, 20 respondents replied that the most important aspect is developing an adaptable risk management system (Figure 32). Also, the results indicated that risk communication is regarded as a critical part of the system. Emphasis is placed upon sharing and disclosing information to the public through Article 42, Disclosure of Information of Chemical Substance, in the Act on Registration and Evaluation, Etc. of Chemical Substance. However, elements such as relevant policies and regulations and taking into consideration of regional characteristics are recognized as less essential aspects comparatively. Additional responses showed that the geo-environmental dimension, well-organized strategies, and social infrastructure might contribute to improving the risk management system for chemical accidents or Natech.

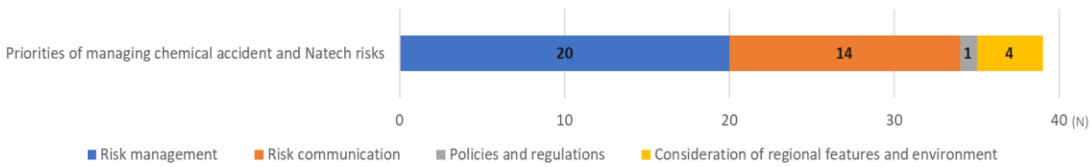


Figure 32. Priorities of the chemical accident and Natech risk management

Moreover, risk communication is recognized as a critical element for managing chemical and Natech risks effectively. Notably, 22 respondents answered that they are highly responsible for disclosing and sharing risk information to the public, including the business sector and neighboring residents (Figure 33). Regarding risk communication, some of the major companies in the national industrial park offer several programs, for example, council meetings with community leaders, promoting campaigns, distributing pamphlets to reduce antipathy towards chemical materials, and build rapport. Although they do not directly address Natech risks or chemical accidents, this could serve as a good initiation to raise and improve risk awareness of the local community.

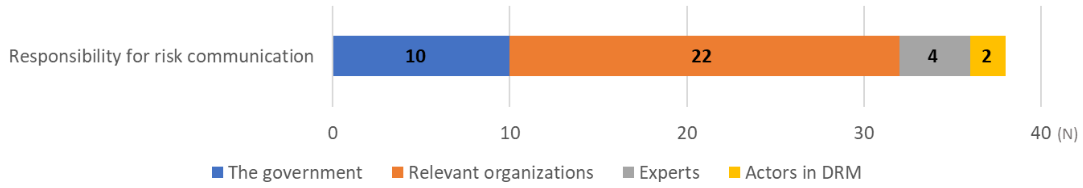
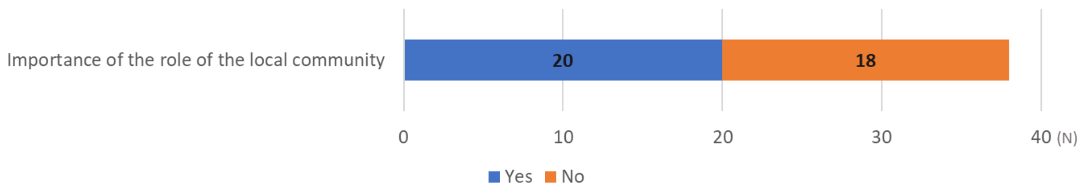


Figure 33. Responsibility for risk communication

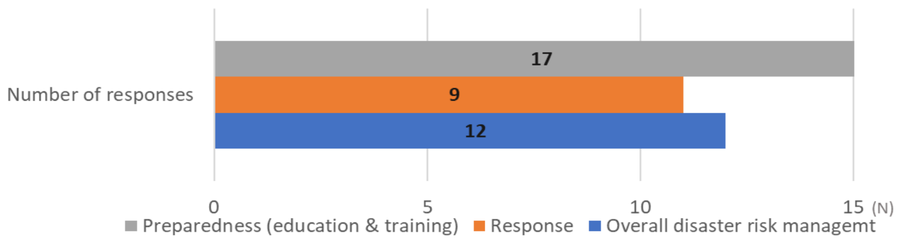
(3) Chemical accident and Natech risk management and community engagement

As evidenced from past Natech and chemical accident cases, the local community nearby the industrial parks or chemical facilities is recognized as the most damaged party immediately after the events. Despite the lack of information/knowledge, there is a need for community participation in DRM due to the uncertainty and complexity of the potential Natech and chemical accidents. In this sub-section, we asked how the respondents in the JICEPCs are aware of the local community as an actor in the process of risk management.

Almost half of the respondents indicated that community participation could serve as a local stakeholder in the risk management for chemical accidents or Natech risks, while half of them did not agree (Figure 34-a). Particularly, during chemical or Natech disasters, unlike single natural disasters, some special limitations affect the residents immediately, including the lack of information or resources, harmfulness of the released substances by chemical reactions, and delayed emergency response. Due to such reasons, a participatory risk management system is required to be established even before potential accidents occur, in order to involve representative members of the community, like the Jishu-Bosai-Soshiki, targeting especially those who know the local environment more than the local government officials and professional first responders that hold indigenous knowledge and abundant experiences.



(a) Community participation's importance



(b) Possible roles of the local community from government perspectives

Figure 34. Community participation in a risk management system

According to this viewpoint, the results show how the community can contribute to improving the management of chemical accidents and Natech risks. As shown in Figure 34-b again, 17 respondents stated that the community could support the experts or the system by participating in education or training programs. However, they mentioned that there is still a lack of educational programs for residents nearby the industrial complexes to increase their risk awareness and preparedness or allow those interested in proactively engaging in emergency response to develop the appropriate response skills. Furthermore, 9 (out of 38) highlighted the importance of response, but here, only evacuation activities following released guidelines and regulations or warnings are considered. Lastly, 12 participants mentioned that the community committee could contribute to the overall risk management process adding a perspective of community-based on the community-based mechanism in DRM. In particular, it is expected that the community can participate in the planning process as an informative resource.

With regard to sharing relevant information, the 19 responses indicated that the JICEPCs provide proper information to and communicate with the community (Figure 35). However, the respondents mentioned that information sharing is focused on transmitting simplified and unspecific risk information to the public. In order to improve the mechanism for risk communication towards both way communication, the relevant organizations require to develop programs, tools, and opportunities to involve the interested community groups.

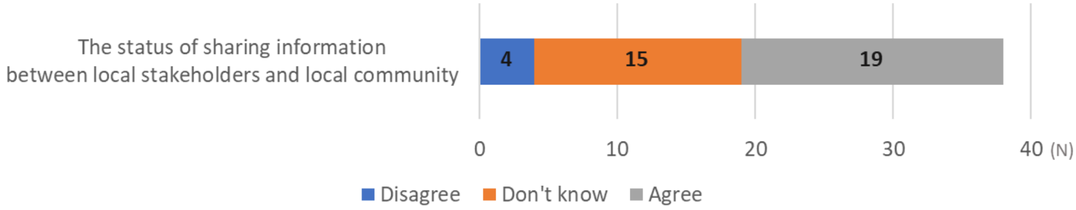


Figure 35. The status of sharing information

Through questionnaire surveys to three JICEPCs to explore the government perspectives, the study presents the government agencies' insights on chemical and Natech accidents and risk management. Also, this survey identified gaps between regulations and practices and chemical and Natech risk management issues. By looking at employees' viewpoints in government agencies, the results are expected to support building new approaches that can promote chemical accidents and Natech risk management in the industrial parks and local community.

Even though respondents of JICEPCs were aware of the technological accidents that could be triggered by natural hazards, such as earthquakes and typhoons, there is still a lack of Natech-specific risk knowledge and risk awareness. However, the need to expand their knowledge and contemplation of Natech risks in their risk management systems has been identified. Also, since most activities of each team are based on chemical accident risk management depending on employees' expertise in general, considering Natech risks will help to improve the organizational collaborative Natech risk management and increase their Natech risk awareness.

In terms of risk communication, we have identified that despite the enacted regulation to disclosure risk information regarding chemical material hazards to the public, there are no communication channels between the government agencies and the resident living near industrial parks and facilities. The results presented that risk communication and risk information disclosure are an essential element in chemical and Natech accident risk management. However, there is a low perception of the threat of the potential accidents to the local community, and it presented they are concerned that sharing risk information would make the resident fear or panic about potential chemical and/or Natech accidents.

In order to reduce a gap between enacted regulations and practical applications, this survey found that comprehensive both natural and technological hazards and Natech risk must be considered in the implementation of risk management considering lessons-learned from past Natech disasters and developing Natech scenarios through intensive risk assessment. It shows that there is a need for a strategic approach for risk communication and risk information disclosure to the public and encouraging community participation in chemical and Natech risk management systems.

Conclusively, there are differences between Japanese and Korean government activities. In Japan, even though the government has separated disaster risk management systems, which are mainly focused on several types of natural hazards, there is no comprehensive system for managing both chemical accidents and Natech events. In Korea, the government highlights the importance of inter-organizational agency to implement comprehensive risk management for chemical and Natech hazard risks, as well as natural hazards, through a multi-disciplinary approach. However, in both countries, there is a lack of continuity of government officials due to work rotations every 2-3 years. Therefore, it makes difficulties that relevant officials could have proper knowledge and expertise and build trust and better partnerships with other stakeholders. Finally, this study result found that the level of Natech risk awareness and preparedness are still low in both countries. Therefore, enhancing the government's insight on Natech risk management and considering Natech risks in DRM is required to better prepare for the potential Natech disasters.

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Chapter 7 Discussion

The main goal of this thesis is to investigate how to improve the coping capacity of the local community for Natech risks and to suggest Natech risk management focusing on the roles of the local community, and recommendations for successful Natech risk management at the local level. The previous chapters provided a background, literature review, and described the methods used to conduct field surveys in this research and presented the results. The results of the research indicate the need for a community-based Natech risk management framework from the perspectives of community members, first responders, and government.

This chapter discusses the different perspectives and proposes community-based Natech risk management based on the conceptual framework described in Chapter 3. Also, it provides research contributions, limitations of the community-based Natech risk management based on the study. This discussion is linked to the research questions and objectives combined into community-based Natech risk management.

7.1 Towards community-based Natech risk management

7.1.1 Local community perspectives

As discussed, the literature review in Chapter 2, several studies highlighted that effective DRM needs active community participation. It is caused by the delayed responses by first responders and search and rescue teams, uncertainty regarding how an event will evolve, and complexity related to each individual's situation, location, and capacities at the time of a disaster (Briones et al., 2019; Tozier de la Poterie & Baudoin, 2015; Twigg & Mosel, 2017). Specifically, in order to have effective DRM at the local level, Ainuddin et al. (2013) and Berkes and Ross (2013) stressed the need for collaborative partnerships and risk governance and building local organizations. The need to consider local characteristics is pointed out as an important aspect by Allen

(2006). The reason is that every local community has different environmental, social, and cultural backgrounds, as well as different levels of coping capacity and systems, risk perception, local resources, and community engagement level.

