Disaster Risk Analysis of the Emergency Transportation Road for Large-scale Disasters in Japan

大規模災害を対象とした緊急輸送道路の災害リスク分析

A Dissertation Presented To The Academic Faculty

By

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Executive Summary

Historically, destructive natural disasters have posed the greatest challenge for Japanese society. Unfavorable geographical, topographical and meteorological conditions of the country have made it one of the most disaster prone countries in the world. Although its territory accounts merely for the 0.25 % of the planet's land area, Japan is subject to about 20 % earthquakes with the magnitude 6 or more and 7 % the world's active volcanoes is located on its territory.

The most frequent natural hazards in Japan are earthquakes, tsunamis, typhoons, volcano eruptions, floods and landslides. Occasional torrential rains and heavy snows are another challenge for the country. The high number of earthquakes, tsunamis and active volcanoes are the conditioned by the fact that territory of Japan forms the part Circum-Pacific Seismic Belt which is sometimes called as the Pacific Ring of Fire.

Although remarkable successes has been achieved in increasing preparedness of the country –crucial role of them, MLIT and Prefectural government is must be emphasized in disaster preparedness – to earthquakes and tsunamis, the big disaster caused by them –Great Hanshin-Awaji Earthquake and Great East Japan Earthquakes demonstrated that they still remain as the biggest challenge for disaster management system in the country.

Based on the lessons of Japan's Great Hanshin-Awaji Earthquake, emergency transportation routes set to provide rescuing activities and transportation of goods immediately after the occurrence of earthquakes. The emergency transportation routes connect with the expressways, general highways and main roads and also links together with disaster prevention

bases those are designated by the government.

In recent years, natural disasters occur frequently in Japan. Not only the large-scale low-frequency disaster like earthquakes or eruption, but also the small-scale high-frequency disaster like landslides or flood occur frequently accompanied by the heavy torrential rain. For such a situation, the designation of the emergency transportation road is accomplished for a large-scale earthquake disaster in Japan. The network of designated road is maintained to become able to transport smooth supplies at the time of a large-scale disaster.

Although emergency transportation route is a cornerstone of emergency transport, research of vulnerability as a road network for disaster risk and disasters of emergency transportation route has not been sufficiently carried out so far.

In this study, in chapter 4; the risk of emergency transportation road network was quantitatively evaluated considering the various hazards such as earthquakes, floods, landslides, tsunami, volcanic and storm surges. As a result, the currently disaster risk of the road that is designated the emergency transportation road network is high, and it became clear to be impassable in the case of floods, landslides, and volcanic disaster. In addition, emergency transportation road network at the time of Tokai, Tonankai and Nankai earthquakes it became clear the risk is high to be impassable.

In chapter 5, it is analyzed the reachability between disaster prevention bases, e.g. Prefectural and municipal offices in consideration of the building collapse of the emergency transportation road within 6 prefectures. In this study, we analyzed the disaster risk of emergency transportation roads regarding the flood and building collapse those are responsible for road blockage caused by river flooding and earthquake respectively. Based on the analysis of disaster risk, we analyzed reachability of emergency transportation road between the prefectural and municipal offices. The target area of the study is the six prefectures namely Ishikawa, Toyama, Fukui, Niigata, Nagano and Gifu. The network analysis of impassable section of the emergency transport road that could be flooded by the river flooding, except the Niigata and Nagano Prefecture, it is revealed that more than 80% was unreachable between the disaster prevention bases e.g. prefecture and municipal offices. In the analysis of the building collapsed by earthquake that make road blockage, we considered the road-side building of emergency transportation roads. For the building collapse, we take the measurement seismic intensity which is a 2% exceedance probability for 50 years. Among the wide range of the six prefectures, the maximum unreachability cases occurred for the municipal offices were in the Niigata and Nagano Prefecture.

In chapter 6, as a case study, it is analyzed the actual situation and evacuation behavior of a large scale flood disaster e.g. Asanogawa flood, 2008 in Kanazawa city of Japan.

Table of Contents

List of figures

Chapter 6

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List of Tables

List of Acronyms

1. AS: Administrative Support

2. DIE: Disaster Information Email

3. DPB: Disaster Prevention Broadcast

4. DPRI: Disaster Prevention Research Institute

5. EMA: Emergency Management Australia

6. EM-DAT: Emergency Disasters Database

7. ESRI: Environmental Systems Research Institute

8. ETR: Emergency Transportation Road

9. FDMA: Fire and Disaster Management Agency

10. FEMA: Federal Emergency Management Agency

11. GIS: Geographic Information System

12. GSL: Geological Society of London

13. ICHARM: International Centre for Water Hazard and Risk Management

14. JICE: Japan Institute of Construction Engineering

15. JMA: Japan Meteorological Agency

16. J-SHIS: Japan Seismic Hazard Information Station

17. MILT: Ministry of Infrastructure, Land and Transport

18. NATCAT: National Catastrophe Team

19. NIED: National Research Institute for Earth Science and Disaster

20. OECD: Organization for Economic Cooperation and Development.

21. RMCC: River Management Consideration Committee

22. TEA: Timing of Evacuation Advisory

23. TED: Timing of Evacuation Directive

24. TEP: Timing of Evacuation Preparation

25. UNESCO: United Nations Educational, Scientific and Cultural Organization

26. VS: Volunteer Support

27. WMO: World Meteorological Organization

Chapter 1

Research Background

1. Introduction

Disaster is a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceeds the ability of the affected community or society to cope using its own resources. Disasters are events of huge magnitude and negative impacts on society and the environment. Disaster is also defined as a crisis situation causing widespread damage which far exceeds our ability to recover (Wassenhove, Van L.N, 2006).

Disaster studies towards the end of the 20th Century demonstrated the inability of science and technology to reduce social vulnerability and enhance adaptive capacity (Haque, 1988; Rasid and Mallik, 1995; Hewitt, 1997; Godschalk et al., 1998). The research drew awareness to the need for the public's input in disaster management (Dorcey et al., 1994; Mileti, 1999; Pearce, 2003). Policy recommendations from this body of research encouraged more anticipatory and sustainable solutions to address livelihood risk and increase citizen representation in risk decision-making (Lavell, 1998; Patton et al., 2000; Wisner et al., 2004).

Disaster can hit anywhere, at any time and take any form, it can be natural disasters as we have seen too often in our recent past or man-made. They affect communities and nations, causing human life losses and material damages. One classification of disasters includes the following four causes (Star, 2007) namely; by human error and technological failures, by intentional malevolence, by acts of nature, and combinations of some or all the previous. The four causes of disasters are considered, generally, low probability-high impact events, meaning, they are events with low probability of occurrence but with high impact on the community or the environment. Regarding by acts of nature, the International Disaster Database EM-DAT categorized the natural disaster into 5 sub-groups, which in turn cover 12 disaster types and more than 30 sub-types (Figure 1).

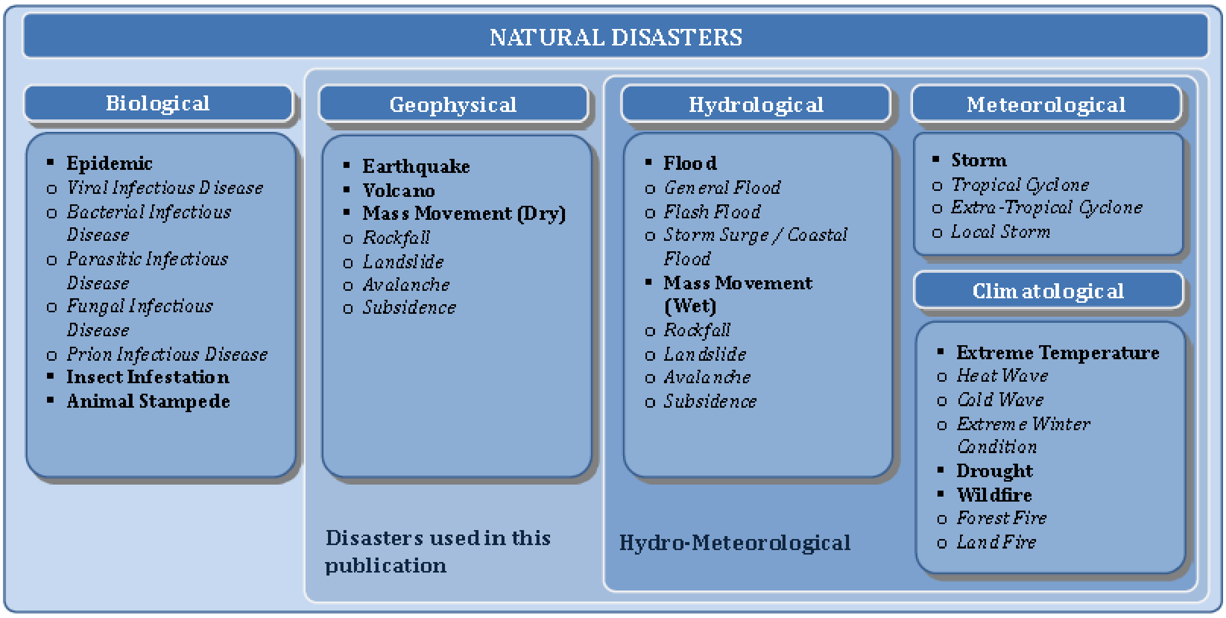

Figure 1: Natural disaster classifications (Annual Disaster Statistical Data 2012; EMDAT)

In the last four decades, based on the International Disaster Database (EM-DAT), between 1970-1979 and 2000-2012, the number of natural disaster events reported globally increased significantly from 837 to 4,939 or increased almost six times. Over the whole period of 1970-2012, 40.8 percent of these natural disasters occurred in Asia. Figure 2 portrays the increasing trend of natural disasters reported by region of the continent. Such increases are allegedly associated with the increasing of population exposed to hazards.

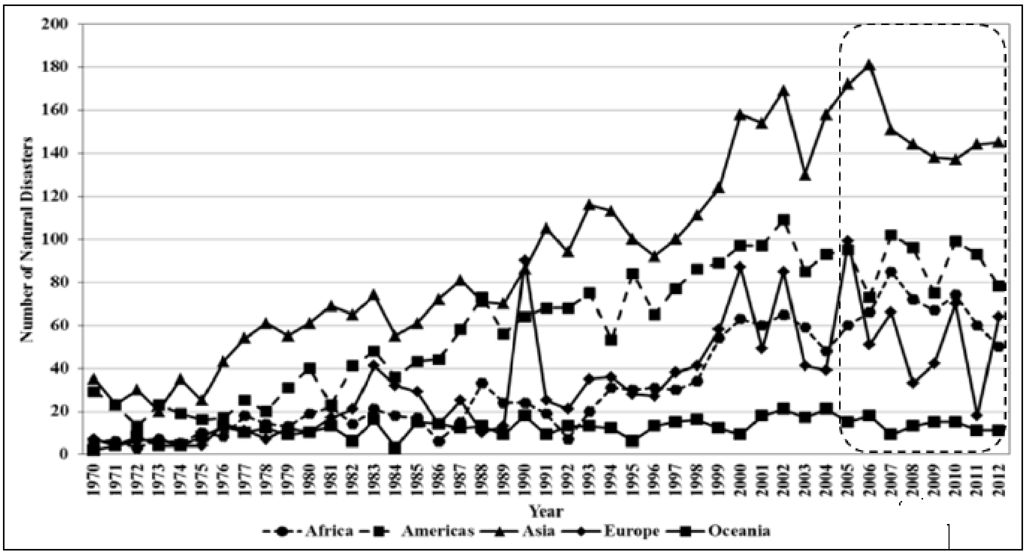

Figure 2: Number of natural disasters reported, 1970-2012.

Recently, natural disasters with devastating effects on human settlements have proliferated. Since urban settlements are habitats of human beings where are densely populated and constructed (infrastructure and buildings), they have high natural disaster risks. Unless the new planning strategies integrated with disaster mitigation approaches are not applied into the urbanization process, urban settlements unfortunately will still have high natural disaster risks. There are some main principles, policies, strategies, and standards to guide disaster prone urban settlements to mitigate disasters.

The concept of disaster resilience has been developed in the 21st century, in lieu of the previous concept of disaster resistance. Unlike the concept of disaster resistance, the concept of disaster resilience emphasizes elasticity and flexibility in coping with the particular challenges of the various natural disasters (Vale, L. J., Campanella, T. J.; 2005). Especially, with regard to the uncertainty of natural disasters, the term of resilience can provide a better guidance to produce effective disaster mitigation approaches in urban settlements. The disaster resilience concept is defined in terms of the adaptation capacity of a settlement system (built up and non-built up environment as well as community of life) potentially exposed to natural hazards with a view to maintaining or restoring an acceptable level of functioning and structure (Greiving et al.,2006).

The escalation of large-scale natural disasters in recent years such as the devastation earthquake and tsunami event in Japan and Indonesia in March 2011 and December 2004, respectively, the extreme floods in India, Germany and Switzerland in July and August 2005, the extensive bushfires due to severe droughts in Portugal and Spain in the same period, and Hurricane Katrina, which devastated the south-east coast of United States in August 2005 have caused fatalities, disruptions of livelihood, and enormous economic loss. These events show dramatically how the ongoing global environmental change and also an inadequate coastal defense, lack of early warning and unsustainable practices, and even neglect can affect people all over the world. Table 1 describes the natural disaster occurrences and impacts by region.

In 2012, Asia was most often hit by natural disasters (40.6%), followed by the Americas (22.1%), Europe (18.2%), Africa (16.0%) and Oceania (3.1%). This regional distribution of disaster occurrence is comparable to the profiled observed from 2001 to 2010, but all continents except Europe showed numbers of disasters below their 2002-2011 average. In Europe, in 2012, disasters occurred three times more than in 2011. Asia accounted in 2012 for 64.5% of worldwide reported disaster victims, while Africa accounted for 30.4%.Compared to the annual average number of victims from 2002 to 2011, the number of victims in Africa and Oceania increased, whereas fewer victims were reported in the Americas, Asia and Europe.

Table 1: Natural disaster occurrence and impacts: regional figures

No. of natural disasters	Africa	Americas	Asia	Europe	Oceania	*Global*
Climatological 2012	16	12	12	45	0	***85***
Avg. 2002-11	14	14	12	17	1	***59***
Geophysical 2012	0	6	23	3	0	***32***
Avg. 2002-11	3	7	22	2	2	***36***
Hydrological 2012	30	26	71	16	7	***150***
Avg. 2002-11	46	41	82	23	5	***197***
Meteorological 2012	11	35	39	1	4	***90***
Avg. 2002-11	9	34	39	14	7	***102***
Total 2012	**57**	**79**	**145**	**65**	**11**	**357**
Avg. 2002-11	***72***	***95***	***156***	***56***	***16***	***394***

No. of victims (millions)	Africa	Americas	Asia	Europe	Oceania	Global
Climatological 2012	28.01	1.82	6.37	0.45	0.00	***35.21***
Avg. 2002-11	23.86	1.36	76.80	0.27	0.00	***102.57***
Geophysical 2012	0.00	1.41	1.48	0.03	0.00	***2.91***
Avg. 2002-11	0.08	0.83	7.13	0.01	0.07	***8.12***
Hydrological 2012	9.34	1.54	53.52	0.10	0.24	***64.74***
Avg. 2002-11	2.08	4.26	111.05	0.28	0.06	***117.71***
Meteorological 2012	0.47	0.80	18.93	0.00	0.02	***20.22***
Avg. 2002-11	0.37	2.19	37.05	0.11	0.04	***39.75***
Total 2012	**37.82**	**5.57**	**80.29**	**0.58**	**0.26**	***124.52***
Avg. 2002-11	***26.38***	***8.64***	***232.03***	***0.66***	***0.17***	***267.88***

Damages (2011 US$ bn)	Africa	Americas	Asia	Europe	Oceania	Global
Climatological 2012	0.00	22.46	0.02	4.15	0.00	**26.63**
Avg. 2002-11	0.04	2.79	3.50	2.76	0.39	**102.57**
Geophysical 2012	0.00	0.68	2.14	15.80	0.00	**18.62**
Avg. 2002-11	0.57	4.08	36.73	0.53	2.47	**44.36**
Hydrological 2012	0.83	0.58	19.25	4.24	0.70	**25.61**
Avg. 2002-11	0.31	3.95	13.51	4.73	1.16	**23.66**
Meteorological 2012	0.10	79.67	6.56	0.01	0.15	**86.48**
Avg. 2002-11	0.07	39.14	8.19	3.64	0.77	**51.81**
Total 2011	**0.93**	**103.38**	**27.97**	**24.20**	**0.85**	**157.34**
Avg. 2002-11	***0.99***	***49.96***	***61.93***	***11.66***	***4.78***	***129.33***

[Source: Annual Disaster Statistical Review 2012: The numbers and trends]

2. Natural Hazards and Associated Disasters

Natural hazards are severe and extreme weather and climate events that occur naturally in all parts of the world, although some regions are more vulnerable to certain hazards than others. Natural hazards become natural disasters when people's lives and livelihoods are destroyed. Human and material losses caused by natural disasters are a major obstacle to sustainable development. By issuing accurate forecasts and warnings in a form that is readily understood and by educating people how to prepare against such hazards, before they become disasters, lives and property can be protected.

By natural hazards we refer to potentially damaging physical events and phenomena, which may cause the loss of life, injury or human life disruption, property damage, social, economic, and political disruption, or environmental degradation. Natural hazards can be divided into different groups: geological, hydro-meteorological, climatological, outer space, and biological1 hazards (e.g., AIDS or Ebola). Natural hazards can be single, multiple, or concatenated in time and local, regional and global in space. Each natural hazard is characterized by its location, intensity and probability.

A disaster can be referred to a serious disruption of the normal functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community/society to cope using its own resources. A disaster is a function of the risk process, and results from the combination of hazards, conditions of vulnerability and insufficient capacity or measures or even interest to reduce the potential negative consequences of risk, and exposure.

For the last 35 years the frequency of the disasters associated with natural hazard events has been steadily increasing (Fig. 3). An average number of 405 events per year were registered by Munich Re in 1980-1989, 650 events in the 1990s, 780 events for the period of 2000-2009, and more than 800 events in the 2010s (Wirtz et al. 2014). Figure 3 shows that the number of geological disasters has not been much changed in the last 30 years compared to the number of hydro-meteorological and climatological events.

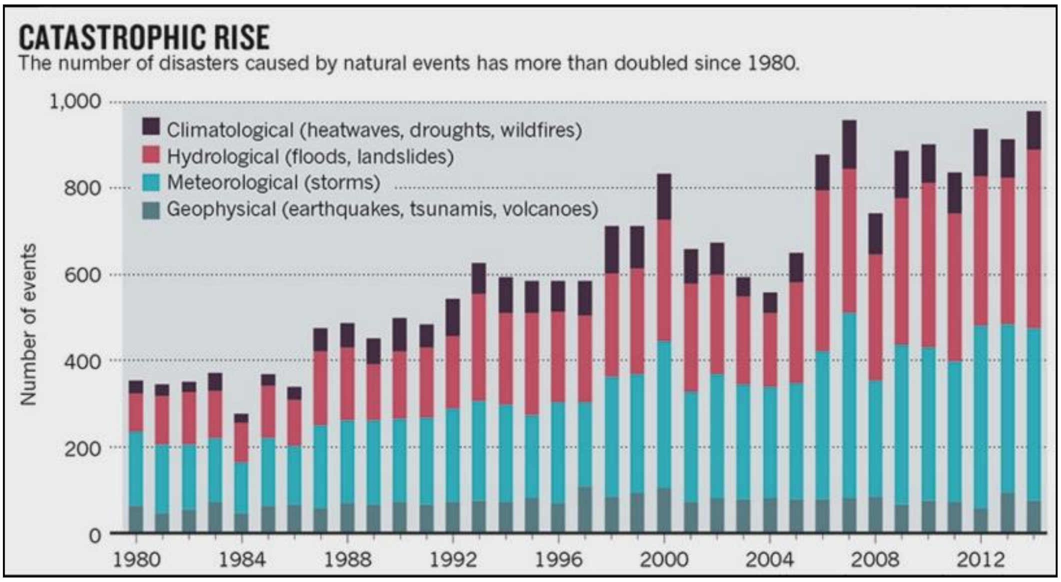

Figure 3: Annual number of disasters associated with natural events from 1980 to 2013 [Source: NatCat SERVICE, Munich Re, 2014].

3. Flood and other water related disaster in the world

Since the dawn of civilization, destructive floods have jeopardized settlements located in river valleys and plains. Despite developments in technology and extensive investments in flood control works, flood occurrences and accompanying hardship and material damages are not decreasing significantly. Now, the global flood losses have grown worldwide to the level of billions of dollars per year.

Trends in natural disasters show they are continually increasing in most regions of the world. Among all observed natural and anthropogenic adversities, water-related disasters are undoubtedly the most recurrent, and pose major impediments to achieving human security and sustainable socio-economic development, as recently witnessed with disasters such as the Indian Ocean tsunami in 2004, Hurricane Katrina in 2005, Cyclone Sidr in 2007, Cyclone Nargis in2008 and many others. During the period 2000 to 2006, 2,163 water-related disasters were reported globally in the EM-DAT database, killing more than 290,000 people, afflicting more than 1.5billion people and inflicting more than US$422billion in damages (Yoganath Adikari and Junichi Yoshitani, 2009, ICHARM). Figure 4 shows the Global trends of water related disaster. Among all the water related disaster, flood is the most common disaster across the globe.

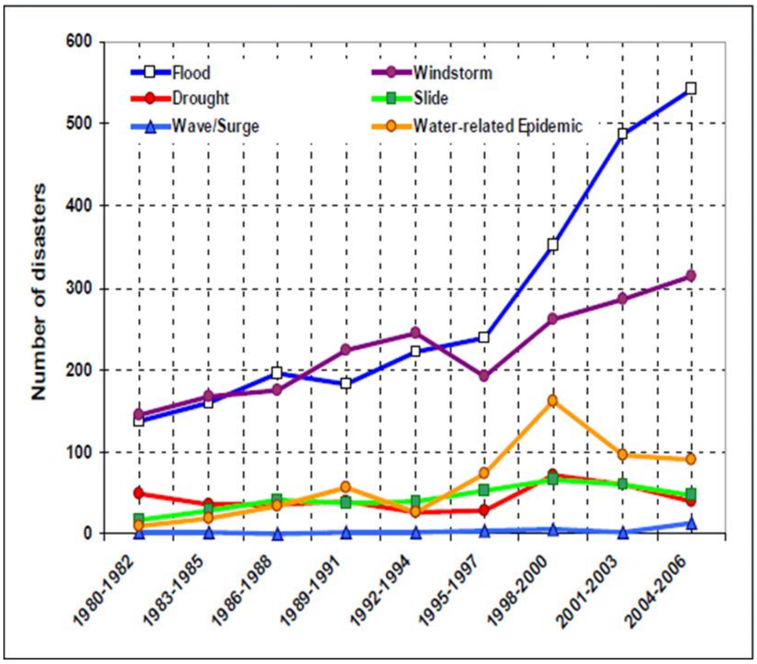

Figure 4: Increase of flood events worldwide (OECD Japan, 2006)

4. Disaster Concept

The word "disaster" is a complicated (Quarantelli, 1985) and vague (Kreps, 1984, 1985) concept. Establishing a clear conceptualization of an issue is important for public policy (Dynes & Drabek, 1994). For example, a clear understanding of the word disaster can provide guidance on the proper classification of particular historical events as disasters (Kreps, 1985). Proper categorization is vital in policymaking, such as in disaster declarations and dispatching resources for response and recovery. Similarly, in organizations, an unambiguous understanding of the definition of disasters has implications for decision-making. For instance, having a clear understanding of what constitutes disaster would enable organizations to know the appropriate mitigation and preparedness measures to adopt, e.g., whether or not to tie down business equipment. In addition, it is important to have a good definition of disasters in order to improve data gathering and analysis (Quarantelli, 2003), be able to generalize the findings of disaster research (Stallings, 2006), and advance theoretical understanding of disaster research (Quarantelli, 1985, 2003). The need for a clear conceptualization and definition of disaster is important in the disaster management literature that disaster researchers have spent much time on defining this concept (e.g., Kreps, 1984, 1985; Quarantelli, 1985, 1987; Auf der Heide, 1989; Mileti, 1999; Perry, 2006; Gerber, 2007). Furthermore, the *International Journal of Mass Emergencies and Disasters* devoted an issue to discussing disasters in 1995 (Mileti, 1999). The question-what is a disaster?-Has received much attention from disaster researchers, especially after the publication of Quarantelli's (1987) presidential address to the International Research Committee on Disasters. Before then, disaster researchers have generally avoided this topic (Quarantelli, 1985). Despite the attention and avoidance, there is no consensus on its definition and conceptualization (Quarantelli, 1985, 1987), to the extent that Quarantelli (1987) stated that disaster research might be at the threshold of a possible paradigmatic revolution. The following paragraph discusses some definitions of disasters to highlight the differences in meaning and conceptualization. According to Perry (2006), one can trace early definition of disaster to the work of Carr (1932). Carr defines disaster as the "collapse of cultural protections" (Carr, 1932 p 211). This perspective sees disasters as a negative consequence event, a view still in existence today (Perry, 2006). Fritz defines disasters as "…an event, concentrated in time and space, in which a society or a relatively self-sufficient subdivision of a society, undergoes severe danger and incurs such losses to its members and physical appurtenances that the social structure is disrupted and the fulfillment of all or some of the essential function of the society is prevented." Cited in Quarantelli (1987 p 655).According to Mileti (1999), most people agreed with Fritz's definition of disasters until recently when opinion began to diverge. The deviation has led to other definitions of disasters. For instance, Quarantelli (1985) views a disaster as an event in which the demand for action exceeds the capacity to respond. This perspective treats disasters as social "occasions" (Quarantelli, 1985 p 50). Nigg (1996) argues that social scientists define disaster based on social disruption and not on physical characteristics. She sees disasters occurring only "when the built and social environments are so disrupted that the resources of the social system are overwhelmed and the system is unable to meet the demands placed on it for goods and services that are routinely expected by its citizens" (Nigg, 1996 p 5). As a way forward, Quarantelli (1987) notes, among other suggestions, that having consensus on one definition of disaster is not important; clarity of the term and what the term refers to when the word is used are what is important. In the same vein, Perry (2006) recommends having a classification system that the disaster community can scrutinize with the goal of attaining some consensus (Perry, 2006).

5. Disasters as "Human-made" or "Natural"

There is a literature on disasters that focuses on the distinctions between natural and man-made/technological disasters (e.g., Quarantelli, 1987; Dynes & Drabek, 1994).

Quarantelli (1987) provides a good historical account of disasters and traces the sources of disasters-to the stars, God, nature, men and women, and to society. The initial understanding of disasters was that they are “acts of God” (Dynes & Drabek, 1994 p 6). The occurrence of myriad natural disasters prompted many communities to see industrialization and technological advancements as solutions to the problems created by disasters (Ibid). For instance, communities built dams to address flooding caused by natural systems. Unfortunately, technological solutions led to increased development and subsequently more disasters (Ibid). This led to the realization that disasters may be “natural or technological” (Dynes & Drabek, 1994 p 7) / “acts of men” (Quarantelli, 1987 p 9). I do not distinguish between natural or technological/man-made disasters because this study is about the determinants of mitigation and preparedness not about the causes of disasters. Although, some may argue that the causes of disasters can affect how organizations mitigate and prepare for them. In other words, some organizations may mitigate differently depending on whether a disaster is natural or man-made. This study assumes that the distinction between natural and man-made disasters is not relevant in understanding the determinants of mitigation and preparedness.

6. Expected Losses from Disasters

Researchers have documented the pernicious nature of disasters (e.g., Auf de Heide, 1989). The following examples highlight the monumental losses that can result from disasters. The Loma Prieta earthquake of 1989 caused 62 deaths, injured 3,757 people, displaced over 20,000 people, destroyed 18,306 homes and businesses, and caused over 6 billion dollars in economic losses (Mileti & O’Brien, 1992). The estimate of economic losses from Hurricane Katrina is over $200 billion (Burby, 2006). The Midwest floods of June 2008 caused 24 fatalities, injuries to 150 people, destroyed 40,000 properties and 5 million acres of agricultural land (Munich Reinsurance Group, 2008). While these costs vary by year, a new study by FEMA in 2006 indicates that the Annual Estimated Losses (AEL) to the national building stock are $5.3 billion (FEMA, 2007). In the first six months of 2008, the United States has suffered 154 fatalities and about $20.3 billion in estimated total losses to disasters (Munich Reinsurance Group, 2008). Evidence from the disaster literature (e.g., Mileti, 1999; Waugh, 2000) and the insurance community (e.g., Munich Reinsurance Group, 2008) suggest continued increases in losses from disasters. The reasons for the expected increases include, but not limited to rising population density, more settlements in high-risk areas, and increases in technological risks (Auf der Heide, 1989).In 1995, more than 6,400 people died in the Great Hanshin-Awaji Earthquake. Also, in 2011, more than 18,000 people died or went missing due to the Great East Japan Earthquake (Disaster Management Cabinet Office, 2014).

Chapter 2

Disasters in Japan

1. Introduction

In recent years, natural disasters occur frequently in Japan. Not only the large-scale low-frequency disaster like earthquakes or eruption, but also the small-scale high-frequency disaster like landslides or flood occurs frequently accompanied by the guerrilla heavy rain or torrential rain. Japan is located in the Circum-Pacific Mobile Belt where seismic and volcanic activities occur constantly. Although the country covers only 0.25% of the land area on the planet, the number of earthquakes and active volcanoes is quite high. In addition, because of geographical, topographical and meteorological conditions, the country is subject to frequent natural disaster such as typhoons, torrential rains, floods and heavy snowfalls, as well as earthquakes and tsunami.

2. The ratio of natural disasters in Japan to those in of the world (Earthquakes and Volcanoes)

Among the countries of the world which suffer the most violent forces unleashed by nature, mention must unquestionably be made of Japan, with an abundant record of catastrophic events, produced on some occasions by earthquakes and on others by volcanoes, typhoons or tsunamis.

In Japan, of all the damaged produced between 1955 and 2004 by natural disasters, 2% were due to flooding, 22% to wind and 76% to earthquakes (Kikugawa, H. and Bienkiewicz; 2005). Although Japan takes up only 0.25% of the earth’s surface area, it is the focus for a large percentage of the world’s earthquakes and volcanoes. 18.5% of earthquakes of magnitude 6 or more have occurred in Japan (2004-2013), where 7.1% of active volcanoes (2014) are also concentrated here (Disaster Management Cabinet Office, 2014, Japan). It is shown in figure 1, 2 and 3.

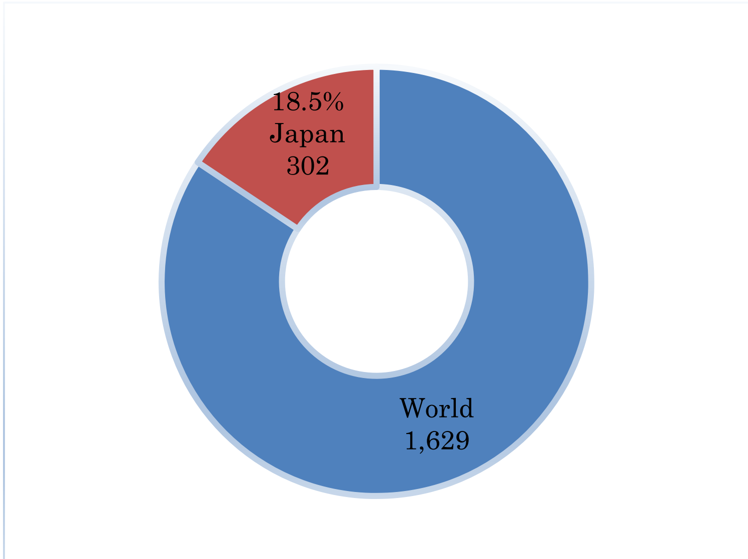

Figure 1: Number of earthquakes with magnitude of 6.0 or greater (2004-2013)

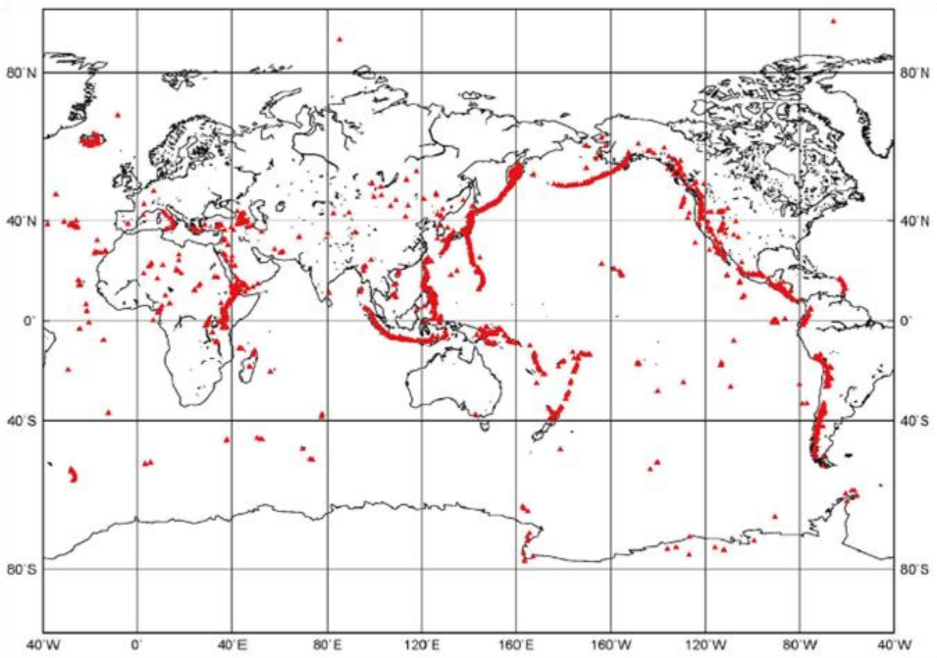

Figure 2: Principal Volcanoes in the World

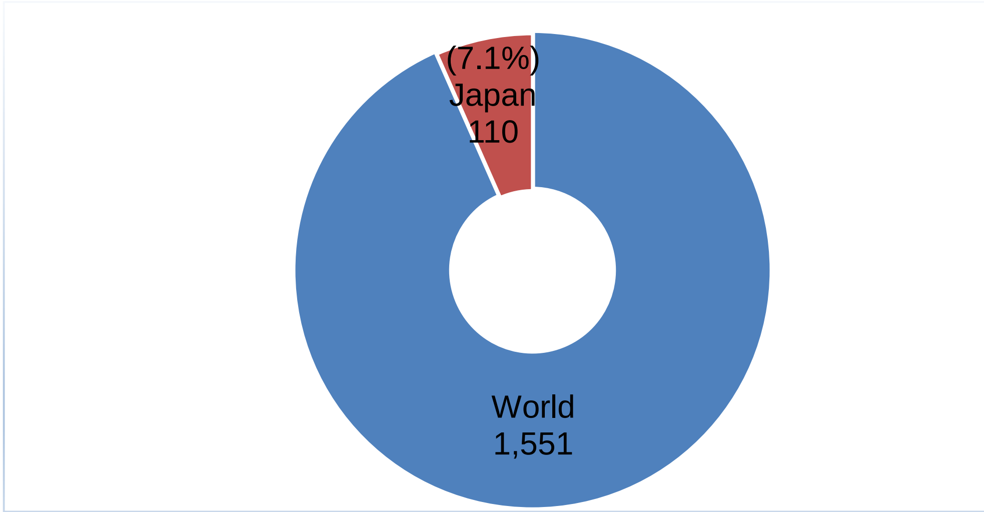

Figure 3: Number of active volcanoes (2014)

3. Deaths and missing persons caused by natural disaster in Japan

Disasters cause death, economic and environmental damage, and severe setbacks for social development. As the 2011 Great Eastern Japan Earthquake has made all too clear, natural disasters can be very difficult to predict and fully prepare against, and have incredibly far-reaching consequences for the safety and wellbeing of individuals and communities. Japan is affected by earthquakes, typhoons and tsunamis. In addition to these natural disasters, Japan is also home to several volcanoes.

