Doctoral Dissertation

A Study Toward More Accessible and Suitable Spatial Information for Risk Communication in Indonesia: Focusing on Supply and User Side

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Doctoral Program in Policy Science
Graduate School of Policy Science
Ritsumeikan University

KARTIKA Puspita Sari

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A Study Toward More Accessible and Suitable Spatial Information for Risk Communication in Indonesia: Focusing on Supply and User Side
（インドネシアにおけるリスクコミュニケーションの為のよりアクセス可能で適正な空間情報に向けた研究：供給側とユーザ側に焦点）

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KARTIKA Puspita Sari

カルティカ　プスピタ　サリ

Supervisor：Professor KANEGAE Hidehiko

研究指導教員：鐘ヶ江　秀彦教授

Abstract of Doctoral Dissertation

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Widespread understanding of disaster risks is one of the main priorities in disaster risk reduction, and can motivate individuals to take protective action. Spatial information (maps) can be a useful visualization tool for facilitating this understanding since many disasters, particularly natural disasters, are spatial in nature. Advancements in technology have revolutionized how spatial information about disasters is created, used, and disseminated. Despite the importance and growing availability of methods of risk communication, there have been limited studies examining the dissemination and adoption of spatial information for disaster management, including risk communication.

To fill the gap in existing literature, this study aims to provide knowledge and empirical findings on the way spatial information is utilized for disaster risk communication in a developing country. It examines case studies in Indonesia from two sides: from the supply side (i.e., governments as the information providers) and the user side (i.e., public and relevant users who require this information). Specifically, there are three objectives of this study, and each is explained in a separate chapter of this dissertation.

Chapter 1 focuses on the supply side as it examines the way spatial information (maps) about disasters is disseminated to the public for risk communication purposes in Indonesia. It includes an examination of relevant policies and regulations, and the role of each level of government. A thorough online examination found that spatial information about disasters is not widely available online, and the way it is produced by different levels of government varies. Moreover, based on an evaluation using effective map criteria, it was found that the available information was not suitable for risk communication.

Chapter 2 provides an evaluation from the user side. First, it shows the effects of spatial information about disasters in risk communication. It was found that to some extent, spatial information about disasters can affect one's awareness of hazards and risk perception. This chapter also shows the effectiveness of different types of spatial information for visualizing hazard risks, and details findings that maps displayed on a disaster application are more readable than conventional printed maps.

Chapter 3 identifies the factors needed to improve the distribution and utilization of spatial information about disasters in Indonesia, from both the supply and user sides, so that this information can become more accessible and effective as a medium for risk communication. Findings from the supply side emphasize the need for clear regulation, guidelines, and the role of each level of government in the production and dissemination of information. The evaluation on the user side firstly highlights issues of lack of use and low awareness of the presence of information, which indicates the need for better promotion of the information. It also emphasizes perceived usefulness and user satisfaction of the application as factors significantly influencing users' intentions to use spatial information as a source of disaster information.

The final section concludes the study and suggests some recommendations for future studies.

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RESEARCH ACHIEVEMENTS

1. Papers/Proceedings

a. Published

1) Sari, K.P. (2018). A Spatial Study on Risk Analysis of Disasters caused by Natural Hazards to Cultural Heritage in Indonesia. *Journal of Disaster Mitigation for Historical Cities, Institute of Disaster Mitigation for Urban Cultural Heritage*, 12 (July 2018), 185 – 192.
2) Sari, K.P., & Kanegae, H. (2019). Using Interactive Maps to Disseminate Information and Communicate Disaster Risks by Local Governments in Indonesia. *Proceeding Book of the 16th Pacific Regional Science Conference Organization (PRSCO 2019),* (1), pp136 – 142. Pacific Regional Science Conference Organization (PRSCO) Summer Institute. **Chapter 1**
3) Sari, K.P., Kanegae, H., & Roychani, M. (2020). Assessing Awareness, Perception, and Usage Intention of a Disaster Information System: A Case of SIKK Magelang. *Journal of Disaster Mitigation for Historical Cities, Institute of Disaster Mitigation for Urban Cultural Heritage*, 14 (July 2020), 231 – 238. **Chapter 3**
4) Sari, K. P., Komalasari, R., & Kanegae, H. (2020, November). Disaster learning through a map-based mobile application: an evaluation of its readability and user satisfaction. In IOP Conference Series: Earth and Environmental Science (Vol. 592, No. 1, p. 012004). IOP Publishing. doi:10.1088/1755-1315/592/1/012004. **Chapter 2**
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b. Forthcoming

1) Sari, K.P., Kanegae, H., & Roychani, M. Local Risk Managers' and Disaster Volunteers' Awareness of, Attitudes Toward, and Intention to Use a Local Government-Developed Disaster Information System: A Case Study of SIKK Magelang. *IOP Conference Series: Earth and Environmental Science* (2021). **Chapter 3**

c. Under Review

1) Sari, K.P and Kanegae, H. How suitable are publicly available local disaster maps for risk communication in Indonesia? *International Journal of Cartography* (Submitted in May 2020). **Chapter 1**

d. Will submit

1) Sari, K.P and Kanegae, H. Can Map-Mediated Risk Communication Improve High School Students' Risk Perceptions and Intentions to Take Protective Actions? *Progress in Disaster Science* (Will be submitted in December 2020) **Chapter 2**

2. Presentations

a. Presentations at international conferences

1) Comparing the Availability and Features of Disaster-themed Web-Mapping Provided by Different Levels of Government: A Case Study of Indonesia. Presented at the International Symposium on Disaster Resilience and Sustainable Development held in March 2019 at Asian Institute of Technology Thailand, Pathumthani, Thailand.
2) Web Maps for Risk Communication: Assessing Availability of Online Disaster Maps on Government Web Sites in Indonesia. Presented at the International Cartographic Conference (ICC) Tokyo 2019 held in July 2019 at Plaza Heisei and Miraikan, Tokyo, Japan.
3) Development of a Framework to Assess Acceptability of Online Hazard Maps as a Source of Information on Disaster: A Literature Study. Presented at the 16th Pacific Regional Science Conference Organization Summer Institute held in July 2019 at Chulalongkorn University, Bangkok, Thailand.

4) Disseminating Information and Communicating Disaster Risks to Public by Interactive Maps: Case studies of Magelang Regency, Banda Aceh, and Sleman Regency, Indonesia. Presented at the 16th Pacific Regional Science Conference Organization Summer Institute held in July 2019 at Chulalongkorn University, Bangkok, Thailand.
5) Integrating Technology with Local Knowledge for Disaster Education: Utilizing e-Maps for Risk Communication in Two Javanese Cities. Presented at the 1st International Colloquium on Asian Paths of Civilization and Development in Conjunction with the 5th International Sustainable Technology, Energy, And Civilization Conference (ISTECC 2019) held in October 2019 at Conference Hall, Tun Abdullah Ahmad Badawi's Office, Putrajaya, Malaysia.
6) Local Risk Managers' and Disaster Volunteers' Awareness of, Attitudes Toward, and Intention to Use a Local Government-Developed Disaster Information System: A Case Study of SIKK Magelang. Presented online at the 2nd International Conference of Disaster Management held on 30 September – 1 October 2020 at Andalas University, Padang, Indonesia.
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1) A Study on Spatial Distribution of Disaster-related Geospatial Information Availability on Local Government Websites in Indonesia. Presented at the 55th Annual Meeting of the Japan Section of the RSAI

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3) Predicting User's Acceptance and Use of Online Hazard Maps for Risk Communication. Presented at Rice Ball Seminar held in July 2019 at Ritsumeikan University Osaka Ibaraki Campus, Ibaraki, Japan.

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LIST OF ABBREVIATIONS AND NON-ENGLISH WORDS

Abbreviations

API	Application Programming Interface
Bappeda	*Badan Perencanaan Pembangunan Daerah* (Municipal or Provincial Development Planning Agency)
Bappenas	*Badan Perencanaan Pembangunan Nasional* (National Development Planning Agency)
BIG	*Badan Informasi Geospasial* (Geospatial Information Agency)
BMKG	*Badan Meteorologi, Klimatologi, dan Geofisika* (Indonesian Agency for Meteorology, Climatology, and Geophysics)
BNPB	*Badan Nasional Penanggulangan Bencana* (National Disaster Management Agency)
BPBD	*Badan Penanggulangan Bencana Daerah* (National Disaster Management Agency)
DIBI	*Data dan Informasi Bencana Indonesia* (Indonesia Disaster Database)
DRR	Disaster Risk Reduction
EM-DAT	Emergency Events Database
FOSS	Free and Open-Source Software
GIS	Geographic Information System
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
INATEWS	Indonesia-Tsunami Early Warning System
IRBI	*Indeks Risiko Bencana Indonesia* (Indonesian Index for Disaster Risk).
PHP	Hypertext Preprocessor
PVMBG	*Pusat Vulkanologi dan Mitigasi Bencana Geologi* (the Centre of Volcanology and Geological Hazard Mitigation)
SFDRR	Sendai Framework for Disaster Risk Reduction 2015-2030

SIKK Magelang	*Sistem Informasi Kebencanaan Kabupaten Magelang* (Disaster Information System of Magelang Regency)
TAM	Technology Acceptance Model
UN	United Nations
UNDRR	United Nations for Disaster Risk Reduction
UNU-EHS	United Nations University Institute for Environment and Human Security
WRI	World Risk Index

Non-English Words

Kabupaten	Regency
Kecamatan	Sub-district
Kota	City
Provinsi	Province

INTRODUCTION

A. Research Background

Understanding Disaster Risks through Risk Communication

Disaster risk reduction (DRR) includes concepts and practices for preventing new and reducing existing disaster risk and managing residual risk to strengthen disaster resilience and, therefore, to achieve sustainable development (UNDRR, 2020). One of the main priorities of disaster risk reduction is understanding disaster risk. Disaster risk is the potential loss of life, injury, or destroyed or damaged assets that could occur to a system, society, or a community in a specific time, that determined probabilistically as a function of hazard, exposure, vulnerability, and capacity (UNDRR, 2020). Understanding disaster risk includes an approach to convince people that risk is real, describe its characteristics, and provide information on what to do about it (Lundgren & McMakin, 2018). Understanding the causes, effects, and geographic patterns of local hazard risk is essential in promoting risk awareness and making educated decisions about responding to the threat (Battersby et al., 2011).