Based on the results, the Shimobara district is recognized as a well-organized local community that implemented successful DRM before/during/after the Natech disaster in 2018. The local community established the Jishu-Bosai-Soshiki in the Shimobara district as a community-based DRM system to prepare for floods and earthquakes. Despite the fact that some accidents have occurred at the aluminum factory prior to the 2018 Natech, there was no official information from the factory or any relevant stakeholder strategies for subsequent events caused by natural hazards. Though the community organization considers several potential disasters, the results from the field survey indicate that uncertain risks and their effects (e.g., cascading effects or Natech events) were not considered before the heavy rain and floods of 2018. The Natech disaster in the Shimobara district served as a reminder of the need to manage Natech risks in communities neighboring chemical facilities or factories. Hence, in the context of Natech disasters, there are three key findings from several field surveys, particularly the in-depth interviews, the focus group discussions, and field notes.

(1) The need for Natech risk management at the local level

Disasters cause different impacts and damages depending on different environmental and social backgrounds, coping capacity, knowledge level, and risk perception and awareness (Vermaak & van Niekerk, 2004). In order to better DRM against increasing multi-hazard risks, several studies highlighted building coping capacity (Mercer et al., 2010; Pandey & Okazaki, 2005), understanding local characteristics (Kwok et al., 2018; Moreno et al., 2019), and increasing multi-hazard risk perception and awareness (Allen, 2006; Briones et al., 2019) at the local level. These are recognized more importantly when the government and first responders cannot reach the local community that is affected by multi-hazards.

Through the Natech accident that occurred in 2018, the local community members, mainly the Jishu-Bosai-Soshiki, came to understand the high-risk, but low-probability nature of Natech disasters. When the Natech accident occurred near the local community, it was difficult for the government agencies to provide a formal response immediately after the Natech accident occurred and respond effectively to such unexpected emergency, including dispatching experts or first responders without having planned for them in advance. Due to the lack of knowledge and uncertainty regarding Natech accidents, potential consequences, as well as a lack of community experiences and knowledge about these types of events, they are rarely considered in DRM at the local level. The Jishu-Bosai-Soshiki, as a part of the DRM system, was unlikely to have experienced such disasters historically and had no collective memory of such events in the past. Unlike natural disasters that the community is relatively familiar with, Natech, which is a product of advancing technological development, was both unknown and overwhelmed the community coping capacity for this new type of disaster.

Thus, Natech risk management focusing on the local community is required to reduce Natech risks and impacts by supplementing and improving the coping capacity of the community. The Jishu-Bosai-Soshiki could contribute to assessing and reducing Natech risks by developing and encouraging local government to develop Natech strategies and plans with Natech hazard and risk maps considering local environments. Also, the community's active engagement in Natech risk management might help community members to understand Natech risks and local environmental risks, and increase risk awareness of various risks and hazards.

(2) Flexible and expanded evacuation processes that reflected various situations

Steinberg et al. (2008) described evacuation during the Natech accident might be different depending on the types of natural hazards and the location of industrial facilities. For instance, if the local community can have sufficient time to evacuate to safe areas during slow-onset disasters (e.g., floods, hurricanes), the exposure of people to a Natech accident can be decreased. Also, evacuation during disasters is affected by risk perception level, socio-demographics of the affected community, and the location where people are (Yu et al., 2017; Yu & Hokugo, 2015). However, since Natech accidents could have occurred concurrently with natural disasters, the evacuation processes also must be considered depending on the accident sequences or slow and rapid onset in emergency plans.

The Shimobara community did not expect the aluminum factory explosion during the heavy rain and floods. Usually, their evacuation process draws on experience from previous disasters, such as flooding and earthquakes. Following the 2018 floods and explosion, community members examined ways in which Natech could be integrated into the community's DRM plans, including their evacuation plans. The local community was concerned about any impacts on their evacuation activities, such as possible sequenced explosions of the factory. However, there were no specific evacuation processes for the conditions that prevailed in 2018. The local community, that in this case, if there had not been an explosion, maybe, they could not have evacuated before the floods, as they had recommended vertical evacuation. One important lesson from this study is the need to develop emergency response and evacuation plans for such high uncertain conditions, considering scenarios with varying disaster occurrence sequences. For example, disaster sequences that involve heavy rain-chemical accidents (e.g., explosions, fires, or oil spills)-floods (as was the case of Shimobara) or heavy rain-floods-chemical accidents (as was the case of Omachi town). Also, community vulnerability (e.g., gender, age, health condition, emergency preparedness level) and risk perception should be contemplated to make proper decisions on time depending on the circumstances in the community DRM strategy.

(3) An effective liaison and collaboration with other stakeholders

In the previous chapters, community collaboration with other multi-stakeholders is consistently highlighted as an important element in community-based DRM ((Briones et al., 2019; Maskrey, 2011; Twigg & Mosel, 2017). The government, sometimes, tends to restrict the independent activities of local stakeholders in DRM (Twigg & Mosel, 2017). When disasters occur, the government or professional first responders cannot reach affected local communities in a timely manner, and the relevant information, regarding emergency responses or relief, and cooperative networks or support are limited. It means that there is a need for collaborative systems to prepare for potential disaster situations.

During technological accidents caused by natural hazards, the local community could be faced with several challenges, including any decision making with limited experiences, knowledge, resources, and expertise (e.g., evacuation or shelter in place).

Thus, collaboration with other stakeholders should be emphasized at the local level during cascading disasters. During disasters, local community members must play several roles, such as first responders, first aid assistants, support to evacuation, or communicators, and have a good network with local stakeholders, including government, first responders, NGOs, and industrial facility managers or operators. In this study, the Jishu-Bosai-Soshiki in the Shimobara district served as a local liaison during the Natech accident.

The Jishu-Bosai-Soshiki coordinated community emergency responses and collaborated with the government and first responders through collecting and sharing information and supporting other community members. However, the industrial facility operators/owners of the aluminum furnace where the explosion occurred did not cooperate with the local community nor other local stakeholders during the Natech disaster. It made it difficult to know the accident situation. For these reasons, the local community living near industrial facilities needs to build networks with industrial companies in order to share risk and safety information and establish proper risk communication. Industry and private businesses can support and contribute to reducing Natech risks at the local level.

7.1.2 First responders' perspectives

All people, who face disasters, not only firefighters but police, are first responders during disasters (Coleman et al., 2019). In reality, the first responders, particularly firefighters and police, often suffer from limited human and response resources during unexpected catastrophic disasters (Adams et al., 2011). They may lack expertise, knowledge, and skills (IGMA Press, 2007), particularly in the case of cascading disaster events such as Natechs. In general, first responders' duties refer to emergency and DRM strategies from the government in a top-down approach. First responders are recognized as the most important actor in emergency planning, but their opinions are not well taken into consideration in emergency planning for potential catastrophic disasters at the local level (Schafer et al., 2008).

Therefore, it is important to listen to the first responders' voices to reflect on unexpected potential disasters in order to improve the present DRM. In particular, since first responders are responsible for managing chemical material usages and response to chemical accidents in small industrial facilities near local communities in Japan and Korea, their perspectives on Natech accidents are essential for managing Natech risks. Several first responders' perspectives, particularly in Omachi town, Shimobara district, and Korean chemical accident response teams, on the existing DRM and Natech risk management, were investigated. Even though the risk of a potential chemical accident that could impact neighboring communities was identified, risk management for a chemical event caused by natural hazards had not been considered explicitly in either the community- or the local- DRM system yet. Finally, through several field surveys and interviews with first responders, two main findings emerge in terms of Natech risk management.

(1) Comprehensive and collaborative management for Natech risks under uncertainty

As mentioned earlier, the current DRM, which is focusing on multi natural hazards, does not involve any potential for cascading effects or complex disasters considering the related uncertainty and unpredictability of such events. Through lessons learned from the Natech events in Omachi town and Shimobara district and interviews with JICEPCs in Korea, it is evident that there is a need for improving DRM for potential Natech disasters due to a lack of Natech risk management systems and proper risk information. This fact was highlighted by first responders in our study as well. Also, they underlined that the existing DRM systems be revised to incorporate flexible DRM elements reflecting on various possible scenarios for the purposes of reducing Natech risks and impacts on the local community and the district.

From the first responders' perspectives, there are several challenges of community engagement, including different knowledge levels and viewpoints on the DRM system and disaster occurrences. Interviews with first responders showed that some challenges, such as immediate response after the occurrence/or concurrence of the potential Natech accidents, cooperation between all stakeholders, and a lack of Natech risk management systems at the local level, were founded. To deal with these issues, the need to develop community-based Natech risk management systems that 1) provide adequate information to local stakeholders; 2) estimate potential Natech accident risks through intensive risk assessment; 3) and collaborate with other stakeholders, including local community members, has emerged. The findings show that a unit of the local community should draft their own emergency plan, including evacuation processes, evacuation places in their daily lives, by using hazard maps issued by the city or town government, and that consider local environmental conditions in practice because all affected local community cannot be protected and rescued by first responders immediately during Natech disasters. The first responders, also expected Natech risk management at the local level might minimize uncertain Natech risks and reduce possible damages at the local level by the first responders.

(2) Liaison and collaboration with other stakeholders in DRM

During disasters, since infrastructures, including transportations and telecommunications, might be destroyed, information sharing and cooperation and collaboration with other stakeholders have been known as parts of effective DRM systems (Kapucu, 2015; Waugh Jr. & Streib, 2006). Working with other stakeholders under different authorities, referring to different documents, and a general lack of communication and information could be major issues in DRM at the local level if there are no agreement and collaboration liaison. However, some consideration in updating and sharing DRM strategies and plans, upgrading equipment or systems for information sharing, and structuring a support and cooperation system might be helpful further to enhance DRM at the local level. Also, since Natech accidents occur rarely, but unexpectedly compared to other natural disasters, it is important to establish liaison for a collaborative Natech risk management system before the occurrence of Natech disasters in order to manage Natech risks and respond to Natech accidents effectively. Before and after Natech accidents, all documented Natech cases hold precious data, and therefore sharing and disseminating such cases could provide great lessons learned to other stakeholders to better prepare for potential future Natech accidents.

7.1.3 The government perspectives

The government is responsible for protecting the citizens and providing comprehensive systems in order to promote disaster risk reduction (Balamir, 2006; Luna, 2007; Shi, 2012). The government leads national DRM systems and support local DRM systems through 1) appropriate regulation; 2) decision empowerment; 3) human and physical resources; 4) financial support; 5) cooperation with relevant stakeholders, including government, local community, and NGOs; 6) and developing standard educational programs that could increase public risk awareness (Shi, 2012; UNISDR, 2017). At the local level, the national and local government covers limitations in the local or community-based DRM through improving social and political systems for successful DRM and promoting local stakeholders to participate in their DRM systems (Maskrey, 2011). Considering the Natech risk management system must be improved from the existing systems (Eisner, 2015), which is focusing on natural hazards, it is important to understand the government's perspective on Natech accidents and its risk management. Thus, here, the findings show two requirements to manage Natech risks effectively from government perspectives.

(1) The need for a comprehensive Natech risk management system

At the government level in Japan and Korea, most responsibilities have been appointed focused on managing chemical or Natech accident risks within their authorities and chemical accident response. Even though they offer various programs to the business sector in order to reduce chemical accident risks and raise risk awareness of hazardous materials, including education, training, and risk assessment, the public is not considered in their educational and risk management program.