Recent large-scale disasters, including the devastating earthquake and tsunami in Japan of March 2011, highlight the value of national preparedness for disaster. Figure 4 shows the number of deaths and missing persons caused by natural disasters (1945-2013). Figure 5 shows the number of deaths and missing persons by type of disaster (Past 20 years: 1994-2013

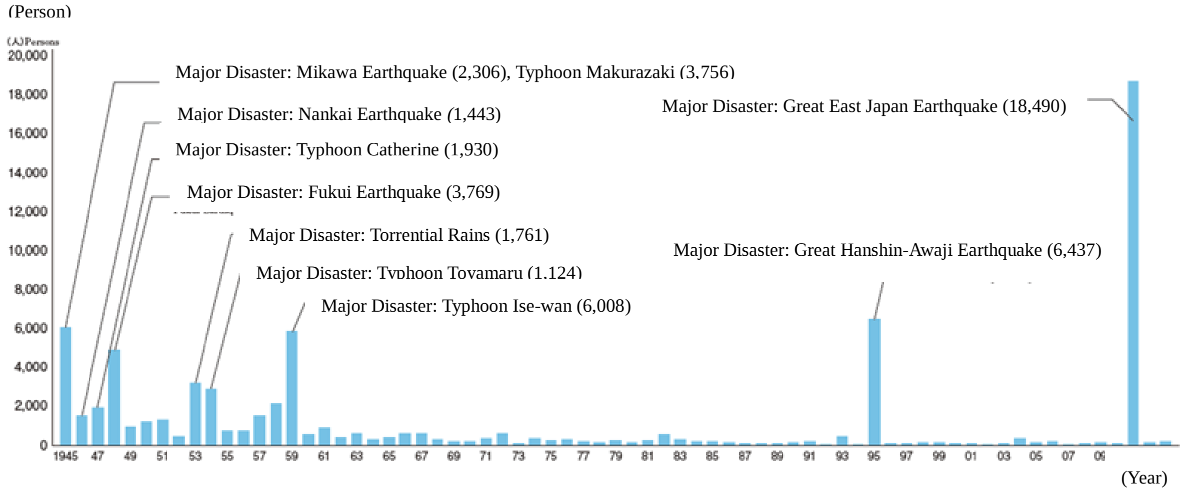

Figure 4: The number of deaths and missing persons caused by natural disasters (1945-2013)

[Source: 1945: Rika nenpyo, 1946〜52: Japan Weather Disaster Annual Table, 1953〜62: National Police Agency, 1963〜: Fire and Disaster Management Agency]

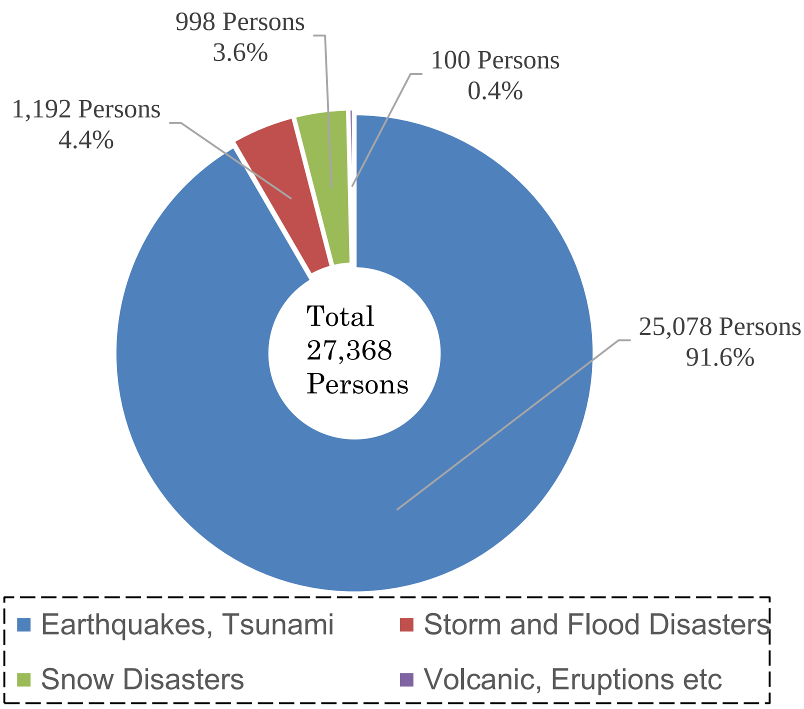

Figure 5: The number of deaths and missing persons by type of disaster (Past 20years:1994-2013)

[Source: White Paper on Disaster Management, Japan, 2013]

4. Disaster risk in Japan

Japan is a country that has been subjected to large-scale natural disasters periodically. Because of its natural conditions such as geographical position, topography, geology and climate, Japan is prone to be stricken by an earthquake, a typhoon, intensive rain, or volcanic eruption leading to disaster. Its climatic conditions, when combined with the country's rugged, steep mountainous topography particular to an island country, can sometimes lead to serious damage from intensive rain caused by a typhoon or a seasonal rain front, a flood or a landslide. Checking the distribution of seismic centers and volcanoes with a map of plate locations on the globe will reveal that places frequented by seismic activities coincide with plate borders. Japan is located right on the border of an oceanic plate and a terrestrial plate. Further, as it is surrounded by the sea, it is also vulnerable to tsunamis, which can also cause serious damage. In FY2003 alone, Japan recorded 2,179 sensible earthquakes and eruption of 4 volcanoes. In the future, it is also considered necessary to promote disaster-preventing measures from a national point of view, rather than to leave them to regional level efforts.

The 2011 Great East Japan Earthquake (also known as the 2011 off the Pacific coast of Tohoku Earthquake) had a magnitude of 9.0 – the largest recorded in Japan since instrumental seismic observation began (JMA, 2013). The massive tsunami it generated hit Japanese coastal areas and caused severe damage, with the number of deaths and missing people reaching 18,490 (Fire and Disaster Management Agency, Japan). The myriad problems that resulted from the 2011 earthquake disaster exemplified the limitations of scientific understanding of the disaster itself, as well as the increasing vulnerabilities caused by current changes in japan social structures (Suzuki et al, 2015).

Figure 6: The Great East Japan Earthquake (11 Mar. 2011)
[Source: The Daily Asahi Shinbun File Photo]

On August 20, 2014, the landslide disaster occurred by the heavy rain at more than 166 places in Asa-minami ward and Asa-kita ward of Hiroshima City, Japan. The serious damage caused by this heavy rain was 74 dead persons, 44 injured persons and 3,562 material damages, etc. (Fire and Disaster Management Agency, 2014). Following torrential rain in which a month's worth fell in a single day, several landslides were triggered near a mountain beside the city of Hiroshima. Asakita-ku was the hardest-hit ward. It received 217.5 millimeters (8.56 in) of rain from 1:30 am to 4:30 am causing two landslides which occurred between 4 am and 6 am. Hiroshima issued an evacuation advisory at 4:15 am. Figure 7 is the image that shows the Hiroshima landslide disaster on 20th August, 2014.

Figure 7: Hiroshima Landslide (20 Aug. 2014)

[Source: Geospatial Information Authority of Japan (2014)]

The Kinugawa River has burst through a flood barrier, sending a tsunami-like wall of water into Joso, about 50 kilometers northeast of Tokyo on 10th September, 2015 (AP report)

Figure 8: Overflow of the Kinugawa River (10 Sep. 2015)

[Source: Jiji Press/AFP/Getty Images]

5. Large-scale flood disaster in Japan

5.1 Geographical general context in Japan

Japan has a geographic area of about 378 000 square kilometers, which is divided between four main islands. The country has a temperate climate, subject to extensive regional variation, with three periods of heavy precipitation. The country is exposed to a series of natural hazards –geo-seismic (earthquakes and volcanic activity, with the subsequent risk of tsunamis), as well as hydro-meteorological events – typhoons occur frequently in September and October. Floods are frequent events and have caused great damage in the past. The country is fairly mountainous, and rivers are relatively short and steep. With a population of 127 million, population density is very high. Most residential and industrial areas tend to be located in lowland areas, along rivers; these areas are highly flood-prone. According to a 1985 study, 48.7 percent of the population and 75 percent of holdings are located within flood-prone areas (MILT, Japan 2005).In the eastern part of the Greater Tokyo Area, several wards and cities find themselves below the water level of several rivers, most importantly the Arakawa and Edo Rivers.

5.2 Experiences with floods

Japan is exposed to all types of floods, in particular (definitions from Munich Reinsurance):

Storm surge: Water pressed to shore (coast or large seas) by strong winds, which, when coinciding with the tide, can create a considerable rise in sea levels.

River floods: Such floods are the result of heavy rainfall over several days and over large areas. The water level rises when the soil is saturated.

Flash floods: Caused by intense rain over a small area. The soil is not saturated, but the rainfall exceeds the infiltration rate and runs off the surface.

Tsunamis: waves generated by large volumes of water being displaced (by earthquakes, landslides or volcanic eruptions). Tsunamis can travel through the open sea for hundreds of kilometers without losing their energy and increase in height when they reach shore – up to ten meters.

In Japan, risks related to tsunamis are, however, addressed as part of earthquake preparedness, and will therefore not be further considered in this paper. The worst flooding in modern Japanese history was caused by the Ise-wan typhoon in 1959, which took more than 5 000 lives. It occurred at the end of a period of twenty-five years of extreme climatic conditions: in the years between 1934 and 1959, there were six flood disasters, mainly caused by typhoons, which killed between 1 000 and 3 000 persons each. In recent years, there have been several flooding events in Japan, including the Tokai Heavy Rain in 2000, as well as several events in 2004 related to them any typhoons which hit the country, most notably the typhoons Songda and Tokage (see table 1).

Table 1: Significant flooding disaster in Japan, 2000-2004 (JICE 2001, 2005)

Event	Description	Economic loss		Human loss
		Insured loss	Total damage	
Tokai Heavy Rain, September 2000	Floods and landslides in Nagoya area	USD 990 million	USD 7 billion	18
Fukui-Nigata-Fukushima Torrential Rain, July 2004	More than 12500 hectares damaged, 5800 homeless	USD 279 million	USD 1.95 billion	20 dead, 1 missing
Typhoone Songda/No. 18, September 2004	Winds up to 212km/h, torrential rain	USD 3.59 billion	USD 7.17 billion	41dead, 4 missing
Typhoone Meari/No.21, September 2004	Winds up to 160km/h, rain, floods, landslides	USD 291 million	USD 798 million	26 dead, 1 missing
Typhoone Ma-on/No.22, October 2004	Winds up to 162km/h, rain, floods,	USD 241 million	USD 603 million	7 dead, 4 missing
Typhoone Tokage/No.23, October 2004	Winds up to 229km/h, 23210 houses destroyed	USD 1.12 billion	USD 3.2 billion	94 dead, 3 missing

6. Flood and landslide disaster caused by heavy rainfall in Japan

6.1 Heavy Rains and Floods in Japan

The number of heavy rainfalls---over 100 millimeters per hour---doubled from 2.2 times a year between 1976 to 1995 to 4.7 times a in the past decade. The concreting of rivers in municipalities has made flash floods very dangerous. Rain runs off into rivers quickly and builds up speed rapidly as there is no soil or vegetation to slow the water down.

In 1938, 700 died or went missing in the Great Hanshin Flood that hit Kobe and surrounding areas. In July 1982, a flood in Nagasaki produced by 187 millimeters of rain in a single day killed nearly 300 people. Major landmarks such as the Megane bashi Bridge were washed away. The owner of a busy restaurant that was inundated with 2.2 meters of water told the Yomiuri Shimbun, she heard a deep roar: “It was the sound of the river’s raging water, although I did not realize what it was. It was really scary.”

In August 1999, 13 people who camped on an island in the Kurokauragawa River in Kanagawa Prefecture were swept away and killed after torrential rains caused the river to quickly rise and cover the island. Five people on the island were rescued. The campers had been warned that the river was going to flood but didn't respond.

In July 2003, landslides and floods triggered by torrential rains during the summer rainy season left 22 dead in Kyushu. Damage around the city of Minamata was the worst. Hundreds of troops and firefighters were employed in a search for missing people. The same storm, which dropped up to four inches of rain an hour is some places, derailed a train in Nagasaki and flooded subways stations in Fukuoka.

On 13 July 2004, torrential rains fell over the Chuetsu region of the Niigata Prefecture that were remarkable for the total rainfall and the amount of rainfall within a relatively short period of time that triggered hundreds of landslide events-collapsing hillsides, mudslides, and debris-and in the alluvial lowlands, the Ikarashi, the Kariyata, and other small to medium-sized rivers feedinginto the Shinano River broke through their levees. Large-scale flooding devastated Sanjo City, Mitsuke City, and Nakanoshima Town where 16 people died, 2,500 hectares of land were inundated, 29 homes completely destroyed, 158 homes partly destroyed, 13,289 homes with major water damage, and6, 199 other buildings severely damaged. This disaster is referred to as the Niigata flood of 2004. Figure 9 shows the terrible situation of Nigata flood.

Figure 9: Flood water flowing into the housing area from the bank of the Kariyata River (NIED, 2006)

6.2 Heavy Rains in 2008, 2009 and 2010 in Japan

Heavy rains in August 2008, caused severe damage, particularly in Aichi Prefecture, and generated floods and landslides in several locations around Nagoya and Tokyo. New hourly precipitation records were set in 32 locations.

Rainfall in Okazaki in Aichi Prefecture reached 148 millimeters per hour, the seventh highest on record. In Tokyo itself more than 700homes were flooded. Two people were killed: an 80-year-old swept away by a swollen river in Okazaki and a 73-year-old woman who died when her flooded house. The body of the 80-year-old woman was found 40 kilometers from her home.

Waters in Okazaki reached waist-level. Some train lines were flooded, causing passengers to spend the night in the trains. The rain came from storms caused by warm humid air over particularly warm water channeled toward the Nagoya and Tokyo area between stalled high- and low- pressure systems off the coast of eastern Japan.

The heavy rains were attributed to “snaking westerlies”---winds that undulate north and south like a snake while moving towards the east---as opposed to the normal west-to-east westerly winds. The snaking pattern was caused by the movement of a large high pressure cell which usually sits over Japan in the summer to the Pacific off of Japan. This caused a front to form over Japan on which cold air from Russia slammed into warm and moist air from the south, producing heavy rains. The same pattern brought rains to Beijing for the Olympics.

In July 2009, ten people were killed in Fukuoka Prefecture in northern Kyushu in floods, mudslides and landslides caused by heavy rains. The dead were swept away by rain-swollen rivers and swallowed up in mudslides that engulfed their homes. A large landslide blocked the Kyushu Expressways. Some places received more than 600 millimeters of rain in less than 24 hours. Around the same time, 16 people were killed in Yamaguchi Prefecture, many of them elderly people killed when a mudslide inundated a nursing home.

Heavy rains during the summer rainy season in 2010 caused some severe damage and killed several people. One bout of intense rain in mid-July killed 13 people in Gifu, Hiroshima and Shimane Prefecture. Some of the victims were swept away by swollen rivers. Others were in homes engulfed by mudslides. Two victims were killed in a house in Matsue struck by four-meter-wide boulders.

Heavy rains in October 2010 on the Amami Island killed three people, downed power lines and caused landslides. More than 2,000 people were cut off by landslides and floods. Large amounts of mud that ran off into the ocean, smothering and killing coral.

6.3 Heavy Rain in Niigata and Fukushima in July 2011

In July 2011, a 67-year-old man was found dead and five people were missing 30 as torrential rains hammered Niigata and Fukushima prefectures, the Asahi Shimbun reported. The Niigata Prefectural Police Department said the man had apparently been driving home from a hospital on the night of July 29, when his car was swept into a river in Tokamachi. His body was found the next morning about 1.8 kilometers downstream.

Four others were missing in Niigata Prefecture, including a 63-year-old man who is believed to have drowned while he was stacking sandbags along a river bank in Ojiya. Embankments broke on the Aburumagawa and Hanegawa rivers in Uonuma, the Ikarashigawa River in Sanjo, and the Chagogawa River in Ojiya and the Makikawa River in Gosen. The Uonogawa and Kariyatagawa rivers in Nagaoka also broke their banks.

About 365,000 people in 15 municipalities, including Sanjo, Niigata and Nagaoka, were advised to evacuate. There was also extensive damage in Fukushima Prefecture, with communities left isolated by landslides and damaged bridges. A total of 711.5 millimeters of rain was recorded at Tadamimachi in Fukushima Prefecture.

On July 29, the rainfall sets all-time records, with an hourly precipitation of up to 121.0 millimeters recorded in some locations. According to the Meteorological Agency, the precipitation was heavier than rains that hit the two prefectures in 2004, killing 15. Hourly rainfall on July 29 hit 93.5 millimeters in Kamo, Niigata Prefecture, 121.0 millimeters in Tokamachi, Niigata Prefecture, and 69.5 millimeters in Tadami, Fukushima Prefecture, setting record highs at those stations. July 30 brought more record downpours in Niigata Prefecture, with 89.5 millimeters recorded in Minami-Uonuma, 70.0 millimeters in Uonuma, 68.0 millimeters in Nagaoka and 58.0 millimeters in Joetsu (Asahi Shimun, 2011).

6.4 Heavy Rain in 2012, Twenty-five Dead in Kyushu

In July 2012, the Yomiuri Shimbun reported: "Torrential rains caused by a seasonal rain front have brought death and destruction to the nation, mainly in western Japan. A number of people have been killed or are missing. The victims were crushed in their homes by mudslides or swept away by rain-swollen rivers. During the past month, there have been over 350 reported landslides. In Matsue, a mudslide on a slope behind a private house caused two huge rocks, each measuring four meters in diameter, to strike the building, killing two residents. In Yaotsucho, Gifu Prefecture, a mudslide crushed a private house, killing three residents. On July 5 this year, an intense rainfall of 107 millimeters per hour was recorded in Tokyo's Itabashi Ward.

In July 2011, 25 people were confirmed dead as a result of torrential rains, flooding, landslides and mudslides caused by a strong seasonal rain front in Kumamoto, Fukuoka and Oita Prefectures in northern Kyushu, according to police. Seven people were missing. More than 240,000 people were advised to evacuate their homes.

In Yame, Fukuoka Prefecture, Yame Police Station confirmed the death of Katsutoshi Matsumoto, a 70-year-old farmer. Matsumoto was engulfed in a mudslide and was found in cardio-respiratory arrest. In the city of Yanagawa, Masayuki Kawaryu, a 28-year-old unemployed man from Miyama in the prefecture, was found near a car that fell into a ditch. According to Yanagawa Police Station, the ditch was used for farming and measured about 24 meters wide and three meters deep. He was later confirmed to have drowned. Earlier a passerby witnessed the car falling into the ditch. But the car immediately sank in the water and rescuers could not find it on that day. In Taketa, Oita Prefecture, a 74-year-old man died in a flooded river.

In Oita Prefecture, the Yamakunigawa River in Nakatsu and the Kagetsugawa River in Hita overflowed. In Hita, an evacuation advisory was given to 33,700 people in 12,000 households. In Fukuoka Prefecture, 190,000 members of 66,000 households across a wide area were advised to evacuate. A similar advisory was issued to about 16,500 people from 6,000 households in the city of Saga.

In northern Kyushu, rainfall of 90 millimeters in one hour was registered in the town of Soeda, Fukuoka Prefecture, at about 5:30 a.m. and 85 millimeters was recorded in Hita at about 7:15 a.m Record-setting hourly rainfalls of 110 millimeters were recorded near Yame and Chikugo in Fukuoka Prefecture around 9:30 a.m. In the three days up to 11:20 a.m., the cumulative rainfall was about 780 millimeters in Aso, Kumamoto Prefecture, 650 millimeters in Yame and 600 millimeters in Hita.

In Aso, Kumamoto Prefecture, 17 people have been found dead, while five others are still missing. In nearby Minami-Aso, a 26-year-old man was found dead in his collapsed house. An 81-year-old woman had not returned to an evacuation center after leaving for her home in Takamori, Kumamoto Prefecture. Jiji Press reported: According to the Japanese Meteorological agency, 108 millimeters of rainfall per hour was recorded shortly before 6 a.m. on July 12 in the city of Aso, Kumamoto Prefecture, which saw a cumulative rainfall of 507.5 millimeters in the 24 hours to noon. According to the

Kumamoto prefectural police headquarters, many houses collapsed due to landslides in Aso. Nine people were confirmed dead in the city. In Aso and the neighboring village of Minami-Aso, the whereabouts of at least 10 people were unknown (Yomiuri Shimbun, 2012)

6.5 Landslides, Other Dangers Associated with Heavy Summer Rains in Japan

A phenomenon that is said to call ‘guerrilla rain ‘sudden downpours into relatively narrow zones, mainly in urban areas---has attracted attention in recent years. Such kind of rain is caused mainly by cumulonimbus clouds that form in a clash of warm and cold air. But some experts think the urban heat island phenomenon and global warming trends have a causal relationship to the sudden downpours. Guerrilla rain is frightening in that it is difficult to predict and the damage it causes occurs all at once. In the summer of 2008, five workers died in Tokyo after being washed away by a surge in sewer water while working underground. Also that summer, a swollen river killed five people, including primary school children, in Kobe.

There are also landslides. In recent years, experts have attributed large-scale mudslides to the so-called deep-seated landslide mechanism. Heavy rain soaks into cracks in the bedrock, which has been weakened over time, and when the bedrock collapses downhill, it takes a large volume of upper soil with it. Unlike shallow landslides, which can be prevented to a certain degree through good forestry practices, there are no known measures to prevent the occurrence of deep-seated landslides. We consider it necessary to urgently study what steps could be taken.

About 200 people are killed every year in Japan in rain-related disasters. A flash flood caused a storm that dropped 23 millimeters of rain in a short period of time produced a flash flood that killed four people in Kobe in July 2008. Three of the victims---an adult and two children---were members of school group playing on the banks of the Togagawa River when the flash flood struck. Others were swept away and rescued. The Togagawa River in Kobe is lined with concrete. Water levels in the river rose 134 centimeters in 10 minutes.

In July 2007, heavy rains associated with the seasonal rain front caused landslides and river flooding in Kyushu. One train was derailed by a landslide of mud and trees. No serious injuries were reported. In July 2006, mudslides caused by heavy rains associated with the rainy season killed 20 people in Nagano, Fukui, Shimane and Okayama prefectures and forced an evacuation of almost 15,000 people from 5,322 homes. Three people were killed when a flash flood washed away their home. Landslides and mudslides swallowed up and carried away homes. A levee broke in one place. Rain in some places was over 500 centimeters over several days. Some places received four centimeters of rain an hour. One place in Nagano Prefecture received 61.3 centimeters of rain (Yomiuri Shimbun, 2010). Table 2 shows the fatalities number because of the rainfall disaster in Japan for only three consecutive years e.g. from July 2005 to July 2007.

Table 2: Death occurred by heavy rainfall disaster, Japan (Ushima 2007)

Hazard	Number of deaths
Heavy rainfall due to stationary front in July 2005	12
Typhoon No.0514	29
Heavy rainfall due to stationary front in July 2006	32
Typhoon No.0613	9
Heavy rainfall due to stationary front in July 2007	5
Typhoon No.0709	3
Heavy rainfall due to stationary front in July 2007	4
Total	94

7. Trend of increasing frequency of torrential heavy rainfall in Japan

Many climatological studies have shown that there has been a positive trend in heavy rainfall events over the past 100 years (e.g. Iwashima and Yamamoto, 1993; Karl and Knight, 1998; New *et al.*, 2001; Groisman et al., 2005; Fujibe et al., 2006a and 2006b). According to analyses by the Japan Meteorological Agency (JMA) (2009) and Fujibe et al. (2005) that were conducted using observational data, there is no doubt that there has been a recent increase in the frequency of heavy rainfall over most of Japan. However, no sufficiently comprehensive studies based on observational data have yet been conducted to elucidate the mechanism for this positive trend in heavy rainfall (Hiroyuki Iwasaki, 2011). In Japan, the trend of increasing frequency of heavy rain is expected to continue. Both hourly and daily rainfall tends to increase. As a result, sometimes this leads to a flash flood in the localities. The figure 10 shows the annual frequency of 100 mm/hour or more precipitation events (per 1,000 localities)

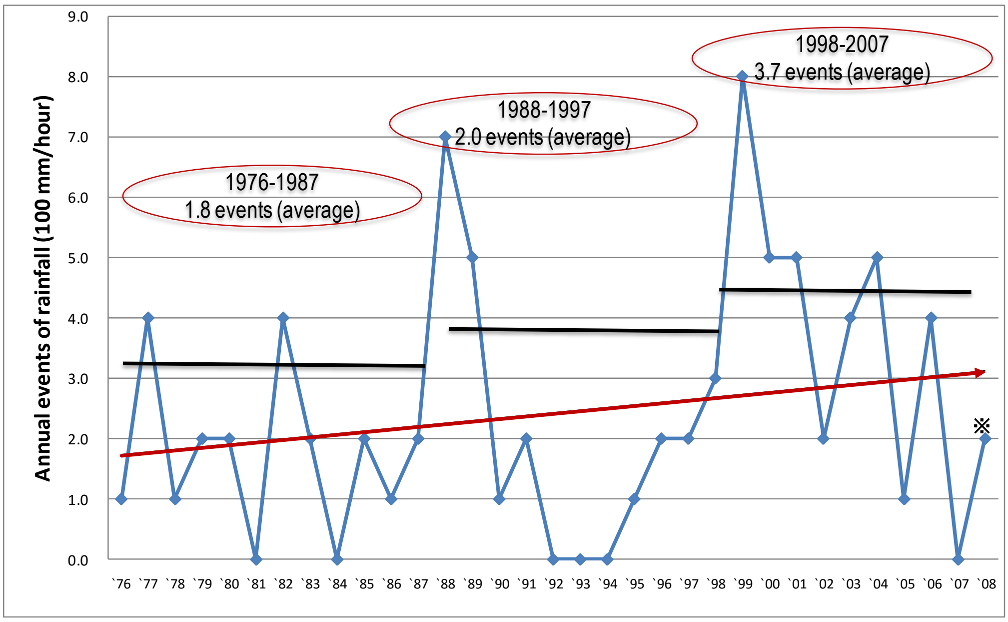

Figure 10*:* The annual frequency of 100 mm/hour or more precipitation events per 1,000 localities (Data source: MILT, Japan. 2009)

Figure 11 shows also the increasing frequency of heavy rain in Japan. It is evident from the figure that the annual frequency of 50 mm/hour or more precipitation events (per 1,000 localities)

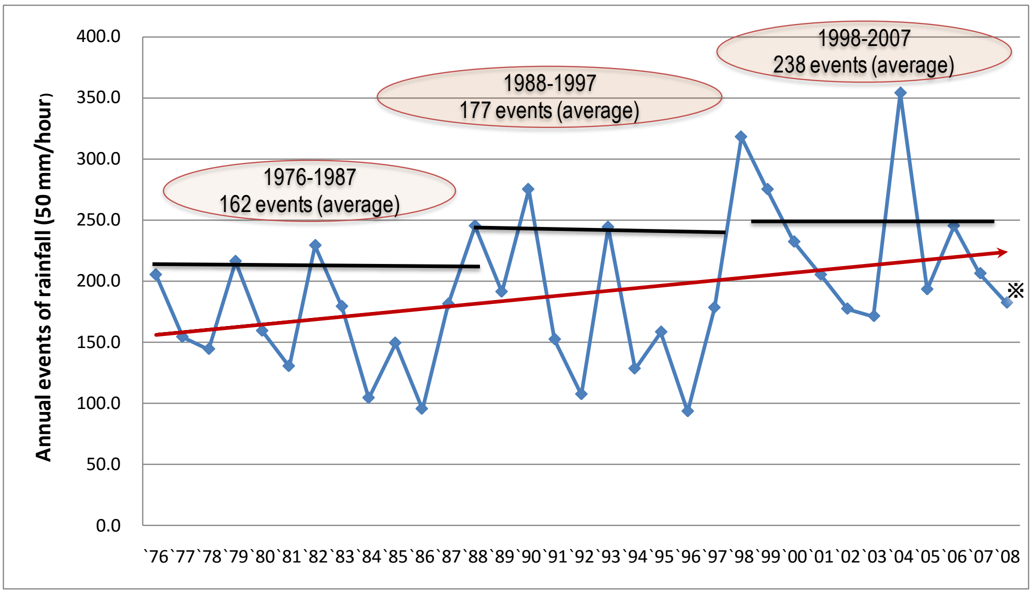

Figure 11: The annual frequency of 50 mm/hour or more precipitation events per 1,000 localities (Data source: MILT, Japan. 2009)

8. Natural disasters caused by heavy rainfall

Rainfall disaster have been deeply noticed since the ancient age of the human being. In spite of the development of modern technology the problems related to them are not yet solved today (K. Takeo, 1994).

Heavy rainfall can lead to numerous hazards, for example:

- **Flooding,** including risk to human life, damage to buildings and infrastructure, and loss of crops and livestock

- **Landslides**, which can threaten human life, disrupt transport and communications, and cause damage to buildings and infrastructure.
- **Soil erosion**, Soil erosion is a process that affects all landforms. In agriculture, soil erosion refers to the wearing a way of a field's topsoil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage.

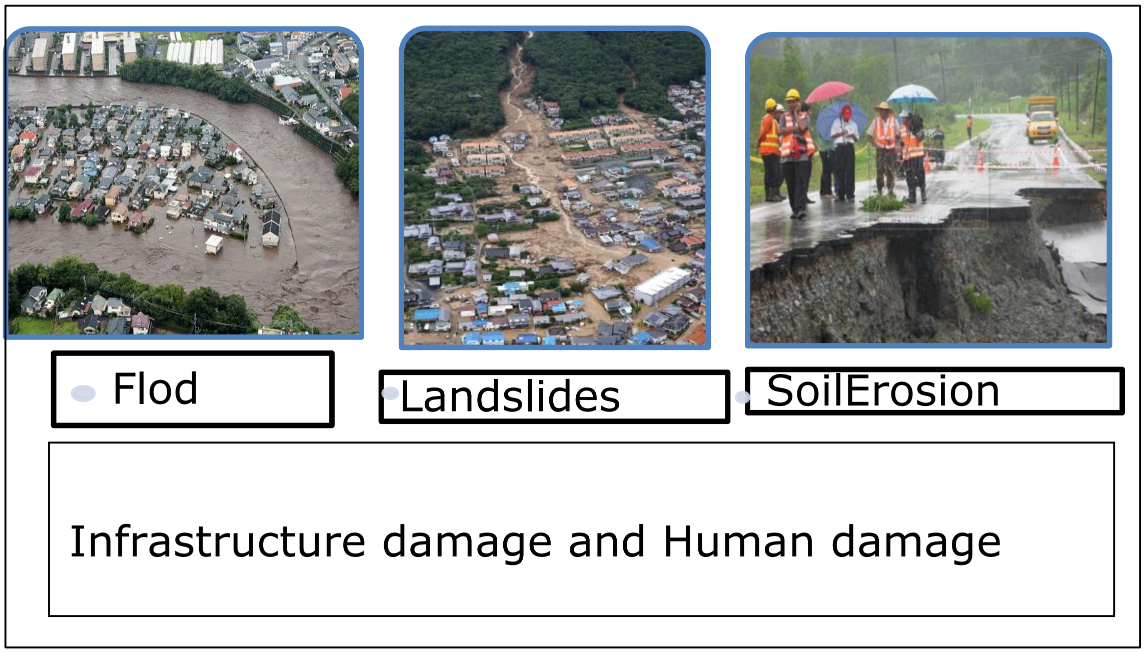

Figure 12: Natural disaster caused by heavy rainfall

<u>Sources of images (Figure 12)</u>

Flood image: *Aerial view-Flooding in Kyushu Island, Japan* (http://www.disaster-report.com/2012/07/natural-disasters-list-july-14-2012.html)

Landslides image: *An aerial view of houses and roads devastated by a major landslide in Asaminami-ku, Hiroshima, western Japan*, on 20 August 2014. EPA/HIROTO NOMOTO/YOMIURI SHIMBUN/Soil erosion image: *Road collapsed due to soil erosion after heavy rain.* (http://www.theborneopost.com/2013/01/24)

9. The classifications of rains

The classification of rains by the Japan Meteorological Agency, the Ministry of Land, and Infrastructure, Transport and Tourism and other relevant organizations is shown in Table 3.

Table 3: The classifications of rain

_	**Sudden Showers**	**Localized Heavy Rain**	**Concentrated Torrential Rain**	**Heavy Rain Arising from a Typhoon, front, or other weather phenomenon**
Characteristics	Occurs suddenly and stops in a short time	Temporary and heavy rain	Continuous for several hours	Continuous for several days
Total rainfall amount	Not large	Several tens of milimeters(localized to specific area and concentrated in a short time)	Several hundreds of milimeters(concentrated in a small area)	Considerably large
Occurrence factor	Formation of a comulonimbus	Formation and development of a cumulonimbus	Repeated cycle of the formation and development of a cumulonimbus at the same location	A typhoon, or a front stimulated by typhoon
predictability	_	Difficult to predict, for the time being	Relatively easy to predict	Relatively easy to predict
Typical example	_	**Toshima City, Tokyo(August 5, 2008)** Torrential rainfall : 82mm; Largest hourly rainfall: 66mm; Rainfall duration: approx. 1.5 hours	**SuginamiCity,Tokyo**(September 4, 2005) Total rainfall: 264mm; Largest hourly rainfall: 114mm; Rainfall duration: approx. 4 hours **Kanazawa City** (Jly 28, 2008) Total rainfall: 142mm; Largest hourly rainfall: 60mm; Rainfall duration: approx. 3 to 4 hours	**The rain commonly known as the Tokai Torrential Rain (September 2000)** [daily rainfall in Nagoya city: 567mm] **The Nigata-Fukushima Torrential Rain (July 2004**) [Total rainfall in Tochio City: 431mm]

Chapter 3
Objective and Methodology of the Research

1. Objective of the Research

Based on the lessons learned from the Great Hanshin-Awaji Earthquake, the emergency transport road is set for smooth emergency transport immediately after the earthquake for a high-speed automobile for national highway, the general highway and the trunk road which is designated by the prefectures to contact mutually between the disaster prevention bases. The emergency transport road (ETR) is categorized of primary, secondary and tertiary type for each prefecture. It is seen a little difference in the name and selection criteria, but basically the primary road covers the wide area range of high-speed automobile national highway, the general national highway and the trunk road. Then it shapes such a way that secondary and tertiary road can connect with primary road and also can communicate mutually between the disaster prevention bases as well as with the government offices.

During the Kobe earthquake (Hyogoken-Nanbu Earthquake) that occurred in January 17, 1995. The earthquake damaged the elevated structure, such as a highway, railway, blocked of road surface by the collapsed of roadside building, the capacity of the affected areas was significantly reduced. In addition, the traffic demand was different than of normal or ordinary time because of the evacuation activities after the accident occurred, emergency and rescue activities, relief activities, in relation to the recovery and reconstruction activities, etc. From the fact that the main trunk line which is responsible for Japan's east-west traffic were damaged, the next day of disaster occurred e.g. on the 18th January, emergency transportation route 2 of the east-west has been set to compensate for the damage situation. However, to regulate the passage only by the emergency vehicle was actually difficult. The above-mentioned contents are shown as a collection of Hanshin Awaji great earthquake disaster lesson information book in conjunction with the emergency transportation by the road traffic by the Cabinet Office As it has also been mentioned in the Great Hanshin-Awaji Earthquake lesson information book, road blockage caused by a roadside building collapse during the earthquake, that it can be assumed that the roads were impassible. In addition, such as flood damage on the road by the river flooding or building collapsed on the road by an earthquake is assumed not to be able to pass by traffics. There have been accomplished a lot of researches accomplished in respect of general road blockages due to collapse of the roadside building so far (Kondo et al., 2010; Ichikawa et al., 2004; Tamura et al., 2005). On the other hand, study and of the road section that may become impassable due to a disaster, consider between certain two points, or connectivity that is impassable interval is guaranteed even in the event, or the arrival delay, such as how much arrival delay occurs, it is important from the point of view of emergency transport in the event of a disaster, but it is the present condition that such a study has not done sufficiently. Therefore, in this study, we analyzed the emergency transportation at the time of the river flooding, at the time of the earthquake using the emergency transportation route and analyze the section that might be flooded by the flooding, the section that it might block up by the collapse of the building of the emergency transportation roads. Based on the result, we analyzed it by network analysis about the reachability between prefectural offices and municipal offices e.g. city, town and village offices.

An emergency transportation road network is designated for a large-scale seismic hazard, and a network is maintained so that it may become possible to do smooth transportation of goods when a large-scale disaster happens in Japan. However, while frequency and the kind of accidents are diverse, emergency transportation roads are not quantitatively grasped how degree have a disaster risk. In this study, the risk of emergency transportation road network were quantitatively evaluated considering the various hazards such as earthquakes, floods, landslides, tsunami, volcanic and storm surges.

Therefore, in this study, we analyzed firstly, the risk of emergency transportation road network were quantitatively evaluated considering the various hazards such as earthquakes, floods, landslides, tsunami, volcanic and storm surges.

Secondly, we analyzed the emergency transportation at the time of the river flooding, at the time of the earthquake using the emergency transportation route and analyze the section that might be flooded by the flooding, the section that it might block up by the collapse of the building of the emergency transportation roads. Based on the result, we analyzed it by network analysis about the reachability between prefectural offices and municipal offices e.g. city, town and village offices.

Thirdly, as a case study of a large-scale river disaster, it is analyzed the actual situation and evacuation behavior of a large scale flood disaster e.g. Asanogawa flood 2008.

2. Methodology of the Research

2.1 Evaluation of Emergency Transportation Road Network to Various Hazards in Japan

As a disaster in Japan, it can be mentioned the name of the earthquake, flood, tsunami, high tide and volcano. For the earthquake hazard assessment, the probability is equal to or greater than 5 of the seismic intensity in 30 years, has been assessed by the measured seismic intensity that becomes each exceedance probability of 30-50 years (J-SHIS: Japan seismic hazard information station (in Japanese).For the flood hazard assessment, we used the data relating to flood provided by the county, prefectures or metropolitan that is evaluated as a boundary at 3.0m,0.5m with 3 phases (Ministry of Land, Infrastructure, Transport and Tourism: Guidance of Flood Hazard Mapping). In addition, 5.0m is added to the border when flood levels exceeding 5.0m, then it is widely distributed with the boundary at 5.0m.The relationship between the boundary height and the happening phenomenon is for 0.5m, flooded above 1stfloor level of the building; for 3.0m flooded 2nd floor surface of the building; for 5.0m, 2ndfloor is submerged with water and there is possibility of 3rdfloor surface is flooded. For the tsunami and high tide, as it varies according to the areas, we examine a rational external force level depending on a local characteristic and on the basis of condition setting in table1, chapter 4(Japan Meteorological Agency: About active volcano). About the volcano, the risk is evaluated by the total number of Japan's active volcano with the proportion of the existing volcanic hazard map. The total number of Japan's active volcano is 110, of which, the number of hazard map that has been published is 82.

The total number of the active volcano of our Japan is 110 and the number of hazard map which is officially published is 82 (Ministry of Land, Infrastructure, Transport and Tourism: Hazard map portal site).Therefore, the risk of the volcano is estimated to be 74.5%.