Experiences in disasters can raise awareness and risk understanding. Thus, people with disaster experiences may have already developed awareness and understood the risk. However, some who have already experienced disasters still need to be reminded of the importance of being prepared. On the other hand, for those with no disaster experiences, giving access to disaster risk information is a way to understand disaster risk.

Disaster risk information is comprehensive information on all dimensions of disaster risk, including hazard, exposure, vulnerability, and capacity, associated with persons, communities, organizations, countries, and their assets (UNDRR, 2020). It includes all information and mapping required to understand drivers of disaster risks and underlying risk factors (UNDRR, 2020). Increasing citizens' opportunities to access disaster risk information (and multi-hazard early warning systems) is one of the seven targets of the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030, which supports almost all the priorities of the framework, especially its first priority (UNISDR, 2015). This global DRR framework encourages local government to share and disseminate non-sensitive disaster risk information and data with the best use of geospatial information technology and make collaboration on these actions with non-governmental and community-based organizations. As the framework aligns with the Sustainable Development Goals (SDGs) and sharing information about disasters may lead to the enhancement of community resilience; thus it can support targets of the goals related to disaster risk reduction, especially the achievement of goal number 11 (i.e., sustainable cities and communities) (UNDRR, 2015).

Delivering disaster risk information or exchanging the risk information about hazard and its associated risk among stakeholders (individuals, groups, or organizations) can be done through risk communication or sometimes take place as hazard communication. Although some aspects of risk communication may be similar to hazard communication, including informing people of potential dangers, predictions of future events, and technical information on how the threat is likely to materialize and what to do about it, hazard communication is more toward communicating well-understood hazards or emergencies (G. O. Rogers, 2020). In hazard communication, prior experiences of disasters is essential in determining the communication context and which behaviors are most appropriate under such circumstances (G. O. Rogers, 2020). Risk communication, on the other hand, deals with risks that are themselves often fraught with uncertainty, complexity, and incompleteness.

The literature on risk communication has been vast and varied, traditionally associated with environmental management, public health, and emergency management traditions. Many fundamental concepts of risk communication have a long history, but the identification of risk communication as a distinct subject matter has only occurred since the early 1980s (Lindell & Perry, 2004). Risk communication seeks to inform people about potential future harm and the associated dangers so that they might take action to mitigate the risk. Among the very first scholars studying risk communication is Covello et al. (1986). They define risk communication as the act of conveying or transmitting information between interested parties about: (1) levels of health or environmental risks, (2) the significance or meaning of health or environmental risks, or (3) the decisions, actions, or policies aimed at managing or controlling health or environmental hazards. Risk communication can also be seen as public awareness initiatives or public education about disasters, aiming to increase the awareness of communities and other stakeholders on risks and protective actions (Susmayadi et al., 2014). Communication can be delivered as spoken or verbal, non-verbal, written, active listening, and visual (including spatial) communication (Willkomm, 2018).

Risk communication is an essential and integral component of risk management (Vincent T. Covello et al., 1989; Dransch et al., 2010; Kammerbauer & Minnery, 2019). Understanding how people perceive risks and how to communicate risk information effectively are keys to improving risk management (Vincent T. Covello et al., 1989). It is one of the three pillars of risk management that connects risk assessment and risk management, focusing on dissemination and discussion of information among scientist, regulators, politicians, and the public on potential risks and available risk management strategies, which includes public characterization, development messages, and channel, and monitoring and review (Adiyoso, 2018; Teaf & Kuperberg, 2004). While risk assessment is related to an understanding of the extent and magnitude of hazard, risk management refers to developing practical and technically effective qualitative or quantitative goals and decisions regarding safe exposure levels, coupled with methods to minimize or control potential exposures (Teaf & Kuperberg, 2004).

Understanding how an audience's attitudes and opinions about an idea influence their reception to messages is an essential part of the persuasion process. Thus, risk communication is also seen as a social marketing process. According to Coppola & Maloney (2017), social marketing is the practice of utilizing marketing concepts to influence positive behaviors among individuals or designated target populations. Like traditional product marketing, social marketing employs "the marketing mix" to spread their message. In this manner, campaign design is guided by the conventional "four p's of marketing" and the additional "p's," including product, price, place, promotion, public, partnerships, policy, and purse strings.

Coppola & Maloney (2017) claim that all disaster preparedness, communication, and education efforts share a common goal: to reduce individual vulnerability to one or more identified hazard risks as much as possible among as many members of a defined target population as possible. They further state three primary risk communication goals that can be applied partially or in whole to all risk communication efforts:

1. Raising awareness about the hazard risk(s).

2. Guiding behavior, including:
   a. Pre-disaster risk reduction behavior,
   b. Pre-disaster preparedness behavior,
   c. Post-disaster risk reduction behavior, and
   d. Post-disaster preparedness behavior.
3. Warning.

The abovementioned goals are consistent with the classification of risk communication by Covello et al. (1986). They classified risk communication into four general types according to the primary objective or intended effect of the communication: (1) information and education, (2) behavior change and protective action, (3) disaster warnings and emergency information, and (4) joint problem solving and conflict resolution.

It is crucial to maintain effective communication because failure in this issue will undermine the decisions and responses from both emergency operators and citizens, possibly worsening the impact of natural disasters on people and infrastructure (Netten & Van Someren, 2011). Without an effective communication system in place, first responders may not be able to access the right information at the right time. Time and human resource constraints may limit the ability to search for relevant information actively. Poor decisions may ensue due to missing information, misleading information, or overlapping description of the same facts (Tanev et al., 2017). Worse still, decision-makers may become overwhelmed by information overload, potentially resulting in dysfunctional performance and suboptimal outcomes (Netten & Van Someren, 2011).

The Need for Strengthening Situation Awareness and Spatial Thinking of Disasters

Natural hazards and disasters are spatial in nature; thus, it is vital to understand the spatial dimension of disasters. Understanding the spatial patterns of hazardous events, as well as the geographical boundaries of their impacts is critical for both risk reduction actions preceding to an event and response and recovery processes (Aubrecht et al., 2013; Battersby et al., 2011). A better understanding of spatial thought provides us with information that is the cornerstone of spatial behavior and decision making. When knowledge about disasters (understanding the hazard process, elements at risk and their vulnerabilities) is increased without considering its spatial dimension, it may not provide the full picture in order to develop comprehensive management strategies for risk reduction (Aubrecht et al., 2013).

The importance of spatial perspective in disasters was initially the works of geographers and psychologists that led to the emerge of behavioral geography. This clearly showed that both geographers and psychologists are interested in people's behavior in hazardous areas and the decision-making and thought processes that trigger such behaviors (Kitchin et al., 1997). The discussion was started by a geographer named Gilbert F. White in 1945, which was also remarked as the beginning of behavioral geography. He famously declared in his study that: "floods are acts of God, but flood losses are largely acts of man" (White, 1945). Another impetus of behavioral geography in the context of disaster was done by (Kates, 1962). Both of the very first studies examined why people moved into, continued to live in areas that were prone to natural and technological hazards.

One of contemporary approaches for understanding the spatial dimension of disasters is situation awareness. Tomaszewski (2014) introduced the term situation awareness to describe the need understanding the spatial context of disasters. He simply defined situation awareness as knowing what is going on, which is originally used and essential for decision making in a military setting. In the military, this understanding situation refers to knowing the position and status of the troops, enemy locations, terrain, and vital infrastructure such as roads, lines of battles, and other factors. Situation awareness is resulted from situation assessment – a process where information about the relevant factors in the environment is acquired. In his book, he highlighted the benefits of Geographic information system (GIS) in both situation assessment and awareness. In his latest book (Tomaszewski, 2021), he added the generation of Big Data, Machine Learning, Artificial Intelligence, Virtual and Augmented Reality for the future Disaster Management.

Spatial Information as a Risk Communication Tool

Risk understanding can be enhanced through disaster learning by utilizing various tools. Spatial information (maps) can be one of these tools as disasters have a strong spatial component (Dransch et al., 2010). Furthermore, each phase of disaster management is geographically interconnected to where people, places, and things are spatially located (Gunes & Kovel, 2000); thus geographical information technology (GIT), which has the ability to acquire, interpret, analyze, map and disseminate information (Herold & Sawada, 2012), serves as an essential supporting tool in the management of disasters (Mileti & Peek, 2000). Spatial information could visualize the information needed by its readers to improve their situation aspect of on disasters, especially as we are now living in an increasingly visualized society (Lester, 2014).