Despite well-organized structures and regulations, there is still a lack of information and knowledge regarding Natech. There is a low obligation to collaborate with other groups within the risk management process. Past chemical or Natech accidents, show that all stakeholders, mainly including the government, industrial parks, and neighbor local communities, must be considered in comprehensive systems and risk management strategies. In order to manage uncertain chemical and Natech event risks and develop strategies to reduce its risks, the agencies and the system as a whole need the community perspectives, which are related to indigenous knowledge and experiences, so as to effectively minimize the regional vulnerabilities and reduce potential Natech disasters.

However, due to the unique organizational scheme that gathered several ministries with departments and duplicated tasks from different regulations and rules, there is a limitation in implementing detailed risk management in a collaborative framework among all involved stakeholders. Also, through surveys on Korean governmental agencies, which are JICEPCs, we found that there is a need for developing a comprehensive risk management process considering more the uncertainty and severity of Natech to manage risks. Despite considering various risks of chemical accidents, Natech risks are explicitly underestimated in their management system due to the significant features, which are high consequences but low frequencies.

(2) Increasing risk awareness and promoting community engagement in Natech risk management

In the complex and uncertain events, having collaborative partnerships among all actors, especially the government, first responders, chemical companies, and local communities, is a big challenge due to a gap between theoretical, political, and practical knowledge levels and different perspectives. Although communities could be directly affected by a chemical or Natech accident, they are usually considered less in the risk management system. The JICEPCs and local government officials, including local firefighters, little educational programs are provided to only employees by the local government officials. Also, even though the government side provides some educational material related to first aid or fire safety, there is no contemplation for the risks of chemical substances and accidents in the community context.

At the government level in Japan and Korea, they do not organize any activities directly to engage the local community and have less responsibility for providing education and training to the community. Also, their works mostly focused on response activities. Since the governmental agencies and organizations, as well as first responders, cannot rescue all residents in affected areas and support all other stakeholders at the same time, a need for systemic support to the community emerges to increase risk awareness and promote their contributions and participation in the risk management for chemical accidents and Natech.

Moreover, case studies show that risk communication concerning the chemical accident to the local community is still inadequate, and there is a need for information sharing and disclosure and communication between companies and the local community based on an agreement. All stakeholders, including the government, other experts, NGOs, as well as companies in the industrial parks, should make an effort to reduce the public concerns and distrust towards all types of chemical accidents and their risks. For the purpose of facilitating risk management for reducing chemical and Natech accident risks, and minimizing the gap between documented regulations and the real life, it is required to consider promoting education concerning the risks of chemical accidents or Natech and developing a plan for the local community depending on their regional characteristics and risk awareness level.

7.1.4 Towards a community-based Natech risk management framework

As a result of case studies from the three perspectives of the local community, first responder, and government, the need for improving local DRM and community participation in the system to address Natech risk has emerged. Due to the uncertainty and complexity of Natech events, the participants in field surveys have recognized the importance of the role of the local community neighboring industrial parks or chemical facilities during Natech disasters. However, the results indicated that there is still a lack of evidence, knowledge, community experts, and the proper system that makes the local community get involved in such a risk management system.

Here, as a result of this study, a comprehensive community-based Natech risk management framework (C-NRMF) is proposed (Figure 36), using as a starting point the conceptual framework presented in chapter 3 (Figure 8 in Chapter 3). There are several differences between the conceptual framework and the proposed C-NRMF. As shown in Figure 36, the proposed C-NRMF consists of four main elements, including a Natech risk management platform implemented and supported by the government, local community, and mutual assistance mechanisms. First, the national and regional government focuses more on considering Natech risks in the current DRM that must consider multiple hazards. They provide relevant regulations or standard guidelines that facilitate to consider Natech risks in the current DRM system. Also, they allocate appropriate resources and budget to maintain Natech risk management. Unlike the conceptual framework, mutual assistance is divided into the expert and first responder groups for improving natural hazard-oriented DRM and industry safety specialist for understanding present industry circumstances.

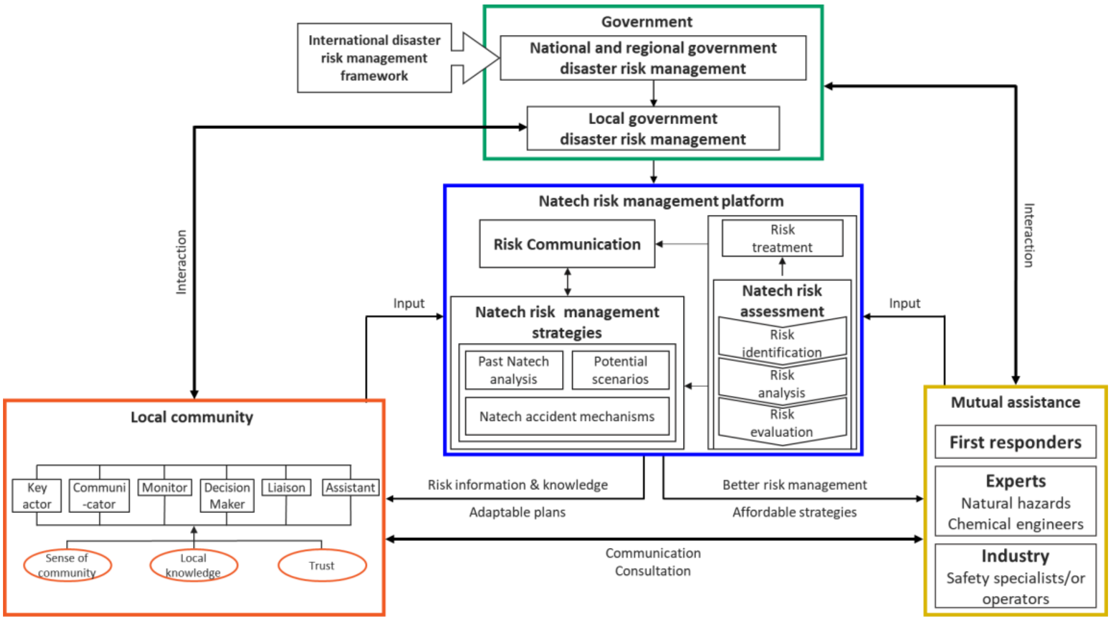

Figure 36. Proposed a community-based Natech risk management framework

The government has a proactive liaison for collaboration between the government and the local community. The local community has possible roles for community-based Natech risk management based on the identified community contribution through direct participation in the proposed framework. Lastly, a platform for Natech risk management is included in the framework. This platform consolidates information and knowledge management, the risk management processes. It develops strategies that provide flexible Natech risk management plans and appropriate information and knowledge to the local community sector and better risk management and affordable strategies for mutual assistance. Figure 36 presents the proposed community-based Natech risk management framework. The next sections explain how the framework works and how it can be implemented.

(1) Government

The role of the government is related to hardware and software structure, including infrastructures, hazard map, comprehensive disaster management strategies focusing on multi-hazards, human resources, and financial supports. Even though national and regional support might not directly reach the community-based activities, the regional government and local government provide opportunities to look at the overall internal and external environment for support to manage Natech disaster risks.

The main challenge of the government level might be the management of chemical facilities and hazardous materials widely used, building trust among relevant stakeholders, and risk information sharing and disclosure to the citizen. The government must consider how they can help to increase risk awareness of Natech accident to promote community participation within community-based Natech risk management.

Several studies have pointed out that the government offers political, economic, and cultural systems that facilitate effective disaster risk reduction, including enhancing financial and resource assurance and promoting community engagement in DRM (Balamir, 2006; Shi, 2012). For instance, the national government could consider Natech disaster risks in the DRM strategies, and provide standard educational programs and materials created by experts. The regional government organizations could provide regional natural and technological hazards risk information and sufficient physical and human resources to facilitate Natech risk management at the local level. Human resources could be affiliated to local community initiatives through mutual assistance, which feeds into the Natech risk management platform. At the local government level, relevant officials support and encourage the local community, as a local expert group, to engage in Natech risk management activities with experts and safety managers from industries located near the community. In particular, the local government cooperates with the mutual assistance group providing resources and improving relevant guidance for Natech risk management.

(2) Mutual assistance

Here, mutual assistance in the proposed community-based Natech risk management is presented as first responders, natural hazard experts, chemical engineers, and industry safety specialists and/or operators. More specifically, the first responders include local firefighters, local emergency managers, private emergency response teams, and governmental organizations, and they provide immediate emergency responses, educational programs, and aid or rescue during natural, chemical and/or Natech accidents. Experts group, involving natural and technological hazards experts and chemical engineers, has proper technical skills, knowledge, and experiences concerning DRM systems, risk management processes, and relevant regulations. Industry specialists and operators that could be safety managers or risk managers are responsible for and are specialized in safety management and risk management processes.

The mutual assistance group also provides communication and consultation, one of the risk management processes suggested by (ISO, 2018) to the stakeholders, including local community members. Risk communication among all stakeholders would promote that the local stakeholders can increase risk awareness and better understand regional and environmental risks that must be managed. In addition, the consultation refers to acquiring information and feedback for appropriate decision making (ISO, 2018). Communication and consultation are required to convey relevant information appropriately since it is directly linked to reduce the risks or minimize impact and damages (Sousa et al., 2012).

This group also promotes local community members in establishing Natech risk management strategies based on the risk assessment processes and past Natech or chemical accident event analysis. In particular, mutual assistants can satisfy the needs of the local community that are a collaboration with the industry side to prepare for Natech risk management and obtaining appropriate information to reduce Natech risks for community safety. Furthermore, due to the uncertainty of Natech accidents, low preparation, and the complexity of managing Natech risks, considering probable scenarios in the strategies or guidance is important (Krausmann et al., 2017).

(3) Local community

Due to its geographical location, Japan has historically faced natural disasters, such as earthquakes, typhoons, heavy rainfall, and floods. This environment condition has led the Japanese government to prepare for disasters and to reduce disaster risks. The local community played in the community-based organization, which is Jishu-Bosai-Soshiki. However, increased government support has made the local community rely on government activities in DRM (Shaw et al., 2011). In 1995, the Hanshin Great Earthquake stimulated and promoted the Jishu-Bosai-Soshiki's role. The roles are organizing disaster drills and education, environment investigation of the local community, and maintenance of response devices in daily life, and support evacuation, rescue, initial first response, and relief during disasters (Bajek et al., 2008; Cabinet

Office, 2018).

In this context, through the local community case study of Natech accident, the specific roles of the local community were identified, that can contribute to activating Natech risk management system as follows: 1) key actors in the community-based DRM, 2) communicators between the residents and other local stakeholders, 3) monitors for identifying hazards and risks, 4) decision-makers during disasters, 5) liaison with relevant experts and participants in DRM, and 6) assistants for their neighbors, particularly more vulnerable groups who need help. Also, the community member's roles are supported by a strong sense of community, indigenous knowledge, and trust and confidence in concerned stakeholder groups.