2.2 Reachability Analysis of Emergency Transportation Road between Prefectural Office and Municipal Offices

In this study, we use the emergency transportation roads of the national numerical land information data. These data is to create a route shape, division of the emergency transportation road, road classification, a route name using a local disaster prevention plan, the documentation about the emergency transportation road network plan which are organized by the metropolis and districts.

As one of the factors that emergency transportation road becomes unusable, it can be considered flood damage. In this study in order to assess the flood damage of ETR, it has been received the use of anticipated flooding zone data of the country numerical information inundation assumption area and assumed inundation depth at the national scale. Bedside the flooding assumption, in this data it is organized the immersion depth of the river and data plan rainfall of the object such as underlying the specified inundation assumption area. Inundation is divided into 5 or 7 level shown in table 2 of chapter 5.The situation where the road becomes unusable by flooding, in this study it is defined as the depth of immersion; car becomes impossible of traveling. Generally, depth immersion of the automobile is unable traveling are the depth of the floor of the vehicle are flooded. Therefore, of the Table 2 of chapter 5, to evaluate as a section that emergency transportation road inundation depth to exist in inundation assumed within the area that fall into more than 0.5m may become unusable by flooding when the rivers flood. In addition, the flood zone of emergency transportation road, as shown in Figure 1 of chapter 5, the emergency transport roads and inundation assumption area data of the country numerical information when it is piled up on a GIS, both of interval were completely matched.

Another factor that emergency transportation road becomes unusable, it is thought that buildings along the roadside comes to collapse on emergency transportation road at the time of the earthquake. To evaluate the risk of a road obstruction by buildings collapsed, it is required the data of the position and height of building, construction time and about structure of the building, etc. Such kind of data is what is readily available with a limited amount of information, if further directed to a wide range of area as in this study, the data's availability is almost nil. Therefore, we tried to make the data available to understand the height and position of the building in the present study. We were using the data creation of a detailed map 201 214 provided by the ESRI Japan. This data is a background map database that has been developed by processing and map data of the ZENRIN Co., Ltd., and base map information and national land numerical information of the Ministry of Land, Infrastructure and Transport. That is, a variety of information on the map data of the individual. The data about the desired building are included in this study in that, and a kind and the height of the building are compiled into a database. Incidentally, the height of the building has been considered by one floor per 3m, the type of buildings are uniquely classified. Such data can take advantage of the position and height as possible grasp the building data. It shows the data of the above example in figure 2 of chapter 5.

However, in order to consider the building collapse due to earthquake, is further necessary structural form of the building and their ages. The structure type of the building, were classified as wooden and non-wooden as shown in Table 3; chapter 5 according to the classification of the data. The building of classification that are assigned to the residence was a wooden, but also includes high-rise dwellings, such as apartment in this classification. For this reason, the fourth floor or more of the building (building height is more than 9m) it was classified as non-wooden. From the fact that information is insufficient with respect to building age, it is assumed that all in the present study is a building that was built with the latest building standards. By this assumption, its results for the building collapse indicated by this study and it will be a minimum damage estimation of the case. Building data created in the above steps, in State buildings to not pull all the data. Therefore, and in areas along emergency transport roads for, and to extract only the data affect the obstruction of emergency transportation roads to collapsed buildings. If the evaluation or a building affect the emergency transportation road when collapsed is performed based on the positional relationship between the height and the emergency transportation of this building. It shows the extraction flow diagram of the building that affect the emergency transportation road in Figure 3; chapter 5. Extraction of the building, to determine the center of gravity of the building, from the center of gravity obtained, after drawing a circle to the height of the building as a radius, affects the emergency transportation roads the building when including emergency transportation roads within the circle. It performed in the procedure that is extracted as a given building. For buildings along emergency transport roads we created in this step, J-SHIS earthquake hazard stations are exposed by earthquake motion estimation map (fig. 7; chapter 5), to determine if there is a possibility of suffering from the shaking intensity of the extent to which expected seismic area grid.

By performing extraction and assumed measurement seismic intensity determination data creation and data necessary as described above, data for evaluating the risk of clogging the emergency transportation roads by building collapse caused by an earthquake are aligned. In order to evaluate the risk, for these data, it applies the damage function of the building due to an earthquake, to determine the total collapse probability of each building. Then the random simulation, it is determined whether or not the building is destroyed, if it is destroyed is evaluated and the building road blockage occurs in the emergency transportation roads adjacent.

Chapter 4

Vulnerability of Emergency Transportation Road Network to Various Hazards in Japan

In Japan, a natural disaster occurs frequently in recent years. An emergency transportation road network is designated for a large-scale seismic hazard, and a network is maintained so that it may become possible to do smooth transportation of goods when a large-scale disaster happens in Japan. However, while frequency and the kind of accidents are diverse, emergency transportation roads are not quantitatively grasped how degree have a disaster risk. In this study, the risk of emergency transportation road network were quantitatively evaluated considering the various hazards such as earthquakes, floods, landslides, tsunami, volcanic and storm surges. As a result, currently disaster risk of the road that is designated the emergency transportation road network is high, and the emergency transportation road network does some disaster, and it became clear to be impassable in the case of floods, landslides, and volcanic disaster. In addition, emergency transportation road network at the time of Tokai, Tonankai and Nankai earthquakes it became clear the risk is high to be impassable. The further study, the possibility of emergency transportation road network can be connected disaster prevention shelter base.

1. Introduction

In recent years, natural disasters occur frequently in Japan. Not only the large-scale low-frequency disaster like earthquakes or eruption, but also the small-scale high-frequency disaster likes landslides or flood occurs frequently accompanied by the guerrilla heavy rain or torrential rain. For such a situation, the designation of the emergency transportation road is accomplished for a large-scale earthquake disaster in Japan.

The network of designated road is maintained to become able to transport smooth supplies at the time of a large-scale disaster, but there are few studies that evaluate how the degree of disaster risk can be controlled by the emergency transportation road while the type and frequency of the disaster diversify quantitatively. And again, it is the present conditions that it does not perform the evaluation that assumed a complex disaster.

In this study, it is intended to evaluate quantitatively the risk of emergency transportation roads that is hit by various hazards such as earthquakes, floods, landslides, tsunami, volcanic and high tide, and we also conducted an analysis of the disaster risk of emergency transportation roads. In this study, we will describe the risk of emergency transport roads to various hazards such as earthquakes, landslides and flooding.

2. Hazard Assessment in this study

Whenever disasters in Japan are mentioned, the name of an earthquake, flood, or volcano comes to mind. The evaluation index of various hazards is shown in table 1.

Table 1: The evaluation index of various hazards

	地震	浸水	津波	
評価基準	30 年間で震度 5 弱以上となる確率	0.5m 未満	外力レベル1	養殖施設等に影響する津波(地上に影響 しない)
	30 年間で震度 5 強以上となる確率	0.5～3.0m 未満	外力レベル2	設計外力(既往最大津波)
	30 年間で震度 6 弱以上となる確率	3.0m 以上	外力レベル3	想定最大津波(想定地震規模、最悪震源 位置)
	30 年間で震度 6 強以上となる確率	5.0m 以上		
	30 年間超過確率 3%となる計測震度			
	30 年間超過確率 6%となる計測震度			
	50 年間超過確率 2%となる計測震度			
	50 年間超過確率 5%となる計測震度			
	50 年間超過確率 10%となる計測震度			
	50 年間超過確率 39%となる計測震度			

高潮		火山	
外力レベル1	発生頻度の高い高潮	①火山ハザードマップ公表数	82（インターネット公開：58）
外力レベル2	設計外力(既往最大又は想定最大[既往 最大規模・最悪進路])	②わが国の活火山の総数	110
外力レベル3	想定最大高潮(わが国既往最大規模・最 悪進路)	①÷②×100	82÷110×100=74.5

For earthquake hazard assessment, the probability of an earthquake with a seismic intensity equal to or greater than 5 has been assessed using the measured seismic intensity in the past, and has been found to be increasing since the last 30–50 years. Here, Seismic intensity is the index which shows the strength of the earthquake ground motion. The seismic intensity is ranged from greater than 0.5 to 4.5 is 1cut and from less than 4.5 to greater than 6.5 is divided into 10 stages of 0.5 cut.

For the hazard assessment of floods, the data provided is sorted by county, prefectures, and metropolitan cities, and is evaluated with a flood boundary of 3.0 m and 0.5 m with three phases. In addition, 5.0 m is added to the border when the flood levels begin exceeding 5.0 m, then it is widely distributed with the boundary at 5.0 m. The relationship between the boundary height and the flooding phenomenon is given by the following: at 0.5 m, flooding occurs in the first floor of the building; at 3.0 m, flooding occurs in the second floor of the building; at 5.0 m, the second floor is submerged with water, and there is a possibility that the third floor might also be flooded.

For volcanos, the risk is calculated by dividing the total number of active volcanos in Japan with the proportion of the existing volcanic hazard map. Presently, the total number of active volcanos in Japan is 110, and the number of hazard maps which have been officially published is 82. Therefore, the risk of the volcano is estimated to be 74.5%.

3. Emergency transportation road in Japan

Based on the lessons learned from the Great Hanshin–Awaji Earthquake, the emergency transport road network is set up to provide seamless emergency transportation immediately after an earthquake for a high-speed automobile national highway, the general national highway and the trunk road which is designated by the governor to enable mutual contact between the disaster prevention bases. Emergency transportation road has been promoting the strengthening of the planned network for secure and emergency transportation, including the regional disaster prevention plans for each prefecture as the rapid relief activities of the road closures, etc., such as impassable was seen many areas that require a long period of time.

The emergency transportation road is categorized as the primary road for each prefecture. There is a little difference in the name and selection criteria, but basically the primary road covers a wide range of area of the national highway, highway, and the trunk road. It is also shaped in such a way that secondary and tertiary roads can connect with the primary road and enable mutual communication with disaster prevention bases and government offices. Table 2 shows the total length of each specified rank of emergency transportation road and Figure 1 shows the road network diagram of emergency transportation road. The emergency transportation roads have occupied a high percentage of the national highway for high-speed automobiles and the general national highway, as well as the total extension accounts for a high ratio. Therefore, it is believed that enough of the wide area has been secured via the emergency transportation roads.

Table 2: The total length of each specified rank

(Unit:km)	National highway & Highway	Prefectural road	Municipal roads	Total length
Primary	45928.63	8077.59	1063.4	55069.62
Secondary	13368.92	22380.69	2428.48	38178.09
Tertiary	799.69	3152.69	714.29	4666.67
Unspecified	93.58	23.11	—	116.69
Total	60190.82	33634.08	4206.17	98031.07

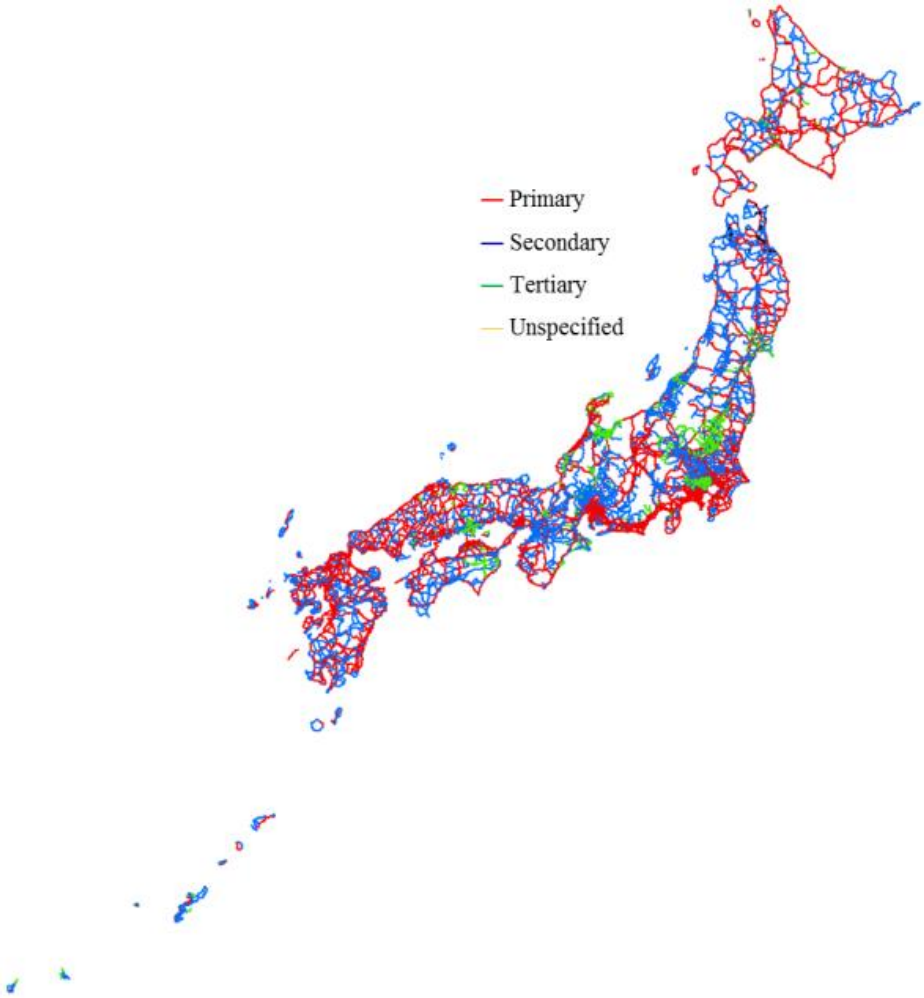

Figure 1: The road network diagram of emergency transportation road

4. Analysis of disaster risk of the emergency transportation road

4.1 The disaster risk due to earthquake

The disaster potential of the emergency transportation roads was analyzed for earthquakes, floods, and landslides. For an earthquake, the results of the analysis of these roads were overlapped within the predicted seismic intensity distribution.

Emergency transport roads were overlapped in each evaluation criteria listed in figure 2, where ① –④ denotes a hit probability by earthquake on the emergency transportation road is divided by color into 10 stages at the range of 0 to 1 about each of seismic intensity a little less than 5, a little more than 5, a little less than 6 and a little more than 6. ⑤ –⑩ are divided by color into 6 stages of seismic intensity less than 4.5 to more than 6.5 about the hit assumption on the emergency transportation road with exceedance probability of 30 years and 50 years. In any case, the Pacific side showed a dangerously high value of risk, and, at every measurement of seismic intensity, it is added to the Pacific side again, and even the Itoigawa–Shizuoka tectonic line was found to possess a large disaster risk in ③. In case of the probability of the occurrence of an earthquake with a seismic intensity less than 6, it is observed that the risk of the Kanto region is large, followed by Tokai. The risk of a capital earthquake directly above the focus in addition to Tokai and Tonankai region was also observed.

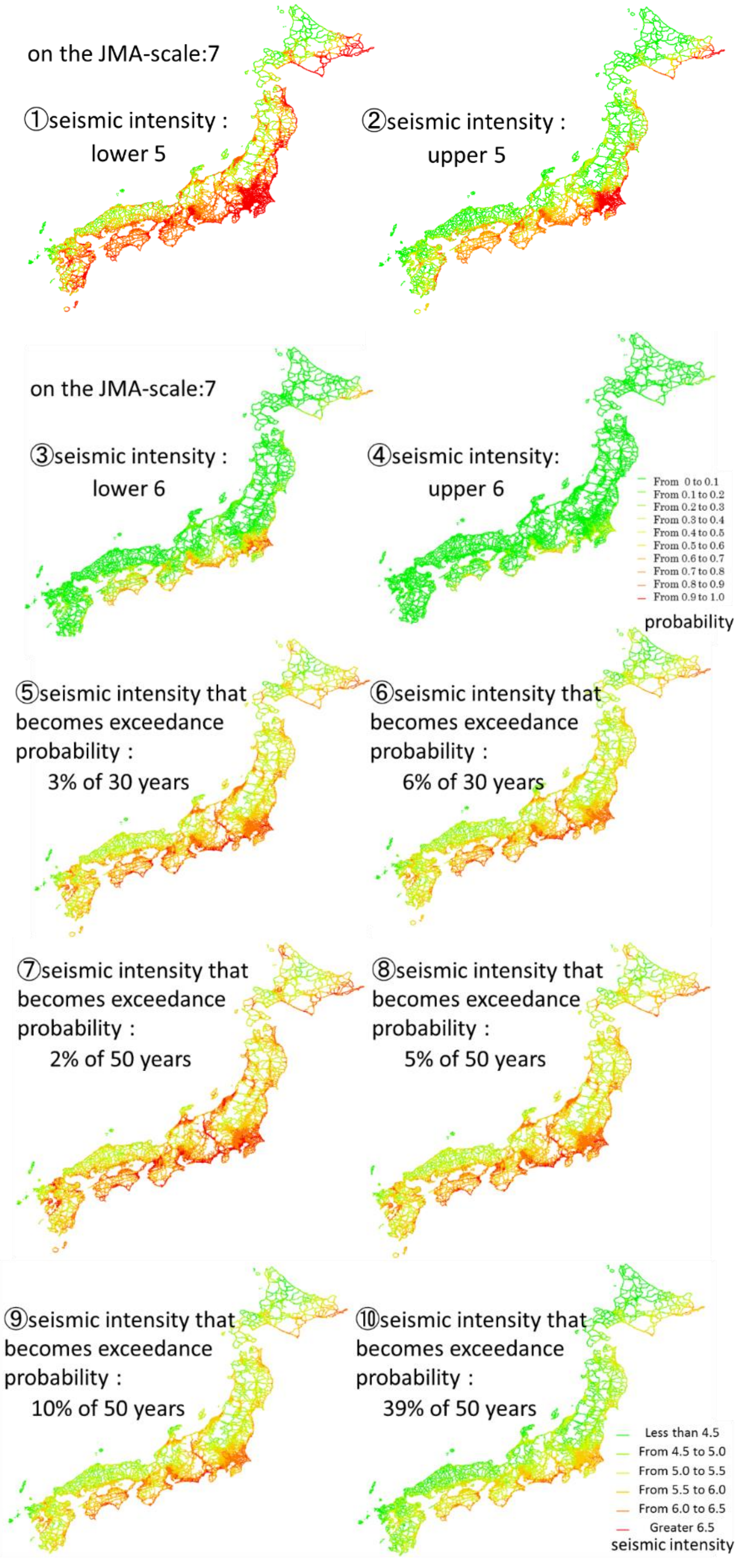

Figure 2: Disaster risk of emergency transportation road viewed with different predicted seismic intensity

4.2 The disaster risk due to landslides

For landslides, the overlap ratio of the emergency transportation roads and landslide danger zone was analyzed to determine the disaster risk in every metropolis and district. In addition, the overlap ratio was given by: (the extension of the emergency transport roads are duplicated in each hazard area) / (total extension of emergency transportation road). The disaster risk for each portion of an avalanche such as debris flow, steep slope place collapse, and landslide was also studied. Furthermore, the aggregate result of the primary road alone has been described in this paper. Figure 3 shows a graph that plots the overlap ratio for each item on the primary road.

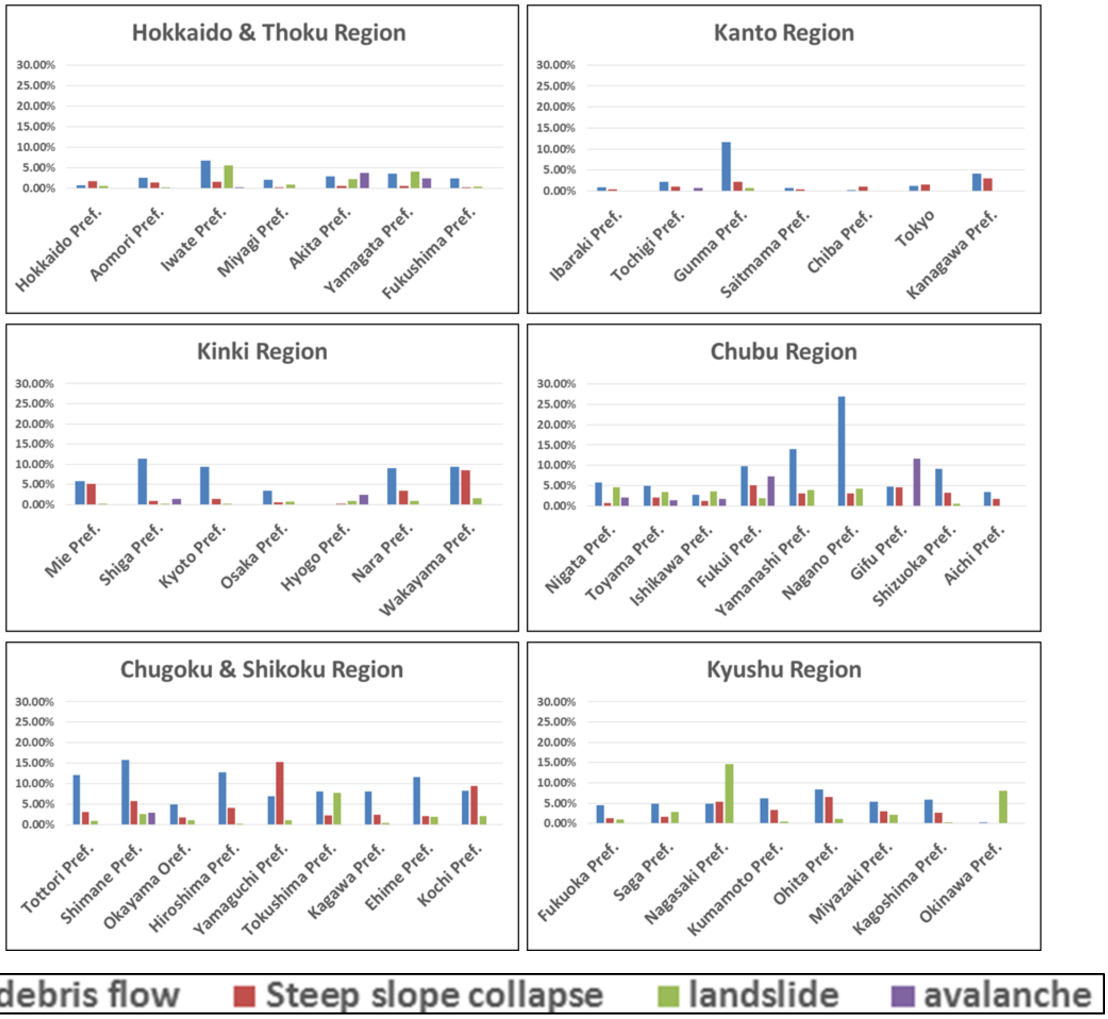

Figure 3: Overlap ratio of landslide disaster and emergency transportation road (primary road)

From Figure 3, it can be observed that the overlap ratios in the Chubu, Chugoku, and Shikoku districts were distinctly larger. Additionally, it can be noted that the Nagano prefecture has the highest ratio of debris flow compared to other prefectures. When comparing the highest values of each factor among different prefectures, it is revealed that the debris flow in the Nagano prefecture, steep slope collapse in the Yamaguchi prefecture, landslides in the Tokushima prefecture, and avalanche in the Gifu prefecture has resulted in most overlap. The analysis of the overlap ratio for each item for the secondary road can be seen in Figure 4.

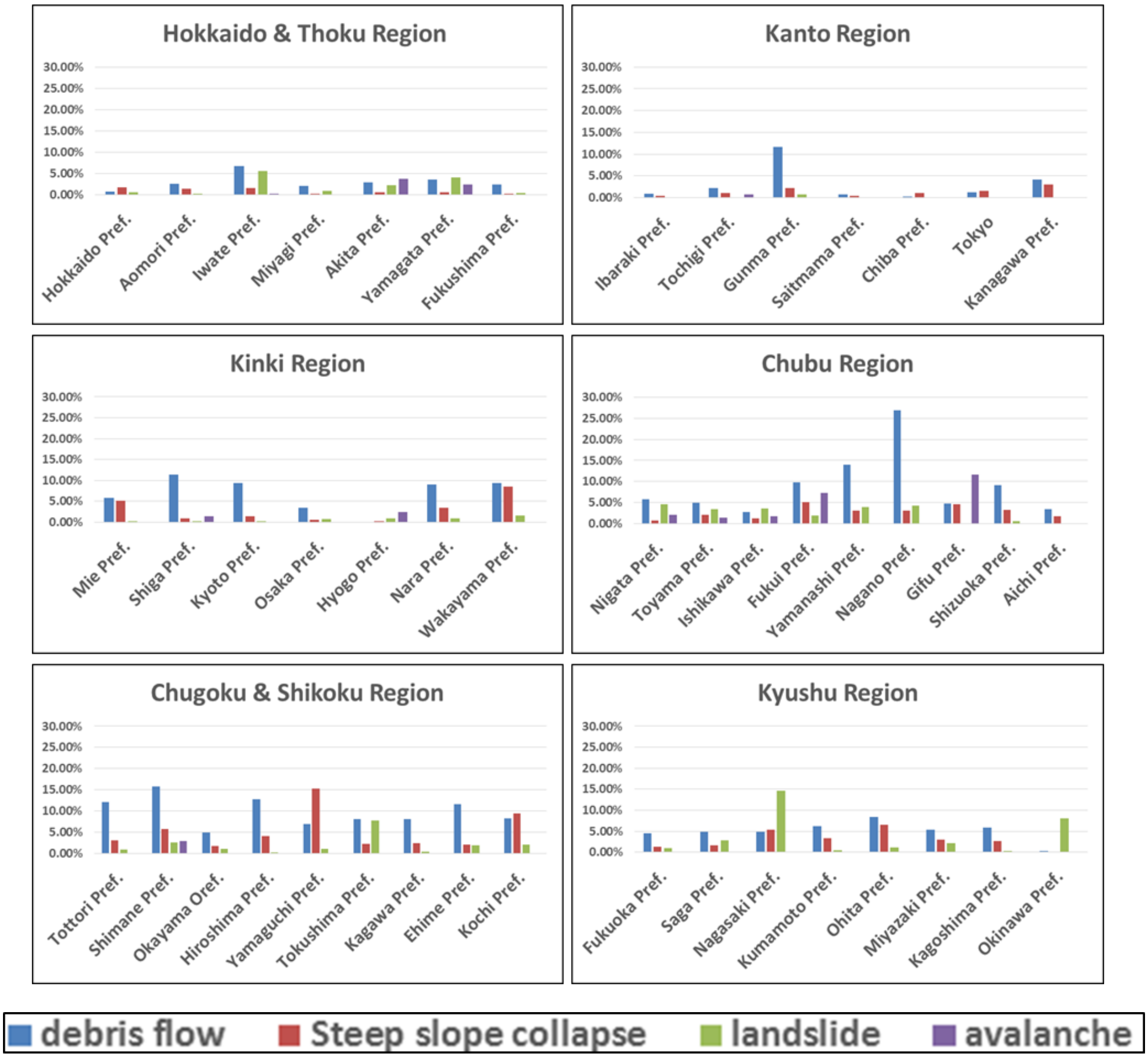

Figure 4. Overlap ratio of landslide disaster and emergency transportation road (secondary road)

The secondary road does not show a large difference in values when compared to each item of the primary road. While the risk of avalanche or landslide seems to have increased, the overall risk of each item has increased only slightly in most of the metropolitan cities and districts. The latter has a higher percentage of prefectural and municipal roads when compared to the former, and the reason behind the increasing percentage is that the roads chosen here are mountainous in nature. Additionally, it must be considered that the width of mountainous roads is smaller and slanted lines are lesser in number when compared to the roads in the city. For these reasons, there is a high risk of the road becoming impassable to traffic because of a landslide. Figure 5 shows a graph analyzing the overlap ratio for each item for the tertiary road.

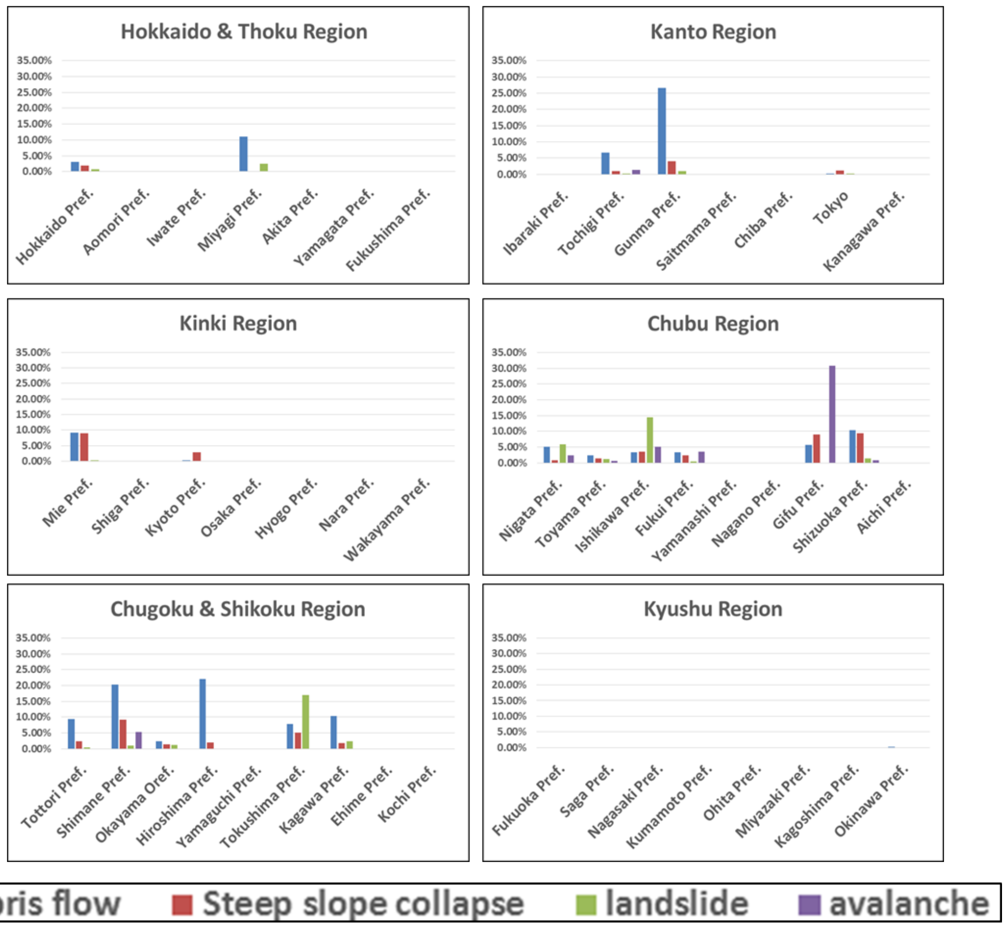

Figure 5: Overlap ratio of landslide disaster and emergency transportation road (tertiary road)

For studying the tertiary road, we have analyzed 18 selected metropolitan cities and districts. Compared to the primary and secondary roads, it is observed that there is a larger disaster risk in different parts because of an avalanche in the Gifu prefecture. As avalanches cause widespread damage, it seems that the road also becomes impassable at wide range in the same way. There is a high risk of avalanches in the case where the slope gradient is 35–45 degrees and consists of sparse vegetation, compared to slopes with shrubs and forests. It can be assumed that tertiary roads in the mountainous areas are concentrated on slopes such as the ones described above. The drop in the supplementation and the lack of function of the emergency transportation road in the metropolitan cities and districts is the result of the high disaster risk of the tertiary road.

4.3 Disaster risk due to flood

Similar to the disaster risk due to landslide, the duplicate ratio was analyzed by considering the flood assumption area and emergency transportation road in every prefecture. It can be noted that the disaster risk was analyzed by defining ‘flooded’ with 0.5 m for flood estimated areas, using data with boundaries of 0.5 m, 1 m, 2 m, and 5 m. This study was also designed to be consider transportation by car, with the exhaust port and non-driving motors completely flooded, to specify the rank. Figure 6 shows the graph that sums up the duplicate ratio for every designated rank.

Both primary and secondary roads show a higher overlap ratio in the Saitama prefecture, and the tertiary road showed a higher overlap ratio in the Niigata prefecture and the Hokuriku region of the Toyama prefecture. It should be noted that in the Saitama prefecture, the roads are concentrated around the river, which increases the risk of flooding due to overflowing. For the Hokuriku region, rainfall throughout the year is definitely a factor to consider. For the Toyama and Nigata prefectures, as the selection criteria for the tertiary road, the primary and secondary roads are set up here to contact the disaster prevention bases. This means that the overlap ratio of tertiary roads is high along emergency transportation roads, indicating that high disaster risks could be found in the areas around the disaster prevention centers.

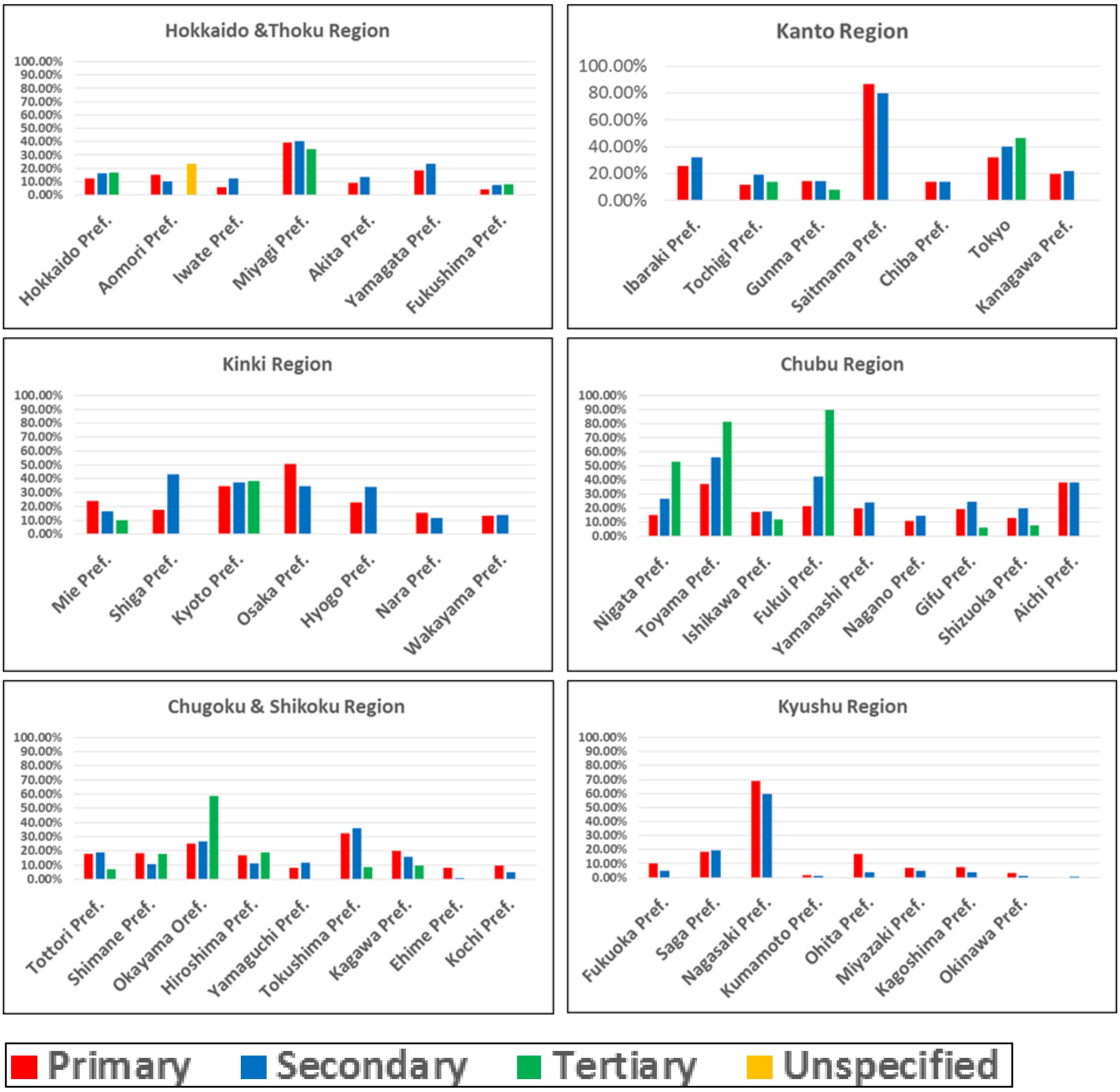

Figure 6: Overlap ratio of flood estimated areas and emergency transportation roads

5. The summary of this study and future plan

In this study, the disaster risk of the emergency transportation road network was estimated using three factors i.e., earthquakes, landslides, and floods. It was explained that an emergency transportation road was likely to be impassable to traffic at the time of the disaster. Regarding the earthquake, it was reealed that not only the Pacific side but also the tectonic dislocation carried a huge risk. It can be considered that the situation of broad-based transportation becomes difficult as the Itoigawa–Shizuoka tectonic line fault spread toward the north-south road network, which was split into east and west by the earthquake. Overlap was frequently observed in hilly and mountainous areas because of landslide disasters. When we consider a road in a mountainous region becoming impassable to traffic because of a landslide, then not only must the road itself be considered, but also the substitute characteristics of the road must be considered. A difference was seen between metropolitan cities and districts regarding flood risk. Because of a flood, a wide range area can be restricted regionally, and runs the risk of becoming impassable to the traffic above a certain level, in comparison to a landslide disaster. In this way, it was revealed that the disaster risk to the emergency transportation road was large even if we focused on individual hazards, such as earthquakes, landslides, and flooding.

In the future, we will study the importance of emergency transport roads, focusing on alternative issues such as the extent to which the roads are affected by avalanches and typhoons, combined with various kinds of seasonal hazards. We want to push this study forward with a focus on the probability of a hazard occurring in real life.