Hazard, risk, and evacuation maps, both in the printed form and as an interactive tool, are examples of how spatial information is used to learn the geographical pattern of disasters. Printed maps used to be the most common medium, for example, to prepare people for emergency evacuation. Unfortunately, these types of maps are poorly understood and often ignored by people (Burigat & Chittaro, 2016). Advances in mobile and geographic information technology and the revolution in online maps, particularly after the invention of Google Maps in 2005 and its mobile version in 2007 (Peterson, 2012), have altered how maps are produced, distributed, and used. Map-mediated risk communication is no longer limited to the use of static or printed maps, which may provide little functional benefit. Maps now are more interactive, allowing users, at the very least, to pan the map, zoom in and out, share their location, and search for points of interest (Muehlenhaus, 2014). They are often designed to be more user-friendly and more uncomplicated than desktop Geographic Information System (GIS) and can also be created at a lower cost (Abo El Ezz et al., 2019; Cinnamon et al., 2009; Sevtap Selcuk-Kestel et al., 2012).

New freely available digital maps, mostly incorporated into a disaster information system or formed as an application, have become popular tools for coping with disasters (Meechang et al., 2020). A map-based disaster application on smartphones and tablets with location-based services enables users to locate themselves on real-time geographic data accurately. With this feature, one mobile device can perform various place-based disaster management decision-support functions, from assisting a person’s routing for evacuation based on traffic flows to conveying place-specific disaster warnings (Thomas, 2018).

Changes in Spatial Information as the Effect of Changing Technology

Spatial information was formerly recorded on paper maps. It was previously the area of interest of navigators, surveyors, astronomers, and engineers. This setting remained principally unchanged until the dawn of modern computers which has permitted maps to be produced digitally, and spatial information to be disseminated in digitized forms. Nowadays, spatial information, especially digital maps, has been also gained interest from computer scientists, web developers and self-taught coders. Geospatial Information Technology (GIT), including Geographic Information System (GIS), Remote Sensing (RS), and Global Positioning System (GPS), has greatly transformed how people produce and engage with geographic or spatial information. Online maps for instance have shaped the primary user experience, serving as both the means of creation and the mechanism for information sharing and delivery. Interactive GIS maps are now used widely, allowing people to create and combine their own digital layers of all kinds in their maps for a richer, more meaningful perspective about their world, to help solving real-world problems. GIS has also evolved into a means for data sharing and collaboration, especially with the Web GIS which makes it possible for individuals to access and put to store maps virtually by everyone everywhere. Nowadays, so many organizations are sharing their work and creating billions of maps every day to tell stories and reveal patterns, trends, and relationships about everything.

Although the developments and implementations of geospatial information technology may considerably vary across nations, the 1960s can be seen as the begin of spatial information changing due to the inventions of various spatial-information related technologies. Spatial information was no longer limited to two-dimensional manually produced maps since then. The birth of first computerized Geographic Information System (GIS) in 1962 by Roger Tomlinson, marked as the first introduction of digital cartographic technologies. During this period, the Internet was also first introduced in 1969. Augmented Reality (AR) and Virtual Reality (VR), which nowadays have been combined with geospatial technology and seen as a promising trend for GIS technology, were also initially developed during the decade.

In 1960s-1970s, the main focus geospatial information technology development was to replace human labor with machine processing, which was represented as the birth of "automated mapping" and digital mapping techniques (Morita, 2005). The first digital thematic maps were used for analyzing location-specific data such as populations within cities or census tracts. In these periods, the first earth observation monitoring, Landsat was also launched in 1973, adding a rapid progress of geographic information.

The application of GIS was significantly accelerated with the advent of the computer, particularly with the presence of affordable and portable computers and software in the late 1980s and 1990s, the increased popularity of the Internet in the mid-1990s and followed by the dawn of mobile platforms and wireless data in the 2000s. In the 1980s, GIS technology was commenced as a thematic mapping technique which incorporates a range of database (Morita, 2005). During this period, interactive mapping was first initiated, although it was noticeably difficult to manipulate and could only be used effectively by specialists. In the following decade (i.e., 1990s), spatial information (maps) was presented more interactively through multimedia cartographic features with technical supports of rapid advancements of personal computers and introduction of high-capacity storage devices. Texts, voices, and multimedia graphics such as photographs and videos are embedded to enhance map functionality. Since the 2000s, ubiquitous computing environment has significantly transformed spatial information to be used and created anytime and anywhere.

In the middle of 1990s, numerous spatial information on the Internet were become more accessible, particularly after the introduction of the World Wide Web[1] in 1993. The Internet itself was firstly introduced in 1969; however, it did not gain any popularity until the 1990s. In 1990, Tim Berners-Lee, dramatically changed the way Internet was used by inventing the world's first Web server and a Web browser. He and his colleagues also invented the way to easily share and exchange documents through Hypertext Transfer Protocol (HTTP), Hypertext Markup Language (HTML), and the Uniform Resource Locator (URL). The Web drastically changed the way maps are delivered (Peterson, 2012). Originally, online maps were dominated by scanned paper maps. However, along with the growth of data centers, database driven maps appeared later. Online maps then can be formed as static maps or dynamic maps which included animated and interactive maps (Peterson, 2003).

The Web GIS, the combination of the Web and GIS, in particular, has helped paving the way for the information highway, which allows an unprecedented informed-based society and changes in the way people live and work (Fu & Sun, 2011). Moreover, the integration of GPS has made it enabled for individuals to accurately project their location onto maps (Morita, 2005). With the rise of the Internet, cartography then shifted away from the paper medium to Internet mapping and exploratory geo-visualization (Muehlenhaus, 2014).

The launch of Google Maps in 2005 has even revolutionized web mapping service applications on the Internet, leading some to proclaim the "democratization of mapping" (Schmidt and Weiser, 2012). Google Maps changed the online mapping landscape and

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[1] The World Wide Web is a system of interlinked hypertext documents and programs that can be accessed via the Internet primarily by using HTTP ((Fu & Sun, 2011)

changed the way people interact with maps, especially from the map user's perspective (Peterson, 2012). It was the first implementation of a tile-based mapping system based on Asynchronous JavaScript and XML (AJAX) that facilitated zooming and panning. Since that time, online mapping has been defined by Application Programming Interfaces (APIs) which make maps friendlier to developers. From the user perspective, APIs has helped improving user experience for instance, for scrolling across locations from a map view.

In the last few years, due to the widespread use of mobile devices such as smartphones and tablet computers, maps are not only interactive but mobile and tangible. Wireless environment had made it possible to obtain and view real-time spatial information. Mobile devices started to be used greatly for map distribution beginning with the introduction of Apple's iPhone in 2007. Spatial information is no longer limited to Web maps but has also shifted to mapps (digital map applications' made for mobile devices) (Muehlenhaus, 2014). Digital-map-enabled applications on mobile devices have since become a primary way that maps are distributed to users. Some scholars claim that the future challenges of spatial information, specifically digital mapping, are making the map work offline and creating accurate maps of the indoors, which will be led by sensors, including beacons.

Advancements in geospatial information and communication technology have revolutionized the way spatial aspect of disaster risks is communicated as the spatial information about disasters have become:

1. more interesting and end-user friendly because of the dynamic and interactive visualization;
2. more location-accurate because of the location-based feature;

3. more personalized because of the self-navigation enable; and
4. cheaper to produce because of the availability of free and open source technology.

B. Research Objectives

Previous section has explained the important values of spatial information about disasters as a risk communication tool to increase the spatial awareness of hazard risks. It also described how technology has advanced the information. As a consequence, nowadays, numerous web maps and map-based applications with various quality are available on the Internet. Despite this growing phenomenon, Thomas (2018) argued that little is known about the way geographic information technologies for disaster management are adopted and disseminated. She also added that little research recently exists on how maps influence risk perception and decision-making as the ways in which people understand and interpret maps varies.

To address the problems and to fill the gap in literature on the way spatial information in disaster management, including in risk communication is adopted and disseminated as mentioned in the previous section, this study aims to provide knowledge on the way spatial information is utilized in a developing country for public risk communication purposes by using two approaches both from the supply side (i.e., governments as the information providers) and the user side (i.e., public and relevant users). To reach the aim of this study, three sub-objectives are defined as follow:

1. To examine the existing situation in Indonesia regarding the way spatial information (maps) about disasters is disseminated to the public for risk communication purposes (**RO1**).

2. To assess the effectiveness of using spatial information for risk communication (**RO2**).
3. To identify factors needed for improvements of dissemination and adoption of spatial information about disasters for risk communication (**RO3**).

C. Research Questions

With the underlying research objectives, the accompanying research questions are as follow:

1. Questions for **RO1**:

   RQ1.1: How is spatial information about disasters disseminated to the public for risk communication purposes in Indonesia?

   RQ1.2: How suitable is the available information for communicating the spatial aspect of disaster risks?

2. Questions for **RO2**:

   RQ2.1: To what extent does currently available spatial information about disasters can affect one's spatial awareness hazards and risk perception?