In the proposed community-based Natech risk management, the local community is recognized as a local professional group. As any sort of disaster is an issue that is directly connected to residents' lives and livelihoods, the local community must know what will happen during Natech and how they can contribute to reducing Natech risks. In order to proactive and efficient community participation, community members can be supported through communication and consultation activities from mutual assistance. Considering local community environments and coping capacity is an important aspect to understand localized risks and establish Natech risk management strategies at the local level. The residents provide their experiences, past disaster information, and local knowledge to support the Natech risk management platform. The provided sources are analyzed to create potential Natech accident scenarios and establish Natech risk management strategies. Through community members' participation and collaboration with mutual assistance, residents are expected to have a better understanding of Natech risks and increase their risk awareness.

(4) Natech risk management platform

Natech risk management platform is composed of three parts, which are Natech risk assessment and risk treatment, risk communication based on risk information and Knowledge, and Natech risk management strategies. The platform has a systemic connection between three parts. First, the risk management process is divided into risk assessment, involving risk identification, risk analysis, and risk evaluation, and risk treatment. Natech risk assessment must consider 1) natural hazards: actors (governments, industry, and citizens), specific types of natural hazards, and regional characteristics, and 2) chemical hazards: actors (government, industry, regulator, first responders) and industry hazard (e.g., process safety, operation procedures, human error, and facility maintenance). This section requires specific technical skills of experts to assess various risks since the local community does not have professional skills and expertise to implement risk assessment. The Mutual assistance, having explicit and comprehensive Knowledge of Natech risk management processes, must be a major operator to conduct this part. In particular, the community participants, who have low skillful knowledge, could contribute to implementing risk identification considering risk sources of surrounding environments, vulnerabilities, capabilities, environmental contexts, cultural aspects, and a lack of knowledge and information from the community perspectives. The risk treatment section, based on the results of risk assessment, provides opportunities to reduce various risks. For instance, local multi-stakeholder could develop Natech risk maps considering natural hazard impact factors (e.g., river flow velocity, river depth, and river capacity), relocate residential areas or chemical facilities, increase risk capacity for uncertainty, and sustain risk and safety management strategies for natural disasters and chemical accidents. Explicitly, for sustainable risk management, government or relevant organizations could provide a certificate, that could give strong motivations and inspiration, to a company that prepared and shared appropriate safety documents and information.

Second, risk communication could be implemented by all stakeholders, including local communities, industries, and government, and first responders. This process is explicitly an essential element for a successful Natech risk management platform. Local communities provide local knowledge, past experiences, available physical and human resources, and information regarding regional environment and hazards. Particularly, indigenous knowledge or localized risk information should be made available to residents and other stakeholders. Industries must share information about chemical materials using in the facility, operation processes, environmental and human impact of chemical materials, results of risk assessment, and educational programs. Lastly, government and first responders provide relevant regulations regarding natural and chemical risk management, Natech disaster emergency strategies and manuals, details concerning natural and chemical hazards risks. This section operates as a local database to accumulate various information from external and internal sources.

Third, Natech risk management strategies could be developed through understanding past Natech analysis, potential Natech scenarios, and Natech accident mechanisms. Past Natech analysis will give lessons learned to establish and develop Natech emergency plans, including resource allocation before Natech disasters. The potential scenarios provide opportunities to consider how the local stakeholders could prepare uncertainties and possible responses. Also, it enables to allocate emergency shelters depending on environmental factors, chemical accident types, and occurrence mechanisms. Lastly, the process of Natech accident mechanisms helps consider interconnections between natural and chemical hazards, concurrence, or sequence of Natech accidents, which could be time or space specified, and real-time weather and accident information. These combinations in the Natech risk management platform could provide flexible Natech risk management strategies, that refer to practical and empirical data, to local multi-stakeholders that they can apply the strategies to prepare for any Natech disaster situations.

The discovered risks across risk assessment must be treated in ways of hardware, including enhancing facility maintenance and obtaining preventive equipment, or software, including improving regulations or developing educational and preparedness programs. Also, a mutual group provides monitoring and review on activities of the local community and implementation of the Natech risk management process to improve the quality of the system through the feedback process. This feedback offers opportunities to recognize insufficient information or knowledge and any gap in the Natech risk management strategies requiring improvement.

This Natech risk management platform will give benefits to the local community near industrial or chemical facilities and the mutual group, including experts, first responders, and industry safety specialists. To the local community, the platform provides adequate information and knowledge that is written by their language and entirely understandable. It will help the community participants to follow any guidelines and make community members increase risk awareness of Natech risks. Another benefit is that communities can have adaptable plans for managing Natech risk management, which is flexibly adaptable to different local environments. Even, Natech risk management plan must be a part of integrated local DRM plans.

The platform ensures mutual actors, having significant responsibility for making safety society, to carry out better Natech risk management activities for mutual assistance. Because this platform gives more chances to all participants, including neighbor community members, the mutual group could have several opportunities that decline miscommunication, conspiracy, and any conflict between local stakeholders. Further, this platform gives cost-benefit strategies for managing Natech risks before Natech events that cause massive damages. Under the significant uncertainty of Natech accidents, contemplating various potential scenarios and variables to determine community coping capacities are expected to reduce Natech risk management and recovery cost over the longer term.

(5) Implementation of the community-based Natech risk management framework

i) Government

- Regulation

  The existing DRM mainly focuses on natural hazard risks, but it considers separately technological hazards as multi-hazards. In order to manage Natech risks, the government must contemplate and include associated regulations regarding technological accidents/disasters that could be triggered by natural hazards. It will legally support and promote local stakeholders, including the local community and NGOs, to participate in Natech risk management systems. Also, the international frameworks and regulations might help to develop or improve the existing systems.

- Recourse allocation

  Even though there are well-organized systems for natural disasters, there are several challenges to confirm accessible human or physical resources to immediate response, assign tasks, and distribute required resources due to the uncertainty and high interconnection of Natech accidents. The government must allocate possible resources to minimize consequences considering various scenarios based on localized Natech risk assessment and aid agreements with other authorities. Also, here, it needs to consider specifically jurisdiction scope in vulnerable areas near industrial parks and chemical facilities, population, the government budget, natural and technological accident management staff, access plans to the accident areas, and chemical accident response guidelines and equipment. It supports quick responses to and from secondary and tertiary effects of Natech accidents.

- Institutional organization

The government must have an institutional organization in order to operate the Natech risk management platform. If the local authorities can have institutions near local communities subjected to Natech risks, local stakeholders, including local communities, are expected that they could support to manage both natural disaster and chemical accident risks through immediate resource allocation and specific consideration of localized Natech risks.

ii) Mutual assistance

- Interaction with government

As above mentioned, the manual assistance consists of 1) city government officials, who are in charge of disaster/emergency/crisis management; 2) firefighters; 3) governmental organization's employees; 4) natural hazard experts (e.g., flood risk, seismic risks, geology); 5) technological hazard experts (e.g., urban planning, infrastructure); 6) chemical engineering, risk management, including risk assessment); 7) safety managers and operators in industrial facilities; 8) and NGOs. This mutual assistance group provides local administrative circumstances, which are related to budget, resources, and regulations, to improve the existing DRM system through systemic collaboration. To do this, the mutual assistance group offers relevant professional knowledge and experiences.

- Input into Natech risk management platform: Technical support for risk assessment

In order to implement the Natech risk management platform comprehensively, there is a need for chemical material knowledge, both natural and technological information (e.g., industrial facility and operation), technical skills for Natech risk assessment, and building strategies. For example, experts of chemical accident risk management carry out a risk assessment and identify resolution for reducing potential risks through direct engagement in the platform. Here, the experts contemplate chemical companies' information, accident consequences, the probability of chemical accidents, relevant regulation and documents, and the resilience level of the companies for minimizing subsequent impacts.

- Communication and consultation to the local community

The mutual assistance group disclosures must risk information regarding chemical and Natech accident risks to the local community. Even though the government disseminates various risk information with hazard maps, it is challenging to identify detailed information regarding both natural and technological hazard risks in the territory. Thus, the mutual assistance must disclosure hazardous material types and their impacts, chemical facilities locations, disaster, and emergency management procedures and strategies, and accessible emergency infrastructures and relief goods.

- Internal interaction in the mutual assistant group

Since the mutual assistance group brings different fields of experts and actors together, inter interaction must be preserved to facilitate effective risk management. Good cooperation among relevant stakeholders will facilitate making a proper decision, generate accurate risk information on time, and supporting the local community and the government.

iii) Local community

- Interaction with local (or city) government

The government encourages the local community to participate in DRM at the local level by adding the responsibility of the local community in DRM. The government provides financial support to continue and improve community-DRM activities for managing both natural and technological hazards.

- Input

  In order to implement the Natech risk management platform, indigenous knowledge, and environmental information from the local community are essential to understand laid down potential chemical accident risks. The local community must provide experiences regarding accident experiences that occurred in companies or industrial facilities, information concerning environment circumstances, vulnerable people, physical and human resources, and coping capacity level. This input makes the Natech risk management platform to be customized to the local community.

- Local community's roles and resilience

  The local community is not anymore the only recipient of DRM from the government or first responders. As a local partner, the local community can play several roles, including communication and liaison between the government and mutual assistant group, hazard monitoring, decision making, and assistant for emergency management. Even though natural disaster experiences improve most of the local community's roles, their activities can contribute to reducing the damage of both natural and technological disasters through participating in the Natech risk management platform, particularly in risk communication and risk assessment processes.

iv) Natech risk management platform

- Risk communication

  In the platform, risk communication helps to understand localized hazard risks and the reason of Natech risk management at the local level. The contents of risk communication must consider potential and major natural hazards and chemical materials in the industrial facilities. In particular, it is necessary to contain probable consequences regarding possible movement direction of released chemical materials, health or environment impacts, and initial response procedures.

- Natech risk assessment and risk treatment

Natech risk assessment processes provide not only separated but combined consideration of Natech risks. First of all, more specific and diverse natural hazard risk factors must be considered, for example, in order to estimate oil spill accidents that can be triggered by heavy rain and floods, risk factors that can contribute to occurring floods, and impact on industrial facilities nearby rivers. Those include not only depth level of rivers but river flow velocity and direction, river capacity, river design (if it is planned river), river maintenance level, expected anticipation, and predicted the worst impact on industrial facilities. In terms of industrial facilities, the degree of oil or gas tank aging, contained chemical material volume, hazardous material quality, facility location, facility design, and safety operation system. It is highlighted that practical risk factors need to be considered in the Natech risk assessment, then the assessment can provide a suitable solution that can deal with Natech risks in practices at the local level.

- Natech risk management strategies

Natech risk management strategies are established based on risk assessment and collected information through risk communication in the context of local characteristics. The risk assessment processes considering both natural and technological hazard risks enable us to develop Natech accident scenarios and understand how Natech disasters can be occurred and affect to local community and environment. This consideration contributes to understanding the uncertainty and high interconnections of the mechanism of Natech disaster occurrence. Also, lessons-learned from past Natech disasters might provide different solutions and insight to deal with and prepare for potential Natech accidents. In the strategies, one of the crucial things is that how this Natech risk management platform can be sustained to manage Natech risks to the local community and the mutual assistant group. There is an example of a Japanese NGO to manage risks in terms of businesses. The NGO provides a sustainable risk management system among the government, experts, business party, and the local community. Based on government regulation, the NGO certificate businesses and companies that meet risk management requirements, including having resilience, proper emergency management plans, and capacities to respond potential accidents, through a thorough risk assessment by experts. Particularly, in the risk assessment, the NGO evaluates educational program performance, document preparation, actual field environment investigation, and facilities to issue certification to the company and to disseminate accurate information to the public. Since this process helps to develop a practices-based risk management plan, it leads to reduce the cost to recovery and rehabilitation, to offer opportunities to collaborate with other mutual assistants, and to provide an adaptable community-based plan, considering natural and chemical accident risk information in practices to the local community.