Chapter 5

Reachability Analysis between Prefectural Office and Municipal Offices While Considering the Disaster Risk of Emergency Transportation Road

In this study, it is intended to analyze the reachability between disaster prevention bases while considering the disaster risk of emergency transportation routes (ETR). Based on the lessons of Japan's Great Hanshin-Awaji Earthquake, emergency transportation routes set to provide rescuing activities and transportation of goods immediately after the occurrence of earthquakes. The emergency transportation routes connect with the expressways, general highways and main roads and also links together with disaster prevention bases which are designated by the government. There have been accomplished a lot of researches in respect of general road blockage due to collapse of the roadside building so far. But there have been only a few studies done about securing the emergency transportation routes until now. We analyzed the risk of emergency transportation route obstruction by flooding, road blockage by buildings collapsed caused by earthquake and clarified the reachability between disaster prevention bases e.g. the prefectural offices and municipal offices.

1. Background of the study

During the Kobe earthquake (Hyogoken-Nanbu Earthquake) that occurred in 5:46 January 17, 1995. The earthquake damaged the elevated structure, such as a highway, railway, blocked of road surface by the collapsed of roadside building, the capacity of the affected areas was significantly reduced. In addition, the traffic demand was different than of normal or ordinary time because of the evacuation activities after the accident occurred. It was started emergency and rescue activities, relief activities, in relation to the recovery and reconstruction activities, etc. From the fact that the main trunk line which is used for Japan's east-west traffic were damaged, the next day of disaster occurred e.g. on the 18th January, emergency transportation route 2 of the east-west has been set to compensate for the damage situation. However, to regulate the route only by the emergency vehicle was actually difficult. The above-mentioned contents are shown as a collection of Hanshin Awaji Great Earthquake Disaster Lesson Information book in aggregation with the emergency transportation by the road traffic of Cabinet Office As it has also been mentioned in the Great Hanshin-Awaji Earthquake lesson information book, road blockage caused by a roadside building collapse during the earthquake, that it can be assumed that the roads were impassible. In addition, such as flood damage on the road by the river flooding or building collapsed on the road by an earthquake is assumed not to be able to pass by traffics. There have been accomplished a lot of researches in respect of general road blockages due to collapse of the roadside building so far (Kondo et al., 2010; Ichikawa et al., 2004; Tamura et al., 2005). On the other hand, study about the road section that may become impassable due to a disaster, considering between certain two points, or connectivity that is impassable interval is guaranteed even in the event, or the arrival delay, such as how much arrival delay occurs, it is important from the point of view of emergency transport in the event of a disaster. But it is the present condition that such a study has not done sufficiently. Therefore, in this study, we analyzed the emergency transportation at the time of the river flooding, at the time of the earthquake using the emergency transportation route and analyze the section that might be flooded by the flooding, the section that it might block up by the collapse of the building of the emergency transportation roads. Based on the result, we analyzed it by network analysis about the reachability between prefectural offices and municipal offices e.g. city, town and village offices.

Table 1: Type and position of emergency transportation road

Type	Position
NO. 1 （1,102.4km）	High-standard highways-roads made transportation of wide important routes such as the General Highway and access roads
No. 2 （ 651.9km）	The emergency transportation road which links cities, towns and villages government office and link the important base with no.1 type
No. 3 （ 233.0km）	The emergency transportation road which link the cities, towns and villages government office branch and link no.1 & no.2 type

2. Evaluation of this study and arrangement of the related past studies

There are some researches on the evaluation of the road blockage caused by the earthquake (Kotani et al., Otani et al. and Akakura et al.). They show the risk evaluation formula of a road obstruction and extracts the environmental characteristics which is a factor to be advanced or suppress the obstruction by the damage aspects from those roads (Kotani et al.). Furthermore, by using the evaluation formula, we divide the Kanazawa city roads into 53 routes, which analyzes the different road blockage risk and road damages appearance by routes. Otani et al., write about the spread of cities and towns include (10 km square) factors that affect the disaster of road immediately after the earthquake. They also write about district facilities, such as road and highway facilities, such as road, bridge, footbridge and pedestrian bridge, roadside private facility (on the ground), water pipe, gas pipe, assesses the impact of road blockage by calculating the traffic capacity expected from it and set the private facilities (underground) considering each affected function fitting road blockage effects. Akakura et al. shows the model outbreak of the street blockage by earthquake vibration strength and street width and perform a damage prediction when Yokohama-shi center caught the earthquake of the scale equal to the Great Kanto Earthquake. In addition, there is the study example of the road blockage that utilized GIS. Minamoto et al. creates a road network that has applied for a prediction of the road obstruction. Minamoto et al. settle down a blockage probability calculation model and estimated blockage probability according to the collapse of the road side building, they divided the road's width of less than 4m and the road's width of more than 4m and less than 8m.

There have been researches about the evacuation at the time of the disaster that was focused on road blockage, and also studies in the wide area disaster (Kondo et al., Ichikawa et al., and Tamura et al.). Hypothesis of Kondo et al. about street blockades, motions for damage to bridges, landslides collapse of the slope failure hazard area, specify the landslide site, districts control of sand erosion, tsunami inundation to road construction, and model isolated communities. Ichikawa et al. flow out the debris opens in all directions and width sets a collapse model to determine to the building height of the building individual and judges the road captivity basis on GIS. Tamura et al., have done the evacuation simulation at the time of tsunami inundation that takes into account the fact that street blockage occurs due to building collapse during an earthquake. Above in the previous studies, has focused on road obstruction by ground motion and multiple disaster (Kotani et al., Otani et al., Akakuraet al., and Minamoto et al.), the blockage situation of the road in the target areas in (Ichikawa, et al., Kondo et al.) isolation of days caused by the road blockage caused by the disaster in the village in the target area, Tamura et al., has a perspective of evacuation simulation from the flood damage caused by the tsunami in consideration of the road blockage caused by the ground motion. Therefore, this study stands in a viewpoint called the emergency transportation in consideration of the collapse of the building by the earthquake vibration. In addition, as an impassable factor by the flooding damage of the road, we intend for a tsunami, but assume it river flooding and marshes in this study. From the perspective of building collapse, this study follow as well as the Akakura et al., Ichikawa et al., and Minamoto et al., but while those studies are intended for a relatively limited area, whereas this study targeted a wide area e.g. between metropolis and districts agency and city and district town and village offices during emergency transport. Also, when the analysis of the road obstruction due to building collapse, Minamoto et al. and Ichikawa et al. used the GIS as well. However, Minamoto et al. calculate the probability of road blockage in consideration of the road's width and they did not consider the height of the building. In this study, we determine the blockage of the road by the height of the building.

3. Evaluation method of the disaster risk of ETR and construction method of the ETR network

3.1 Data source of emergency transportation road network

In this study, we use the emergency transportation roads of the national numerical land information data. These data is to create a route shape, division of the emergency transportation road, road classification, a route name using a local disaster prevention plan, the documentation about the emergency transportation road network plan which are organized by the metropolis and districts.

3.2 Evaluation method of the disaster risk of ETR caused by the river flooding

As one of the factors that emergency transportation road becomes unusable, it can be considered flood damage. In this study in order to assess the flood damage of ETR, it has been received the use of anticipated flooding zone data of the country numerical information inundation assumption area and assumed inundation depth at the national scale. Bedside the flooding assumption, in this data it is organized the immersion depth of the river and data plan rainfall of the object such as underlying the specified inundation assumption area. Inundation is divided into 5 or 7 level shown in table 2.The situation where the road becomes unusable by flooding, in this study it is defined as the depth of immersion; car becomes impossible of traveling. Generally, depth immersion of the automobile is unable traveling are the depth of the floor of the vehicle are flooded.

Table 2: Inundation depth level and road conditions

Inundation Depth Level		Road Condition
5 Levels	7 Levels	
below 0 ~ 0.5m	below 0 ~ 0.5m	Not flooded
below 0.5m ~ 1.0	below 0.5m ~ 1.0m	Flooded
below 1.0 ~ 2.0m	below 1.0m ~ 2.0m	
below 2.0m ~ 5.0m	below 2.0m ~ 3.0m	
above 5.0m	below 3.0m ~ 4.0m	
	below 4.0m ~ 5.0m	
	above 5.0m	

Therefore, of the Table 2, to evaluate as a section that emergency transportation road inundation depth to exist in inundation assumed within the area that fall into more than 0.5m may become unusable by flooding when the rivers flood. In addition, the flood zone of emergency transportation road, as shown in Figure 1, the emergency transport roads and inundation assumption area data of the country numerical information when it is piled up on a GIS, both of interval were completely matched.

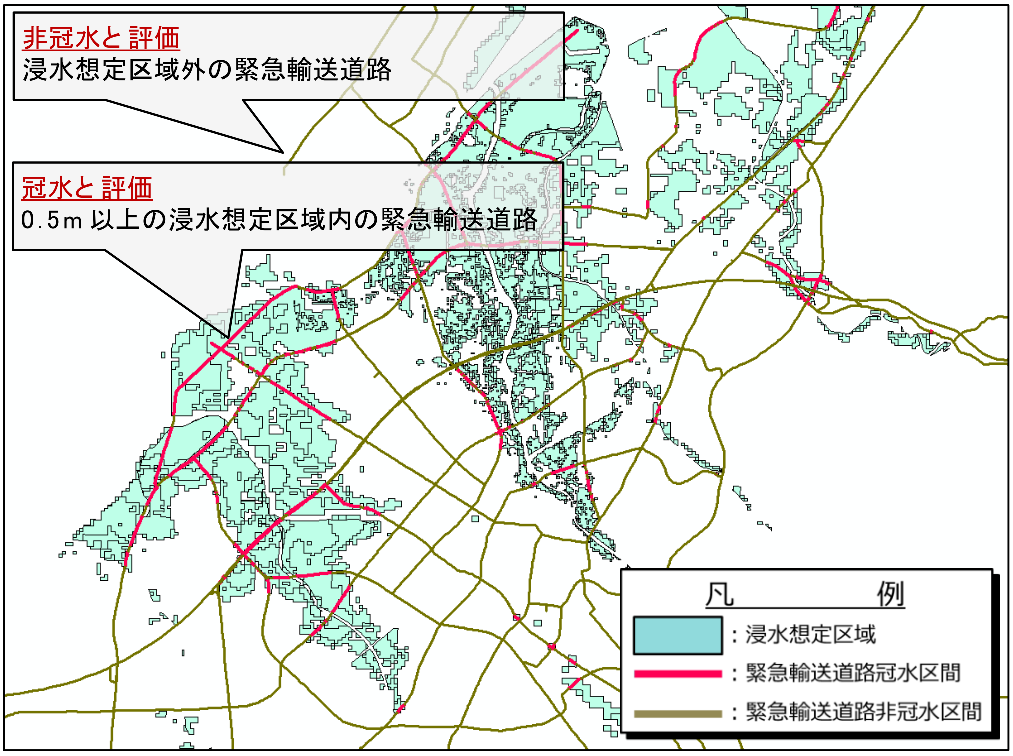

Figure 1: Evaluation of conceptual diagram of the inundation zone of the ETR

3.3 Evaluation method of the risk related to building collapse and road blockage caused by the earthquake

Another factor that emergency transportation road becomes unusable, it is thought that buildings along the roadside comes to collapse on emergency transportation road at the time of the earthquake. To evaluate the risk of a road obstruction by buildings collapsed, it is required the data of the position and height of building, construction time and about the structure of the building, etc. Such kind of data is what is freely available with a limited amount of information, if further directed to a wide range of area as in this study, the data's availability is almost nil. Therefore, we tried to make the data available to understand the height and position of the building in the present study. We were using the data creation of a detailed map 201 214 provided by the ESRI Japan. This data is a background map database that has been developed by processing and map data of the ZENRIN Co., Ltd., and base map information and national land numerical information of the Ministry of Land, Infrastructure and Transport. That is, a variety of information on the map data of the individual. The data about the desired building are included in this study, kind and height of the building are compiled into a database. Incidentally, the height of the building has been considered by one floor per 3m, the type of buildings are uniquely classified. Such data can take advantage of the position and height as possible grasp of the building data. It shows the data of the above example in Figure 2.

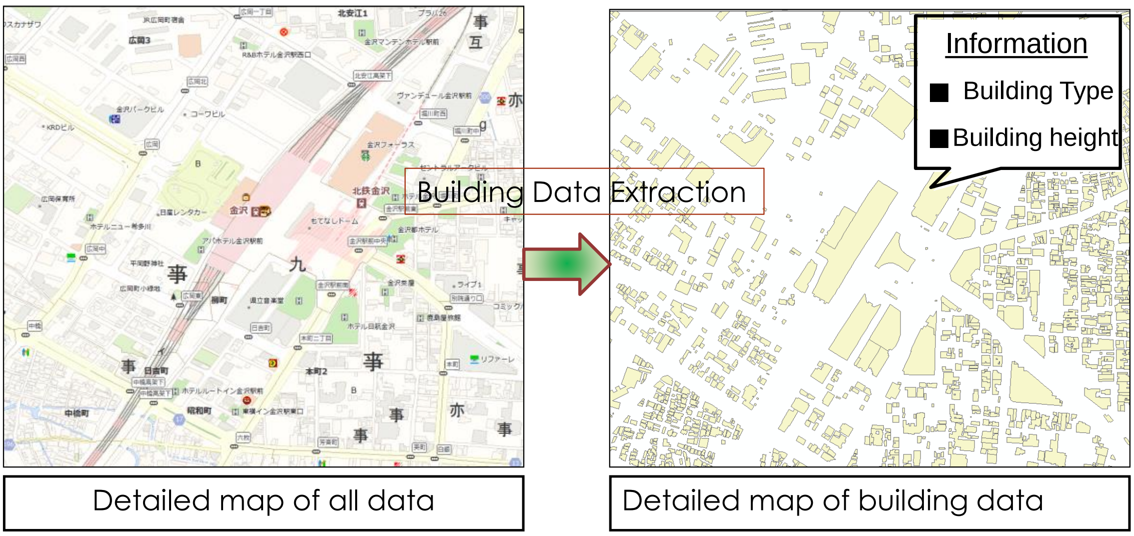

Figure 2: Example of all detailed map data and building data

However, in order to consider the building collapse due to earthquake, it is further necessary the structural form information of the building such as building ages. The structure type of the building, were classified as wooden and non-wooden as shown in Table 3 according to the classification of the data. The building classification that are assigned to the residence was a wooden, but also includes high-rise dwellings, such as apartment in this classification. For this reason, the fourth floor or more of the building (building height is more than 9m) it was classified as non-wooden. From the fact that information is insufficient with respect to building age, it is assumed that all in the present study is a building that was built with the latest building standards. By this assumption, its results for the building collapse indicated by this study and it will be a minimum damage estimation of the case. Building data created in the above steps, in government buildings not to appeal all the data. Therefore, in areas along emergency transport roads, and to extract only the data that affect the obstruction of emergency transportation roads to collapsed buildings.

Table 3: Classification of structural form by building type

Type of Building	Structural Form	Type of Building	Structural Form
Target object(Accomodation facilities)	Non-wooden	Target object(Public facilities)	Non-wooden
Target object(Commercial facilities)	Non-wooden	Target object(Hospital)	Non-wooden
Target object(School)	Non-wooden	Target object(Transport)	Non-wooden
Target object(ammusement park etc)	Non-wooden	General house (and other) o below 3rd floor	Wooden
Target object (Target object)	Non-wooden	General house (and other) above 4th floor	Non-wooden

If a building affect the emergency transportation road when collapsed it is evaluated based on the positional relationship between the height of that building and the place where it is collapsed on the road. It shows the extraction flow diagram of the building that affect the emergency transportation road in Figure 3. Extraction of the building, to determine the center of gravity of the building, from the center of gravity obtained, after drawing a circle to the height of the building as a radius, the building affects the emergency transportation roads when the road including within the circle. It performed in the procedure that is extracted as a given building. For buildings along emergency transport roads we created in this step, J-SHIS earthquake hazard stations are exposed by earthquake motion estimation map, to determine if there is a possibility of suffering from the shaking intensity of the extent to which expected seismic area grid.

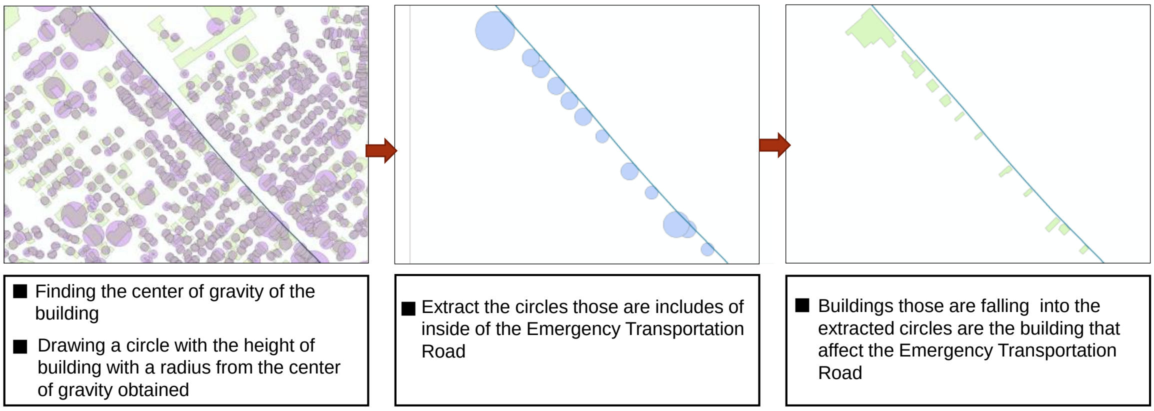

Figure 3: Extraction flow diagram of the building that affect the emergency transportation road

By performing extraction and assumed measurement seismic intensity determination data creation and data necessary as described above, data for evaluating the risk of blockage the emergency transportation roads by building collapse caused by an earthquake are associated. In order to evaluate the risk, for these data, it applies the damage function of the building due to an earthquake, to determine the total collapse probability of each building. Then the random simulation, it is determined whether or not the building is destroyed, if it is destroyed then assessed that building occurs a road blockage in the emergency transportation roads adjacent.

3.4 How to build an emergency transportation road network in consideration of disaster risk.

Figure 4 shows a conceptual diagram of how to build an emergency transportation road network when considering disaster risk. Emergency transportation road network when considering disaster risk e.g. deleted network as an impassable section of the affected part of peacetime emergency transportation road network. Therefore, when considering the flooding of the road by the river flood deletes the submerged section, when considering a road obstruction caused by building collapse due to the earthquake, the results of random simulations, road building, which is determined to be destroyed due to an earthquake is adjacent it is sufficient to remove a section. The link connecting the emergency transportation road network and shelter is required in order to perform network analysis. This link we created as a straight line of the shortest connecting from the shelter to the nearest emergency transportation road.

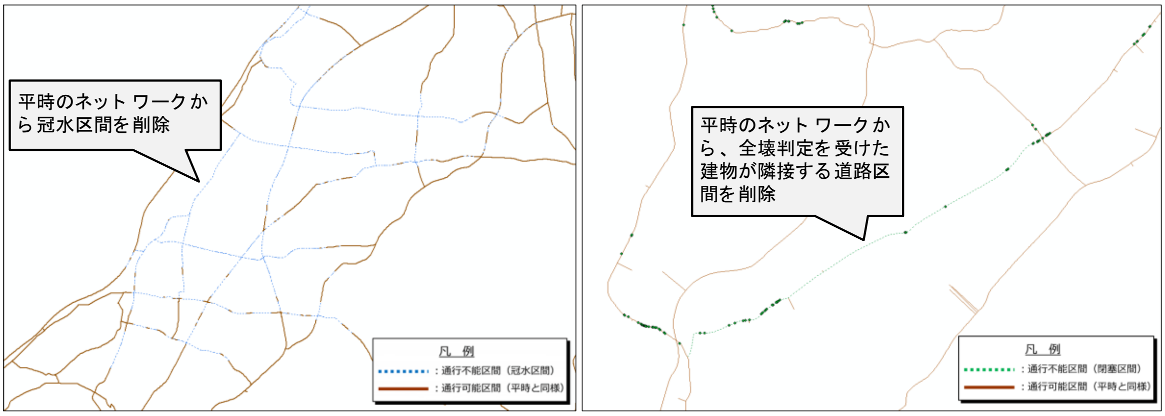

Figure 4: How to build a conceptual diagram of ETR network in consideration of disaster risk

4. Analysis of reachability between Prefectural and municipal offices

4.1 The target area, factors of disasters and impassable of emergency transportation road, and municipal offices.

The study area is intended for Niigata, Toyama, Ishikawa, Fukui, Nagano and Gifu Prefecture. Figure 5 shows the emergency transport road network of peacetime and it is studied by each prefecture. It is intended for disaster in both river flooding caused by earthquake and rainfall and complex cases. The impassable factors of emergency transportation road, it is assumed and the obstruction of emergency transportation road caused by the collapsed of the road side building by an earthquake, a flood of emergency transportation road by the river flooding. It indicates the targeted number of local government office in Table 4. Municipal office of concern, was set on the basis of the municipal office data of digital national land information.

Table 4: The number of targeted municipal offices of 6 prefectures to be analyzed

Niigata	Toyama	Ishikawa	Fukui	Nagano	Gifu
36	15	19	17	77	42

The present data about the special districts and municipal offices of nationwide is the time of August 31, 2014. It is included about the main offices and their branch offices, their locations, respectively personal and their name and designations. However it extracts only the Prefectures from the agency data for national and prefectural of the country numerical information about six Prefecture and used in the analysis.

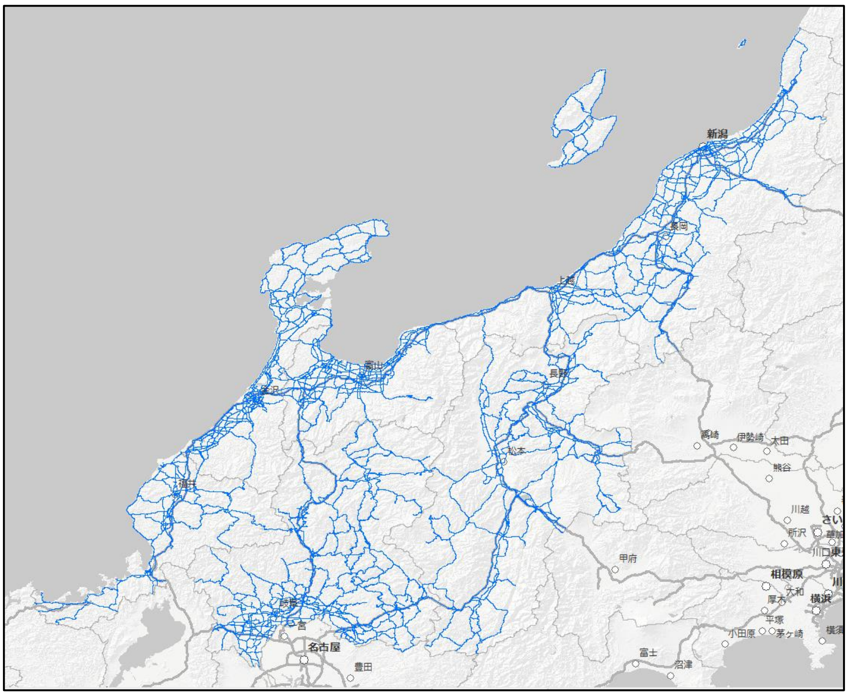

Figure 5: Emergency transportation road network diagram of peace time in the target area

4.2 Analysis of reachability between the prefectural government and the local government office in consideration of the flood of emergency transportation road by the river flooding.

The emergency transportation road section that may flood is caused by river flooding in Figure 6, we show the emergency transportation road network in consideration of immersion depth was evaluated as it is described in section 3.2 in which there is a risk of flooding the road section to be than 0.5m. It is revealed the effect to the reachability in this study, from the Prefectural Government office using emergency transportation roads to each local government office trying to reach emergency transport roads in the case of river flooding. Therefore, the data is shown all emergency transportation roads contained 0.5 m or more in the flooding expected area. The flooding is expected in the area of sections impassable due to flooding. In Table 5, it shows the numbers of unreachability and delays to the municipality offices while considering the flood risk of emergency transportation road.

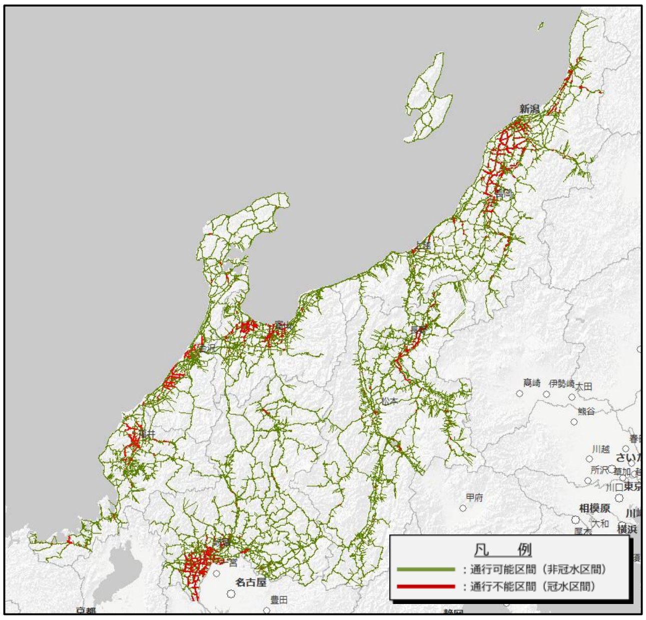

Figure 6: Emergency transportation road network diagram in consideration of the flood risk

Table 5: Numbers of unreachability and delays to the municipality offices while considering the flood risk of ETR

Prefectures	Niigata	Toyama	Ishikawa	Fukui	Nagano	Gifu
Target no. of municipal offices	36	15	19	17	77	42
Number of unreachability	16	14	16	16	35	41
Percentage of unreachability	44.4%	93.3%	84.2%	94.1%	45.5%	97.6%
Number of delays	18	0	2	1	35	0
Percentage of delays	50.0%	0.0%	10.5%	5.9%	45.5%	0.0%

In addition, it shows the service area from the normal time of the prefectural government at the time of flooding consider using emergency transportation road network of six prefectures that targets in figure 7. From table 5, it suggests that the flood risk that could become unreachable on emergency transportation road connecting the prefectural government and municipal office in any of six prefectures is abundant. In particular, Toyama Prefecture, Fukui Prefecture, Gifu Prefecture, local government office that can be reached without the risk in Ishikawa Prefecture is limited. Toyama, Fukui, Gifu Prefecture is through the river near the prefectural government, for emergency transportation road with flood risk is dense, it becomes a state of emergency transportation road network has been cut off in the vicinity of the prefectural government. The service area shown in figure 7 has become a result that does not extend only a small range in the vicinity of the prefectural government. Also, unlike these three prefectures, but it will not be cut off emergency transportation road network in the vicinity of the prefectural government, because it is a long and narrow terrain from north to south, is limited emergency transportation road that can be moved to the north-south direction. In addition to this, these emergency transportation roads and through rivers in the form of crossing, and has a form of access to the north and south are shredded from the Prefectural central portion of a flood risk existing in the surrounding. For this reason, it became a result of the service area is extended only to the province center. For emergency transportation road network in the northeast portion is cut off because of the flood risk from rivers flowing through the province northeast in Nagano Prefecture, that there is a part to reach impassable interval and, reaching through the northeast from the prefectural government. It is because within the municipal offices can be reached in the shortest, also the delay has occurred in many cases. In the Niigata Prefecture, there is presence of flood risk in a wide range of emergency transportation road by the Shinano and Agano, but because the county center does not exist rivers, by emergency transportation road passing through the area of north-south it can be read from figure 7 that the connection of emergency transportation road network is barely maintained.

4.3 Analysis of reachability between Prefectural government offices and municipal offices in consideration of buildings collapsed that make the road blockage by the earthquake.

The assumption of ground motion for consideration of the building collapse, it is conceivable to use a stochastic ground motion expected to map and scenario earthquake. In this study, we aimed to analyze the affected possibility of emergency transportation road upon comprehensively considering disasters that might occur in the future. Because the scenario earthquake is only one of the earthquake which may occur future utilize probabilistic seismic hazard map we are comprehensively predict earthquakes which can occur in the future. As a result it can be analyzed the likely disaster emergency transportation roads from a long-term perspective, and will prove useful to the disaster measures and priority selection.

As we consider the building collapsed due to an earthquake, in the present study measuring seismic intensity distribution in the case of a 2 percent of 50-year exceedance probability of the J-SHIS earthquake hazard station probabilistic seismic hazard map (figure 8) is used. In addition, demolished curve rate (Figure 9, figure 10) that have been shown in Tokyo disaster prevention envisioned as damage function of the building was adopted. It gave a total collapse rate in building data created by the procedure described in 3.3

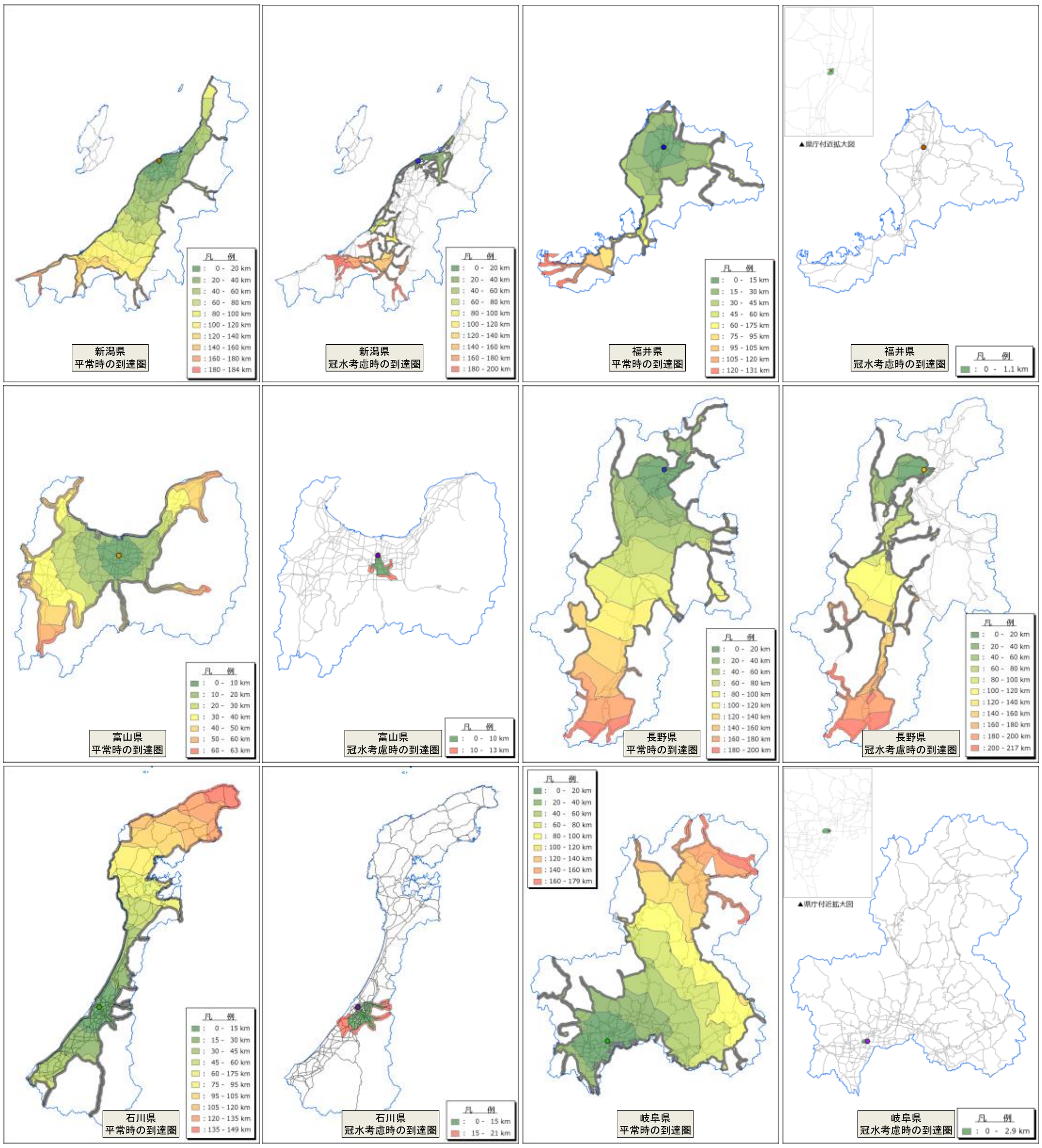

Figure 7: Service area from the core capital of six prefectures using ETR in peace time while considering flood disaster.

The height of the building has been calculated according to rank as the one floor or per floor is 3m. In other words, it has become a value of height 15m as long as it is a building of five-story. In addition, the type of building has its own classification. Such data can be used as available building data to understand the position and height. As shown in Fig. 2, we extract only the data which is related to the buildings form the information of detailed map. The type and height of the building is a database. However, in order to consider the building collapsed due to the earthquake, it is further needed the information of building structures. The structure type of the building, were classified as wooden and non-wooden as shown in Table 3 according to the classification of the data.

All of this research is assumed to be a building that was built in the current building standards. With this assumption, the risk of road blockage due to collapse of the building indicated by the present study is the minimum damage estimation case.

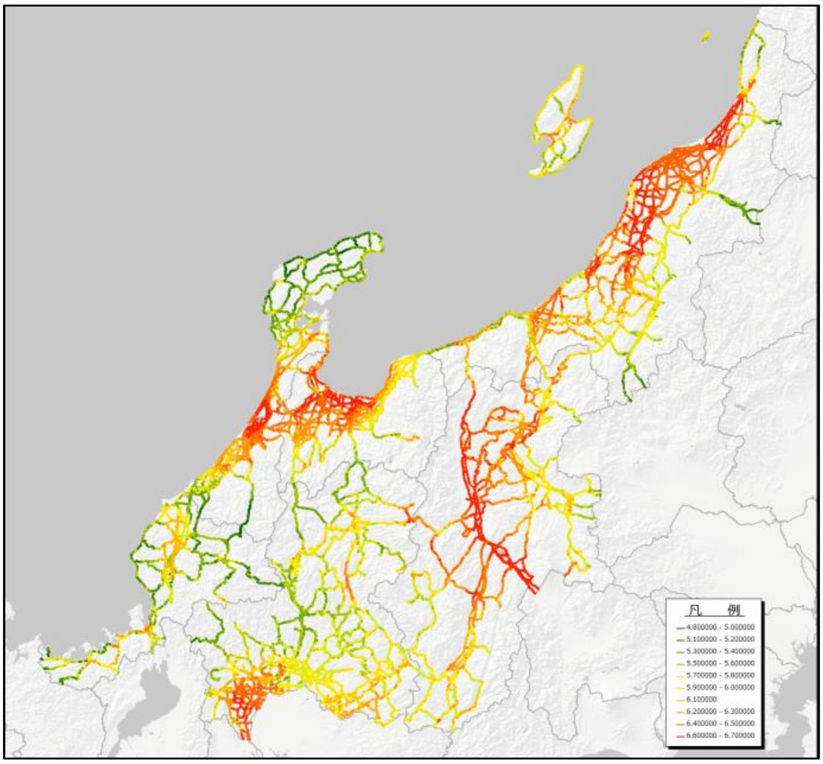

Figure 8: Distribution on ETR of measuring seismic intensity which is a 2% of 50 years exceedance probability

Numbers of buildings along emergency transport roads, 0 to 100 in increments of 0.1 random-number generation, exceeding the rate of collapse occurs and completely destroyed the building, choking emergency transport roads adjacent to and building collapse simulation. Emergency transport road network by considering the road blockages shown in Figure 11. However, in this study it shows one time random simulation. It shows a comparison result of the emergency transportation road network at the peace time in Table 6. In addition, it shows the service area from each of the prefectural government in the case of considering the building collapsed due to an earthquake in six prefectures in Figure 12. In this simulation, exception of Niigata and Nagano Prefecture, all the other four prefectures, there was no unreachable occurrence in the municipal offices. On the other hand, in the five prefectures except for the Niigata Prefecture has resulted in municipal office a delay occurs before reaching occupies the majority. From Figure 12, the service area in any of the six prefectures subject extends widely in the prefecture whole area. However, as is evident from Figure 8 in Niigata and Nagano Prefecture, the emergency transportation roads with high measurement seismic intensity is expected to have abundant.