   RQ2.2: How readable are both printed maps and map-based disaster applications as sources of the spatial information about disasters?

3. Questions for **RO3**:

   RQ3.1: What aspects should be improved for better spatial information-mediated risk communication?

   RQ3.2: What factors influence individuals' intention to use spatial information about disasters?

D. Research Hypotheses

In regard with the research objectives and research questions, several research hypotheses and propositions have been constructed, which are:

1. Propositions for **RQ1.1** and **RQ1.2**:

   RH1.1: Spatial information about disasters is not widely available online and the way it is produced by different levels of government vary.

   RH1.2: Based on an evaluation using effective map criteria, the available information is not suitable for risk communication.

2. Propositions for **RQ2.1** and **RQ2.2**:

   RH2.1: Spatial information to some extent can affect one's spatial awareness of hazards and risk perception.

   RH2.2: Compared to printed maps, map-based disaster applications are more readable.

3. Propositions for **RQ3.1** and **RQ3.2**:

   RH3.1: Based on the evaluation of recent conditions and learning from best practices from other countries, visualization aspects and use of proper technology are among the important aspects for the improvement.

   RH3.2: Information quality, system quality or ease of use, user satisfaction, perceived usefulness, map-related factors, risk perceptions, and facilitating conditions (e.g., available resources and internet connection quality) significantly influence intention to use.

E. Rationale

Studying the dissemination and adoption of spatial information for risk communication has theoretical, practical and societal implications. In communicating disaster risks, we should put more considerations on the role of spatial information, especially with the continuous advancements in geospatial information technology and information and communication technology that consequently changes the way spatial information about disasters is produced and delivered to the public. In communication research, the issue of visual-spatial communication use for public risk awareness is rare and is primarily still focusing on the development of its tools. In regard to the new form of maps as a part of spatial information technology, most of the studies mainly focused on evaluation of users from the cartographic perspective rather than from the perspective of technology users.

F. Research Framework

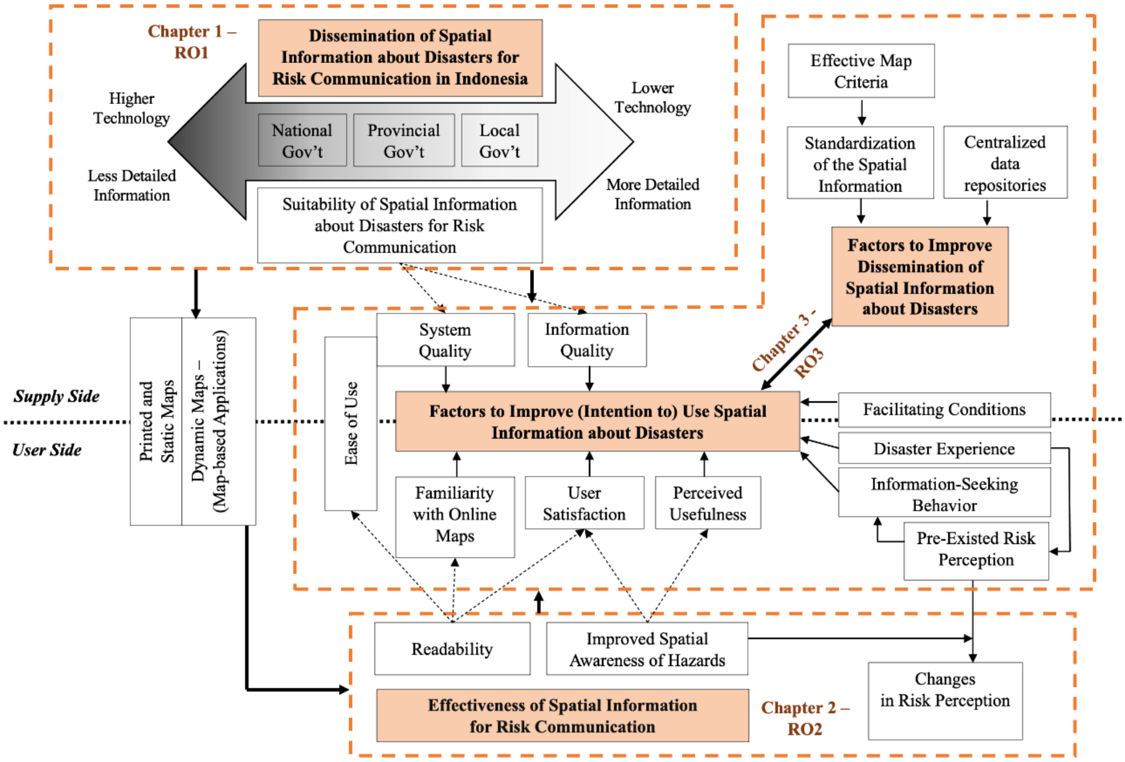

Figure 1 Research Framework

CHAPTER 1
LACK OF AVAILABLE AND SUITABLE SPATIAL INFORMATION (MAPS) ABOUT DISASTERS FOR RISK COMMUNICATION IN INDONESIA

1.1 Objectives

This chapter reviews Indonesia's existing situation regarding the way spatial information (maps) about disasters caused by natural hazards is disseminated to the public. The chapter begins with a description of the country's administrative and social profile, followed by a short discussion of how the country is vulnerable to various disasters and a brief explanation of existing disaster management policies. It then presents an examination of the supply side of the spatial information about disasters, which focuses on how different levels of government disseminate spatial information about disasters to the public. This chapter highlights the disparity between spatial information and technology utilization for disaster management at the national and local levels (i.e., provincial and municipal levels). While the technology used to disseminate the spatial information has progressed at the national level, the opposite is true at the local level. However, in terms of the details that are provided, it was found that the spatial data and information about disasters produced by the local government can be more comprehensive and more location-specific than those produced by the national government.

1.2 The Need to Provide Accessible and Suitable Spatial Information about Disasters as Part of Risk Communication

In Indonesia, disasters have been more frequent than in the past and they have resulted in high economic and human losses. Thus, disaster risk reduction is inevitable. One way to reduce risk is through risk communication, before and during disasters. Emergency managers and the various emergency services have exerted extensive effort in preparing for, mitigating, responding to, and recovering from a full and growing list of disasters that, each year, affect thousands of people nationwide and destroy billions of rupiahs in property, infrastructure, and personal and national wealth. However, in the case of risk communication, especially for preparedness, this effort has not been optimized. Although the new policy in Indonesia has resulted in the disaster management policy framework being more proactive than it has been before, evidence from the implementation demonstrates that disaster management in the country still focuses more on recovery and less on mitigation and preparedness.

The Center for Strategic and International Studies (CSIS) reports that several issues need to be further considered to strengthen disaster preparedness (CSIS, 2020). Related to risk communication issues, the obstacles impeding disaster preparedness include the absence of an integrated disaster data-sharing mechanism and poor use of the right technology. Specifically, at the national level, the problems include a poor early warning system, in terms of both quantity and quality, the lack of a disaster-resilient infrastructure, and a budget that is insufficient for funding preparedness actions. At the local level, the problems include the limited quality of human resources, other supporting technological resources, and equipment, and the lack of preparedness in local development plans.

Indonesia's disaster management laws and regulations have encouraged an active role from the community in terms of its efforts to mitigate risk, particularly in risk communication either among community members or between the community and the government. This risk communication aims to provide information and persuade the community to be prepared and to reduce its risk of disasters so that a resilient community can be built. Risk communication includes production, delivery, and reception of messages between individuals, directly or through the media, before an event, during an emergency, and after an event.

Although hazards and disasters are spatial in nature, and because the geographical aspects of disasters are essential in risk communication in Indonesia (Lestari, 2018), public risk communication for preparedness practices in the country are still dominated by textual, verbal, and non-spatial visual communication methods. A wide range of risk communication media have been used, ranging from traditional tools, such *kentongan*, speakers at mosques, two-way radios, mobile phones, pamphlets, brochures, websites, and social media (Lestari, 2018; Zulfadrim et al., 2017) to direct public gatherings with volunteers and organizations (e.g., *Taruna Siaga Bencana* [Tagana], *Forum Pengurangan Risiko Bencana* [FPRB], non-government organizations) or disaster simulation and drills to learn about disasters, preparedness, and mitigation. Contingency plans are a way to accommodate risk perception in Indonesia at the community level (Rachmawati et al., 2014). However, they still lack spatial aspects. While some spatial elements of disasters have been communicated during emergency drills, and through formal education at school, posters, disaster simulations, social media, or emergency websites, they lack visual-spatial aspects.

Spatial information for disaster preparedness has been used, for instance, to communicate about volcanic eruption preparedness. In addition to the infographics on eruption status that are available in newspapers or on television, the use of maps has been endorsed by the National Disaster Management Agency and mentioned in the Indonesia National Standard Training Guidelines for community preparedness to anticipate the hazards related to volcanic eruptions (Andreastuti et al., 2018). During a normal level of risk, volcanic hazard maps are distributed and explained to a community, so that they can understand the situation regarding their settlement within the volcanic hazard areas visualized on the map.