(6) Challenges in the framework implementation

This framework was developed from lessons learned from the past Natech accidents, the literature, the actual perspective of local stakeholders, including the local community, first responders, and government. However, there are some practical challenges to implement the framework.

First is how chemical and/or Natech accident risks should be considered in the community-based Natech risk management. Chemical and/or Natech accidents can occur in tangible or intangible ways, such as fires, explosions, and oil or gas releases, depending on types of natural hazards, and it might influence decision making for evacuation in the local community. For example, during the aluminum furnace explosion caused by floods in the Shimobara district, 2018, local community members recalled that they had decided quick evacuation immediately after the explosion due to high concerns about a secondary explosion at the factory. They also mentioned that if there were no explosions, they would not have evacuated to the safe place on time. Furthermore, it shows that the local community also must determine evacuation timing according to primary impact, as natural hazards, or secondary effects, like chemical or Natech accidents. Thus, the local community must be conscious of the consequences of any kind of chemical and Natech accident risks during emergencies, and to do this, specific and technical skills are needed to assess various situations to deal with uncertainty.

Second is that how and which kind of risk information should be informed to the public and between local stakeholders, for instance, government officials, industry, and first responders, to understand better their environmental circumstances and the uncertainty of chemical and/or Natech accidents. Results of this thesis and some literature (Funabashi, 2012; Funabashi & Kitazawa, 2012) showed that lack of Natech risk information could increase public mistrust to government, experts, and industries. Risk communication processes often occur issues concerning social conflict regarding risk understanding, political issues, and land uses. On the other hand, effective risk communication is enabled to carry out DRM and increases risk perception. Due to the challenges of risk communication, including trust, transparency, and adequacy, it is challenging to provide proper chemical and/or Natech risk information to the public. However, appropriate risk information disclosures may help increasing risk awareness of the resident about chemical and Natech accidents. Therefore, there is a need for developing communication channels and information database for Natech risk management. Also, ongoing studies at the Disaster Risk Management laboratory at Kyoto University are researching how to build effective risk communication channels and contents that encourage community participation in DRM systems.

Lastly, there is a limitation of the application of the typical emergency measures during unexpected situations of chemical and Natech accidents. For instance, when oil spills occur from chemical facilities, evacuation shelters that are designated according to natural hazard risks but not consider chemical accidents could not be used during the emergency. If the shelters are affected by the spilled oils, evacuees should move to different places. Also, since the evacuation area could be included within the scope of oil spills, the potential impact must be contemplated in emergency planning for chemical and Natech accidents so that the local stakeholders and other volunteers can respond and decontaminate the pollution. Explicitly, emergency measures, response tools, and demanded protectors should be applied depending on the accident materials and circumstances. Thus, in the Natech risk management strategies, more specific emergency measures need to be included based on the risk assessment and chemical material information and process safety of industries.

7.2 Contribution

The consequences of Natech disasters have shown a low level of preparedness for potential Natech accidents, a need for improving Natech risk management systems for the local stakeholders, and environmental improvement for a safe society. This thesis gives opportunities to scrutinize how the local community could implement better DRM and can engage in Natech risk management at the local level. By looking at unique community activities, which is the Jishu-Bosai-Soshiki, this research presents the potentials and capability of the local community as a body of participants in community-based Natech risk management at the local level. According to several international frameworks for disaster risk reductions and programs for managing natural and technological disaster risks, including Natech risks, local communities' roles are gradually highlighted to manage disaster risks. In terms of this, the local community members' roles, such as coordinator, communicator, monitor, and community disaster manager, are significantly expected to help reducing disaster risks in each local community. Also, increased risk awareness and acceptance of Natech risks influence on flourishing community-based Natech risk management system as well as DRM in general.

In this thesis, some flood hazard maps were investigated to identify risk information regarding potential Natech events and the possible damage caused by Natech accidents near local communities. However, hazard maps indicated technically estimated potential inundation areas. Even though some maps showed evacuation directions in hazard maps, they only consider the predicted anticipation of the 100-year or 1000-year return period flood events, not the frequency of floods, localized risks, such as industrial facilities and hazardous substances placed in or near residential areas. In particular, estimated impact and the direction of chemical accidents triggered by natural hazards (e.g., in oil spills) can contribute to urban (community) planning allowing local stakeholders to identify the more risky area and develop risk management plans. Each small local community has a different historical, cultural, environmental, and demographic background, that can determine community-based DRM activities. Thus, it is pointed out that the flood hazard maps are required to consider those aspects in order to minimize flood risks and Natech risks caused by floods.

Basically, engineering is about how science and technology can not only be adapted to make better human life and society but also build a safe society. In this perspective, the proposed community-based Natech risk management framework involving the Natech risk management platform provides a window to 1) improve potential Natech risk management skills, 2) increase local stakeholders' risk awareness of Natech, and 3) build trust that makes better and proactive collaboration in risk management systems. In fact, the Sendai Framework called for active participation of multi-stakeholders, explicitly local community members, to manage multi disaster risks, including technological hazards and Natech. With regard to this, the proposed framework and platform in this thesis are expected to reduce the risks and minimize damage in residential areas near chemical facilities and complexes. It also directly connects to decrease expenses to recover ruinous marks of disasters and economic losses. Furthermore, the proposed framework can contribute to reassessing the adequacy of infrastructures, including telecommunication, transportation, river maintenance, and several lifelines against Natech accidents and plan land uses. It also offers the opportunity for the preparation of customized risk management strategies, including Natech risk maps and Natech emergency operation plans at the local level based on extensive risk assessment, understanding the occurrence mechanism, and estimation of the probability of Natech accidents.

The Natech risk management platform can offer a transit space for relevant risk information and knowledge, issued in several previous studies, regarding Natech between mutual assistance actors and local community members. This proposed Natech risk management framework also can be adapted to managing not only other types of cascading disasters but also singular natural and technological disasters. However, there is no validation method or enough information, which can evaluate whether or not community-based Natech risk management is successful and effective in the practical field. This thesis also provides the impetus for further research, investigation, and consideration to explore indicators and criteria in successful Natech risk management.

7.3 Limitations

Even though we carried out several case studies to investigate different perspectives from the local community, first responders, and government in order to develop a community-based Natech risk management framework in the context of empirical perspectives, there were some limitations to obtain valid data and to complete this research.

1) The first limitation was that there was not enough opportunity to conduct interviews with local government officials. The government has separated divisions and responsibilities for managing disasters/emergencies and hazardous materials. The government has specialized human and physical resources such as special equipment and vehicles, and well-educated expertise. Officials have designated roles to perform according to regulations. However, their positions are rotated regularly, often every two or three years. This rotation causes a loss of expertise and accountability, as well as continuity within assigned tasks. Thus, it was difficult to investigate the current detailed situation regarding chemical or Natech accident risk management at the local level.

2) The second limitation had no chance to conduct interviews with industrial safety specialists and/or operators of chemical facilities. Since locations of chemical factories or facilities are related to investment, land use and/or prices and residential environment, informing risks or chemical materials that are used in the company is often recognized as sensitive social issues, and it is concerned with their businesses. Therefore, companies tended to avoid revealing their weakness or businesses regarding chemical materials or safety systems that could be confidential information to the public.

3) The third limitation is that the developed framework has not yet been applied in practice due to time limitations in this study. In order to validate and apply the framework, many aspects should be considered, for instance, the local community's motivation, selecting a proper area, conducting risk management processes, providing an educational program to make active participation of local stakeholders, organizing risk information, and gather potential participants. However, even though it takes a longer time to implement the community-based Natech risk management framework, the usefulness is expected to increase risk awareness of both potential natural and technological disasters for multi-local stakeholders.

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Chapter 8 Conclusions

This chapter briefly concludes the research findings, future works, and proposes recommendations to enhance local stakeholders' coping capacity for unexpected potential technological disasters that could be caused by multi natural hazards at the local level.

8.1 General conclusions

Increasing both natural and technological disaster risks, due to urbanization, industrialization, the concentration of population in urban areas, and environmental deterioration, has led not only the global society but local communities to be more vulnerable and expose to multi-hazards. Disasters become more uncertain, complex, and unpredicted. Due to these changes, local communities are recognizing as one of the essential stakeholders to implement DRM and manage multi-hazard risks within risk governance in DRM. In the context of Natech, several Natech disasters remind us that there are a wide and long-term consequence and a lack of knowledge on Natech disasters at the local level. It means that natural and technological hazard risks must be managed comprehensively under the interactions among local stakeholders, such as the local community, first responders, industrial safety specialists and/or operators, engineers, and government, in the existing DRM.

This thesis explores how the local stakeholders, especially the government, first responders, and local community, can prepare for Natech disasters. Also, it investigated the required elements for developing a community-based Natech risk management framework through three case studies focusing on activities and perspectives of the local community, first responders, and government regarding chemical and Natech risk management. A community-based Natech risk management framework was proposed to enhance the coping capacity for Natech at the local level.

At the local community, the results showed the local community could play several critical roles in community-based DRM: 1) local experts (localized knowledge and experiences); 2) risk communicators (information translation and dissemination); 3) monitors (risk and hazard identification); 4) decision-makers (determination for all DRM activities); 5) liaison persons (the connection between external stakeholders and community members); and 6) assistants (rescue and help vulnerable neighbors). Also, a strong sense of community, abundant local knowledge, and trust among the community members and other local stakeholders were identified as a great impetus to enable DRM activities at the local level. Even though the local community members are aware of the seriousness of natural and technological disaster risks, there is no yet Natech risk management system, and the local community is not considered in risk management processes for technological disasters. Also, there is a lack of risk information and knowledge about Natech risks. Thus, the results addressed the need for an integrated natural and technological DRM system, involving effective collaboration with other stakeholders and reflection of the social and physical environment of the community, that can be used at the local level.

By looking at local first responders' DRM activities and perspectives on Natech disaster risks, the results show that there are still: 1) a lack of proper risk assessment based-strategies considering natural, technological and/ or other hazards; 2) a lack of considering the uncertainty and unexpected consequences of Natech accidents; 3) no proper channel to provide specific hazard and risk information to residents; 4) and a lack of cooperation with local community stakeholders. In general, the primary roles of first responders are mainly to provide search and rescue, first aid, fire suppression, and evacuation support for the residents. However, regarding Natech accidents, first responders have limited knowledge and resources about chemical and Natech accident hazards and the risk that poses to local residents. It can make a delayed response to Natech accidents. First responders can play an important role in Natech risk management as they are familiar with the local environment if they can have adequate Natech risk information and enough personnel and physical resources. Thus, first responders are expected to support local community members to identify natural and technological hazards and risks and assist them in implementing Natech risk reduction and emergency response measures.