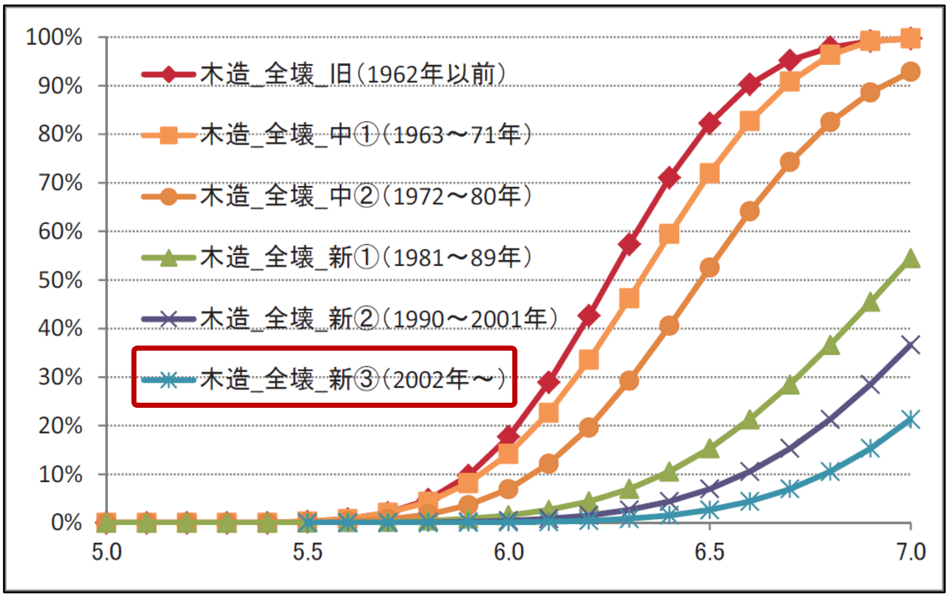

Figure 9: Fragility curves of wooden building

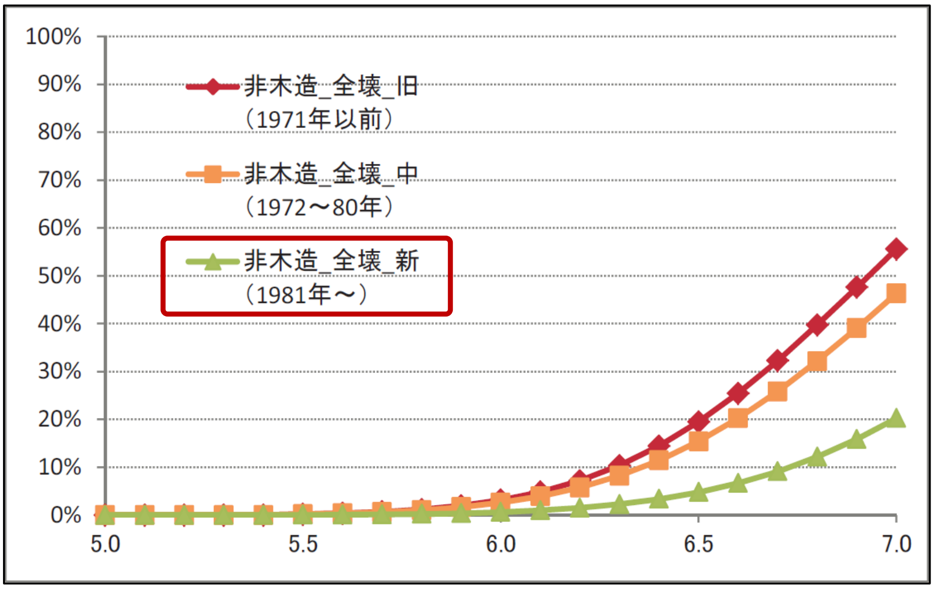

Figure 10: Fragility curves of non-wooden building

Like these two prefectures (Niigata and Nagano), there are some region of Ishikawa, Toyama and Gifu Prefecture where the emergency transportation road is expected to high seismic intensity. As part of the road is blocked, it is possible to substitute other emergency transportation roads in these three prefectures, and they will not be unreachable. However, a delay occurs when a such a road block section overlap each other on the shortest route to the municipal office. From this fact, it is considered to be a road block section caused by the building collapse was overlapped in these shortest path in five prefectures exception of Niigata Prefecture.

So, there is a clear tendency to highway blockages by roadside buildings in this two prefectures. In addition, emergency transportation roads such high seismic intensity is expected to be present enough in the network is sparse part. It cannot be substitute any other emergency transport roads resulted from collapsed buildings in these areas. There are some partially unreachable regions can be read from Figure12.

Table 6: Number of unreachability and delays to the municipal offices when considering the building collapsed and road blockage caused by the earthquake

Prefectures	Niigata	Toyama	Ishikawa	Fukui	Nagano	Gifu
Target no. of municipal offices	36	15	19	17	77	42
Number of unreachability	3	1	0	0	9	0
Percentage of unreachability	8.3%	6.7%	0.0%	0.0%	11.7%	0.0%
Number of delays	9	14	19	17	58	42
Percentage of delays	25.0%	93.3%	100.0%	100.0%	75.3%	100.0%

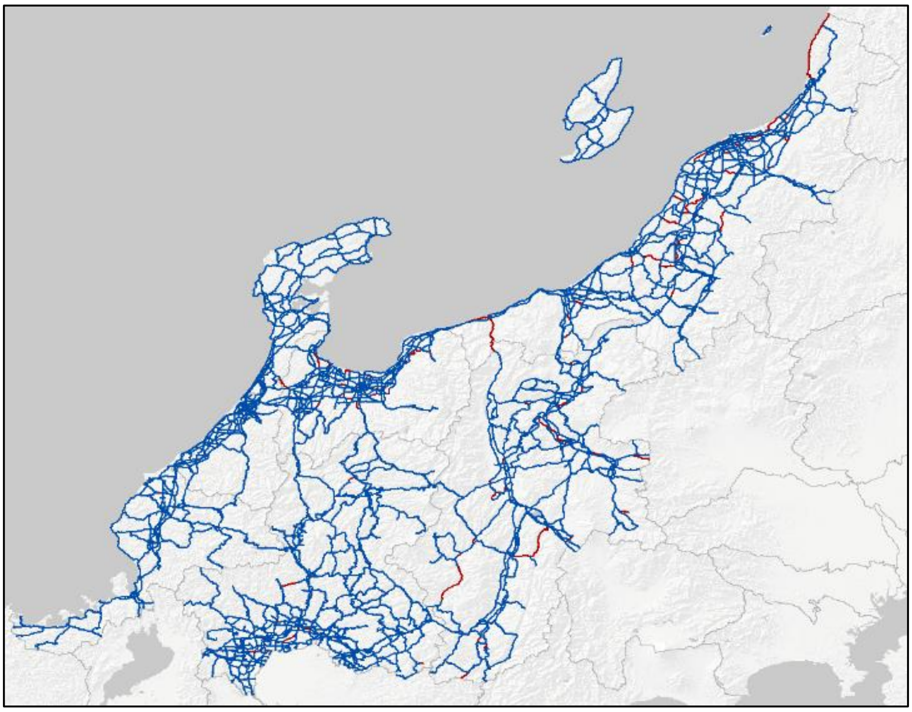

Figure 11: ETR network in consideration of the building collapsed and road blockage caused by the earthquake

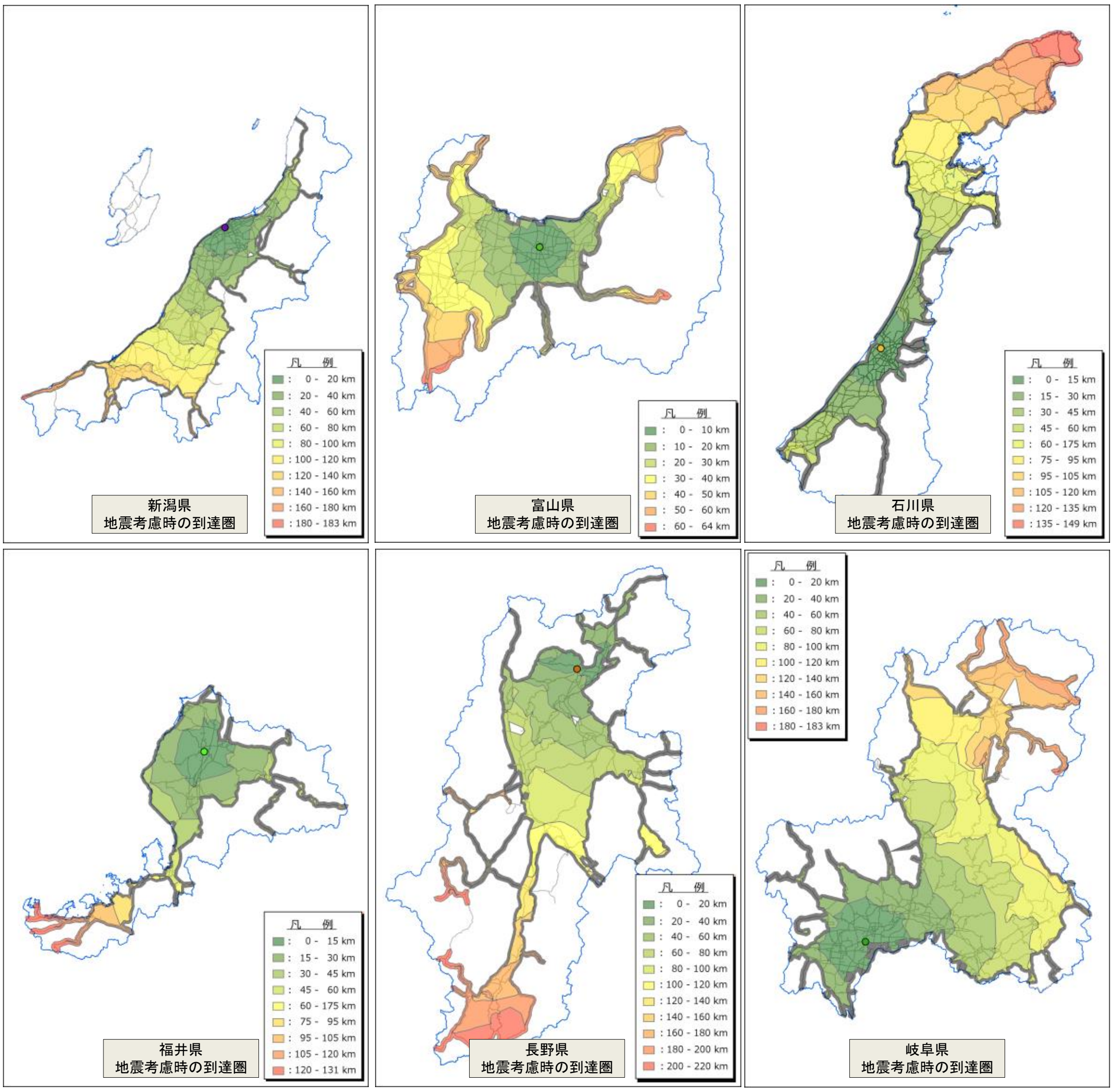

Figure 12: Service area from the core capital of 6 prefectures with ETR at the time of building collapsed due to an earthquake

4.4 Analysis of reachability between the Prefectural and the local office in consideration of the complex case of earthquake and river flooding

In the Great East Japan Earthquake that occurred on March 11, 2011, it was not only the earthquake, a number of disasters such as tsunami and fire disaster occurred in combination and resulted in extensive damage. In recent years natural disasters have been occurred frequently those are not only individual disasters, they are in form of a number of disasters or complex disaster. Therefore it is increasing the importance of analyzing the damage in the case of complex disaster. Based on this background, in the present study, consider the flood of emergency transportation road by the river flooding, the road blockage and cases that occur at the same time due to the building collapse caused by the earthquake. Emergency transportation road network to be analyzed in this case is a network that was all the intervals has become impassable in each disaster case, as shown in Figure 13. It should be noted that the present case is to be referred to as a complex case. It shows a comparison result of the emergency transportation road network at the peace time in Table 7. It also shows the service area from the prefectural government of a complex case in the six prefectures subject in Figure 14. Than the influence of road obstruction due to building collapse by earthquake in all prefectures in Figure12. From table-5, table-6 and Figure 7 which is a big impact of flooding by the river flooding. The overall result is reaching the municipal office becomes difficult when the road blockage by buildings collapsed overlaps a section that is generally not influenced by the flood.

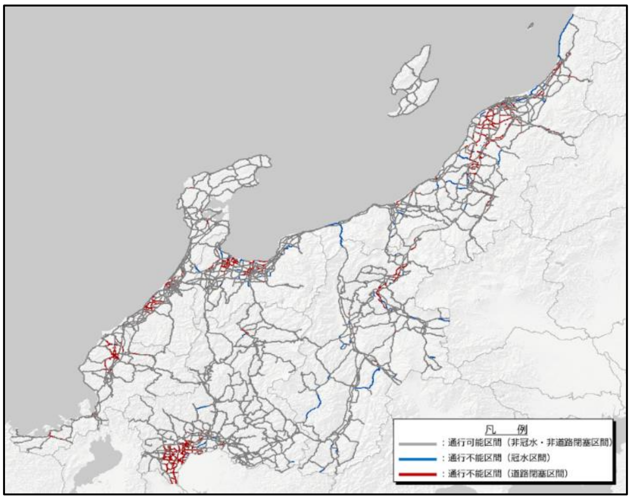

Figure 13: Emergency transportation road network diagram in consideration of the complex case

Table 7: Number of unreachability and delays to the municipal office of the complex case

Prefectures	Niigata	Toyama	Ishikawa	Fukui	Nagano	Gifu
Target no. of municipal offices	36	15	19	17	77	42
Number of unreachability	18	14	16	16	67	41
Percentage of unreachability	50.0%	93.3%	84.2%	94.1%	87.0%	97.6%
Number of delays	16	0	2	1	9	0
Percentage of delays	44.4%	0.0%	10.5%	5.9%	11.7%	0.0%

From Table 7, it can be seen, in the Niigata and Nagano Prefecture, impact of flooding was less than another prefecture, but the local government office to be a maximum unreachable in Nagano Prefecture has occurred. In particular, in the Nagano Prefecture, but only affected by flooding the road network had been kept connectivity in the north and south, was revealed from the service area of Figure 14. That caused road blockages caused by collapsed buildings in the sector was not affected by the flooding, extends only to the northern side of Prefectural Government is impeding North-South service area. On the other hand, Niigata Prefecture, is a network that connects the north and south of the prefecture at the impact of the flooding had become sparse, it did not overlap with the road obstruction by building collapse in the interval. In Nigata, it is not observed significant steep of unreachability of the service area, such as the Nagano Prefecture. Also, it can hardly reach to the provinces north and south of the municipal office in the impact of the flooding in the Ishikawa Prefecture. But no change was observed in the area which were affected by the earthquake in the middle part of Ishikawa. The network has received a devastating impact by flooding in Toyama, Fukui and Gifu Prefecture, from that section in which connectivity is maintained was very limited from the prefectural government, though the impact of the earthquake is not seen.

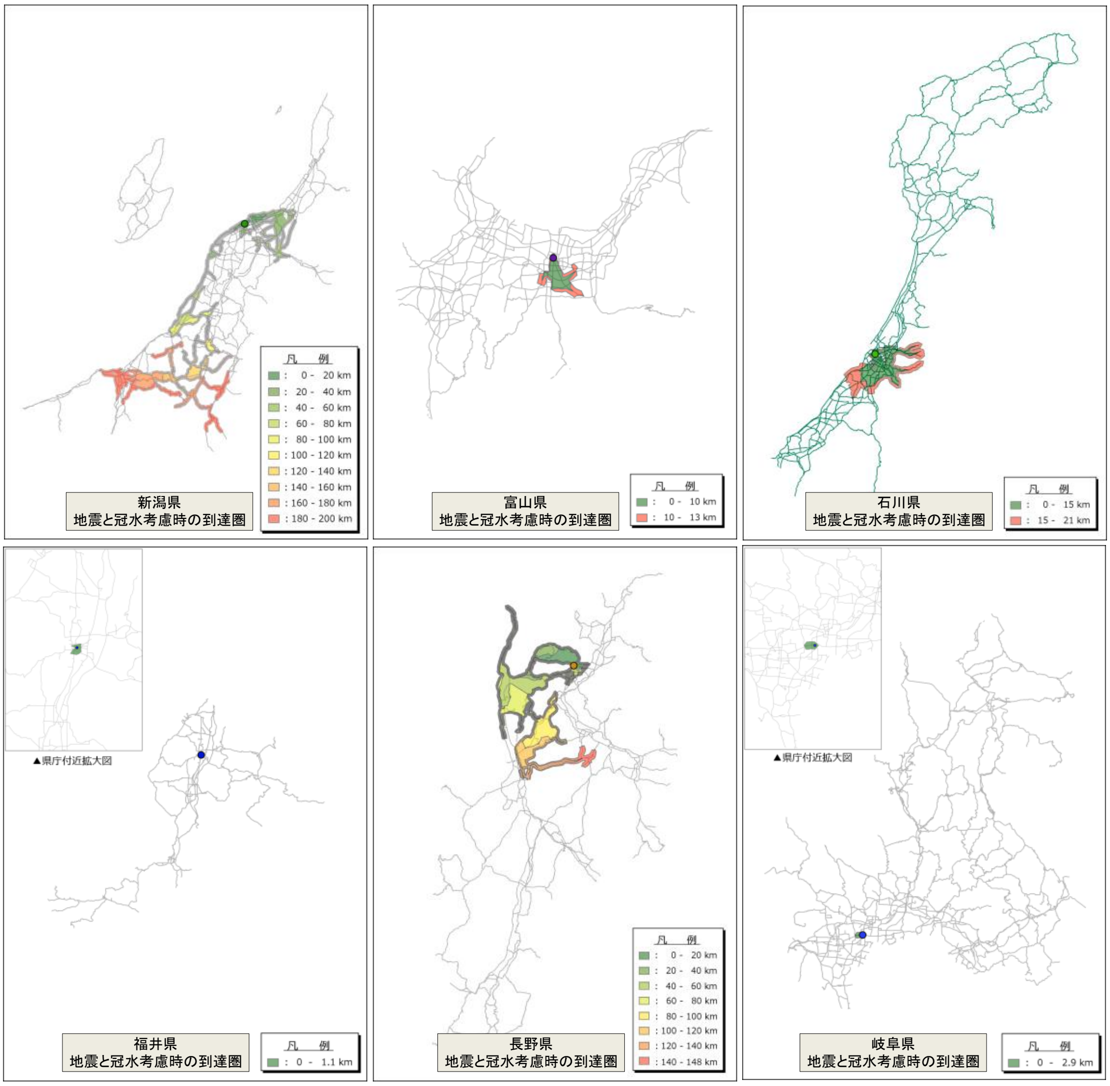

Figure 14: Service area of emergency transportation road of 6 prefectures with the complex case

5. Conclusion

In the present study, it is analyzed the disaster vulnerability of emergency transportation road in the case of flooding due to river flooding, road blockage due to building collapse caused by the earthquake, and both the complex case of flooding and earthquake. Based on the analysis of disaster risk, then we analyzed reachability of emergency transportation road between the prefectural and municipal offices. The target area of the study is the six prefectures namely Ishikawa, Toyama, Fukui, Niigata, Nagano and Gifu. The network analysis of impassable section of the emergency transport road that could be flooded by the river flooding, except the Niigata and Nagano Prefecture, it is revealed that more than 80% was unreachable between the prefecture and municipal offices. In particular, there is a threatening of flooding by the rivers those are flowing near the prefectural offices of Toyama, Fukui and Gifu prefecture. It is a possibility that many emergency transportation roads around the prefectural office could be flooded, that is why it became a result that it is impossible to reach the municipal offices from the prefecture.

In the analysis of the building collapsed by earthquake that make road blockage, we considered the road-side building of emergency transportation roads. For the building collapse, we take the measurement seismic intensity which is a 2% exceedance probability of 50 years. Among the wide range of six prefectures, the maximum unreachability cases occurred in the municipal offices of Niigata and Nagano Prefecture. Like these two prefectures, there are some region of Ishikawa, Toyama and Gifu Prefecture where the emergency transportation road is expected to high seismic intensity. As part of the road is blocked, it is possible to substitute other emergency transportation roads in these three prefectures, and they will not be unreachable. However, a delay occurs when a such a road block section overlap each other on the shortest route to the municipal office.

In the analysis of complex cases of flood and earthquake, Niigata, Nagano, effect of submergence, has occurred is sparse part to passable of emergency transportation road network. Of these, in Nagano Prefecture road block section due to building collapse caused by the earthquake has overlapped with this sparse part. If evaluated the impact of roads closed due to flooding and collapsed buildings, each alone, it was kept the network connectivity. Reduced service area from the Prefectural Government and also increased municipal network is disrupted in the complex case, it becomes unreachable.

In this study, it was analyzed the building data of GIS. Targeting a broad-area, there is an advantage to be able to consider the height of the building. But we did not consider the road width. So there is a chance for over-estimating the road obstruction. As for the collapse judgment of the building, it is carried out the judgment process only one time by random number, so there are still remain challenges in result refinement.

Chapter 6

Large-scale River Disaster in Kanazawa City, Japan: A case of Asanogawa Flood, 2008

1 Introduction

In recent years, frequent floods are occurring caused by the local torrential heavy rain and typhoon nationwide. Residents are able to receive information such as forecasting and warning before the flood disaster occurs and can take pre-preparation and evacuation unlike earthquakes. However, because of the lack of awareness and previous experiences of the disaster, despite the providing evacuation information, residents don't get well-prepared themselves and hence, the evacuation process is delayed. In that case the damage is increased.

In July 28, 2008 early morning, Kanazawa City was hit by record heavy rain. This heavy rain was recorded as 100mm or more within one hour in the central Kanazawa city. As a result, Asanogawa is flooded for the first time in '55 years, and large-scale flooding has occurred in Kanazawa city. During that enormous damage, about 20000 households were provided evacuation advisory information among 50,000 residents in the Asanogawa basin.

Figure 1 shows the ranking of prefectures about the cumulative flood damage costs in past 10 years. Cumulative maximum amount of damage of the past 10 years is 4,696 billion yen in Hyogo Prefecture. The average amount of damage across the country is 57.6 billion yen. The cumulative amount of damage in Ishikawa prefecture is about 10 billion yen, which was 30th in the nation.

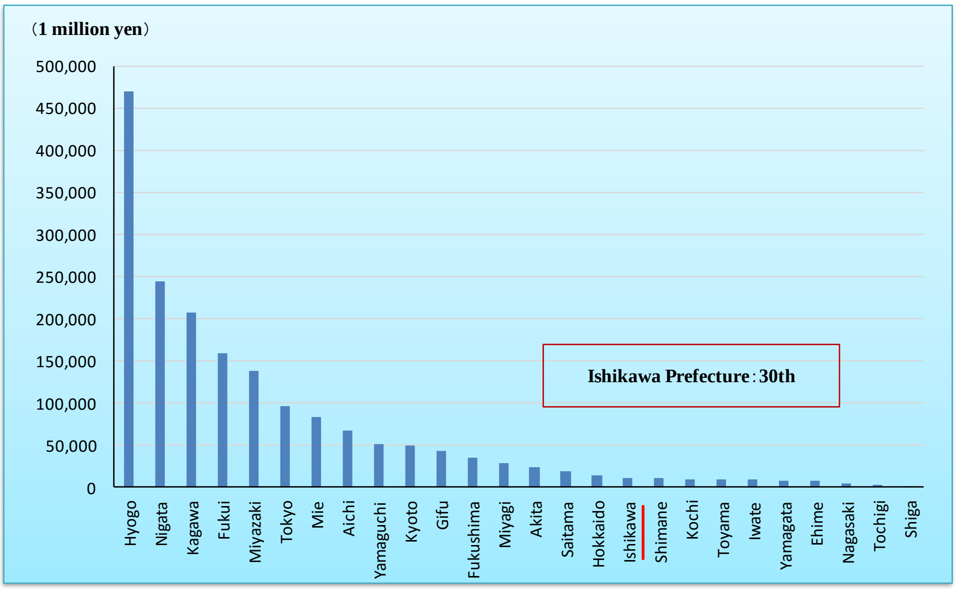

Figure 1: Cumulative costs of flood damage of last 10 years in different prefectures in Japan (MILT River Bureau, Japan; 2012)

Figure 2 shows the transition of the past 10 years by prefecture flood damage costs. In the figure it is shown that the amount of cumulative damage of Hyogo Prefecture is the highest compared with those of three prefectures of Hokuriku in the past 10 years. In the past 10 years, in Ishikawa prefecture, the damage was 1 billion yen annually; however, the damage of about 10 billion yen has occurred during the 2008 flood. In addition, Ishikawa prefecture tended a large amount of damage than those of Toyama and Fukui prefectures. One can assume about the frequent flood in Kanazawa City from the above information. It is not in areas where extensive damage has occurred in the past, are considered vulnerable areas from both sides of the hardware and software for disaster prevention.

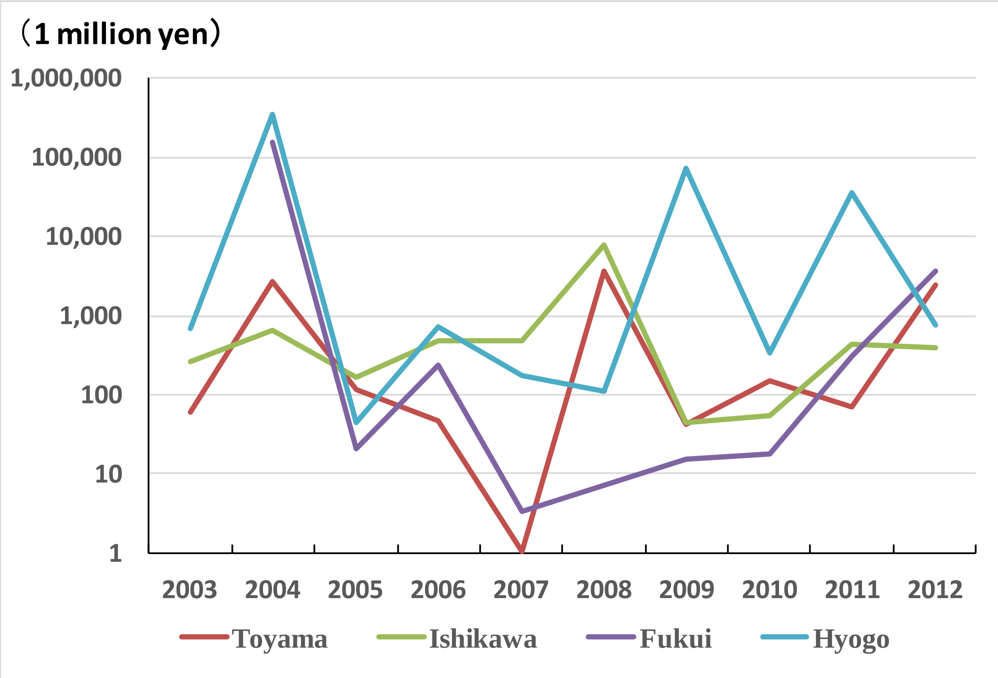

Figure 2: Evolution of the cost of flood damage over the past decade in different prefectures (MILT River Bureau, Japan; 2012)

A lot of researches have been done focusing on the conventional evacuation behavior and consciousness of residents at the time of flood disaster. The study (Katada et al., 2001; Oikawa et al., 2002) revealed that the decision-making processes and disaster experience impacts the evacuation. Moreover, the study (Katada et al., 2001)takes account into the decision making in the evacuation activity of the inhabitant, and analyzed the effect of flood experience of the inhabitant on the disaster consciousness and the decision making process of the evacuation activity. They also concluded that the atrophy of disaster consciousness delays the evacuation activity, and though the damage experience in the flood disaster enhance the disaster consciousness, the damage experience of the intermediate level delays the decision making and start timing of the evacuation activity.

In addition, research (Oikawa and Katada, 1999) conducted on analysis of flood damage and residence behavior about disaster information in large urban areas (Tokai heavy rain, 2000).

There are studies of Asanogawa flood, carried out by MILT, River Bureau 2012 and New River Management Committee (Ishikawa Prefecture), Japan. MILT, River Bureau 2012, discussed the role of the construction development in recovery and reconstruction from flood damage at the local city. New River Management Committee (Ishikawa Prefecture), reported about the flood that hits the local city after 55 years. On the other hand, Kurooka, and Tamai discussed Asanogawa flood from the point of view of government, such as counseling assistance and flood control system to the victims. Moreover, as a result of the review of the Asanogawa flood disaster, it is found that the local city government has lack of infrastructure development, experience and reality analysis as the flood occurred after 55 years.

In this study, both hardware and software technology are paying attention to the vulnerable areas to local city and flood. At the time of Kanazawa Asanogawa heavy rain disaster that occurred in July 2008, specifically "evacuation preparation information", "evacuation advisory", and "evacuation order" a questionnaire survey was conducted targeting the districts that has been flooded, and it is intended to clarify the actual condition of the evacuation, and awareness of disaster prevention.

2. Importance of Evacuation

Evacuation is considered a way to prepare people when at risk from an impending hazard (Taylor and Freeman, 2010). It is an important part of disaster management and is an effective way of minimizing loss of lives and property damage (Na et al., 2012). It is considered a process(as presented in Figure 1)that constitutes hazard detection, issuance of warning, preparation to evacuate, movement to identified shelters through network(Stepanov and Smith, 2009), and reentry to the community after disaster(EMA,2005). In addition, the process comprises route assignment and management approaches, providing emergency-related services as well as attending to people with special needs such as the elderly and disabled, and coordination and management of evacuation fleets (Hsu and Peeta, 2012).

Effective communication is crucial to the management of evacuations from flooding, hurricanes, and other disaster events that are forewarned by improving systems of prediction and monitoring(Sorensen 2000).However, evacuation orders do not lead to complete compliance; some residents refuse to leave and choose to stay (Miletiet al. 1975), others leave when they are not at significant risk. Despite the importance of efficient and effective evacuations (Lindell andPrater 2007; SimonovicandAhmad2005), a relatively scarce amount of research has examined disaster message communication.

As we see time and time again, for as much research as has been conducted on the issue of evacuation, our understanding of evacuations extremely limited. Those expected to evacuate often do not, and those who should not evacuate at least in the estimation of emergency managers often do. The following focuses on the body of literature that specifically emphasized understanding evacuation compliance with a discussion of the small, but growing literature focused on the evacuation decision-making process itself. Research on evacuation has focused on the characteristics of those who evacuate and those who do not (Baker 1979; Cross1979; Baker 1991; Fischer et al. 1995; Dow and Cutter 1998; Drabek 1999) or on difficulties associated with evacuation (Baker1980; Mileti and Sorenson 1987). Other research, such as (Perry and colleagues 1981, Gladwin and Peacock 1997, and Whitehead et al. 2000) attempted to model evacuation compliance, while (Lindell et al. 2005) focused on household decision making as it relates to hurricane evacuation. It appears that overtime, more complex models of evacuation compliance have developed, often, but not always, with risk perception as a central focus and with more reliable indicators of evacuation behavior (Baker 1991).

From field surveys of real cases such as the Niigata flood disaster in 2004 (Gunma University, 2004; Intensive Heavy Rainfall Disaster Policy Committee, 2004), many people know where the refuge is but they do not know how the situation will progress with certainty and which route is safe under the emergency situation. Static hazard maps may not always help them when an actual disaster happens. Instructions that do not consider the evolution of damage over time and threats of probable additional destruction and deterioration can result in suboptimal decisions that can lead to unnecessarily impose risk and unnecessarily lost lives (Miller-Hooks and Krauthammer, 2002). In addition, people's evacuation behaviors such as evacuation time and walking speed also have an effect on the optimal strategy.

3. Flood Disaster of Asanogawa River, Kanazawa, Ishikawa

3.1 Asanogawa flood Overview

Asanogawa River is the secondary river of the Onogawa river basin system, the overall length is about 32.5km (Figure 3). In addition, it originates in the vicinity of Jun-

Oyama (883m) which is located on the border of the Toyama prefecture. Asanogawa is flowing in the central part of Kanazawa city and it joins to the Onogawa in the port area of Kanazawa. This river flows very gently and offers a moderate

Waterfront to the citizen living around it. Before the July 2008 flood, in the past 55 years no flood occurred in Asanogawa River which has no dam. The last flood disaster occurred in 23rd July 1953 e.g. the Kaga flood of the Asanogawa River.

Previously in 1952 and 1953 Asanoga River was flooded by localized torrential heavy rain. As a result, a lot of bridges washed away and it took a new disaster prevention measures. Then it was decided that a dam construction was required to complete the waterway to the Saigawariver.As there was no suitable terrain for dam construction in Asanogawa basin, that's why in 1974, a water channel was constructed to direct the flood water to Saigawa River. However, July 28, 2008 occurred flooding in 55 years in torrential rain, Yuwaku hot spring and its downstream, the surrounding Higashi Chaya District was damaged. Temporary evacuation order has been issued to about 20,000 households among 50,000 residents in the Asanogawa river basin. At this time, the water channel to Saigawawas running; however, the excess water cross the capacity of the river, therefore damage expanded to the basin area.

Figure 3: Basin area of Asanogawa, Saigawa and Onogawa rivers (RMCC, Ishikawa Chapter 2008)

3.2 Rainfall situation of Asanogawa basin

Figure 4 shows the rainfall situation (up to 3 hours) in the Asanogawa river basin area in 28 July, 2008. Maximum precipitation reached to 60mm/hr. in Iouzen [11] and 138mm/hr. at Shibahara-Bashi (Ishikawa prefecture). According to the observation of Ishikawa prefecture, at Shibahara-Bashi (which joint place of Asanogawa and Iouzen Yamagawa), there was a rainfall up to 300mm in 3hours (5a. m to 8a. m). (Ishikawa prefecture Disaster Weather Information 2008).

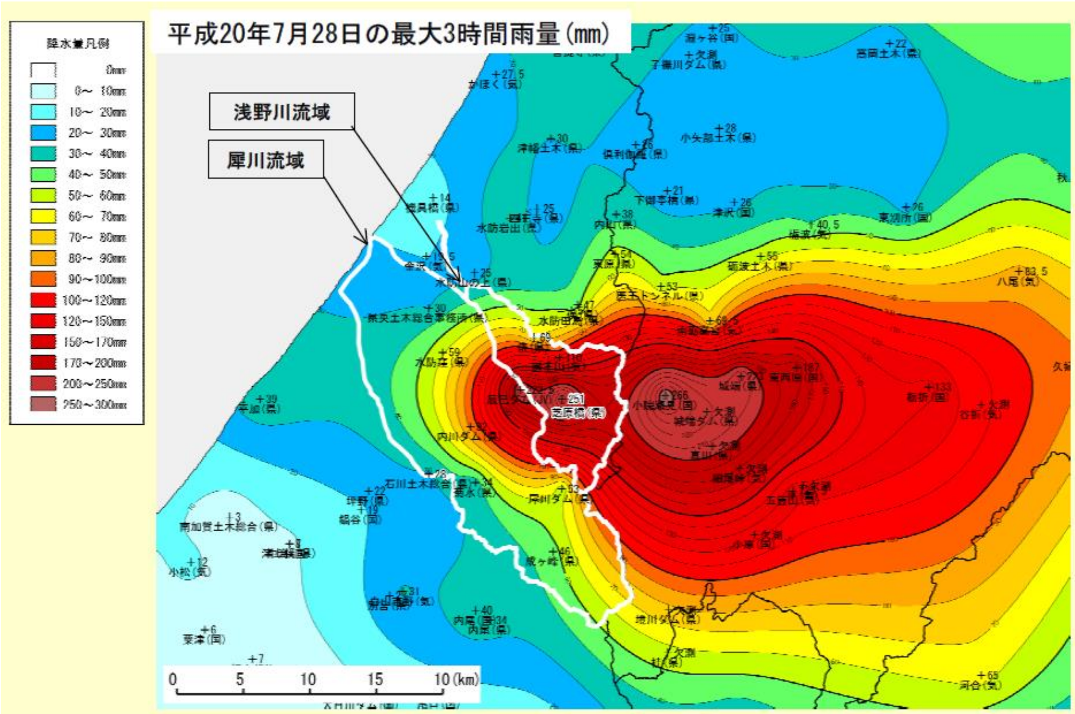

Figure 4: Rainfall situation (up to 3 hours) in the Asanogawa basin (RMCC, Ishikawa Chapter 2008)

3.3 Rainfall measurement result of Asanogawa basin

Figure 5 shows the measurement data of rain gauge (Shibahara bridge-position) that is installed by Ishikawa Prefecture in Asanogawa river basin. It shows that the rainfall was 114mm at 7 a.m., and 111mm at 8 a.m. Furthermore, it is understood and it is from the measurement results of the 10 minute interval rainfall and there was rainfall of 138mm per hour at the time of 6:30 to 7:30. On the other hand, with the rainfall that has been measured since at 9a.m., which was a slight, but almost no change in the total rainfall. There was a rainfall of cumulative 251mm in about 3 hours from 6:00 a.m. to 8 a.m. from the above result. So it can be said that there was a ferocious rainfall of time average 83mm per hour

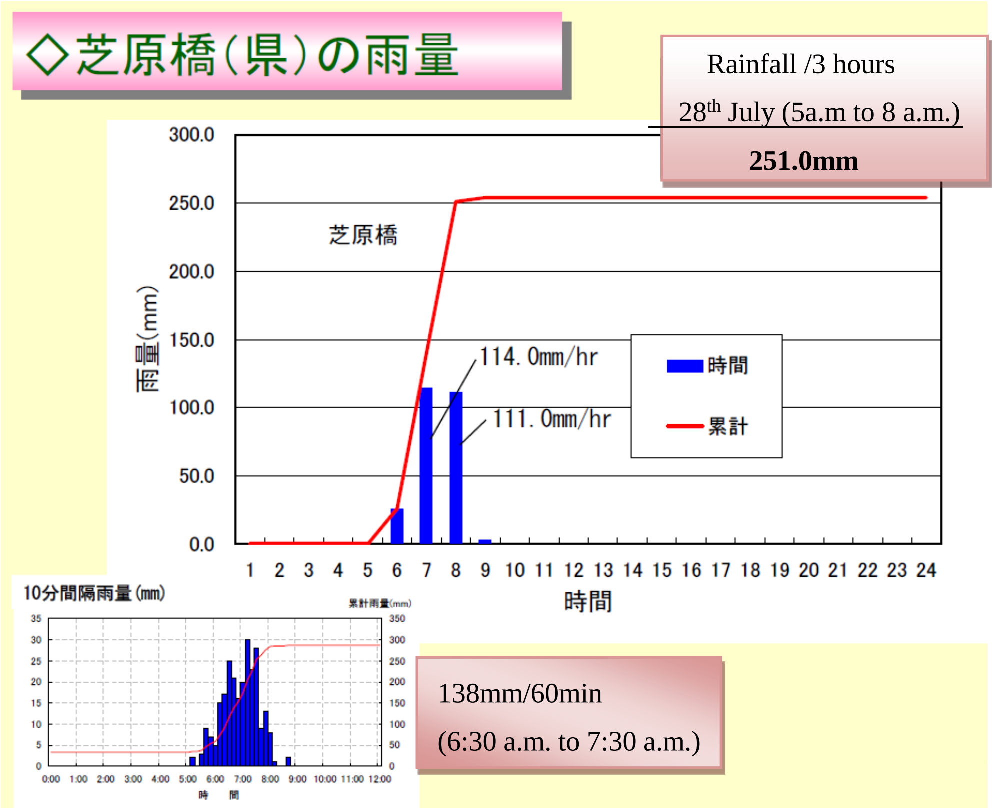

Figure 5: Observations of rain gauge, Asanogawa River basin (RMCC, Ishikawa Chapter 2008)

Figure 6 shows that there is a period precipitation distribution (July 27th to July 29th) of Ishikawa and Toyama prefecture.