The visual-spatial aspects of disasters could enhance the comprehension of the situation of disasters within a geographical context (Tomaszewski, 2021). The visual-spatial aspect of disasters is primarily amplified by the use of spatial information, such as maps (Charrière et al., 2012). Using maps as a risk communication tool has long been a practice in developed countries, such as Japan, the United States, and European countries such the Netherlands, Austria, Luxembourg, and Hungary (de Moel et al., 2009; EXCIMAP, 2007; Henstra & Thistlethwaite, 2018; Shaw et al., 2013). While maps provide the geographic context for disaster management, a Geographic Information System (GIS) can provide a more comprehensive understanding of that context (Tomaszewski, 2021). Maps and GIS are important for increasing spatial knowledge of disasters, including the “where, who, what, when, how, and why” of disasters. First and foremost, the most important function of spatial information (maps) is the way it lets the public know about the “where” aspect of disasters, such as the areas that are most susceptible to flooding impacts, the buildings that are damaged, the roads that are open for evacuation, and where supplies are stationed for planning purposes (Tomaszewski, 2021). While the "who" aspect is shown by maps that are created from census data visualizing the characteristics of the population, the "what" and "when" aspects of a disaster can be seen by a hurricane-tracking map to show weather categories (i.e., tropical depressions, hurricanes, and storms). However, the "how" and "why" aspects represent the deeper level and function of maps for facilitating disaster management decision-making and reasoning, which involves a type of interaction process between the map reader and the map (MacEachren, 2004).

1.3 Administrative and Social Context of Indonesia

Indonesia is the largest archipelago globally with 16,056 islands; it lies on the equator between the continents of Australia and Asia, with a total area of 1,916,906.77 km^2 (Indonesia Statistical Bureau, 2020). Its main islands include Sumatra, Java, Sulawesi, Kalimantan, Maluku, and Papua. According to the Minister of Home Affairs Regulation Number 72/2019, Indonesia's 34 provinces consist of 514 municipalities (98 cities [*Kota*] and 416 regencies [*Kabupaten*]) (Ministry of Home Affairs of Indonesia, 2019).

The country's population was projected to be 268.1 million in 2019, with a population growth ratio of 1.15 (Indonesia Statistical Bureau, 2020), making this country the world's fourth most populous nation (World Bank, 2020). More than half of Indonesian people live in Java. West Java is the province with the highest population in the country with 49.3 million people, followed by East Java and Central Java with 39.7 million and 34.7 million people, respectively. Indonesia's capital city, Jakarta, is located in Java; it is home to more than 10 million people, making it the densest population area with around 15,900 people/km^2 (Indonesia Statistical Bureau, 2020).

The population of Indonesia is predominantly Muslim; the country has the largest Islamic community in the world (World Bank, 2020). In addition to Muslims, the country is home to Christians, Catholics, and smaller groups of Hindus, Buddhists, and Konghuchu. This country is culturally rich, with more than 300 ethnic groups and 700 dialects (Riyanti Djalante et al., 2017; World Bank, 2020).

Figure 1.1 Map of the Republic of Indonesia

Source: Geospatial Information Agency of Indonesia
(*Badan Informasi Geospasial* [BIG]) (2020)

Indonesia is the largest economy in Southeast Asia; it has experienced significant economic growth since overcoming the Asian financial crisis of the late 1990s. The country is the world’s 10th largest economy in terms of purchasing power parity, and it is a member of the G-20. Indonesia has shifted from a lower-middle-income country to an upper-middle-income country with $4,050 of GNI/Capita as of July 1, 2020. Manufacturing, agriculture, forestry, and fishing are the leading sources of the country’s income (Indonesia Statistical Bureau, 2020). Indonesia has made significant gains in poverty reduction, cutting the poverty rate by more than half to 9.78% over the last two decades (World Bank, 2020). Before the COVID-19 crisis, the country maintained consistent economic growth (World Bank, 2020). Despite this economic progress, inequality within the country is still high, with a Gini ratio of 0.40 (1 being total inequality) in urban areas, a ratio of 0.32 in rural areas, and a combined average ratio of 0.38 for urban and rural areas (Indonesia Statistical Bureau, 2020). In 2019, about 28.3 million (11.2%) people were living below the poverty line (Indonesia Statistical Bureau, 2020). As many 5.5–8 million Indonesians could have been pushed into poverty because of the COVID-19 pandemic without a significant expansion of social assistance (World Bank, 2020).

Regarding internet usage, according to a survey done by Statista Research and Analysis although Indonesia has an internet penetration rate of only 68% as of July 2020, lower than many countries in the Asia Pacific, it has the fourth-highest number of internet users globally. It was projected that around 185 million people accessed the internet in 2019 (Statista Research and Analysis, 2020a). Internally, Indonesia's highest internet penetration was recorded in the Java region, at 56.4% (APJII & Indonesia Survey Center, 2020). West Java and Central Java are the two provinces with the highest internet users and internet penetration in Java and Indonesia. The latest statistics showed that there are approximately 35.1 million internet users in West Java Province and 26.5 million users in Central Java (APJII & Indonesia Survey Center, 2020). Although Indonesia has a high number of internet users, it was listed as "partly free" in the Freedom on the Net Index due to blocked content and various restrictions on media freedom, most notably through the passage of the Law on Information and Electronic Transactions (ITE Law). The law applies substantial penalties, such as prison sentences and high fines, for anyone convicted of online defamation charges.

An estimated one-third of the Indonesian population regularly accesses the internet through mobile devices (Statista Research and Analysis, 2020b). On average, internet users in Indonesia were consuming about 4.2 gigabytes of data every quarter in 2019 (Statista Research and Analysis, 2020b). Due to the relatively low price per gigabyte, most of the population can afford a pre-paid internet subscription. A survey found that 97.1% of internet users in Indonesia used internet data packages from cellular network providers as their internet connection source (APJII & Indonesia Survey Center, 2020). Most internet users spend around four to five hours a day on the internet (APJII & Indonesia Survey Center, 2020). With the increasing demand for online video and social media content, mobile data usage is expected to grow over the next few years (Statista Research and Analysis, 2020b).

As of 2020, more than half of the population of Indonesia are active social media users, logging onto social media services at least once a month (Statista Research and Analysis, 2020b). The most popular social networks in Indonesia are YouTube, Facebook, WhatsApp, and Instagram (APJII & Indonesia Survey Center, 2020; Statista Research and Analysis, 2020b). A survey on social media usage conducted in June 2020 revealed that 89% of respondents had accessed Facebook every day in the last three months (Statista Research and Analysis, 2020c), making it the third country globally with the highest Facebook audience. For many Indonesians, social media is a convenient way to contact family members that live in remote locations. It also allows them to continuously interact with friends and it keeps them up to date with the daily news, although it also makes them vulnerable to misinformation and hoaxes.

1.4 Disasters and Disaster Management in Indonesia

This section provides a description of the characteristics of disasters happened and potentially occur in the future in Indonesia. It then moves to an evaluation on how disaster management in Indonesia has been applied including reviews on relevant laws and regulations. In regard to the distribution and use of spatial information about disasters for risk communication to increase hazard awareness of the public in Indonesia, this section also provides an evaluation on relevant regulations and some issues on the institutional aspects.

1.4.1 Indonesia as a Country that is Highly Susceptible to Disasters Caused by Natural Hazards

Indonesia is one of the most disaster-prone countries due to its high exposure to a series of natural and climate hazards as well as significant social vulnerabilities due to high population and poverty (Riyanti Djalante et al., 2017). The country is highly susceptible to various types of natural hazards due to its geographical location and physical environment. Geographically, Indonesia is located in Southeast Asia between the Pacific Ocean and the Indian Ocean. It is acknowledged as an active tectonic region. It comprises three major active tectonic plates: The Pacific plate in the east, the Indo-Australian plate in the south, and the Eurasian plate in the north. The country's southern and eastern regions feature a volcanic arc stretching from Sumatra to Java, Nusa Tenggara, and Sulawesi. The remainder of the region consists of old volcanic mountains and lowlands partly dominated by marshes (Kusumasari, 2019). Indonesia is also located in a tropical climate area; it has two seasons—wet and dry—exhibiting characteristic weather changes, such as temperatures and wind speeds that can be very extreme. These climatic conditions can lead to hydrometeorological disasters, such as floods, landslides, forest fires, and droughts. The 2020 World Risk Report ranked Indonesia as the 40th most at-risk country globally with a World Risk Index (WRI) of 10.39 (in 2019, it was ranked 37th with a WRI of 10.58). Its lack of coping capacities (i.e., a WRI of 78.02) is still the main contributor to this high-risk index.

Based on data from the Emergency Events Database (EM-DAT, 2019) during 2000 - 2019, 278 disaster events were recorded in Indonesia. These events included hydrological, climatological, meteorological, and geophysical disasters. Thus, Indonesia is ranked fifth among the countries with the most frequent disasters after China (577), the United States (467), India (321), and the Philippines (304) (EM-DAT, 2019). Geophysical hazards (e.g., volcanoes, earthquakes, and tsunamis) have caused the most deaths in Indonesia. Hydro-meteorological hazards (e.g., floods, droughts, strong winds/typhoons) are the most frequent disasters, and they affect the most people in Indonesia (Riyanti Djalante et al., 2017).