In the government case, chemical and Natech risk management rules and regulations, including requirements for the disclosure of these risks to the public, have been introduced in the European Union, and in California in the United States, particularly technological disasters triggered by major earthquakes. In Japan, chemical accident risk management and risk information disclosure regulations regarding chemical accident risks have not been introduced. Nevertheless, given the high risk of natural hazards in Japan, the country has strict safety and maintenance regulations to minimize the occurrence of accidents, mainly at oil and petroleum industrial parks. In Korea, chemical accident-risk management regulations, including requirements for the provision of chemical risk information to local residents living near large industrial parks, were explicitly introduced in 2013. Based on several interviews with local and regional government officials, the lack of regulations requiring the disclosure of chemical risk to the public results in little to no inclusion of these types of scenarios in disaster planning at the local community level. However, the government that has appropriate human and physical resources and expertise can offer appropriate regulations and policies and share their advanced knowledge and risk management skills. Thus, the government is expected to improve chemical and Natech risk management not only of the industrial parks they oversee but also of local stakeholders living near the industrial parks.

Through the empirical case studies and literature review, investigated different perspectives of local stakeholders on chemical accidents and Natech risk management was analyzed based on the requirements of local stakeholders and gaps of the Natech risk management system. This thesis identified key elements for the practical implementation of community-based Natech risk management. One of the essential elements concerns active collaboration among all local stakeholders through flexible risk management processes, which are adaptable to both natural and technological hazards risks, and risk communication. The proposed community-based Natech risk management framework consists of: 1) Natech risk management platform centered around the Natech risk identification and assessment process, and risk communication; 2) government which provides proper regulations, and physical human and financial resources to implement Natech risk management at the local level, and supports Natech risk management strategies focusing on the localized risks of natural hazards and chemical accidents; 3) mutual assistant, including local officials, NGOs, natural and technological hazard experts, and industry safety specialists, that operates the Natech risk management platform through assessing Natech risks and potential consequences, and encourages the local community to participate actively in the Natech risk management platform; and 4) the local community which is believed to engage in the Natech risk management processes, explicitly by the hazard and risk identification processes and provide input based on lessons-learned of natural disasters and chemical accidents. Also, the local community provides input for risk assessment and management based on localized knowledge regarding environmental risks, and risk perception, and risk acceptance criteria. Additionally, due to the high uncertainty of Natech disasters, collaboration in the risk assessment processes, among individual experts of natural/chemical accident hazards, and industry specialists, is surely emphasized in the framework.

The proposed framework provides a practical approach through empirical requirements from different perspectives of local stakeholders, including local communities affected by past Natech disasters. The framework is expected to contribute to enhancing disaster resilience and coping capacity of local communities when they are faced with natural and technological hazards. The extensive risk assessment of natural hazards and chemical accidents can contribute to renovate infrastructures, including telecommunication, transportation, river maintenance, and several lifelines against Natech accidents. Furthermore, it offers customized risk management strategies and Natech emergency operation plans at the local level through assessed risks, understanding the occurrence mechanism, and the probability of Natech accidents. Through the comprehensive implementation of Natech risk management, the framework could fulfill the gaps, which are lack of Natech risk information, collaborative interaction, and flexible risk management system at the local level. Particularly, it will enhance the coping capacity and consolidation of local stakeholders, involving local government, first responders, safety management specialists, and the local community.

8.2 Future research

This research performed in this thesis provides a basis for further research to give value to the proposed framework and to advance Natech risk management.

Developing emergency response and evacuation plans for conditions of high uncertain

Due to the high uncertainty of cascading disasters, such as Natech disasters, it is difficult to predict exact disaster occurrence sequences and decide response behavior. For example, as discussed in Discussion, sequences of cascading disasters could be occurred as follows: heavy rain-chemical accidents-floods or heavy rain-floods-chemical accidents. During the 2018 Natech disaster, if there had not been an explosion in the factory, the local community could not evacuate before floods since they had recommended vertical evacuation. Thus, emergency response and evacuation plans, considering scenarios with varying disaster occurrence sequences, must be developed to prepare for such high uncertain conditions.

Carrying out industrial field surveys to collect industries' perspectives

Despite the development of a community-based Natech risk management framework based on the empirical data and perspectives from practical participants in DRM, this research has not been able to gather industries' perspectives. In order to achieve Natech risk management at the local level, a contribution from industrial facilities neighboring local communities is essential to build trust to local stakeholders, particularly the resident, and increase risk awareness.

Collecting and analyzing more Natech accidents data that have impacted community level

Even though there is an effort to build a Natech accident database referring to an industrial accident and natural disaster databases, generally, it contains typical damage, failure of safety management, and accident causes, including paths of hazardous material release at the industrial facilities. There are not enough details about community impacts and damages from chemical and Natech accidents. In order to community participation in Natech risk management, looking at more detailed community impact, human behaviors, different challenges (e.g., vulnerabilities, socio-demographics), and community DRM activities before/during/after Natech accidents are important. Also, it would be useful as a great lessons-learned from past Natech accidents to prepare for potential Natech accidents and to develop educational programs that might help to increase Natech risk awareness for the resident and local stakeholders.

Implementing the proposed community-based Natech risk management framework

As mentioned in the limitations of this research in Chapter 7, the proposed framework needs to be implemented in practice. As extensive work, I will conduct workshops to inform about the framework and apply it with other local stakeholders. It is expected that the implementation activities will give opportunities to confirm local stakeholders' insights of Natech risks, specific strengths, and weaknesses of participants, multidisciplinary contributions, as well as to gather feedback that will help to improve the framework.

8.3 Recommendations

In order to achieve successful risk management of natural hazards and chemical accidents at the local level, several issues still remain. Firstly, it is necessary to develop Natech risk maps based on extensive risk assessment at the local level. For example, the current flood hazard map indicates only potential flood zones and the location of evacuation shelters. However, Natech risk maps are needed that could mean the possible flow direction of released chemical materials. Residents and first responders could use the information to develop emergency response plans and determine the location of emergency shelters, and so on. Sharing hazard and risk information can help affected residents better prepare, and gain knowledge that can help them better assess a disaster when there is limited information or resources.

Second, it is necessary to consider chemical accidents with natural hazards to include in the existing DRM and relevant regulations, which is mostly focusing on natural hazard risks. It requires to involve both natural hazard and chemical accident risks management procedures, specialized skill and knowledge, risk communication rules and channels, and technical tools. Also, educational programs are needed to increase both natural and technological disaster risk awareness and risk information literacy of related stakeholders. It legally supports and promotes local stakeholders to participate in Natech risk management systems.

Third, it is necessary to have coordinative institutions to lead the proposed Natech risk management platform. If the local authorities can have institutions near local communities subjected to Natech risks, local stakeholders, including local communities, are expected that they could manage both natural disaster and chemical accident risks through immediate resource allocation and specific consideration of localized Natech risks. Also, in order to contribute to encouraging active multidisciplinary participation, risk management programs that could be quantified and identified as a system is required to predict the cascade effect of Natech disasters and to consider the probability of Natech disasters.

Finally, there is a need to develop a real-time information analysis system for securing evacuation and rescue routes through the adoption of new technology. During cascading disasters, for instance, floods and chemical accidents, many roads and transportations might be inaccessible. However, it is a challenge to secure an appropriate route in the middle of disasters and to get adequate information. In order to deal with this issue, new technologies could be adopted to obtain sufficient information for accessible routes. For example, during floods and oil spills, real-time video monitor systems using an uninhabited aerial vehicle such a drone could be enabled to collect extensive geographic information. Then, the data would be analyzed in the real-time information analysis system and obtain data involving accessible evacuation routes. This system would be expected to be useful for disaster management practitioners and first responders to rescue the resident in affected areas.

LIST OF APPENDICES

Appendix A: In-depth interview questions for the local community

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Appendix G: Questionnaire for the government agency

Appendix 1: In-depth interview questions for the local community

1. 自主防災組織が保有している防災計画はどんな内容ですか？
   What details is the community-disaster risk reduction plan of the Jishu-Bosai-Soshiki?
2. 自主防災組織の計画を策定するガイドラインや規定がありますか？
   Does the Jishu-Bosai-Soshiki have any guidelines and/or regulations for planning the community-disaster risk reduction?
3. 地域の防災計画の樹立するために参加している方は誰ですか？
   Who does participate in planning the community-disaster risk reduction?
4. 地域の防災計画を樹立には地域の環境と災害状況、過去の災害経験、地域の災害知識や防災能力などは考慮されています？
   Does the local environments and hazards, past disaster experiences, and coping capacity and knowledge levels of the community, and so on, have been considered in the planning of the community-disaster risk reduction?
5. 地域の防災計画には、主に焦点を置いている災害は何ですか？
   Which hazards are focused mainly on community-disaster risk reduction plans?
6. 自主防災組織会で実施する防災訓練や教育はどんなことがありますか？
   Are there any disaster preparedness training and/or educational programs that are performed by the Jishu-Bosai-Soshiki?
7. 去年7月災害をもとに大雨、洪水や地震などによる2次、3次の事故に対する準備の必要性を感じていますか？
   After the disaster caused by heavy rain and floods in 2018, have you considered a need for preparing secondary and/or tertiary disasters and/or any technological accidents that could be caused by the primary natural hazards?
8. 地域の一般の住民や自主防災組織のメンバーは地方政府が樹立した地域防災計画の有無とかその内容にについてご存知でしょうか？
   Do the local community and Jishu-Bosai-Soshiki members are aware of local disaster risk reduction strategies/plans and/or content of the strategies/plans?
9. 様々な災害に対して地域社会の防災力向上のために防災計画に含まれなければならない要素何だと思いますか？
   What do you think about what kind of attributes of local communities is required in the local disaster risk management system in order to enhance the local community’s coping capacity to multi-hazards?

10. 地域の防災活動と訓練時要保護者を助けるために災害計画内に考慮されている特別なことはどれですか？
In the community-disaster risk reduction plan, do your community consider how to help or assist vulnerable residents during emergencies, and do your community have any particular strategies for them?

11. 地域の過去の経験に照らして、総社市と下原地区の災害の要因とかリスクは何だとおもいますか？
What do you think as the main hazards and risk factors cause of disasters in the Shimobara district and Soja city?

Appendix B: In-depth interview questions for first responders

1. Disaster risk reduction in general

1.1. 令和元年(2019)の水害によって発生した油の漏出事故の前、そのような化学事故がどの程度あなたの地域の住民の生命や財産に脅かす可能性があると考えていましたか？
Before the Natech accident in 2019 happened, how probable did you think a Natech accident would be a threat to residents' life or properties?

令和元年(2019)の水害によって発生した油の漏出事故などがあなたの地域の住民の生命や財産にどのような影響をしたと思いますか？
To what scale do you think Natech accidents would have affected residents' life or properties?

1.2. 地域の災害リスク軽減のための 杵藤地区消防本部や大町町分署の任務を教えてください。(予防、建築、危険物、団・自主防災組織支援、災害対応、避難、調査等)
What are Omachi fire department branches' responsibilities for disaster risk reduction?

1.3. 杵藤地区消防本部や大町町分署はどう自然災害によって発生する化学事故に対してどのように対応するか地域の自主防災組織と住民に緊急訓練または教育を提供していますか？もしあれば、その内容は何ですか？
Does the Kito fire department headquarter and Omachi fire department branch provide emergency training or education about how to respond in the case of Natech?