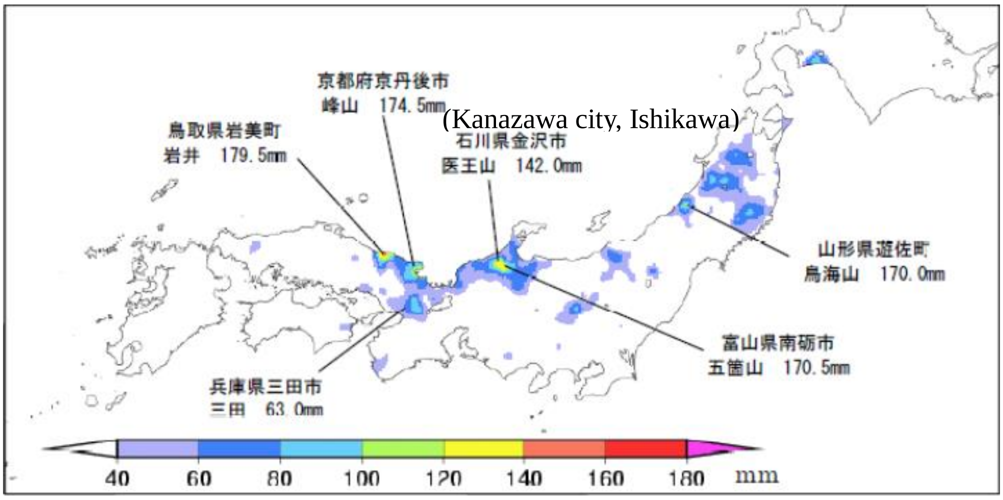

Figure 6: Recording the fierce rain which exceeds time rainfall 100mm (Flood report MILT 2008)

3.4 Issuance status of evacuation information

Table 1 describes the issuance status about evacuation information that has been issued at the time of heavy rainfall on July 28, 2008.Evacuation order has been issued for the whole area of the Asanogawa river basin is 8:50 a.m.to 11:45 a.m. among the 20,739 households where the population is 50,453. There was also evacuation advisory for the Kanazawa city (Onugawa basin) and Uchinada city from 9:50 a.m. to 12:55 respectively (Fire and Disaster Management Agency (FDMA), Japan; 9th September, 2008 [Report on *disaster information and damage situation by heavy rain, etc. of 28 July, 2008 (part-7*)].

The fact is that the peak of the torrential rains observed from 7 a.m.to 8 a.m. And it does not coincide with the timing of the official announcement of evacuation order and advice.

Table 1: Issuance status of evacuation information (FDMA, Japan; 9th September, 2008)

Status of Evacuation Information	City/town/village	Number of households	Population	28th July, 2008						
				7:00	8:00	9:00	10:00	11:00	12:00	13:00
Evacuation Instruction	Kanazawa city (Whole area of Asanogawa basin)	20,739	50,453		8:50 →	→	→	11:45		
Evacuation Advisory	Kanazawa city Onogawa basin	964	2,529			9:50 →	→	→	12:55	
Evacuation Advisory	Uchinada	2,665	7,620			9:50 →	→	→	12:47	

The change inwater level of the Asanogawa River is shown in Figure 7. From this figure, it can be noted that the water level of the Asanogawa river was started rising from 7 a.m.At 7:30, it started overflowing. At 7:40, it exceededthe evacuation judgment water level.In addition, at 7:50 it had reached to inundation dangerous water level.

After that, 8:20 it reaches to flood design rank. At 8:40, it traces the lapse which exceeds the observation upper limit. However, at this point the evacuation instructions have been issued at 8:50 and the surround area of the Asanogawa River had been flooded. Within ten minutes (7:30 a.m. to 7:40 a.m.), maximum rising of water level was 0.43m. Within thirty minutes (7:20 a.m. to 7:50 a.m.), maximum rising of water level was 1.20m.

河川名		浅野川	
日	時間	水位	備考
7/28	6:00	0.49	
	6:10	0.67	
	6:20	0.62	
	6:30	0.57	
	6:40	0.54	
	6:50	0.53	
	7:00	0.69	
	7:10	0.88	
	7:20	1.09	
	7:30	1.46	
	7:40	1.89	
	7:50	2.29	
	8:00	2.45	
	8:10	2.64	
	8:20	2.91	
	8:30	3.29	
	8:40	(3.36)	観測上限値
	8:50	3.35	
	9:00	2.86	
	9:10	2.42	
	9:20	2.05	
	9:30	1.83	
	9:40	1.73	
	9:50	1.63	
	10:00	1.54	
	10:10	1.47	
	10:20	1.44	
	10:30	1.40	
	10:40	1.36	
	10:50	1.34	
	11:00	1.28	
	11:10	1.24	
	11:20	1.21	
	11:30	1.18	
	11:40	1.14	
	11:50	1.10	
	12:00	1.08	

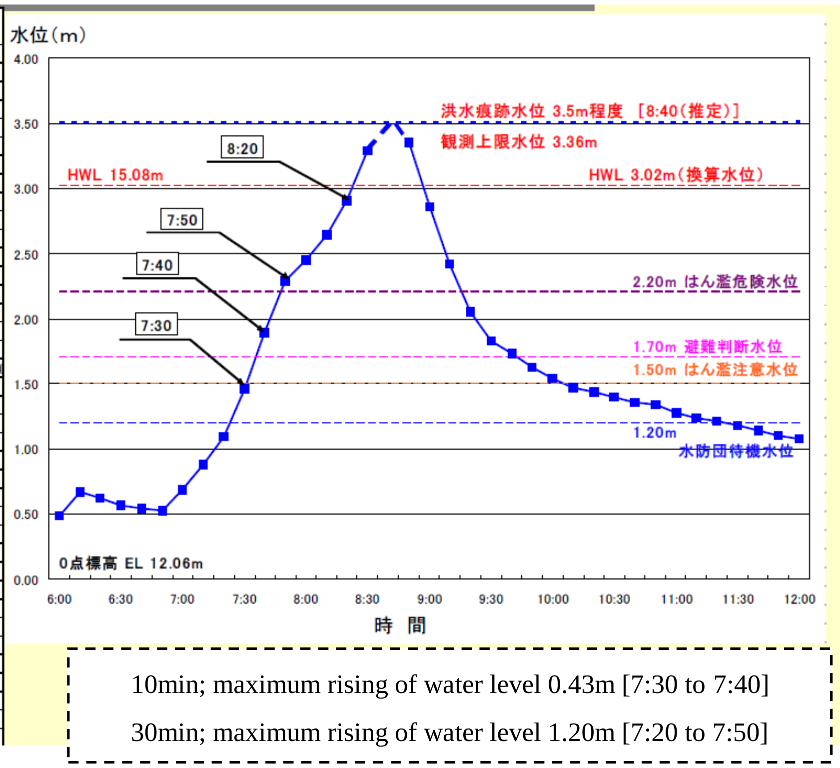

Figure 7: Measurement of the water level of Asanogawa River (RMCC, Ishikawa Chapter 2008)

3.5 Damage circumstance of the Asanogawa river flood, Kanazawa

Though there was no death report for Asanogawa river flood disaster 2008, but a lot of properties had been destroyed. The damage circumstance by the Asanogawa river flood, Kanazawa is shown in Table 2. At the time of the flood damage, flooding on the floor was 507, flooding under the floor was 1,486. In addition, there was complete destruction of 2 houses, half collapsed 9 houses and the partly damage of 6 houses [Fire and Disaster Management Agency (FDMA), Japan; 9thSeptember, 2008 (Report on *disaster information and damage situation by heavy rain, etc. of 28 July, 2008, part-7*]

Table 2: Damage situation of households due to flood (FDMA, Japan; 9th September, 2008)

Damage of households	Number of damaged buildings
Totally collapsed	2
Half collapsed	9
Partly damaged	6
Flooded on the floor	507
Flooded under the floor	1,486

3.6 Anticipated inundation area of the Asanogawa river basin

Figure 8 shows the anticipated inundation zone of the Asanogawa river basin. The flooding has been assumed is a city area of the Asanogawa downstream region. Inundation depth is 2.0m at the maximum. The flooding of 0.5m was supposed even in the area which is far from the Asanogawa River. When Asanogawa was flooded in 2008, the flood damage also has occurred around the anticipated inundation area.

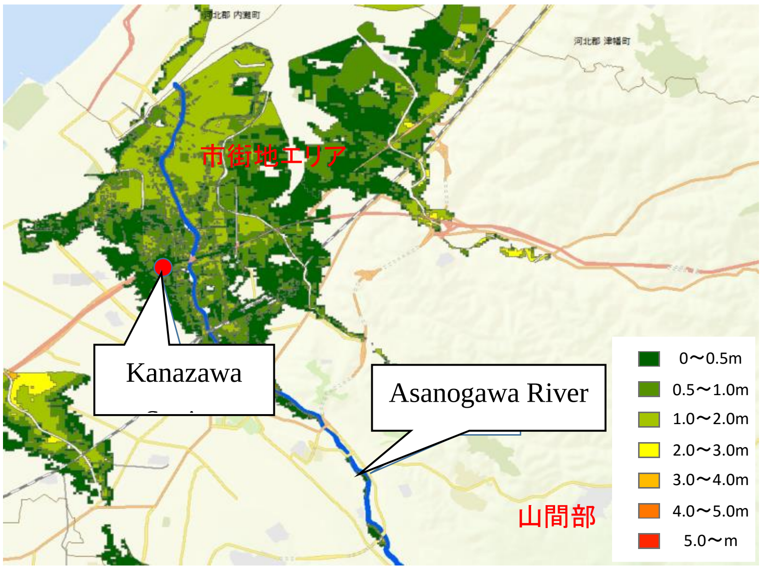

Figure 8: Anticipated inundation area

4. Methodology

This chapter describes the methodology used in this study. The first section discusses the selection of the case study, provides a description of the study area, and describes the methods used for data collection. This section is followed by a description of the statistical techniques for data analysis. The final section provides information about the population sample statistics as well as descriptive statistics of the Asanogawa Flood evacuation survey response data.

4.1 Asanogawa River in Kanazawa city

In Ishikawa prefecture, there are two main rivers, namely Saigawa (34.5 km long) and Asanogawa (28.9km long). Asanogawa is flowing in the center part of Kanazawa city. This river flows very gently and offers a moderate waterfront to the citizen living around it. Before the July 2008 flood, in the past 55 years no flood occurred in Asanogawa River which has no dam. The last flood disaster occurred in 23rd July 1953 e.g. the Kaga flood of the Asanogawa River. Figure 9 shows the Asanogawa river in Kanazawa city.

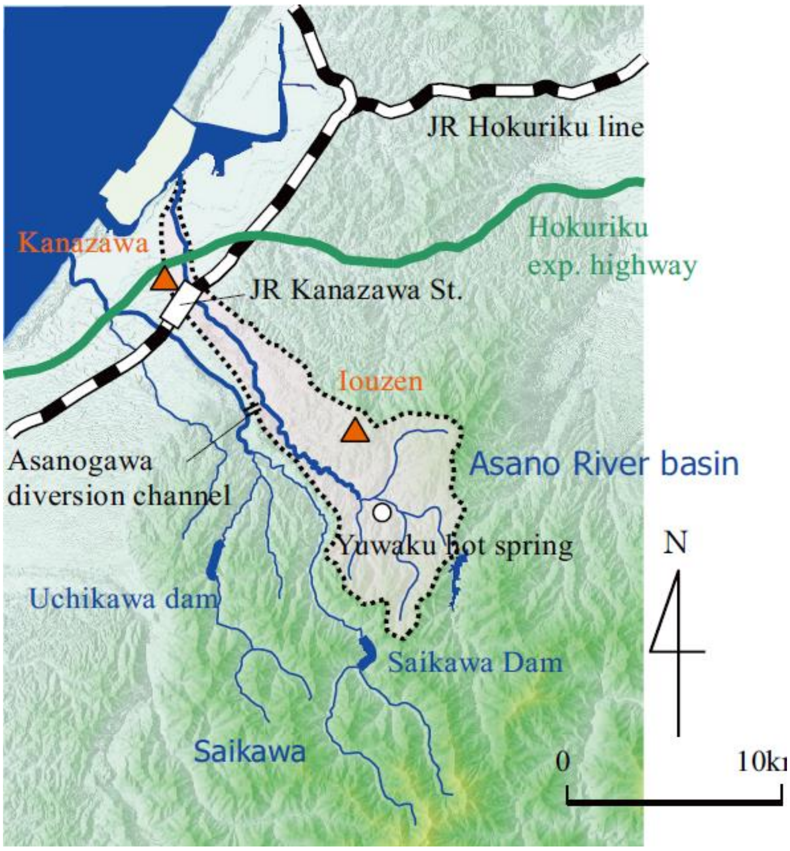

Figure 9: Asanogawa River in Kanazawa, Ishikawa (Annuals of DPRI, Kyoto University, 2009)

4.2 Flooding circumstances of Kanazawa City

On 28 July 2008, there was a localized torrential rainfall over the area around the Asanogawa River in Kanazawa city, Ishikawa Prefecture, Japan. That torrential rainfall was remarkable for the total rainfall and the amount of rainfall within a short period of time that brought backlogs, flooding homes, causing landslides and leaving serious damage.

The muddy flood water flowed into fields and rice paddies, fruit trees were washed down, and the rice was filled up with a large amount of mud. In several areas where the river narrowed, or at bends, flood water overflowed the dike. Because of delays in closing the floodgate, the river overflowed at opening in the dike called ‘kirikaki’.This heavy rainfall caused over topping from the Asanogawa River running through the downtown of Kanazawa City. The inundation water depth was over 1 m and large amount of sediment deposited in the city area. This disaster is referred to as the Asanogawa flood of 2008.

Figure 10 (A): Flooding circumstances of Kanazawa city (MILT, Japan 2008)

Figure 10 (B): Flooding circumstances of Kanazawa city (MILT, Japan 2008)

Figure 11: Residents clean up the mud flooding into their houses on July 28, 2008 in Kanazawa, Ishikawa, Japan. (Photo by the Asahi Shimbun via Getty Images)

4.3 Survey instrument

4.3.1. Population and sample

Table 3 describes the distribution of the sample by gender and profession. It is noticed from the table that the percentage of male and female respondents are 42.86% and 57.13% respectively. Among all types of professions, the maximum response is received from private employees in case of male respondents (33.79%) and housewives in case of female respondents (32.89%).

Table 3: Gender and profession wise distribution of the sample

Profession	Gender	
	Male	Female
Private employee	269	209
Public employee	43	42
Businessmen	144	86
Housewife		349
Part time worker	42	189
Self employed	23	2
Unemployed	245	157
University or vocational student	4	5
Junior or high school	4	1
others	22	21
Total	796	1061

Table 4 shows the distribution of the sample by gender and generation. It reveals that among male respondents, the highest response is received from generation 60 (32.01%), and among female the highest response is received from generation 50 (22.13%).

Table 4: Gender and Generation wise distribution of the sample

Gender	Generation							
	Generation 10	Generation20	Generation 30	Generation 40	Generation 50	Generation 60	Generation 70 or above	Total
Male	2	20	70	86	172	259	200	809
Female	2	62	180	203	238	227	163	1075

4.3.2 Procedure

In order to conduct this survey a questionnaire was first developed covering a wide range of aspects of evacuation information. It is also measured people's opinion about the effectiveness of the evacuation information plan. The survey was performed by the Urban & Transportation Planning Laboratory, Kanazawa University. A flowchart of procedures employed in the survey that is shown in below.

1) Distribution and collection the questionnaire of survey

↓

2) Analysis the survey data

↓

3) Define the result of survey data and think about the more effective method of providing evacuation information

4.3.3 Distribution time of the survey

The survey was carried out from the 1st September to 4th September 2008.

4.3.4 Methods of distribution

There are many methods of distribution of questionnaires like postal, email, SMS, and direct distribution to the individual houses. In our survey, we distributed the questionnaires directly to the residents of their houses.

4.3.5 Type of questions

There may be many formats of questions. However, in our survey, we mainly used the structured type of questions. There were also some multiple choice questions. A few questions were of 5-point scale. The main purpose of the questionnaire is:

1) To understand the actual situation of the affected area for the flood of Asanogawa River, and
2) Clarify the real condition of evacuation information plan on the disastrous day.

4.3.6 What kind of Questions was delivered to answer?

There were four main questions for the responders. They are about to know-

1. The actual situation of the disaster day
2. Satisfaction to the correspondence for the disaster management (to understand the situation about providing evacuation information).
3. Understanding about the consciousness of the affected people.
4. A personal attribute

4.3.6.1 The actual situation of the disaster day

- The actual situation of the evacuation information acquisition (when, where, or how the inhabitants of the precinct concerned were able to obtain information).
- The actual situation of the evacuation (how and where the evacuee sheltered)
- The actual situation of commuting / the attending school (whether a hindrance was reflected on commuting / attending school by the flood. If it is then how the hindrance affected them)
- The actual situation of the traffic regulation and about the inundation or sand volume in the roads.
- The actual situation of home and garage

4.3.6.2 Satisfaction to the correspondence for the disaster management (to understand about the situation of delivered evacuation information)

- In this section, the questions were included about the timing and transmission method of evacuation information. It was also asked to know the actual evacuation instruction, flood control, or restoration in the flood affected area.

- Here it was also heard from the responders about their satisfaction to administrative correspondence.

-

4.3.6.3 Understanding about the consciousness of the affected people

- It was asked what they think about the future river maintenance and what they think about the damage that occurred by this flood disaster.

- Besides, what is their intention about the administrative correspondence?

4.3.6.4 Personal attributes

- Personal information about the responders like his/her address, male/female, age, profession, family members, living in a house or apartment, have a car or not etc.

4.3.7 Data Processing and Statistical analysis

All the data were organized and arranged according to different factors such as gender, profession, generation, etc. the data were also organized according to different aspects of evacuation information. There were different types of analysis like Cross tab, Chi square test, ANOVAs, T-test, etc. These analyses were done by using some statistical software such as SPSS, MS Excel etc.

The purpose of the present study was to clarify the awareness and behavior of residents who were issued an evacuation advisory alert at the time of the Asanogawa Flood, 28 July

2008 and to clarify what the related factors may be.

4.3.7.1 Data Collection

Nine thousand seven hundred and fifty surveys were directly distributed to residents within the evacuation zone roughly 5 weeks after the flood receded. One advantage to direct distributing surveys is that it creates an emotional enthusiasm to respond to the survey among the residents. During the distribution of survey questionnaires, we also provided the return envelope with postal stamps. This prevents the sample population from only including those evacuees whose properties received little to no damage during the flood. It is common practice to conduct hazard research immediately following an anticipated disaster (Tierney, 2002) because this “quick response “approach results in the most reliable findings (Stallings, 2002). Therefore, this study used the quick response approach in order to maximize the usefulness and accuracy of the survey data. Specifically, surveys were distributed to residents during1st September to 4th September 2008.

4.3.7.2 Summary of distribution and collection of the questionnaire survey

In table 5, here it shows the summary of the questionnaire survey regarding the Asanogawa flood, 28th July 2008.

Table 5: The summary of distribution and collection

Number of the zone or area	10
Number of population	86,570
Number of the households	35,421
Number of the households sampled	9,750
Number of the respondents	1,970
Response rate(%)	20

4.3.7.3 Questionnaire execution summary

The survey area is shown in Figure 12. In this research, the elementary school of the districts is designated as the minimum unit (area with red boundary and hatch) of survey, in the area which has been damaged. There are 12 schools in the surveyed area. Eleven school districts exist in the urban area, and one school district (Yuwaku Spa elementary School) is in the mountainous region, where torrential rainfall was very intensive.

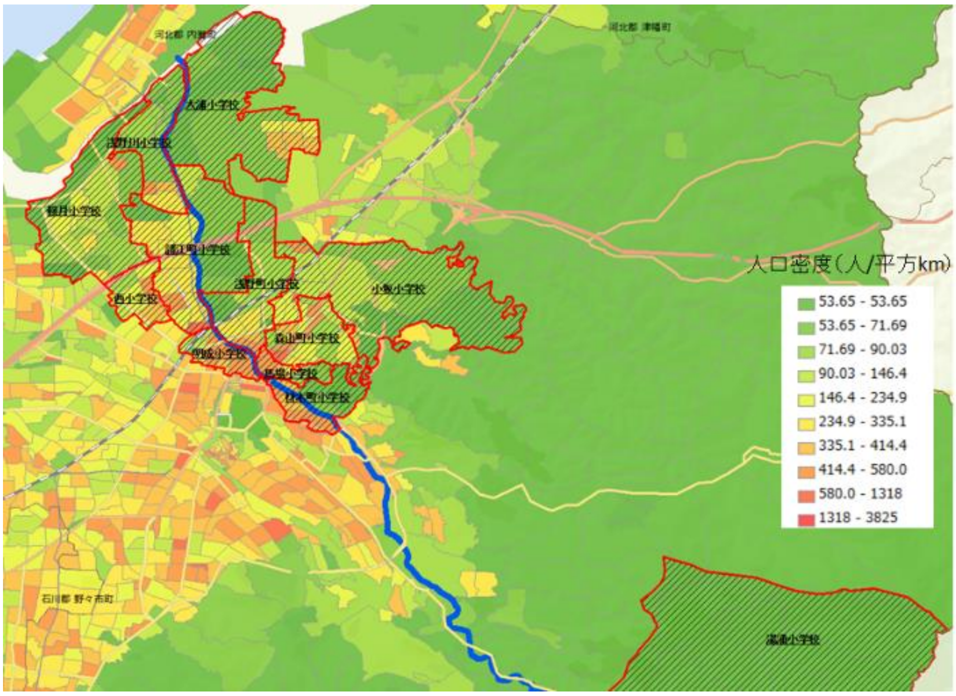

Figure 12: Location and population density of survey area

The questionnaire was distributed to the flood affected residents from 1st September to 4th September, 2008. Table 6 shows the distribution and collection of the questionnaire survey in detail.

Table 6: Distribution and collection of the questionnaire survey

No.	1	2	3	4	5	6	7	8	9	10
School District area	**Zaimou chou**	**Meisei**	**Baba**	**Asano machi**	**Moriya machi**	**Kousaka**	**Moroe machi**	**Asanoga**	**Oura**	**Yuwaku**
Questionnaire Mark	A	B	B	C	B	C	D	E-1 E-2	F	G
No. of Population	6,326	6,372	3,536	6,449	8,478	10,929	15,814	4,899	8,053	1,142
No. of households	2,822	2,974	1,508	2,820	3,606	4,376	6,523	1,769	2,756	462
No. of households sampled	1,800	500	800	1,500	200	500	2,300	1,200	650	300
No. of respondents	251	194	263	286	61	28	505	124	79	73
Response rate (%)	13.9	38.8	32.9	19.1	30.5	5.6	22.0	10.3	12.2	24.3
Enlarged coefficient	11.2	15.3	5.7	9.9	59.1	156.3	12.9	14.3	34.9	6.3

No.	11	12	13	Missing	Total
School District area	**Kuragetsu**	**NishiKanazawa**	**Other**	-	—
Questionnaire Mark	E−1 E−2	D	—	-	—
No. of Population	9,077	5,495	-	-	86,570
No.of households	3,403	2,402	-	-	35,421
No. of households sampled	0	0	0	-	9,750
No. of respondents	-	-	8	98	1,970
Response rate (%)	-	-	-	-	20.2
Enlarged coefficient	-	-	-	-	18.0

4.3.7.4 Justification of the survey

The questionnaire was distributed among the flood affected residents from 1st September to 4th September, 2008.

Interval estimation equation (1) below was applied for official approval of the number of samples, width (largest scope of supply) of confidence interval the number of samples which are settled within the ±5% was calculated at 95% hit ratio. In addition, the parameter of flood damage occurrence at that time has made 20,739 households that issued the evacuation information in Kanazawa city at the disastrous time.

The number of samples assayed, and apply the following interval estimation equation (1), and calculates the number of samples that can fit the width of the confidence interval (maximum allowable range) within ± 5% with 95% hit rate. In addition, the number 20,739 households that issued the evacuation information in Kanazawa city at disastrous times.

The width of the confidence interval = $k\sqrt{N-n/N-1\cdot p(1-p)/n}$ (1)

Where

N = number of original objects (20,739 households)

n = number of samples

k = constant of confidence interval (1.96, when the width of confidence interval is 95%)

From equation (1), the value of samples of 20739 households is 1,430 or more. In this survey, we collected questionnaires from 1,970 households, and valid questionnaires were 1,864.So the survey result is reasonable. It shows the distribution and collection status of the questionnaire in Table 3. Distribution collection circumstance of the questionnaire is shown in table7. As shown in the table, the questionnaire collection is sufficient. The questionnaire distribution was done in the focusing area where damage was severe. In one part of the damaged area, the distribution and collection were very little.

5. Analysis of Result Discussion

5.1. How the disaster affected people's normal life

Here it is tried to clarify how the disaster affected the normal life, especially the actual condition of the commuting, work place (office, etc.) and attending school of the residence on the disastrous day.

The main purpose was:

- First, whether they commute or went to school as usual
- Second, if they had experienced significant delays in the commuting time.
- Third, if they had changed their means of transport.

The result is shown in Figure 13 and 14.

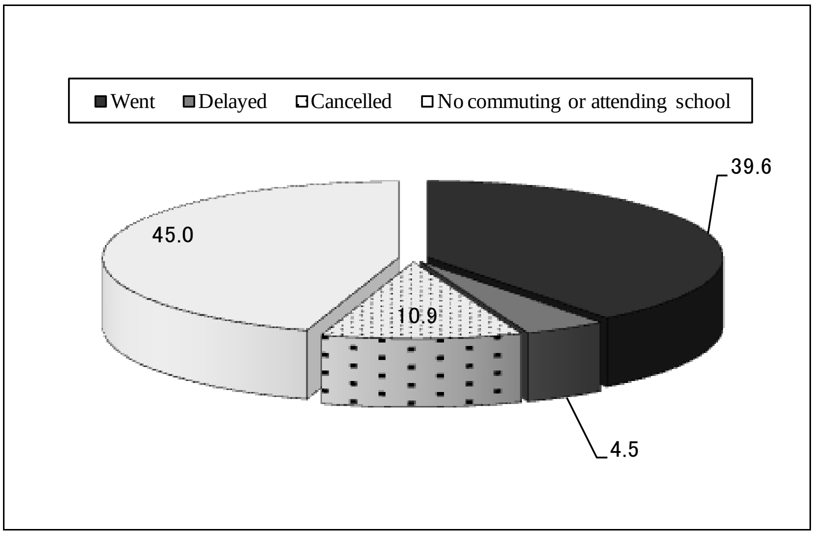

Figure 13: Actual condition of commuting and attending business/school [n=1,658]

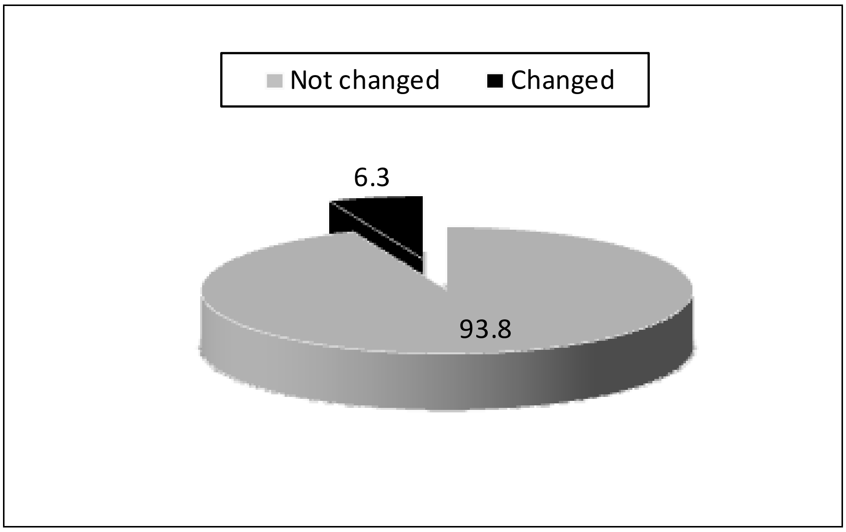

Figure 14: Transformation of the means of transportation [n=704]

The findings of the analysis of the above two figures are:

During the flood about 55% percent of the people commuted. Among them, 70% people commuted as usual. However, about 8% of the people commuted with delay, about 20% was found to cancel the commuting. In addition, on the day of flood damage, about 90% or more residents were not using usual transportation.

From the figure 15, we understand that the delay time extends substantially from 8:00 a.m., delay time has occurred of about 20 minutes on average during the peak. Figure 16 shows the results of calculating the percentage of people who delayed in their commuting by time zones.

When it comes to 10:00 a.m., the information of flood damage is spread out, and the residence made a detour like they bypass the affected area at the time of commuting. Then it shows a tendency to decrease the amount of delay time.

Also, looking at the proportion of people who delayed in commuting, it was found that the rate is going to increase as time passes. On the disaster's day, the affected areas have carried out the traffic regulations. As a result, road congestion was happened in the whole city area.

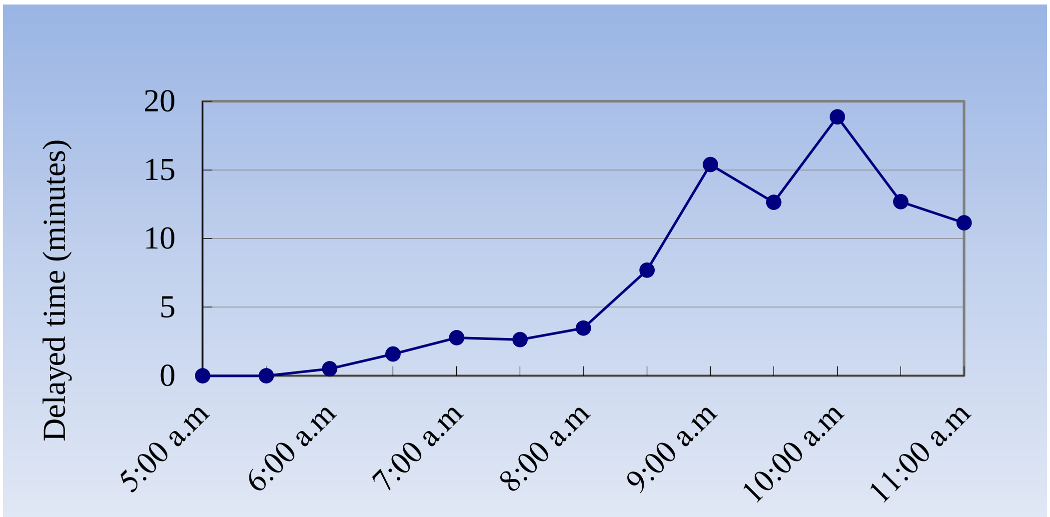

Figure 15: The average delayed time of commuting (n=449)

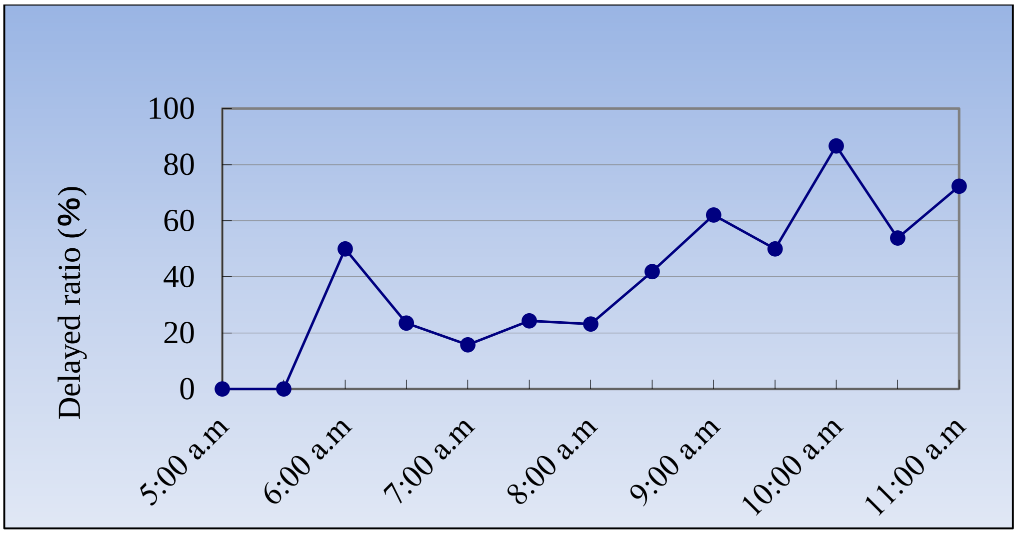

Figure 16: Percentage of people who commute during the delay (n=449)

5.2. Sufficiency degree of correspondence for the disaster

In this part, it analyzes the satisfaction degree of the respondents about the providing time of evacuation information, method of providing information, about the evacuation place, etc. To what degree of their own satisfaction about the disaster response. There was an appropriate score of different 10 stages. Table 7 shows the results of the appropriateness score e.g. in the case of the most appropriate (point score is 5) and the most inappropriate (point score is 1) by the respondents of different school district.

Table 7: Degree of satisfaction of the response to the disaster

(5-step evaluation of average and standard deviation)

	Zaimoku	Meisei	Baba	Asano	Moriyama	Kousaka	Moroe	Asanogawa	Oura	Yuwaku
Timing of Evacuation Preparation	1.8 (0.34)	1.6 (0.43)	1.8 (0.32)	1.7 (0.30)	1.9 (0.68)	2.9 (0.77)	2.4 (0.19)	2.4 (0.37)	2.9 (0.43)	1.8 (0.63)
Timing of Evacuation Advisory	1.7 (0.34)	1.6 (0.43)	1.9 (0.31)	1.7 (0.30)	2.0 (0.67)	3.1 (0.71)	2.5 (0.19)	2.8 (0.34)	3.1 (0.43)	1.9 (0.61)
Timing of Evacuation Order	1.8 (0.35)	1.6 (0.44)	1.8 (0.33)	1.6 (0.30)	2.0 (0.68)	3.2 (0.73)	2.5 (0.19)	2.7 (0.35)	2.9 (0.44)	1.8 (0.62)
Communication Method of Evacuation Information	1.8 (0.33)	1.7 (0.40)	1.8 (0.32)	1.8 (0.29)	1.8 (0.68)	2.7 (0.72)	2.4 (0.19)	2.6 (0.33)	2.9 (0.42)	1.9 (0.59)
Guidance of Evacuation	1.5 (0.39)	1.5 (0.46)	1.5 (0.37)	1.6 (0.32)	1.6 (0.78)	2.3 (0.84)	2.1 (0.22)	2.4 (0.37)	2.1 (0.53)	1.8 (0.63)
Communication Method of Disaster Information	1.6 (0.36)	1.5 (0.43)	1.7 (0.34)	1.7 (0.30)	1.7 (0.75)	2.7 (0.73)	2.1 (0.21)	2.3 (0.37)	2.5 (0.47)	1.7 (0.61)
Flood Control Activities	1.5 (0.39)	1.7 (0.41)	1.7 (0.34)	1.8 (0.30)	1.7 (0.81)	2.7 (0.78)	2.1 (0.25)	2.3 (0.50)	2.5 (0.54)	1.8 (0.59)
Restoration Activities	2.6 (0.28)	2.6 (0.10)	2.9 (0.25)	3.0 (0.22)	2.1 (0.69)	3.0 (0.75)	2.5 (0.22)	2.6 (0.48)	2.7 (0.52)	2.8 (0.45)
Administrative Support	2.3 (0.30)	2.5 (0.32)	2.5 (0.27)	2.7 (0.23)	2.1 (0.71)	2.9 (0.73)	2.4 (0.23)	2.4 (0.48)	2.3 (0.57)	2.5 (0.46)
Volunteer Support	3.0 (0.27)	3.1 (0.32)	3.0 (0.26)	3.4 (0.23)	2.7 (0.63)	3.3 (0.74)	2.8 (0.21)	3.0 (0.46)	3.1 (0.56)	2.9 (0.46)

(Red mark) Districts that have not been issued evacuation information and almost, there were no volunteer activities.

The above table 10 shows that the district areas (Zaimoku, Meisei, Baba, Asanomachi) where the flood damage was big, there was the low satisfaction level of average points.

On the other hand, the district areas where the damage was not big (Kosaka, Moroemachi, Asanogawa, Oura) there was a somewhat higher satisfaction level of average points. Standard deviations are larger in the neighboring school district (Moriyama machi, Kosaka) where there was significant damage but with less flooding.

However, in view of the state that, the result was not more than three points (Neither satisfied nor dissatisfied) by five phases of evaluations. Improvement by providing time of evacuation information, evacuation instruction method and the flood control activity will be necessary.

5.3. Flood damage situation

Here, it is shown that in what extent the damages occurred by the flood disaster for the home, automobile or garage of the residence. It shows the different school district areas by the result of the presence or absence of flooding in the home, garage or automobiles. It is investigated if there was the presence or absence of flood. If flooded then in what extent it was flooded e.g., flooded above the floor level, flooded the floor level.

The result of flood damage to a home (detached/apartment/Mansion), is shown in Figure 17.

From Figure 17, it can be said that the six school districts region of "Yuwaku" "Meisei" "Zaimokuchou" "Asano machi," "Baba", and "Moroe machi", had the flood damage to the home.