More detailed data and information on the frequency and severity of disasters in Indonesia can be found in the national disaster database. Historical data have shown that Indonesia has experienced many disasters, with a significant number of people killed. According to data published by the Indonesian National Agency for Disaster Management (Badan Nasional Penanggulangan Bencana [BNPB]), from 2000 to 2019, Indonesia experienced 28,553 natural disaster events. These events have destroyed more than 1 million houses; they have directly affected more than 12 million people, killed 151,941 people, injured 375,802 people, and resulted in 39,555 missing persons (BNPB, 2020).

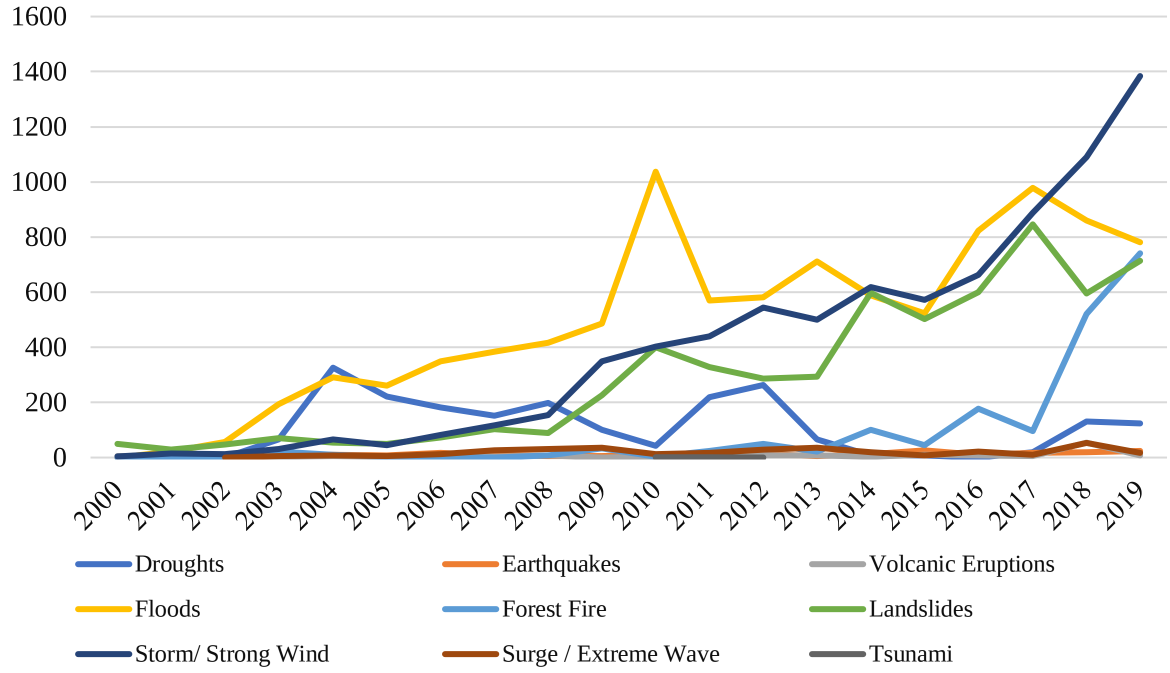

Figure 1.2 Disaster Frequency Trends from 2001 to 2019

Source: The Author analyzed data obtained from DIBI

Over the last two decades, the incidences of flooding, storms, landslides, and forest fires have increased (**Figure 1.2**). Of the numerous disasters that have occurred in Indonesia between 2000 and 2019, the most frequent is flooding (9,910 times), followed by strong winds/typhoons (7,974 times), landslides (5,959 times), droughts (2,124 times), forest fires (1,859 times), and other smaller-scale disasters such as surges and storms. Of the 151,941 people killed by disasters in the last two decades, approximately 87.53% were killed by earthquakes and tsunamis. Another 6.14% were killed by earthquakes, 2.79% were killed by flooding, 1.84% were killed by landslides, and the rest were killed by rest of hazards such as drought and surges. Out of the 12,349,277 people affected by disasters in the same period, 54.54% were affected by flooding, 29.56% were affected by earthquakes, 8.10% were affected by volcanic eruptions, 6.02% were affected by earthquakes and tsunamis, and the rest were affected by other hazards forest fire and droughts.

Based on the disaster records from 1815 to 2019, geographically, three provinces in Java, Central Java, West Java, and East Java, had the highest frequency of disasters. Aceh, Banten, and Bali are the regions with the highest number of deaths caused by disasters. Furthermore, based on the Indonesia Disaster Risk Index 2018, Banten, Bengkulu, and West Sulawesi are the three provinces with the highest disaster risk in Indonesia; the provinces with the lowest disaster risk are Papua, Riau Islands, and Jakarta (BNPB, 2018).

Table 1.1

Top Ten Disasters Caused by Natural Hazards in Indonesia for the Period 2000–2020* Sorted by Numbers of Deaths

Disasters	Date	Location	Number of Deaths
Earthquake and Tsunami	December 26, 2004	Nanggroe Aceh Darussalam, North Sumatra Provinces	165,708
Earthquake	May 26, 2006	Kulonprogo, Sleman, Kota Yogyakarta, Gunungkidul, Bantul Regencies (Yogyakarta Special Province), Purworejo, City of Klaten, Magelang, Klaten, Boyolali Regencies (Central Java Province)	5,778
Earthquake and Tsunami	September 28, 2018	Donggala, Sigi (Donggala), Parigi Moutong, Palu, Poso, North Mamuju (Celebes Isl., Central Sulawesi)	4,340
Earthquake	September 30, 2009	Agam, Mentawai Islands, City of Bukitinggi, City of Padang, City of Padangpanjang, City of Pariaman, City of Pasaman, City of West Pasaman, City of Payakumbuh, City of Sawahlunto, City of Solok, Limapuluhkoto, Padangpariaman, Solok, Solok Selatan, Pesisir Selatan, Sawahlunto/Sijunjung, Tanahdatar Regencies (West Sumatra Province), Kerinci, Merangin Regencies (Jambi Province)	1,195
Earthquake	March 28, 2005	Simeulue, Aceh Singkil Regencies (Nanggroe Aceh Darussalam Province) Nias, South Nias Regencies (Sumatera Utara Province)	915

Earthquake and Tsunami	July 17, 2006	Tasikmalaya, City of Tasikmalaya, Ciamis, Sukabumi, City of Sukabumi, Garut Regencies (West Java Province), Cilacap, Kebumen, Banyumas Regencies (Central Java Province), Gunungkidul, Bantul Regencies (Yogyakarta Special Province)	802
Earthquake	August 5, 2018	Lombok, Sumbawa	564
Earthquake and Tsunami	October 25, 2010	Mentawai Islands Regency (West Sumatra Province)	530
Volcanic Activity	December 22, 2018	Pandenglang, South Lampung, Serang Regencies (Banten Province)	453
Volcanic Activity	October 24, 2010	Klaten, City of Klaten, Magelang, City of Magelang, Boyolali Regency (Central Java Province), Sleman Regency (Yogyakarta Special Province)	322

Source: EM-DAT (2020), last accessed on November 23, 2020 (*per November 2020)

The most recent earthquakes and tsunamis occurred in 2018, namely the Sunda Strait tsunami, the Sulawesi earthquakes, tsunami, and liquefaction, and the Lombok earthquakes, which caused 5,846 fatalities (equals 3.4% of the total deaths due to the 2004 tsunami), thousands of affected people, and severe financial losses. The economic loss and damages from a total of three disasters was approximately 38 trillion IDR (more than 1% of the total state expenditure in 2018) (BNPB, 2020).

Additionally, regarding the COVID-19 pandemic (as of October 4, 2020), Indonesia has consistently shown an increasing incidence of infections (WHO, 2020). Positive case numbers have risen sharply from September to early October 2020; however, testing capacity has been unable to meet demand.

1.4.2 Decentralized Disaster Management in Indonesia

The concept of disaster management has been used in Indonesia for many years, but preparedness and disaster risk reduction are more recent phenomena. Indonesian independence in 1945 marked the critical year in which the government initially acted on and recognized the impact of disasters (Riyanti Djalante & Garschagen, 2017). The 2004

Indian Ocean tsunami and the adoption of the Hyogo Framework for Action (HFA) in 2005 are significant antecedents of the transformational momentum that compelled the Indonesian government to reform its laws, policies, and institutions to better manage disaster risks (Riyanti Djalante et al., 2017; Mardiah et al., 2017). Since then, disaster management in Indonesia has shifted from focusing on the emergency response after disasters to applying a more comprehensive and preventive approach to disaster risk reduction (Riyanti Djalante et al., 2017).

In 2007 and 2008, momentous progress in disaster risk governance occurred in Indonesia due to the enactment of a new disaster management law (i.e., Law No. 24/2007 on Disaster Management) and the establishment of the National Disaster Management Agency (BNPB) through the Presidential Regulation No. 8/2008. Following the enactment of this new law, strategic documents on disaster risk reduction, such as the disaster risk management guidelines, the National Action Plan for disaster risk reduction, were produced. Regulations were issued to complement the new law and provide more specific guidelines. National and community hazard preparedness and early warning systems have been progressively developed and maintained (Riyanti Djalante et al., 2017).