1.4. 杵藤地区消防本部や大町町分署は災害とそのリスク管理のため計画がありますか？もしあるなら、その内容は 自然災害によって発生する化学事故について考えていますか？
Does the Kito fire department headquarter and Omachi fire department branch have a disaster/ disaster risk management plan? If they have, does it consider Natech risk and disaster as cascading disasters?

1.5. もし地域の自主防災組織が公務員、専門家、消防関係者と一緒に自然災害によって発生する化学災害のリスクの管理に参加ができるとすれば、その 自主防災組織はどのような貢献ができるとおもいますか？
What do you think about how the local community can contribute to managing disaster risks?

2. Emergency response during 2019 flooding

2.1. 何が起こったか教えていただけますか？

Can you tell us what happened?

2.2. 特に2019年9月の水害による発生した油の漏出間のあなたの任務は、何でしたか？

What were your duties/responsibilities, specifically during the occurrence of the floods in September 2019?

2.3. 令和元年水害の対応時、杵藤地区消防本部や大町町分署の大変なことは何でしたか？

What were the challenges for Omachi town fire department branch?

2.4. あなたは,令和元年の水害による発生した化学事故時、災害対応について地域/県/中央政府もしくは地域の自主防災組織とから援助を受けましたか？

Did you receive any assistance from the local/prefectural/national government or other parties, especially the Jishu-bosai-soshiki, during the disaster?

2.5. 水害とそれによって発生した化学事故の経験から、現在の緊急計画や災害管理などに修正が必要な個所または提案はありますか？

After learning from the flood disaster, is there any necessity to revise and improve the existing emergency plan? If there is, what is it?

3. Risk communication

3.1. 佐賀県と杵藤地区の災害リスクの情報 共有 及び避難誘導と勧告のプロセスはなんですか？

What are the risk communication and the issuing of an evacuation advisory and/or order process in the Saga Prefecture and Kito region?

and how is information shared and/or disseminated:

- 政府機関と杵藤地区消防本部や大町町分署 間のコミュニケーションにリスクと災害情報の共有と伝達 はどうなっていますか？
  With the government level? (Central, prefectural, local government)
- 消防署と自治体の自主防災組織と杵藤地区消防本部や大町町分署間のコミュニケーションにリスクと災害情報の共有と伝達はどうなっていますか？
  With the local stakeholders' level? (Fire Department/government agencies, and voluntee r disaster response groups)

3.2. 地域の自主防災組織と住民に自然災害による潜在的な化学事故の発生可能性を知らせるプログラムはありますか。

もしあれば、そのプログラムについて内容を教えてください。また化学災害に特化したものがなければその以外の災害の場合について教えてください。

Do you have any program for communicating the potential Natech to the residents?

3.3. 地域の自主防災組織と住民 は 自然災害による潜在的な化学事故の発生危険性と可能性に関してどのようなことを知るべきですか。

What do you think What residents should know about the potential Natech and its risks?

3.4. 杵藤地区消防本部と大町町分の観点から自主防災組織と住民に自然災害による潜在的な化学事故の情報を共有と伝える時、どのような困難や障壁があると思いますか？

What are the barriers or challenges to provide risk information about chemical hazards to the residents from Soja City Fire Department's perspective?

Appendix C: In-depth interview questions for the government

1. General information on the Joint Inter-agency Chemical Emergency Preparedness Centers (JICEPCs)

1.1. Year and purposes of establishment of the JICEPC

1.2. Organizational information of the JICEPC

1.2.1. Organizational configuration of the JICEPC
- Organizational structure
- Task distribution of each division of the JICEPC

1.2.2. The main division (or department) that operates the agency

1.2.3. Tasks and/or responsibilities of each division in ordinary

1.2.4. Tasks and/or responsibilities of each division during chemical and/or Natech accidents

1.2.5. The details (provider) of the budget that needs to operate the agency and its sufficiency for the operation of the agency and task performance

2. The roles of JICEPCs during chemical and Natech accidents

2.1. Does your agency have specific risk/emergency management strategies and regulations for managing chemical and/or Natech accidents?

2.1.1. If you have, what are they (related laws and regulations) and their contents? What do you think are they adequate to manage and respond to chemical/Natech accidents?

2.1.2. If you think it is not adequate, what do you think about which parts are needed to improve?

2.1.3. Do the chemical/Natech accidents risk/emergency management strategies consider types of chemical materials that could occur the accidents frequently?

2.2. Do you have specific emergency management plans for Natech accidents?

- If the agency does not have specific Natech emergency plans, is the probability of technological accidents that could be triggered by natural hazards considered in the existing emergency management strategies for chemical accidents?

2.3. What are the specific roles and activities of the agency, as the government, relevant organization, and experts, before/during/after chemical or Natech accidents?
(e.g., preparedness planning, regulating, conducting educational program and training, and safety monitoring)

3. Chemical accident and/or Natech risk management

3.1. What is the overall process of chemical accidents and/or Natech risk management?

3.2. How do/what kind of internal and external factors are considered in risk management processes?

3.3. Does the agency have any possible scenarios in order to prepare for potential chemical and/or Natech accidents?

- In the scenarios and plans, are risk factors and the probability of the potential accidents considered?
- What kind of internal and external factors are included in the scenarios and potential accident planning?
  (e.g., types of chemical materials, participants in chemical accident preparedness and/or response activities, available response facilities, accessible resources of industrial parks or local areas, potential impacts and damage, and risk information delivery)
- Does the agency develop and have chemical and/or Natech accident hazards risk map? What kind of contents are involved in the map?

3.4 Does the agency provide any specific risk assessment tools or processes with educational programs and training for the potential chemical and/or Natech accidents to chemical companies in the national industrial park? Who are the participants and what kind of contents are provided?

4. Risk communication for chemical and/or Natech accidents

4.1. What is the risk communication and its processes in the national industrial parks during chemical and/or Natech accidents?

and how is information shared and/or disseminated:

- With the government level? (Central, prefectural, local government)
- With the local stakeholders' level? (JICEPCs, Fire Department/government agencies, and volunteer disaster response groups)
- With the local community members

4.2 Do you have any program for communicating the potential chemical and/or Natech accident to the residents and gathering the feedback from the residents?

4.3 What do you think about what residents should know about the potential chemical and/or Natech accidents and its risks?

3.4. What are the barriers or challenges to provide risk information about the chemical and/or Natech accident hazards to the residents from the JICEPCs?

Appendix D: Focus group discussion questions for the local community

1. Opening questions

Quick answer (10-20 sec): total length within 5 min.

1.1 あなたのお名前と自主防災組織の中の役割を教えてください。
Please tell us your name and your position in Jishu-Bosai-Soshiki.

1.2 平成30年(2018)の洪水と爆発の状況について簡単に説明してください。
Can you tell me about your experience during the 2018 flooding and the explosion?

2. Introductory questions

Introduce the general topic of discussion (15 min).

Obtaining information about the role and activities of Jishu-Bosai-Soshiki in general	
Q1	この地域における自主防災組織の中のあなたの実際的な役割は何ですか？ What is the practical role of Jishu-Bosai-Soshiki in this area?
Q2	自主防災組織委員としてどうやって他の住民、公務員、専門家と防災関係についてコミュニケーションを取っていますか？ As a member of Jishu-Bosai-Soshiki, how does the Jishu-bosai-soshiki communicate with other stakeholders (residents, officials, experts)?
Q3	地域の災害管理計画の開発とかリスク確認の活動のために消防署、地域の公務員、専門家などと一緒に会議とかをしていましたでしょうか？していたらあその内容は何でしょうか？ Do you have any public meetings with other stakeholders (ex, fire department, local officials, experts, etc.) to develop any local or district disaster management plan or for risk identification?

Q4	あなたの意見では、この地域の災害リスクを軽減するための自主防災組織の役割はどれくらい重要だと思いますか？ In your opinion, how important is a Jishu-Bosai-Soshiki and its roles as an organization for disaster risk reduction in this area? あなたの地域にはリスクの軽減のための災害管理計画またはその活動がありますか？ Does your community have a disaster management plan or activities for disaster risk management? その内容または活動は 平成30年(2018)の洪水によって発生した爆発事故のような化学事故も考慮していますか？ Does it consider chemical accidents such as the one that occurred last year during the floods in 2018?

3. Transition questions

Move the conversation toward the key questions (25min).

Obtaining information about the role and activities of Jishu-Bosai-Soshiki during Natech	
Q1	平成30年(2018)豪雨、洪水によって工場の爆発事故が発生しました。そんな災害を自然災害によって発生する化学災害と呼びます。 その災害の前に、大雨、台風、雷、地震などの自然災害によって引き起こされる化学事故について経験や、そういった話しを聞いたことがありますか？ There was an explosion of the aluminum furnace during the heavy rain and floods in 2018. This is called a chemical accident triggered by natural hazards. Have you ever experienced or heard about chemical accidents, such as fires, explosions, and oil spills, caused by natural hazards such as heavy rain, typhoon, thunders, earthquake? そのような種類の災害についてどう思いますか？ What did you think about those types of accidents?
Q2	平成30年(2018)の洪水によって発生した工場の爆発事故が起きた時、行政、消防署、警察署、専門家から化学事故に関する情報または警告を受けましたか？ Did you receive any information or warning regarding the explosion at the aluminum plant during or after the accident? 受けましたら、どんな経路で受けましたか？その内容はどのようなものでしたか？ If you did, what kind of warning (evacuation recommendation, advisory, …) did you receive? What information (substances, situation, evacuation, response)? How did you receive it?

Q3	平成30年(2018)の洪水によって発生した爆発事故の前、そんな化学事故がどの程度自分の生命や財産に脅かす可能性があると考えましたか？ Before the Natech accident in 2018 happened, how probable did you think a Natech accident would be a threat to your life or properties? 平成30年(2018)の洪水によって発生した爆発事故などがあなたの生命や財産にどのような影響したと思いますか？ To what scale do you think Natech accidents would have affected your life or properties?
Q3-1	平成30年(2018)の洪水によって発生した爆発事故の後、今はそのような化学事故がどの程度自分の生命や財産に脅かす可能性があると考えますか？ Now, how probable do you think a Natech accident would be a threat to your life or properties? 今、平成30年(2018)の洪水によって発生した爆発事故などがあなたの生命や財産にどれくらい影響すると思いますか？ To what scale do you think Natech accidents would affect your life or properties?

4. Key questions

Two to five questions (45 min).

Obtaining opinions regarding Natech risk management from Jishu-Bosai-Soshiki that experienced a Natech accident	
Q1	平成30年(2018)の洪水によって発生した爆発事故の時、自主防災組織の活動はなんでしたか？ During the explosion of an aluminum furnace caused by heavy rain and flood, what were the activities of Jishu-Bosai-Soshiki? (cooperation, support, help, and so on)?
Q2	他の地域と比べて、あなたの地域の自主防災組織のどの部分が自然災害と化学災害の影響を減らすのに貢献したと思いますか？ Compared to other communities, what capacities of this community could contribute to reducing the impact of Natech disasters?
Q3	平成30年(2018)の災害の経験から、自然災害によって発生する化学災害の前、中、後自主防災組織の役割は何だと思いますか？ Based on the experience, what do you think the Jishu-Bosai-Soshiki should do before, during, and after Natechs?