For flooded above the floor level, it was the highest percentage for "Yuwaku", we understand the magnitude of the damage in the Asano upper basin region. Further, in the flooded the floor level, the percentage of "Meisei" and "Asano Machi" is found to be relatively high. "Asano machi" is in the vicinity of the Shoei machi and Nakajima Ohashi, a school district area where the impact of flood damage was remarkable.

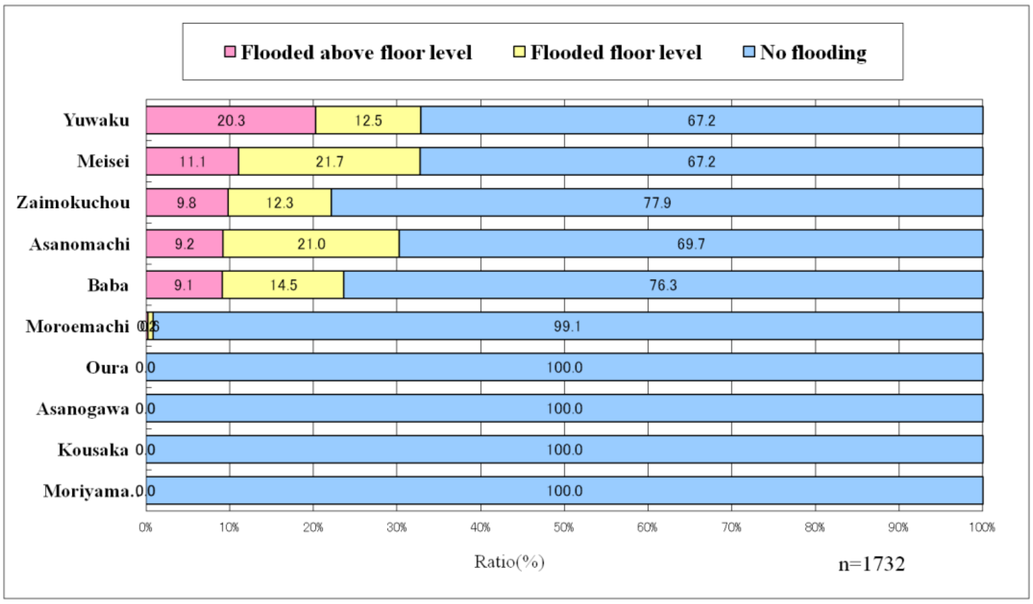

Figure 17: Flood damage situation of home (Detached /apartment /Mansion)

In Figure 18, it shows the result of the flood damage situation of garage. From Figure 18, it is observed that there was a flood damage to the garage in seven school districtarea of "Yuwaku" "Asano machi," "Zaimokuchou" "Baba", "Meisei" "Moroe machi," and "Oura".

The highest proportion of flood damage situation to garage, for both of flooded above floor level or flooded floor level was in Yuwaku school district area.The highest percentage of floor flooded to the home is also in Yuwaku school district area, It can be considered, there were many cases that garage with home were damaged on the floor flooded.

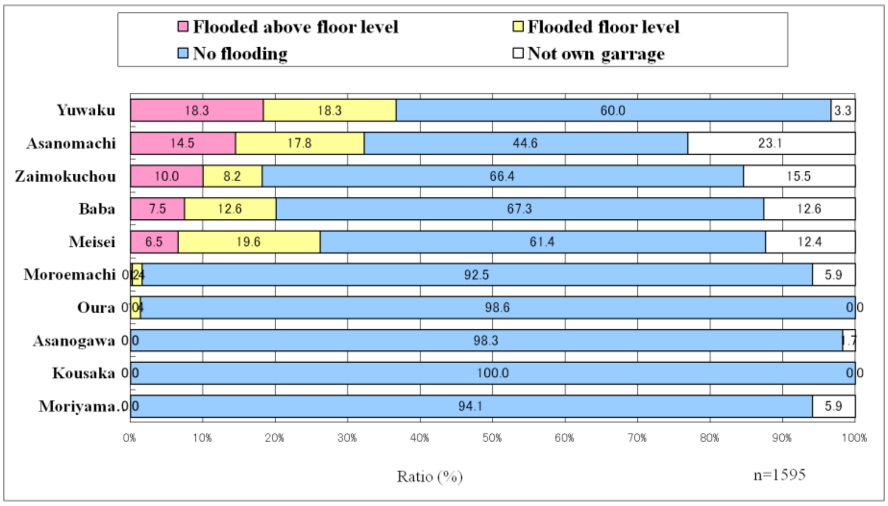

Figure 18: Flood damage situation of garage

Subsequently, in Figure 19 it shows the flood damage situation results of the automobile. From Figure 19, flooded to the car was found in six school districts of "Asano machi" "Yuwaku" "Meisei," "Baba", "Zaimokuchou", and "Moroe machi". The highest proportion of car inundation is in "Asano machi". It is because there is also underground car parking, etc., As a result, when it was flooded level of the home, it can be judged that damage had expanded to more than the floor level to the garage.

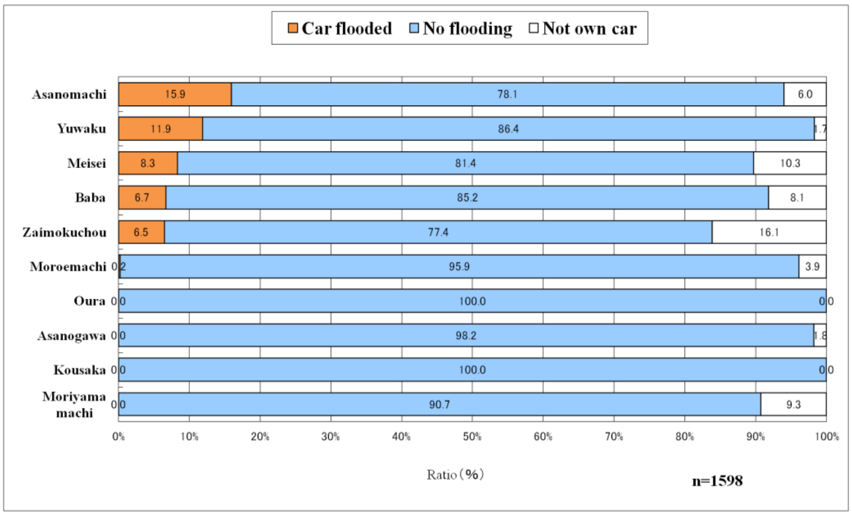

Figure 19: Flood damage situation of the automobile

5.4. Evacuation preparation information

In this study, a questionnaire survey was conducted targeting the district that has been issued an "evacuation instruction." It is found in the figure 20 that, despite the evacuation preparation information is issued, only 23% of the residents had been able to get the information, and 20% of the residents did not know until the broadcast in the media, etc. The remaining about 60% residents, had not been noticed the evacuation preparation information at all. In addition, many residents obtained evacuation information while staying at home mainly by disaster broadcasting and radio.

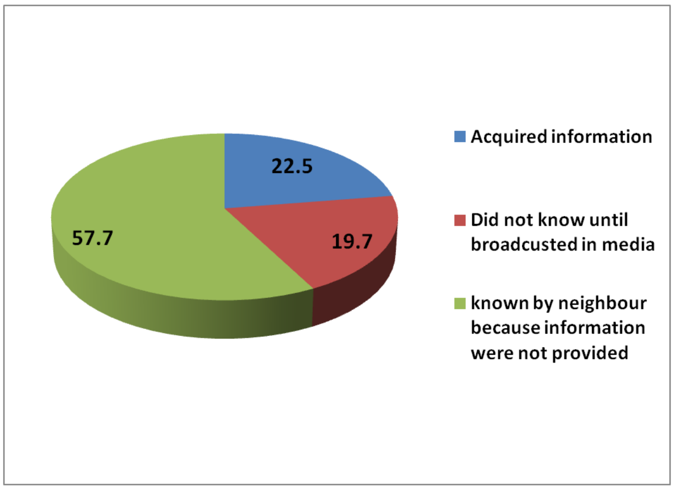

Figure 20: Evacuation preparation information [n=1805]

5.5. The actual situation of evacuation

Here we studied that, after obtaining information, whether residents taken evacuation or not. In Figure 21, it is revealed that most of the affected people did not take evacuation. They have some reason for not taking evacuation. Since it was a flood, there is a possibility that it was thought that it would be sufficient to move to the second floor above. In addition, the evacuation advisory and evacuation instruction has been issued in the time when the flood already has started. Residents also submitted comments that they did not have enough time to escape.

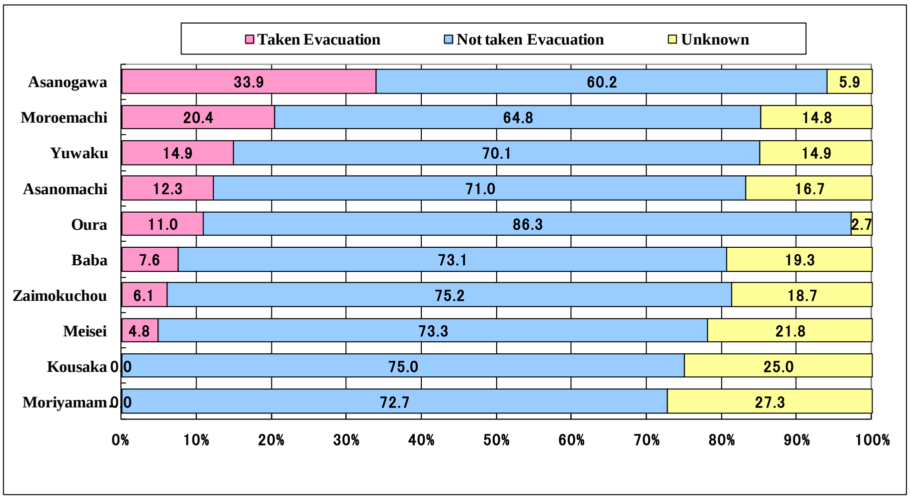

Figure 21: The actual situation of evacuation [n=1,687]

5.6. Transportation at the time of evacuation

At the time of evacuation, how did the affected people evacuate themselves or what kind of transportation they used to move from the flooded areas is shown in the figure 22. From this figure, it is revealed that the ratio of the residence who, moved by walking approximately was 50%, as for about 45% used the automobile. Maximum people chose walking for their evacuation. As the automobile breaks down with influence such as rising flood, also the possibility of becoming the obstruction of the rescue evacuation restoration and there is a chance to be shut in inside of the car. Because of all the above reasons it was desired safe evacuation on foot.

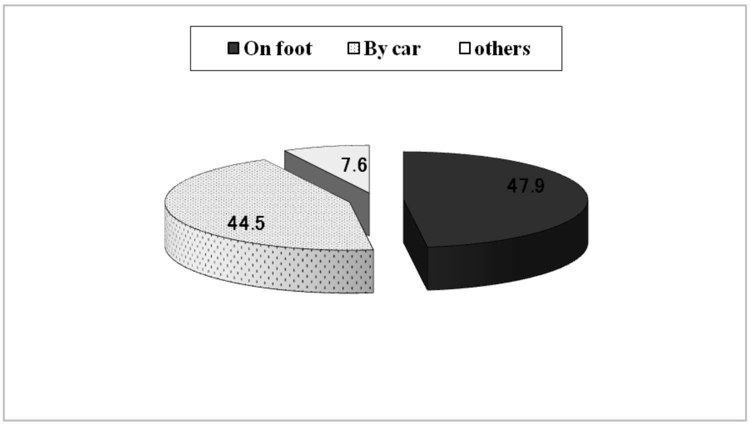

Figure 22: Transportation at the time of evacuation [n=258]

5.7. Administrative response to the flood disaster

Here the survey is trying to clarify the activities of the administrative authority of Kanazawa city. From this survey we had a clear picture of the satisfaction level of the residents in the affected area about the city government's activities at the time of flood disaster.

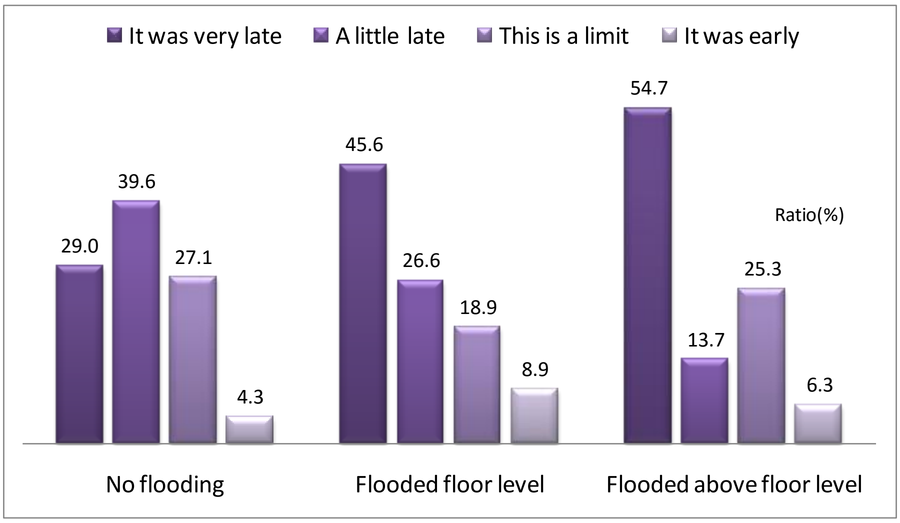

Figure 23: Administrative response to the flood [n= 1,643]

From Figure 23, it is revealed that:

✧ The administrative e.g. the city government correspondence to the flood disaster was not at a satisfactory level at all.

✧ Their activities observed delay in all over the flooded regions. About 50% of the residents said that city government's correspondence was very late.

5.8. A comparison between different sources of information acquisition

Good communications with the public is one of the most important elements of an evacuation plan. The city government evacuation plans should have adequate provisions for communicating basic information to the residents in regards of when they should evacuate, the designated evacuation routes, what they should take with them, the location of shelters, and other information needed before they evacuate. Figure 24 shows the response rate for different sources of providing evacuation information to the residents around the Asanogawa river of Kanazawa city. From the analysis of the data, it is observed that the highest rate of acquisition of information is from DBP (e.g. Disaster Prevention Broadcast), then patrol car and afterwards gradually from television, neighbors, DIE-mail, radio and internet.

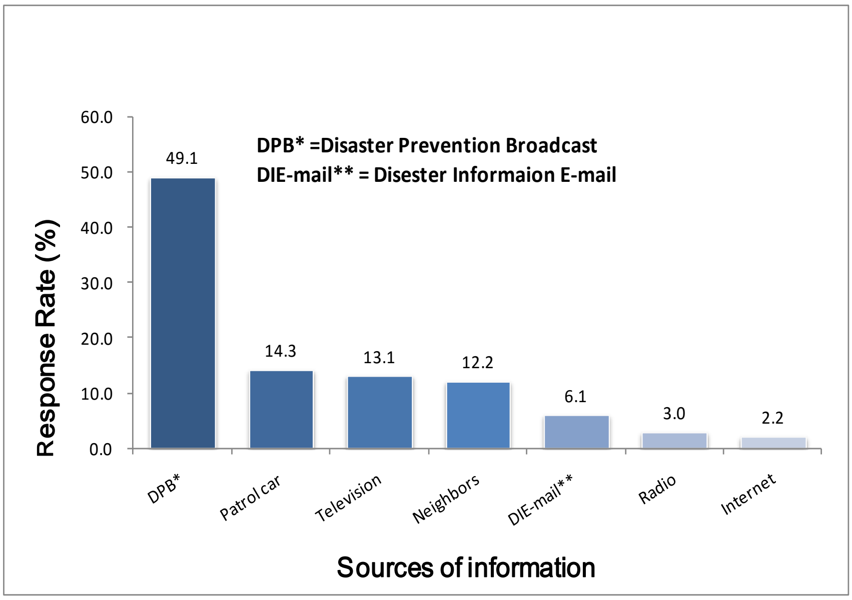

Figure 24: The response rate for different sources of providing evacuation information [n=799]

5.9. Sources of information acquisition within different professions

This study analyzes the methods to distribute evacuation information to the people of different profession, in order to investigate the ways of providing information to maximize evacuation effectiveness and minimize flood damage. The sources of providing evacuation information are as same as mentioned in the previous section. In this section, we shall describe about the different professions.

Through the analysis of the data in figure 25, it is noticed that the acquisition method DBP is the highest response among the people of all professions. Then the patrol car and television is playing an important role as providing information method. A lot of people have information from their neighboring peoples. The response rate of DIE-mail is higher in the public employee, private employee and businessmen.

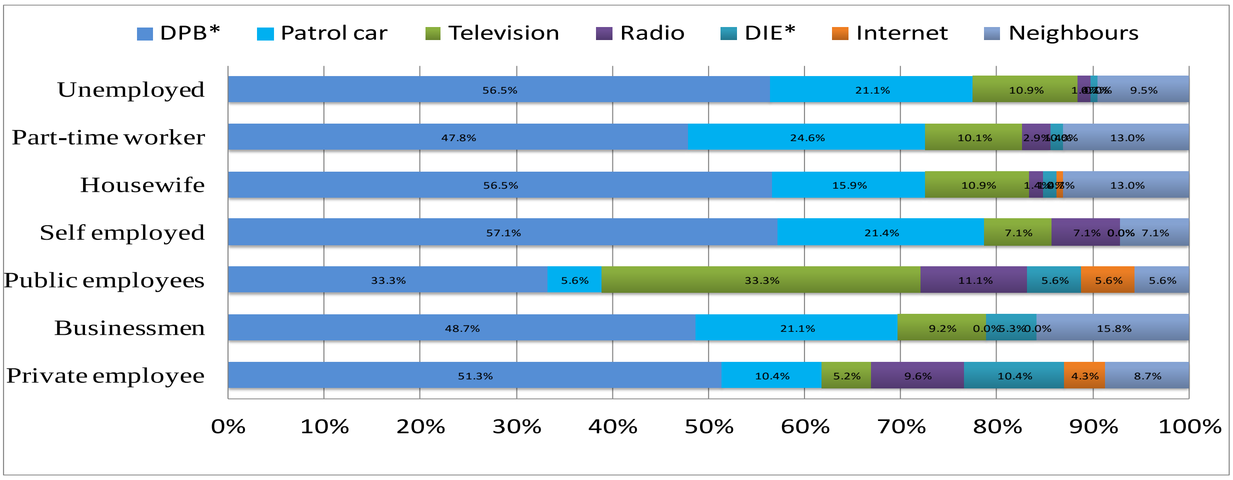

Figure 25: Source of Information acquisition within different professions [n=629]

5.10. Appropriateness of the aspects of evacuation information

Here the intention of the analysis was to find out the appropriate score according to the function of evacuation presence (e.g. Evacuation taken or not taken). The appropriateness score measured in the contrast of five different aspects. And the different aspects are displayed in Table 8.

Table 8: Aspects of evacuation information

*TEP: Timing of evacuation preparation
*TEA: Timing of evacuation advisory
*TED: Timing of evacuation directive
*AS: Administrative support
*VS: Volunteer support

The result will be displayed in figure 27. The total point score is 5 for every aspect of evacuation information like figure 26.

Appropriateness score for different contents				
5	4	3	2	1
Completely appropriate	Aprropriate	Undecided	Not appropriate	Completely inappropriate

Figure 26. Appropriateness score

The findings of figure 27 are: volunteer support (VS) gets highest score that is 3.06 for taken evacuation, and 3.03 for not taken evacuation. Therefore, it may be argued that the support from volunteer was significant. But the degree of appropriateness for other aspects like TEP, TEA, and TED and AS became lower than 3 points. Therefore, the degree of appropriateness of the whole activities was not significant. From the5 stage average points of evaluation of the sufficiency degree, only the voluntary support is above 3 points and other items support is lower than 3 points. So the sufficiency is seen to be low. In particular, evacuation information how to provide within proper timing and transmission will require improved as the appropriateness result is very low.

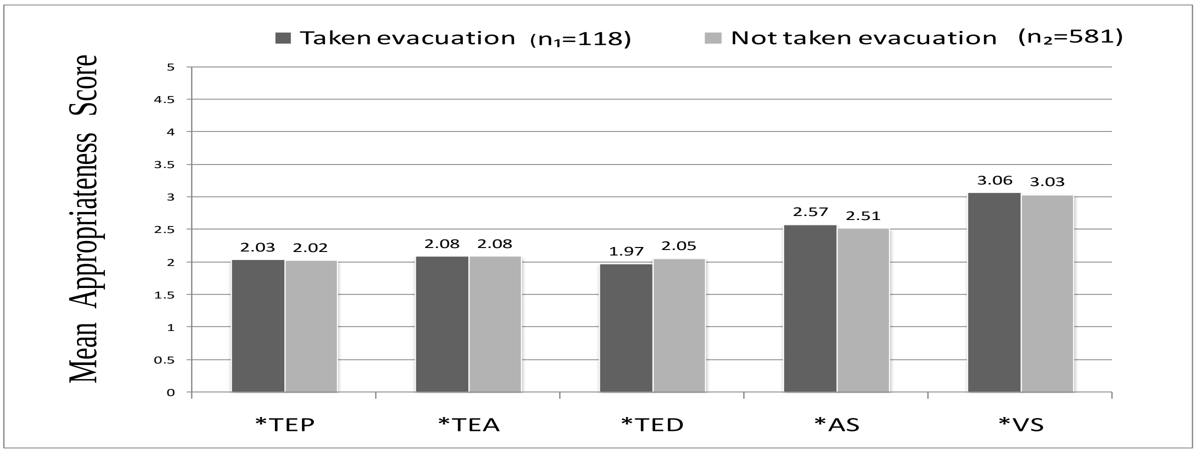

Figure 27: Appropriateness of the aspects of evacuation information

5.11. Abundance of evacuation advisory information announcement in different regions

In this study, we tried to understand mainly, whether it was announced officially all the information like "evacuation advice." And here it also justifies the residents' acquisition level about the announcement information about evacuation advisory.

Figure 28 describes that-

(a) In the upper and middle basin, it is found that information about evacuation advice has not been transmitted sufficiently.

(b) The availability of the announcement is different from place to place. It is observed that the rate of getting information is higher in the lower basin area of Asanogawa River. The rate is becoming lower in the part of middle basin and the upper basin gradually.

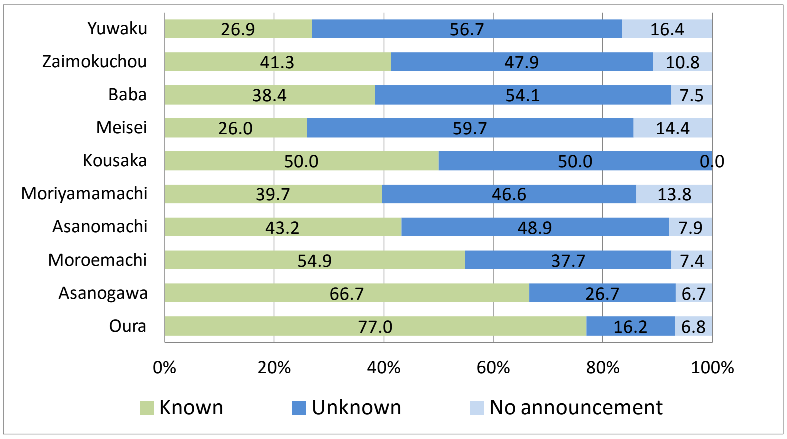

Figure 28: Abundance of obtaining evacuation information [n= 1787]

5.12. Location of the residents while getting the information about evacuation advisory

The information's procurement place of evacuation advice is shown in the figure 29.

The figure shows that the information's procurement place of the people who knew that evacuation advice was announced officially, the majority was the home. If it is the home, there is a possibility information being easy to procure through media such as prevention of disasters broadcast and a patrol car, television and radio. Furthermore, if it is the home, it is thought that it influences also the fact that it is the voice applying from the neighboring association.

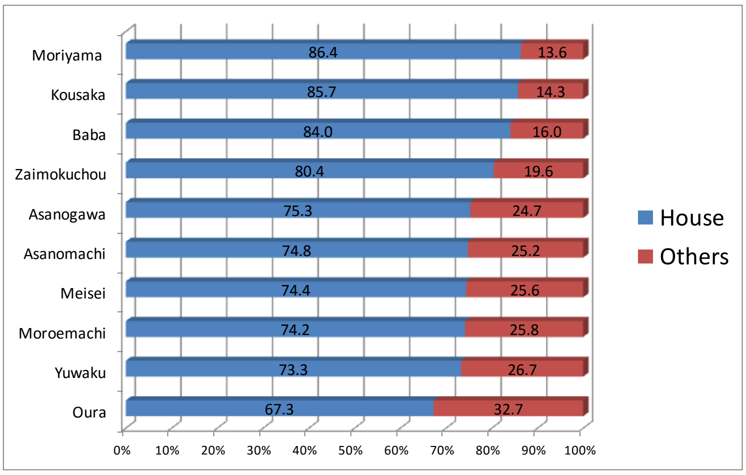

Figure 29: Location of the residents while getting the evacuation information [n=799]

5.13. How the residents acquired the information about evacuation advisory

Table 9 shows the list by which means the residence obtained evacuation order information by successively.

From Table 9, information how the residents obtained the information of evacuation advisory, it was found that 'disaster prevention broadcasting ' is the most common. Then, It was found to be 'from the people' and 'patrol car', and 'Television' in many cases. In Asanogawa lower basin areas such as high recognition rate of evacuation advisory information 'Oura', 'Asano', not only ‘disaster prevention broadcasting’, and people obtained information from the patrol car is the high rate, the efficient patrol car is considered to be important.

In addition, getting information from neighboring people is effective for an earlier appeal, but the information (from a neighbor), sometime may cause confusion such as the information complication, Information acquisition from the correct reporting is expected. The acquisition ratio from the disaster information email was very low, though it is thought very reliable. At the present time, the household possession rates of the mobile telephone exceed 90% (investigation of the mobile telephone household possession rate, Cabinet Office 2008, Japan).So it is thought that the disaster information email by mobile phone should be effective.

Table 9: The information acquisition means of the evacuation advisory

School District Area	Percentile Rank 1		Percentile Rank 2		Percentile Rank 3		Percentile Rank 4		Percentile Rank 5	
Zaimokuchou	DPB	38.8	Television	19.0	Patrol Car	10.7	Neighbors	7.4	DIE-mail	6.6
Meisei	DPB	30.9	Neighbors	23.6	Patrol Car	9.1	Television	9.1	Radio	7.3
Baba	DPB	43.9	Neighbors	17.5	Television	14.0	Patrol Car	12.3	DIE-mail	4.4
Asanomachi	DPB	36.2	Neighbors	16.7	Patrol Car	15.9	Television	8.0	DIE-mail	4.3
Moriyama	DPB	29.7	Television	21.6	DIE-mail	10.8	Radio	10.8	Patrol Car	8.1
Kousaka	DPB	60.0	Television	13.3	Internet	13.3	DIE-mail	6.7	Radio	6.7
Moroemachi	DPB	33.9	Neighbors	16.1	Patrol Car	14.4	Television	11.9	DIE-mail	5.9
Asanogawa	DPB	36.9	Patrol Car	21.4	Neighbors	12.6	Television	5.8	Radio	4.9
Oura	DPB	36.8	Patrol Car—	22.1	Neighbors	7.4	Television	5.9	Radio	5.9
Yuwaku	Neighbors	24.0	Television	16.0	DPB	12.0	Patrol Car	12.0	Radio	8.0

5.14. Actual situation of evacuation order to residence

In Asanogawa basin area, after the announcement of evacuation advisory in the school district areas, within 5 minutes [at 8:50] there was an announcement of the evacuation order. From the figure 30, figure 31 and from the table 10, we can understand the actual situation of an evacuation order, like about the acknowledgement of the evacuation order, where the residence obtained the information and by which mean they obtained the information.

Figure 3o shows, it was same as evacuation advisory that the residence of more affected areas could not get the information properly. Most of the people who lived in the lower basin of Asanogawa river acknowledged the evacuation order. Comparison of the evacuation advisory, the acknowledgement of evacuation order was low on average. It was a very little difference e.g. only five minutes between the proving time of evacuation advisory and evacuation order. That's why, there was a possibility of not getting enough time for evacuation preparation.

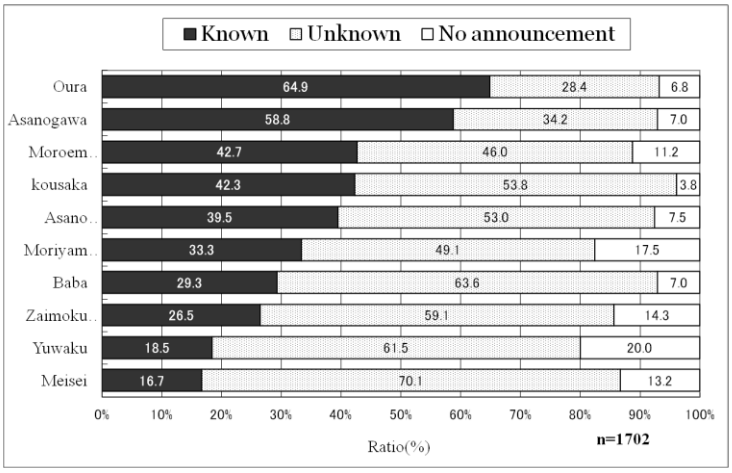

Figure 30: Actual situation of obtaining information about evacuation order

Then, it is shown in Figure31, the location of getting evacuation order information. From Figure 31, people where they accessed for information on evacuation order has been issued, the most was the home the same as in the evacuation advisory.

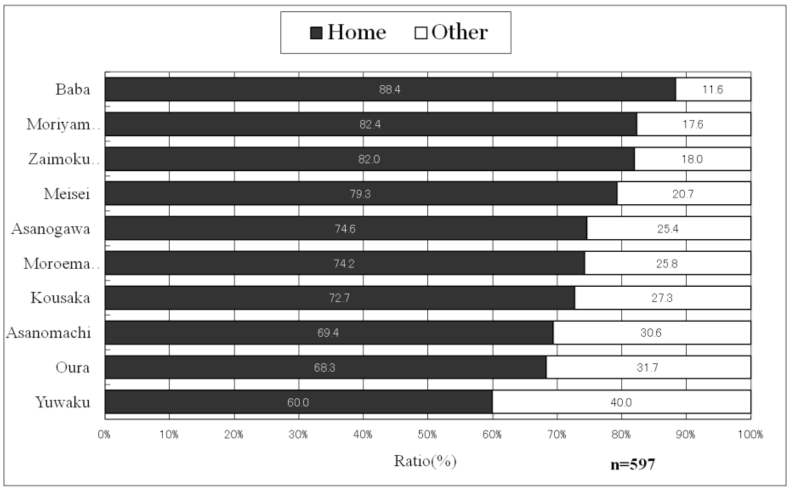

Figure 31: Location of obtaining evacuation order

Then, table 10 shows the list what kind of method the residence obtained evacuation order information by successively. From Table 10, how to obtain the information of evacuation order was also found to be the same as those of the evacuation advisory 'disaster prevention broadcasting ' is the most common. However, compared to the evacuation advisory, the ratio becomes slightly smaller of 'from the neighboring people', it suggests a tendency that the residents were trying to obtain accurate information from such as 'patrol car'.

Table 10: The information acquisition means of the evacuation order

School District Area	Percentile Rank 1		Percentile Rank 2		Percentile Rank 3		Percentile Rank 4		Percentile Rank 5	
Zaimokuchou	DPB	41.6	Television	23.4	Neighbors	9.1	Patrol Car	7.8	DIE-mail	6.5
Meisei	Neighbors	36.8	DPB	26.3	Patrol Car	10.5	DIE-mail	5.3	Television	5.3
Baba	DPB	43.5	Neighbors	18.8	Patrol Car	12.9	Television	12.9	DIE-mail	3.5
Asanomachi	DPB	30.6	Patrol Car	19.8	Neighbors	16.5	DIE-mail	7.4	Television	5.8
Moriyama	DPB	31.0	Patrol Car	17.2	Television	13.8	Radio	13.8	DIE-mail	10.3
Kousaka	DPB	50.0	Internet	25.0	DIE-mail	8.3	Patrol Car	8.3	Television	8.3
Moroemachi	DPB	34.1	Neighbors	19.4	Patrol Car	13.9	Television	12.3	Radio	5.2
Asanogawa	DPB	33.0	Patrol Car	25.5	Neighbors	20.2	Television	7.4	Radio	3.2
Oura	DPB	32.8	Patrol Car	27.9	Neighbors	8.2	Television	8.2	Radio	4.9
Yuwaku	DPB	23.1	Patrol Car	15.4	Neighbors	15.4	Television	7.7	-	

5.15. Information acquisition level of residents about the evacuation place

Sheltering is one of the most important considerations when planning evacuations. However, it is also important if the residents of the city are properly acknowledged about the definite shelter places. In the event of a disaster, depending on whether the shelter is known to residents in advance, we will get a very effective evacuation.

Here it was aimed to understand the acquisition level, e.g., prior knowledge, known by this disaster or unknown about the shelter places of the localities through figure 32.

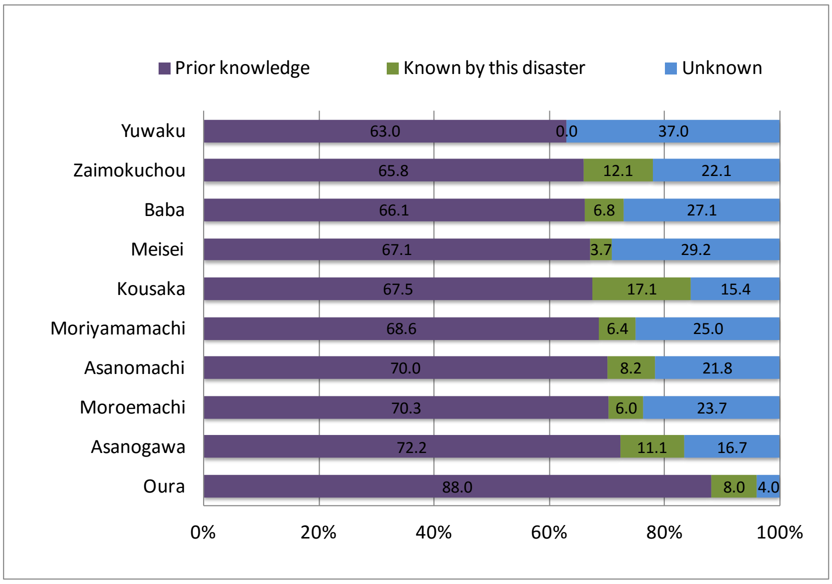

Figure 32: Information acquisition level of the shelter places **[n=1805]**

By analysis, the findings of the figure 32 are:

- ✧ "Oura" has a very large percentage of prior knowledge e.g. about 90%; prior knowledge of the other districts shows about 65% to 70%.
- ✧ Acknowledgement by this disaster has increased significantly in Kousaka, Zaimokuchou and Asanogawa.
- ✧ In many places, nearly from 20% to 30% of the residents do not know about evacuation place at all.
- ✧ The region of Asanogawa town and Moroemachi, where comparatively the resident is many, is thought that prevention of disaster consciousness increased with the latest flood disaster

5.16. Information acquisition level of the shelter places on average

Figure 33 presents a comparison of the acknowledgement in average for all regions. From figure 33, it is found that the large number of people e.g. about 70% have prior knowledge in average about the shelter places.

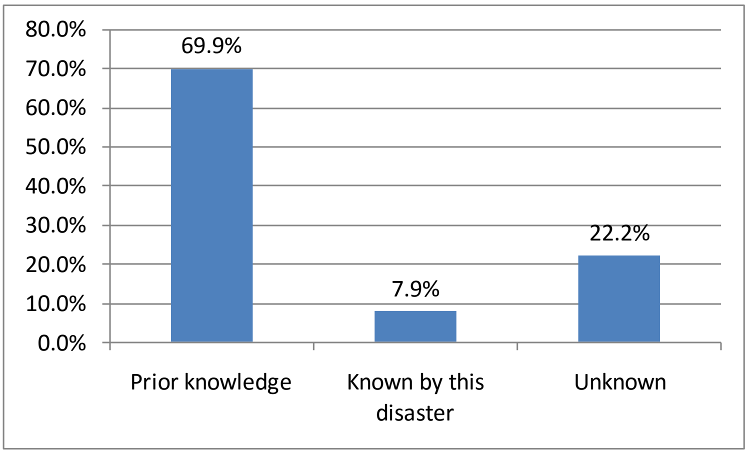

Figure 33: Information acquisition level of the shelter place in average [**n=1805**]

5.17. Acquisition of the flood hazard map

Here in figures 34 to 36, it is shown all about the flood hazard map. The supported data was collected from Ishikawa prefecture. It is revealed that only 25% of the affected residence knew about the flood hazard map. A very few people said that the hazard map was helpful to them.