The law forms a new legal framework for disaster management in Indonesia. It consists of a comprehensive set of provisions allocating national and local government responsibilities, setting community rights and obligations, the roles of business and international institutions, the distinctive disaster management stages and their requirements, and disaster aid finance and management. According to this law, a disaster is defined more widely to incorporate natural, non-natural, and social disasters, which reflects the country's propensity to be subject to many kinds of disasters caused by natural hazards and the potential for non-natural disasters, the possibility of social tensions, and the anticipation of technology failures (e.g., industrial areas). Natural disasters include earthquakes, tsunamis, volcanic eruptions, floods, droughts, typhoons, landslides, and forest fires or wildfires. Non-natural disasters include technology failures, epidemics, and diseases; social disasters include social conflicts and terrorist attacks. Moreover, the law defines disaster management widely as a series of efforts encompassing development policies with disaster risk, disaster prevention, emergency response, and rehabilitation.

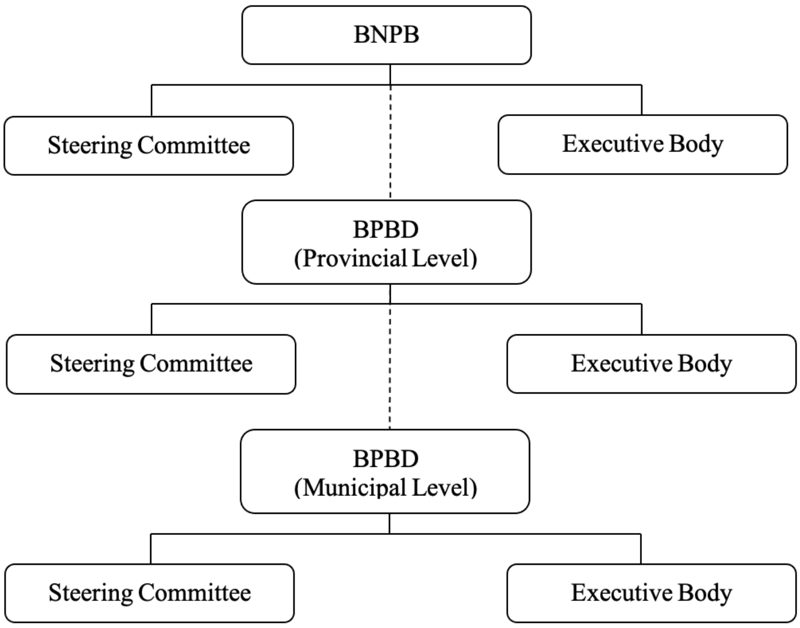

Figure 1.3 Disaster Management Agency Hierarchy in Indonesia

Source: Wibowo et al. (2013)

The new law and regulations led to strengthening the country's disaster management agencies at the national and local levels. Regulation No. 8/2008 elaborates BNPB's position, tasks and functions, organization, procedures, appointments and dismissals, and coordination with the provinces/regencies/cities branches and representatives or *Badan Penanggulangan Bencana Daerah* (BPBDs). **Figure 1.3** illustrates the organizational profile of disaster management in Indonesia. Each level of the Disaster Management Agency consists of a steering committee and an executive body. While BNPB, as the Disaster Management Agency at the national level, is located in the capital city, 34 provincial BPBDs and 514 municipal BPBDs are spread among the provinces/regencies/cities at the provincial level. These newly formed agencies are expected to have more power and mandates, along with the financial and technical capacity to plan and implement disaster risk reduction strategies. The responsibility of disaster risk management and risk reduction has also been shared across different government levels, from heavy reliance on national governments to greater responsibility allocated to local governments. To increase preparedness and resilience at the local and community level, the roles of non-government organizations (NGOs) and local government have been strengthened (Riyanti Djalante, 2012; Kusumasari et al., 2010).

Table 1.2

Transformation of the Disaster Management Policies in Indonesia

Paradigms	• From responsive to preventive • From mere mitigation to comprehensive disaster risk reduction • From centralized to decentralized • From government initiative to shared responsibility among stakeholders • From sectoral to multisectoral
Regulations	• From Presidential Decree to Law No. 24/2007 on Disaster Management • From partial regulations to more integrated regulations (e.g., the adoption of disaster-related issues in Law No. 26/2007 on Spatial Planning) • More comprehensive regulations
Institutional Framework	• From an ad hoc institution to the creation of BNPB • Creation of BPBDs at the local level of government
Stakeholders	Political actors, national and local governments, academic institutions, community, international organizations, private organizations, and businesses.
Development Policy	Inclusion of disaster issues into long-term, medium-term, annual, and sectoral development planning

Source: Adapted from (Adiyoso, 2018; Mardiah et al., 2017)

Mitigation through risk communication has been one of the focuses of disaster management in Indonesia based on the Head of BNPB Regulation No. 21/2008 on Disaster Management Operations. Based on the regulation, mitigation actions in Indonesia aim to reduce the impact of disasters, to serve as the basis of development planning, and to increase public knowledge about disasters in order to prepare for and reduce the risks associated with them. Susanto (2011) tried to illustrate how disaster risk communication is implemented in Indonesia (see **Figure 1.4**), which involves multiple stakeholders (i.e., governments, community, media, and organizations).

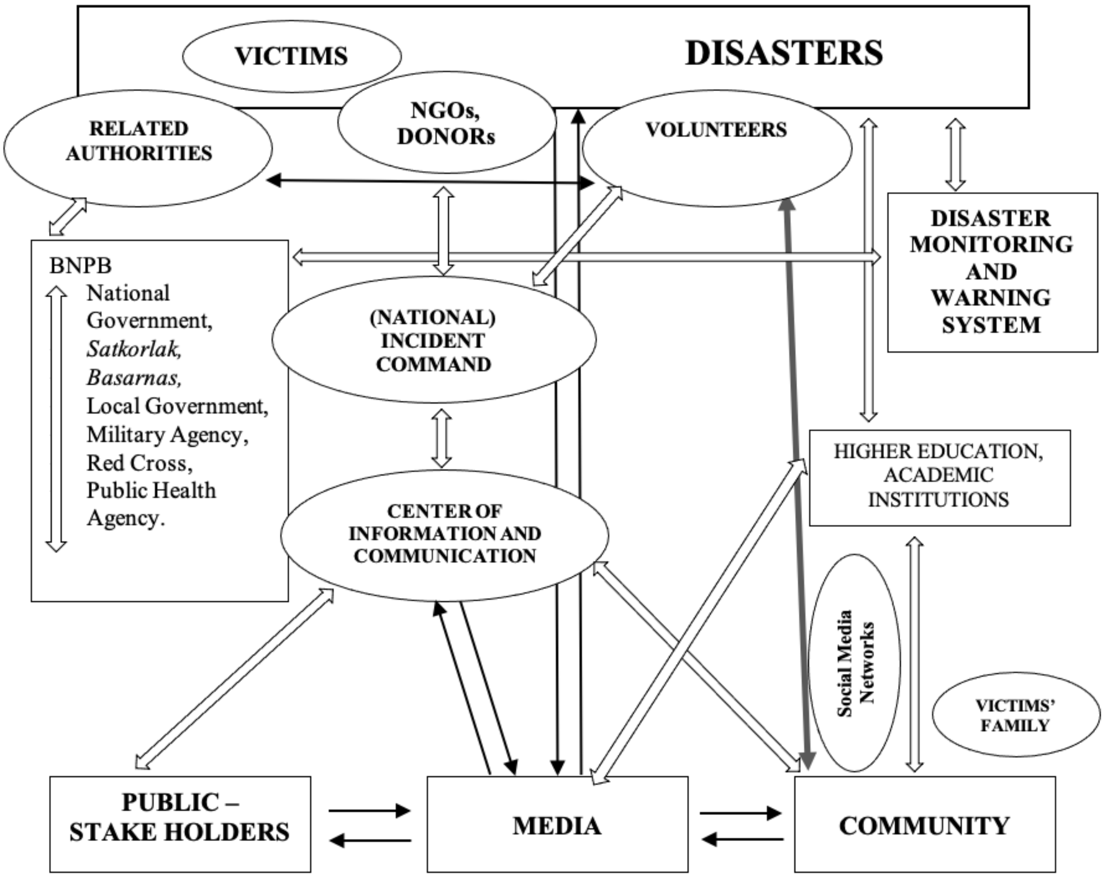

Figure 1.4 Risk Communication Path in Indonesia

Source: Adapted from Susanto (2011)

In terms of disaster funding mechanism and aid management, Law No. 24/2007 calls for the joint responsibility between the national government and local government to allocate disaster management funds. However, it only emphasizes response funds; pre- and post-disaster funds are not explicitly mentioned under the law. In response to this issue, Government Regulation No. 22/2008 on Funding and Disaster Relief Management was issued. The regulation classified three types of disaster management funds: contingency funds, ready-to-use (on-call) funds, and social assistance funds (Das & Luthfi, 2017). There are also two other types of funding: routine funding form annual budget, and funding that originates from the community. Contingency funds are budgeted for preventive programs and major disasters that can occur in the future. Even with so many funding options, disaster management in Indonesia is still facing financial issues. The budget allocated for disaster management is insufficient. Indonesia's government invests about 1–2% of its budget in disaster risk reduction, ranging between US$0.7 billion and US$1 billion for every fiscal year with a general upward trend of funding (Berkeley Economic Review, 2019).