Q4	自主防災組織委員として、自然災害によって発生される潜在的な化学事故に備えて対応する能力を高めるために必要なことはなんだとおもいますか？ As a member of Jishu-Bosai-Soshiki, what do you think is needed to enhance the capacity to prepare for and respond to the potential Natechs?
Q5	もし地域の自主防災組織が公務員、専門家、消防関係者と一緒に自然災害によって発生する化学災害のリスクの管理に参加ができるとすれば、あなたはどのように貢献ができるとおもいますか？ If you can participate in Natech risk management with officials, experts, how can you contribute to better prepare for Natech? また、あなたは彼らがどのように貢献ができるとおもいますか？ And how do you think they can support you?
Q6-1	平成30年(2018)の災害の対応と準備の教訓に基づいて、自主防災組織から地域の災害管理計画や対応の準備で変更することがありますか？ Based on the lessons from the response to the accident in 2018, has the Jishu-Bosai-Soshiki made any changes to disaster response activities?
Q6-2	あなたは自主防災組織の委員として、他の地域や他の自主防災組織に対して、自然災害による潜在的な化学事故について、備えやより良い準備として勧めたいことがありますか？ What can you, as members of the Jishu-bosai-soshiki, recommend to other Jishu-Bosai-Soshiki or other communities to be better prepared for the potential chemical accidents?

5. Ending questions

Closing (5 min)	
Q1	グループディスカッションで話した以外で、話したい事や言えなっかたことはありますか？ Is there anything anyone feels was missed?
	End with a summary and explain how data will be used.

Appendix E: Feedback questionnaire of focus group discussion

参加者の基礎情報調査とフィードバック

Participants feedback questionnaire

1. あなたの年齢はいくつですか？

   What is your age? ___________

2. あなたの性別はどちらですか？

   What is your gender?

   ☐ 男性 ☐ 女性

   ☐ Male ☐ Female

3. あなたの仕事は何ですか？

   What is your work?

常勤職 Full-time job		アルバイト Part-time job	
自営業者 Self-employed		無職 Inoccupation	
その他（例。農業） Other (ex. farmer,...)			

4. 下原地区にはどれくらい住んでいましか？

   How long have you lived in this town?

3 年 以下 Less 3 years		3 - 5 年 3 - 5 years		5 - 10 年 5 - 10 years	
10 - 15 年 10 - 15 years		15 年以 Over 15 years			

5. どのくらいの期間、自主防災組織に参加していますか？

   How long have you joined in Jishu-Bosai-Soshiki?

3 年 以下 Less 3 years		3 - 5 年 3 - 5 years		5 - 10 年 5 - 10 years	
10 - 15 年 10 - 15 years		15 年以 Over 15 years			

6. この地域で他の災害をけいけんしたことがありますか？

   Have you ever experienced any other disasters in this town?

   ☐ ある ☐ ない

   ☐ Yes ☐ No

   もしあれば、質問7に答えてください。

   If yes, please answer Question 7.

7. いつ、どんな災害を経験しましたか？

   Which disasters (hazards) have you experienced?

8. 今日のグループディスカション以外他のご意見があれば、ご自由に記入下さい。

Is there anything else you would like us to inform about your opinion?

Appendix F: Consent from for focus group discussion

Consent on the focus group discussion

We appreciate your cooperation with a focus group discussion on the role of Jishu-bosai-soshiki in disaster risk management for potential Natech disasters. This focus group discussion, as a part of our project, is held at 15:00, 23rd January (Thursday) 2020 at a Shimobara town hall. This project aims to investigate the role of Jishu-bosai-soshiki in Natech risk management and how the local community (particularly, Jishu-Bosai-Soshiki) can contribute to better Natech risk management. The focus group discussion takes approximately 60-95 minutes.

Primary investigator: Hyejeong Park, Ph.D. student, Kyoto University

Faculty advisor: Ana Maria Cruz

We would like to kindly ask you to verify the following.

1. I understand that my responses will be kept in the strictest of confidence and will be available only to the researcher.
2. I understand that I may skip any questions or tasks that I do not wish to answer or complete.
3. I understand that the consent form will be kept separate from the data records to ensure confidentiality.
4. I agree to have my verbal responses recorded and transcribed for further analysis with the understanding that my responses will not be linked to me personally in any way. And I understand after the transcription is completed, the recordings will be destroyed.

I acknowledge that I understand my rights as a research participant as outlined above. I acknowledge that my participation is fully voluntary.

Name: ______________________________________

Signature: ______________________________________ Date: _____________

同意書

この度は,「自然災害によって発生する化学事故のリスク管理のための自主防災組織の役割」に関する調査およびグループディスカッションにご協力頂き、ありがとうございます。このグループディスカッションは令和 2 年(2019 年)1 月 23 日木曜日 15：00 から 下原町の公会堂で行われます 。本プロジェクトの目的は、自然災害によって引き起こされる化学事故時に自主防災組織がどのような役割を果たしているのかを理解するためです。この調査には約 1 時間 30 分ほどかかります。

お忙しいところ恐れ入りますが、ご協力の程どうぞよろしくお願いいたします。

調査者: 京都大学工学研究科都市社会工学専攻・博士 3 年　パクヘジョン（朴慧晶）

指導教授: 京都大学防災研究所　アナ・マリア・クルーズ 教授

グループディスカッションにご参加いただく皆様には、以下のことをご確認いただければ幸いです。

1. グループディスカッションを通して得られる資料（録音された発言・紙資料）は、個人が特定されない形で記録・保管され、研究者のみが分析いたします。
2. グループディスカッションでの質問に対して、回答をしたくない場合は回答しなくても構いません。
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上記のことをご確認の上、グループディスカッションへの参加にご同意いただける場合はご署名をお願いいたします。

年　　　　月　　　　日　ご署名

Appendix G: Questionnaire for government

Questionnaire for Potential Chemical and/or Natech accidents

Thank you very much for participating in this questionnaire survey.
This survey is concerning a study on [chemical and/or Natech risk management at the local level] conducting by the principal investigator.
The objective of this survey is to investigate chemical and/or Natech hazard risks awareness, risk communication between the JICEPCs and local stakeholders, and collect your opinion concerning the existing risk management systems.
Particularly, this survey is only to collect data regarding your opinion of chemical and/or Natech accident risk and emergency management from employees in the JICEPCs. Therefore, the data collected will be used in an aggregated form and only for academic purposes.

Thank you once again for your participation.

February 2019

Urban Management, Graduate School of Engineering, Kyoto University
The principal investigator: Park, Hyejeong
park.hyejeong45a@st.kyoto-u.ac.jp

1. Risk awareness of chemical and Natech accidents

1) Do you understand the difference between general chemical accidents and technological accidents that could be triggered by natural hazards?

Completely disagree	Somewhat disagree	Neither disagree, nor agree	Somewhat agree	Completely agree

2) In your work descriptions, is managing or planning Natech hazard and/or risks?

Yes		No	

2-1) If you answer "Yes", how your work descriptions are considered Natech hazards risk management?

	We have specific strategies and/or plans for managing technological accidents/disasters.
	We do not have specific strategies and/or plans, but we acknowledge to prepare specific strategies and/or plans for managing technological accidents/disasters.

	We gather relevant information and other strategies and/or plans regarding Natech to establish strategies and/or plans.
	We are under the establishment of the strategies and/or plans.
	Others:

3) Have you participated in emergency training or education for managing Natech accidents before/during/after affiliated in the JICEPCs?

Yes		No	

4) Regarding information about chemical and Natech accidents, what do you think about the JICEPCs disseminate and/or share proper information with relevant government agencies, local organizations, and local communities near the national industrial parks?

Completely disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Completely agree

5) During the chemical and Natech accidents, what do you think which participant and their responsibility are the most important to reduce impact and damage?

	The government: disclosure of chemical accident-related information and response regulations and the situation
	Relevant organizations and experts: cooperation with the governmental agency and information sharing for chemical and/or Natech accident response
	JICEPCs: close collaboration among the employees within the centers
	Local community: Sharing environmental information with chemical and/or Natech accident responders
	Others:

2. Chemical and Natech accident risk management

1) What do you think which phases, in terms of disaster risk management, are most associated with your current work descriptions?

Mitigation, preparedness, and response		Response	
Response and recovery		Recovery	
Risk management		Not applicable	

2) According to the current regulations and laws regarding chemical materials and chemical and/or Natech accidents, what do you think the existing risk

management can be applied to manage both chemical and Natech accidents?

Yes		No	

2-1) If you answer "No", what do you think which items must be included or improved in risk management systems for chemical and Natech accidents? (Duplicable response)

Risk information disclosure and sharing systems		Detailed educational program and training	
Improvement of regulations or laws for managing chemical and Natech accidents		Consideration of regional environments	
Others:			

3) In order to manage potential chemical and/or Natech accident risks, what do you think which item is the most important in the risk management system?

Organizational structure for collaboration		Technical improvement (e.g., investigation equipment, risk assessment tools, and computing systems)	
Institutional structure (e.g., appropriate empowerment for decision making and accessible resources allocation for chemical and/or Natech accident response			

4) In your work descriptions, is the specific risk management processes, including risk assessment and treatment, included? If it is included, please describe the process briefly below the answer box.

Yes		No	

5) What do you think which type of natural hazards can probably cause Natech accident in your jurisdiction?

Typhoon		Heavy rainfall		Flood	
Landslide		Earthquake		Strong wind	
Storm		Others:			

6) In your work descriptions, are local community members and/or local community association included as a participant in chemical and/or Natech risk management processes?

Yes		No	

7) In order to effective risk management for potential chemical and/or Natech accidents, what do you think what role of the local community is living near industrial parks and chemical facilities?

	Helping and assisting family and neighbors to evacuate to a shelter following an emergency plan and warning during an emergency
	Providing proper information on the regional characteristics and risk factors during the planning
	Participating in educational program and training for potential chemical and/or Natech accidents
	Making decisions within the local community when the government or JICEPCs provide risk information
	Others:

8) When specific chemical and Natech accident risk management systems, including emergency management, What do you think which factors must be probable contemplated importantly? (Duplicable response)

	Socio-demographic factors (e.g., gender, age, literacy level, and physical limitation)
	Geo-environmental factors (e.g., distance from industrial parks or chemical facilities, land use, river, coastal area, and mountain)
	Political factors (e.g., regulations and/or laws for local communities and environments, disaster or emergency management strategies and/or plans)
	Critical infrastructures (e.g., hospital, energy power plant, shelters, electricity, water, and transportation)
	Others:

3. General information

1) Current affiliation

National Fire Agency		Local government agency	
Ministry of Environment		Ministry of Trade, Industry and Energy	
Ministry of Employment and Labor		Local government	
Etc. ( )			

2) Work experience

Less 3 years		3 – 5 years	
5 - 10 years		Over 10 years	

3) Field of working

General administrative field		Chemical accident/ risk management	
Disaster/Emergency management		Environment management	
Etc. ( )			

4) Specific job duties

( )