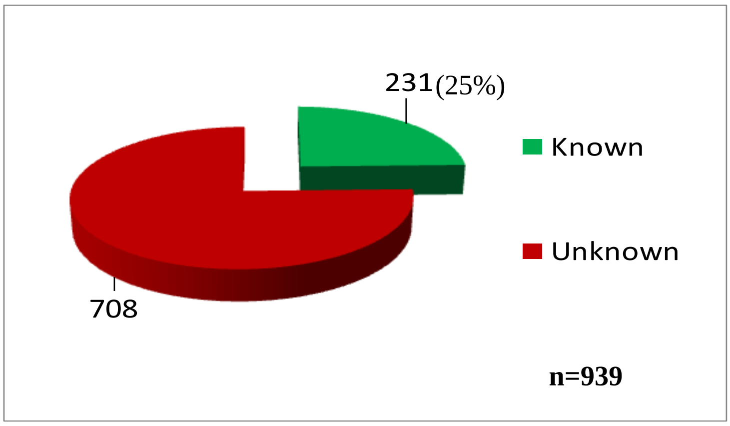

Figure 34: Known or unknown the flood hazard map

5.18. Flood hazard map was helpful or not for this flood, 2008

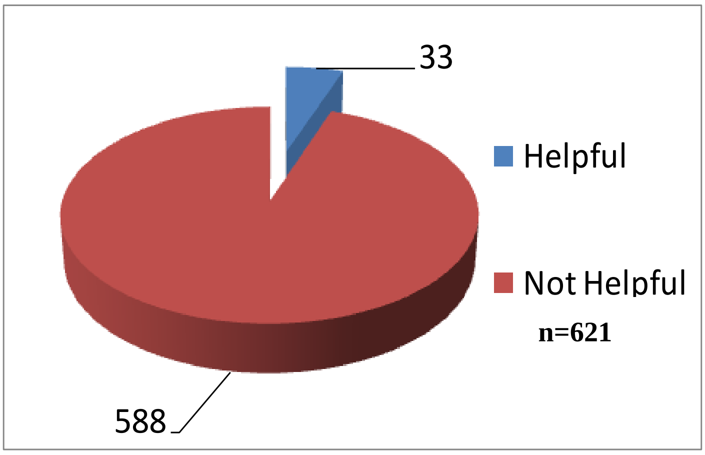

Figure 35: Flood hazard map was helpful or not

5.19 Why flood hazard map was not useful.

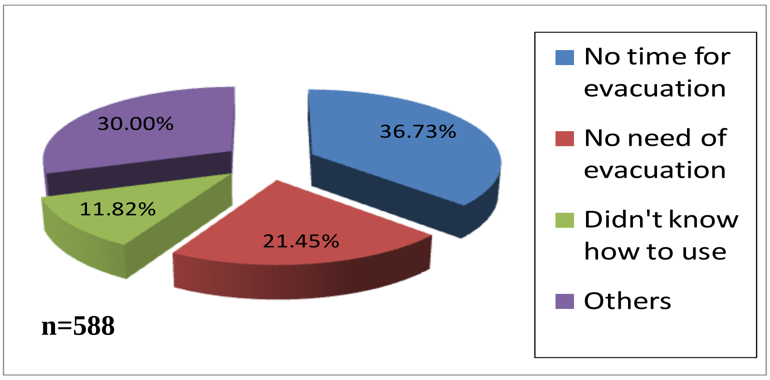

Figure 36: Why flood hazard map was not useful.

5.20. Rate of taking evacuation in response to evacuation preparation information

In this part, the questionnaire is designed to grasp the evacuation situation of the residents, according to their acknowledgement of evacuation preparation information. The city administration made an announcement and called the affected people for taking evacuation.

Here it is analyzed how about the effect of the administration announcement to the victims for taking their evacuation in the designated shelter places of the city. It is explained by figure 37.

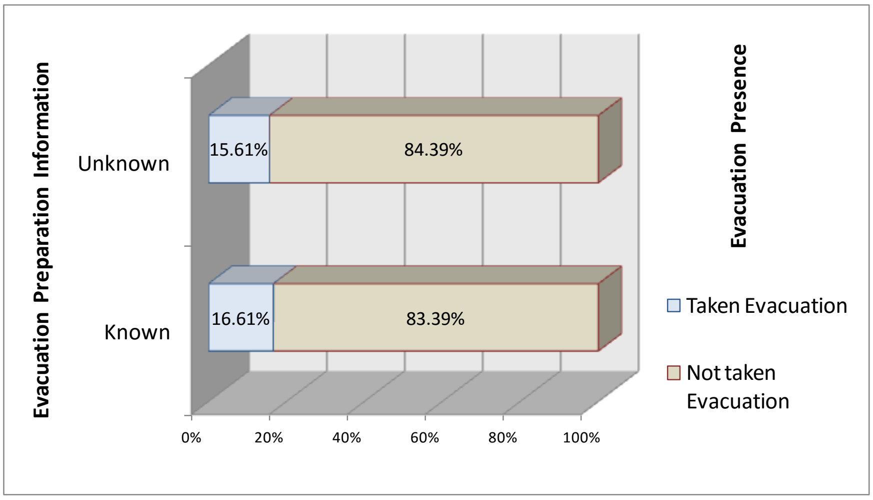

Figure 37: Rate of taking evacuation versus evacuation preparation information [**n=1357**]

It can be remarked by the analysis of figure 37:

(a) The percentage of the people those take evacuation is very low.

(b) A large number of people did not take evacuation though they were informed about the evacuation preparation.

5.21. Awareness and responsiveness to flood risk

The 2008 flood was the first time in 55 years that the around in the Asanogawa River area has been damaged by massive flooding due to the failure of levees. Before the flood disaster, the local inhabitants felt secure in believing that the Asanogawa River would not flood. Now, after the flood damage, based on the survey response it is shown that their concern is rising up.

Figure 38 reflects the resident's opinion about the raising of the river bank, maintenance of the river bed and measuring the flood gate. Now it is shown that 46% people give importance about the maintenance of the river bed.

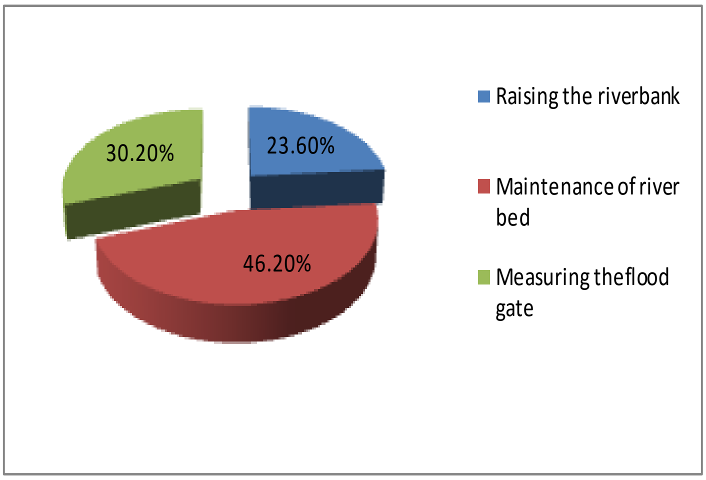

Figure 38: Residents' awareness of flood risk [n= 1496]
(Questionnaire survey, Ishikawa Prefecture)

5.22. Peoples' reaction to the disaster situation

The nature of people's reaction to an event might also depend on the type of flooding. People face slow-onset flooding (riverine floods) with elaborate responses, which are not very limited by warning, delay or "labor force". For fast-onset flooding (flash floods), flood-proofing appears to be the most immediate response, but necessitates a minimum warning because of the speed at which the water rises.

Here, the opinion of the people about the local city government's responsibility can be displayed in figure 39. In this part, a questionnaire was aimed to get an idea of their satisfaction level to the administrative correspondence and the levee protection facility of administration. It was asked to express their satisfaction about the city authorities over all performances against the terrible flood situation. From figure 39 it is found that, according to the respondent's answer, it can be said that they were not happy with the measures taken by the city authority to control the flood situation.

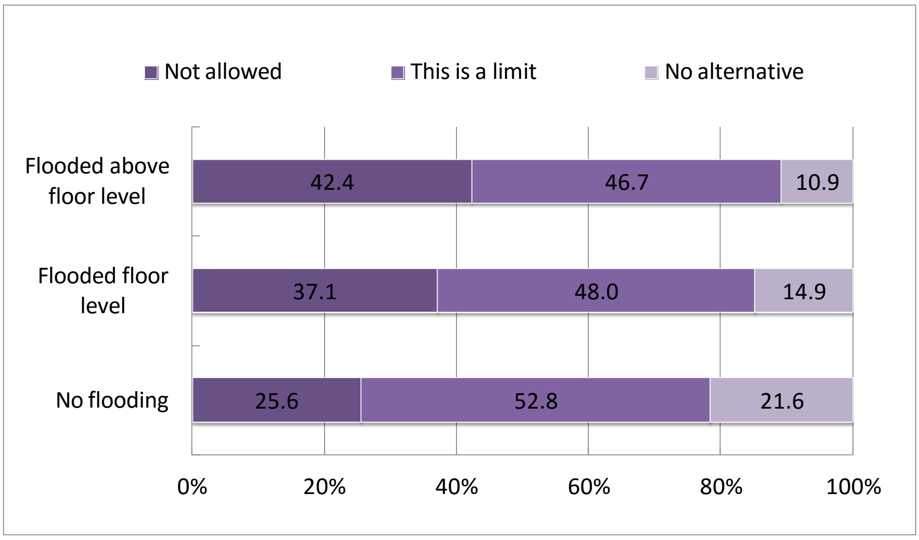

Figure 39: People's reaction to the disaster situation [**n= 1643**]

5.23. Analysis on the personal attributes of residence.

Here it is analyzed the personal information about the responders like his/her address, male/female, age, profession, family members, living in a house or apartment, have a car or not etc.

The distribution of the individuals surveyed in this study is graphically shown in Figure 40 to Figure 45 considering their personal attributes such as gender, age, type of house, family structure, profession and means of transportation for commuting.

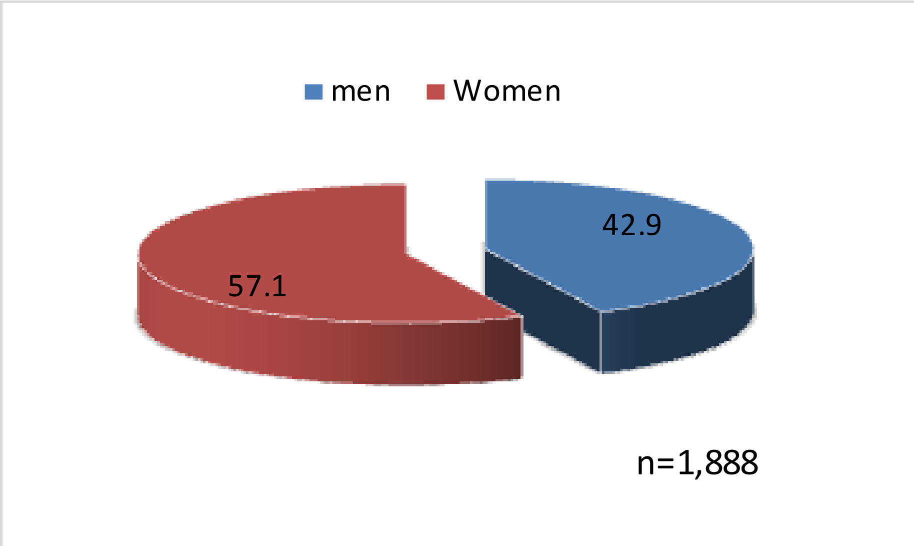

Figure 40: Gender distribution of the sampled residents

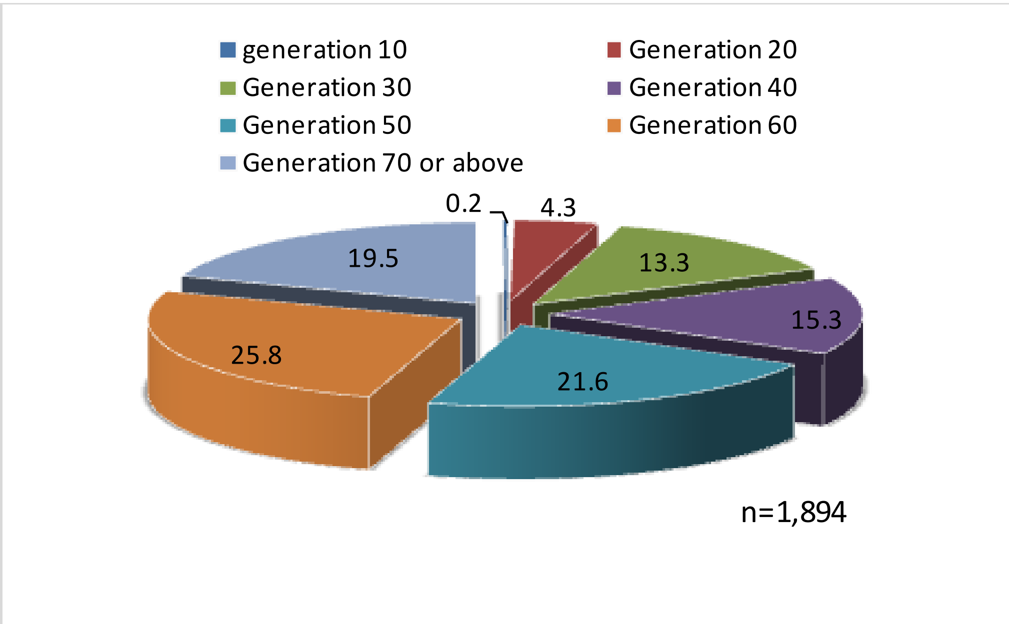

Figure 41: Age distribution of the sampled residents

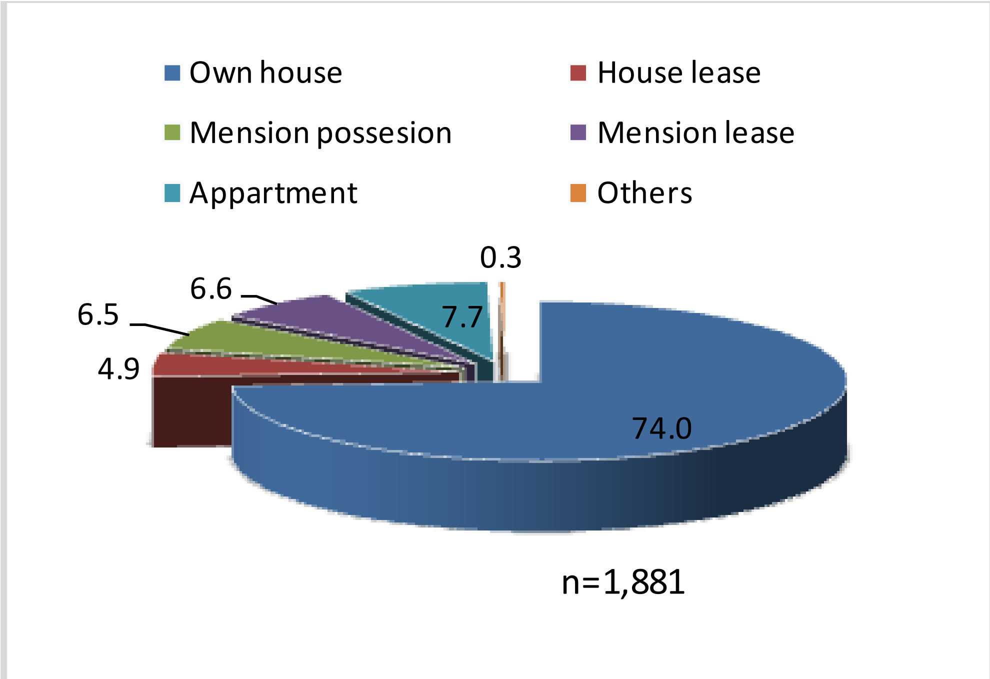

Figure 42: Types of houses of the sampled residents

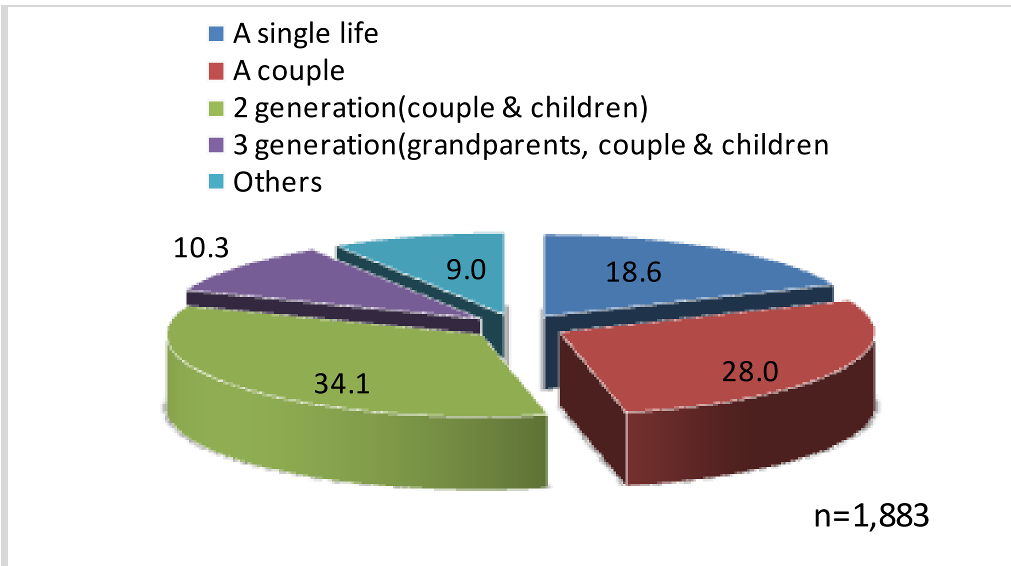

Figure 43: Family structure of the sampled residents

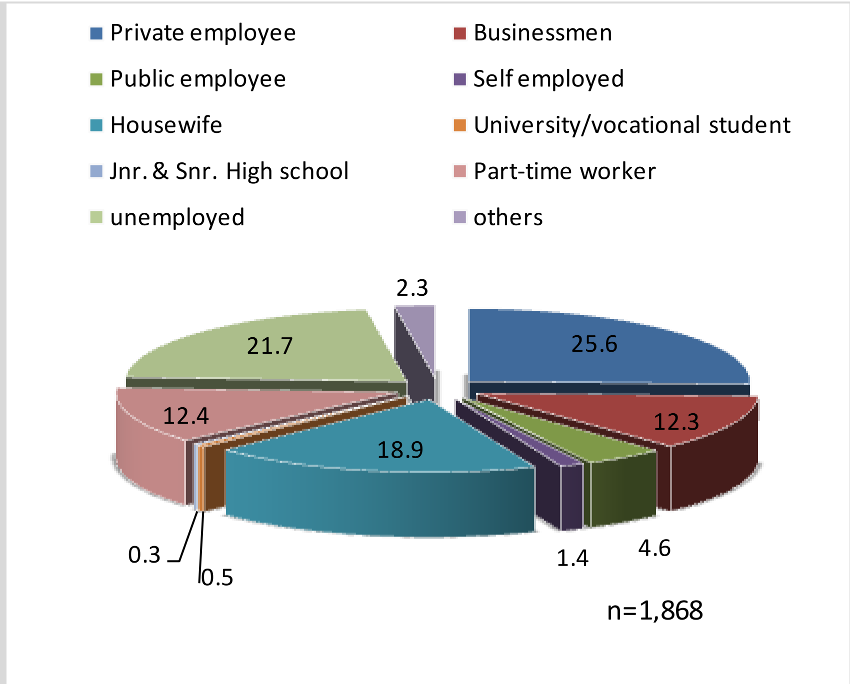

Figure 44: Profession distribution of the sampled residents

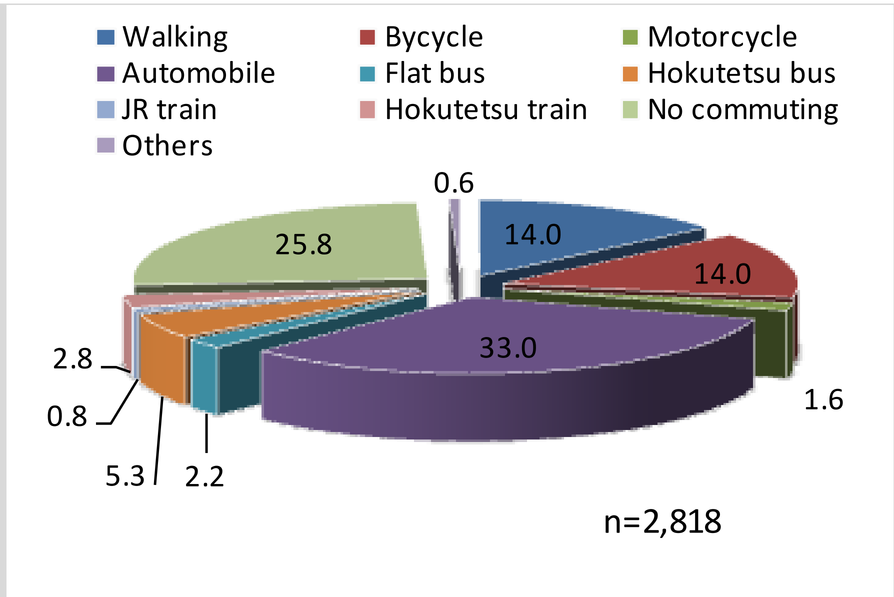

Figure 45: Types of transportation used by the sampled resident

6. Recommendation and Conclusion

6.1 Recommendation

(I) It was analyzed by the collected data that a large number of people got the evacuation information from their neighborhoods.

Though a lot of people have information from their neighborhood, but this kind of information is not always correct. Therefore, it may be better to ignore such information that is provided by the neighboring people.

(Ⅱ) It is observed that the percentage of having information in the DIE-mail is very low e.g. about 6%.

But DIE-mail can be a major source of having evacuation information as a large number of people are using cell phone nowadays. Currently, the household possession rates of the mobile telephone exceed 90% in Japan (Survey Report, Cabinet Office 2008, Japan).

(Ⅲ) People those who are living in the lower basin and upper basin, they have enough prior knowledge about the flood and evacuation. But the people those are living inside of the city area (middle basin), don't have much prior knowledge about the information of flood and as well as about the evacuation place.

Therefore, it may be suggested that it would be better to perform disaster drill frequently, at least once or twice in a year about the evacuation information plan among the people who are living in the city area. By this step, people would be more conscious and trained in the preparation of flood disaster or for any other natural calamities in future.

(Ⅳ) People's knowledge about the flood hazard and about self-protection, as well as good warning information, would help them to better perform emergency measures. Therefore, flood warnings should be released with more detailed information about expected water levels, time to peak flows and recommendations for appropriate response. However, the time and the number of people available to undertake emergency measures are the most important factors during the response phase. Therefore, longer lead times of early warnings are needed, especially in mountainous regions. Further, it would be worthwhile to think about improving response capacities in flood situations, e.g. by activating the neighborhood help or disaster management assistance.

6.2 Conclusion

In July 28, 2008 early morning, Kanazawa city was hit by severe local torrential heavy rain. As a result, Asanogawa is flooded for the first time in 55 years, and large-scale flooding has occurred in Kanazawa city. During that enormous damage, about 20000 households were provided evacuation advisory information among 50,000 residents in the Asanogawa river basin. According the result of the survey, despite the evacuation preparation information is issued, only 23% of the residents had been able to obtain the information, and 20% of the residents did not know until the information broadcasted in the media, etc. The remaining about 60% residents, had not been noticed the evacuation preparation information at all. In addition, many residents obtained evacuation information while staying at home mainly by disaster broadcasting and radio. During the flood about 55% percent of the people commuted. Among them, 70% people commuted to their schools or workplaces as usual. However, about 8% of the people commuted with delay, about 20% were found to cancel the commuting. In addition, on the day of flood damage, about 90% or more residents were not using usual transportation. That means they have changed or intended to ride buses from the car or motorcycle, etc. Many people felt free to commute to job on foot rather than using vehicles.

As described above, it is revealed that many residents did not care about the evacuation information of flood disaster provided by city government. And they followed the usual daily lives on the day of disaster. It is also found that disaster prevention awareness among the residents was very low. In the areas without flood experience, early provided evacuation information was not effective. However, the areas with the previous flood experience, the provided evacuation information were found comparatively effective.

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[115] 国土数値情報 国・都道府県の機関データ : http://nlftp.mlit.go.jp/ksj/gml/datalist/KsjTmplt-P28.html

[116] J-SHIS 地震ハザードステーション J-SHIS MAP : http://www.j-shis.bosai.go.jp/map/.

Annex: Questionnaire Survey (original version in Japanese)

２００８年 ７月２８日 金沢豪雨災害の避難状況に関するアンケートにご協力ください。

７月２８日早朝、金沢市を襲った集中豪雨により、浅野川流域を中心に甚大な被害をもたらしました。現在、復旧活動が続けられていますが、一部地区では、依然として避難勧告が継続中の状態です。本調査では、7月28日 金沢豪雨災害にて、避難準備および避難勧告、避難指示が出された地区を対象に、避難当時の実態をお聞きし、今後の避難計画策定の参考にさせていただきたいと考えております。

お忙しいところ申し訳ありませんが、ご協力をお願いいたします。なお、本調査で得られた結果は、本目的以外に利用することはありません。

＜調査主体＞　金沢大学理工研究域　交通まちづくり研究室　教授 高山純一（担当 轟直希）

問１．お住まいの地域（地区）の避難場所をご存知でしたか。

１．事前に知っていた　２．今回の災害で知った　３．知らない

問２－１．**「避難準備情報」**地区が発令されたことを知っていましたか。

１．知っていた　２．知らなかった　３．出されていない

問２－２．問１－１で「１．知っていた」と答えた方に伺います。いつ、どのような方法で知りましたか。

①いつ（情報入手時間）	午前（____）時　（____）分ころ入手
②どこで（情報入手場所）	１．自宅　２．その他（____________________）
③どのように（情報入手方法）【最初の情報入手について】	１．防災放送（同報防災無線）　２．パトロールカー　３．テレビ　４．ラジオ　５．災害情報メール　６．インターネット　７．近所の人から　８．その他（__________________）

問２－３．**「避難準備情報」**が発令されてから、どのような避難準備をされましたか。あてはまるもの全てに○をつけてください。ご家族分を準備された方は、**１人分**としてお答えください。

①衣服	１.準備なし	２.タオル程度	３.１泊程度	４.２泊程度	５.その他 __________）
②水分	１.準備なし	２.５００mℓ程度	３.１ℓ程度	４.２ℓ程度	５.その他 ________）
③食料	１.準備なし	２.非常食	３.軽食	４.２食分程度	５.その他 ______________）
④通信機器	１.準備なし	２.携帯電話	３.ラジオ	４.パソコン	５.その他 ____________）
⑤貴重品	１．現金	２．通帳	３．貴金属	４．その他（__________________）	
⑥その他	[____]				

問３－１．**「避難勧告」**の情報が発令されたことを知っていましたか。

１．知っていた　２．知らなかった　３．出されていない

問３－２．問３－１で「１．知っていた」と答えた方に伺います。いつ、どのような方法で知りましたか。

①いつ（情報入手時間）	午前（____）時　（____）分ころ入手
②どこで（情報入手場所）	１．自宅　２．その他（____________________）
③どのように（情報入手方法）【最初の情報入手について】	１．防災放送（同報防災無線）　２．パトロールカー　３．テレビ　４．ラジオ　５．災害情報メール　６．インターネット　７．近所の人から　８．その他（__________________）

問４－１.「**避難指示**」の情報が発令されたことを知っていましたか。

１．知っていた　２．知らなかった　３．出されていない

問４－２．問４－１で「１．知っていた」と答えた方に伺います。いつ、どのような方法で知りましたか。

①いつ（情報入手時間）	午前（ ____ ）時 （ ____ ）分ころ入手
②どこで（情報入手場所）	１．自宅　２．その他（ ____________________ ）
③どのように（情報入手方法） 【最初の情報入手について】	１．防災放送（同報防災無線）　２．パトロールカー　３．テレビ ４．ラジオ　５．災害情報メール　６．インターネット ７．近所の人から　８．その他（ __________________ ）

問５．あなたご自身の避難の有無についてお伺いします。避難情報入手後、避難をされましたか。さらには、どこへ避難しましたか。

①避難の有無	１．避難した　２．避難しなかった　３．知らなかった
②避難方法	１．徒歩　２．自動車　３．その他（ ______________ ）
③避難場所	ご記入ください（　　　　　　　　）　小学校・中学校・公民館

問６．避難情報の提供時間（時刻）や提供方法、避難場所の充足度についてお伺いします。あなた自身への避難情報が適切だったかどうか５段階で評価してください。避難情報が適切だったと感じるものは「５」に○をし、不適切（情報が遅い、十分に伝わらないなど）だと感じたものは「１」に○をしてください。

内容	適切 ←→ 不適切				
	適切				不適切
避難準備のタイミング（情報提供時間）	5	4	3	2	1
避難勧告のタイミング（情報提供時間）	5	4	3	2	1
避難指示のタイミング（情報提供時間）	5	4	3	2	1
避難情報の伝達方法	5	4	3	2	1
避難の誘導方法	5	4	3	2	1
災害情報の伝達方法	5	4	3	2	1
水防活動（洪水時）	5	4	3	2	1
復旧活動（洪水後）	5	4	3	2	1
行政の支援	5	4	3	2	1
ボランティアの支援	5	4	3	2	1

問７．災害後に発生した交通混雑の状況についてお伺いします。通勤通学時の浸水状況についてお伺いします。以下の地図中で、①浸水や土砂が堆積し交通が困難だった道路、②交通規制（通行止め）されていた道路を分かる範囲でお答えください。

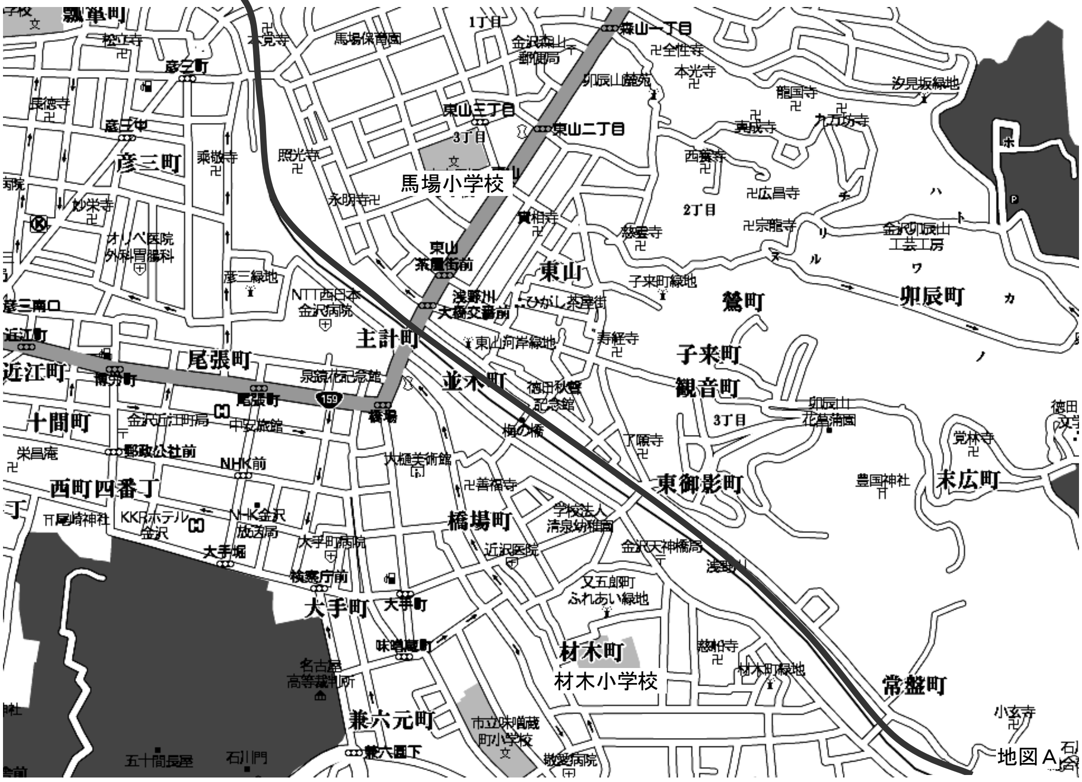
■ 通勤・通学を普段通り　１．行った　２．遅らせた　３．取りやめた

■ 自宅出発時刻　（ ____ ）時　（ ____ ）分　■ 勤務先・学校等到着時刻　（ ____ ）時　（ ____ ）分

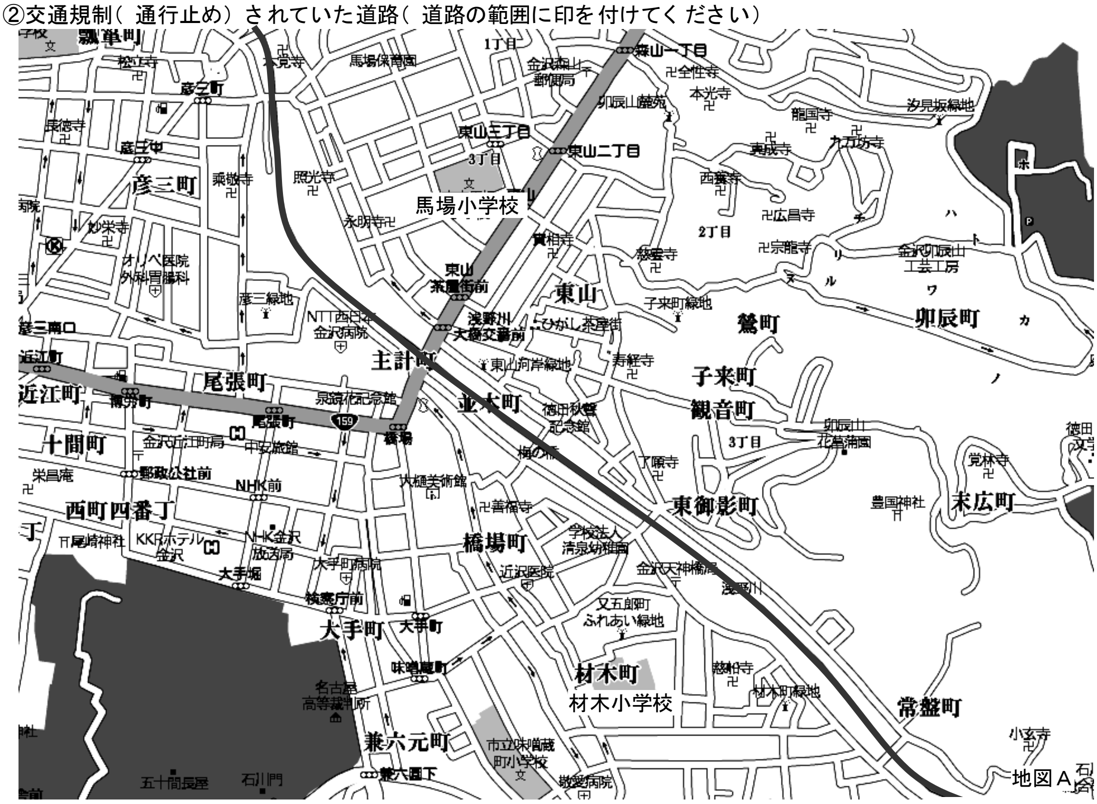
■ 通常時に比べて（ ______ ）分ほど通勤・通学時間が長くかかった。

■ 通勤・通学した場合、交通手段は　１．変わらない　２．変わった（ __________ ）⇒（ __________ ）

①浸水、土砂堆積で交通が困難だった道路（道路の範囲に印を付けてください）



②交通規制（通行止め）されていた道路（道路の範囲に印を付けてください）



問８．ご自宅や自動車等への被災の程度についてお伺いします。あてはまる被災状況に○を付けてください。

①ご自宅（戸建・アパート・マンション）	１．床上浸水	２．床下浸水	３．浸水なし	
②車庫	１．非所有	２．床上浸水	３．床下浸水	４．浸水なし
③自動車	１．非所有	２．車内浸水	３．浸水なし	

問９．今回の水害は、金沢市の山沿いを中心に１時間に１００mm以上の降水を観測し、５５年に１度とも言われる水害でした。また、８月２５日には「局地激甚災害」にも指定されています。このような水害に対するあなた自身の意識についてお伺いします。あてはまるものに○を付けてください。

①洪水の被害　１．これだけの降水量であれば仕方ない　２．もう少し被害を抑えることができた
３．たとえこのような豪雨でも、このような被害が出ることは許されない

②行政の対応　１．早かった　２．これくらいで十分　３．遅かった

③水防施設　１．今回の対応で十分　２．現状の設備内でより効果的に防ぐ（効果的な水門の開閉）
３．さらなる整備が必要（　１．堤防かさ上げ　２．河床整備　３．切り欠き部対策　）

問１０．あなた自身についてお伺いします。

問１０－１．あなたのお住まいをお答えください。

郵便番号□□□－□□□□　（＿＿＿＿＿＿＿＿）町（＿＿＿＿＿＿）丁目

問１０－２．あなたの性別をお答えください。

１．男性　２．女性

問１０－３．あなたの年齢をお答えください。

１．１０代　２．２０代　３．３０代　４．４０代　５．５０代　６．６０代
７．７０代以上

問１０－４．あなたの職業をお答えください。

１．会社員　２．自営業　３．公務員　４．農林漁業　５．主婦　６．大学・専門学校生
７．中高生　８．パート・アルバイト　９．無職　10．その他（＿＿＿＿＿＿＿＿＿＿＿）

問１０－５．あなたの通勤・通学に使う交通手段についてお答えください。(複数選択可)

１．徒歩　２．自転車　３．二輪車（バイク）　４．自動車　５．ふらっとバス
６．北鉄バス　７．JR(鉄道)　８．北鉄(鉄道)　１０．通勤通学なし　１１．その他(＿＿＿＿)

問１０－６．あなたのお住まいの住居形態についてお答えください。

１．戸建て住宅（所有）　２．戸建て住宅（賃貸）　３．マンション（所有）　４．マンション（賃貸）
５．アパート　６．その他（＿＿＿＿＿＿＿＿＿）

問１０－７．あなたの家族構成についてお答えください。

１．一人暮らし　２．夫婦（２人）　３．２世代同居（夫婦と子供）
４．３世代同居（祖父母と夫婦と子供）　５．その他（＿＿＿＿＿＿＿＿＿＿）

ご協力ありがとうございました。お渡しの封筒に入れ、１～２週間以内にお近くのポストにご投函ください。