1.4.3 Management of Disaster Data and Information

Management of disaster data in Indonesia was first regulated explicitly under the Head of BNPB Regulation No. 8/2011 on Standardization of Disaster Data. It regulates how data about disasters are collected from many sources and then processed by Pusdalops or the Disaster Management Operations Control Center at both the national and local levels (**Figure 1.5**). After the data have been processed, they are disseminated through reports. In 2012, BNPB issued Regulation No. 7/2012 on the Management of Disaster Data and Information, in which one of the clauses allows for the use of websites to disseminate disaster information. That information includes data on the distribution of the events, victims of disasters, and damages resulting from disasters as well as detailed information on an incident in a specific area. However, data and information related to pre-disaster events, such as the distribution of shelters, evacuation routes, and even hazard and risk maps, are not well-explained in the regulation.

After the issuance of these two regulations, the dissemination of disaster data and information in Indonesia has significantly progressed. Each level of the Disaster Management Agency is responsible for collecting and delivering data with different levels of detail (**Figure 1.6**). In the last 12 few years, Indonesia has been establishing a national disaster database system. Indonesia is among the countries that have developed and implemented the DesInventar system (Ono & Nagaishi, 2015). In Indonesia, the system is known as *Data dan Informasi Bencana Indonesia* (DIBI). DIBI is an example of using technology to obtain local data and indicators. The database can be accessed as tables and maps. Data on DIBI have also been used for risk mapping and risk indexing. Thus, it can be said that the development of risk maps occurred after the establishment of the local DIBI.

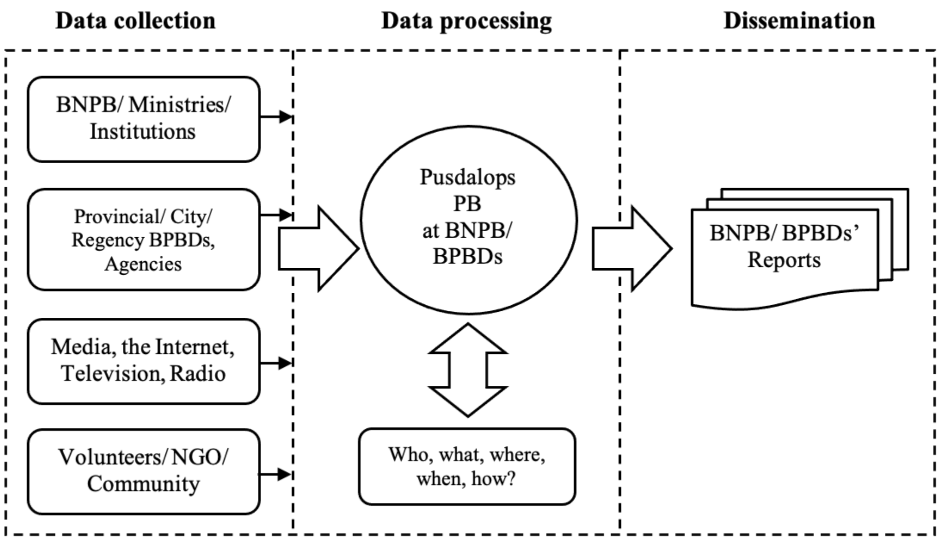

Figure 1.5 Disaster Data and Information Management Cycle in Indonesia

Source: Translated by the Author, and redrawn from the Head of BNPB Regulation No. 8/2011 about Standardization of Disaster Data

Dissemination of disaster data and information is also regulated by Law No. 32/2002 on Broadcasting. Article 36 of this law prohibits the broadcasting any information in which the content is insulting, provocative, misleading, and dishonest. It is also supported by the existence of a regulation regarding Broadcast Program Standards (*Standar Program Siaran* [SPS]), which states that broadcasting programs and coverage of natural disasters or a crisis must consider the recovery process for the victims and communities affected by disasters. Several regulations that have been previously mentioned clearly stipulate how the mass media should position themselves in every disaster event (Lestari, 2018).

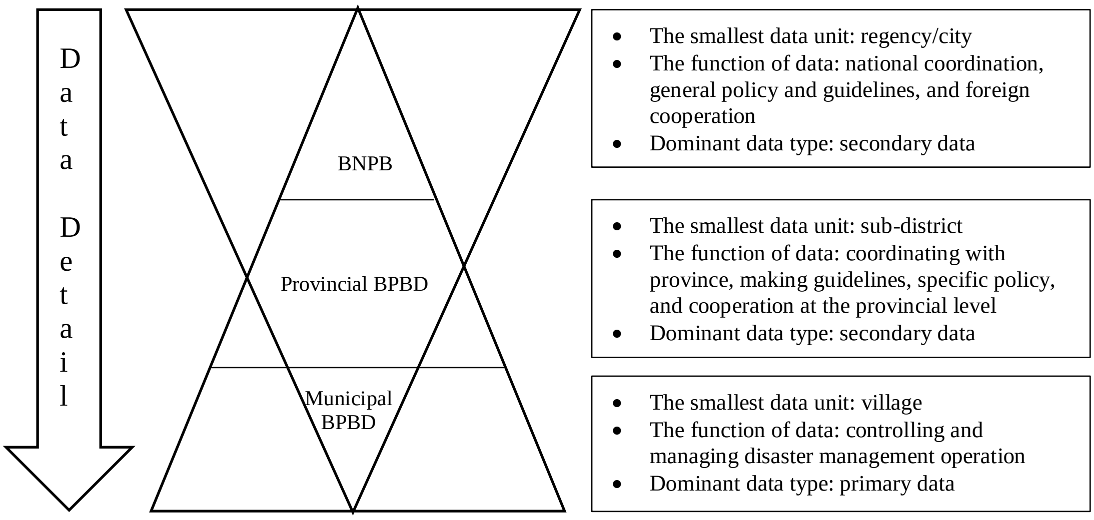

Figure 1.6 Characteristics of Disaster Data and Information in Indonesia

Source: Wibowo et al. (2013)

1.4.4 Absence of Specific Risk Communication on the Distribution of Spatial Information about Disasters

Concerning the use of geospatial information technology for disaster risk management, Law No. 24/2007 on Disaster Management only specifically mandates local governments (i.e., BPBDs) to produce, legalized, and disseminate disaster-prone maps (*peta rawan bencana*) (Article No. 21). However, until recently, it has not been entirely clear how BPBDs should produce and disseminate the disaster-prone maps. First, the definition of disaster-prone maps is unclear, particularly on whether they refer to risk maps, hazard maps, or other types of maps. According to the Government Regulation No. 64/2010 on Disaster Mitigation in Coastal Areas and Small Islands, a disaster-prone map (*peta rawan bencana*) is defined as a hazard map that depicts the levels of hazard(s) in an area in a particular period. A disaster risk map (*peta risiko bencana*) is defined as a map that visualizes the risks of a specific hazard in an area during a particular period that is dynamic and results from the combination of a hazard map and a vulnerability map. From this regulation, it is implied that the disaster-prone maps mentioned in Law 24/2007, which should be provided by local governments, may be referred to as hazard maps.

Maps about disasters are also mentioned in the Head of BNPB Regulation No. 4/2008 on the Disaster Management Plan as part of a passive mitigation effort that should be created during the pre-disaster phase. However, similar to the previous issue, there are no clear definitions of and guidelines for map production. This regulation only briefly states that disaster-prone maps can help visualize the primary hazard risks of an area. It also mentions several types of spatial data required to formulate a disaster management plan. Based on the Author's document analysis, the only specific regulation related to maps in disaster management in Indonesia is the Head of BNPB Regulation No. 2/2012 on the Guidelines for Disaster Risk Assessment. This regulation mentions risk maps, including hazard maps, vulnerability maps, and capacity maps, as part of the risk assessment documents. It also encourages the use of a GIS for map production. The regulation standardizes how each type of map should be produced and presented. Another specific regulation is the Head of the Geospatial Information Agency (*Badan Informasi Geospasial* [BIG]) Regulation No. 8/2015 on Norms, Standards, Procedures, and Criteria for Earthquakes, Volcanic Eruptions, Tsunami and Flooding's Rapid Mapping that stipulates a general guideline for creating spatial rapid assessment of earthquakes, volcanic eruptions, tsunamis and flooding.

At each level of the Disaster Management Agency, the role for providing spatial information about disasters is not well defined. There are no specific regulations on the role of BNPB and the BPBDs regarding the production and dissemination of spatial information about disasters. There are no guidelines for how detailed the risk maps created by these agencies should be. While the Head of BNPB Regulation No. 2/2012 differentiated the scale of risk maps at the provincial and municipal levels, it is not yet clear how these maps are interconnected. For example, in the context of spatial planning, each level of government is interlinked, and so is its spatial plan. For example, the zoning map (scale of 1:5,000) in a detailed spatial plan (*Rencana Detail Tata Ruang* [RDTR]) for a sub-district should be referred to and designed by considering its higher plan, which is the spatial pattern map (scale of 1:25,000 or scale of 1:50,000) in a regency/city spatial plan (*Rencana Tata Ruang Wilayah Kota/Kabupaten* [RTRW]). Next, the spatial pattern map in this regency/city spatial plan (RTRWK) should be referred to and designed by considering the spatial pattern map (scale of 1:250,000) in its provincial spatial plan (*Rencana Tata Ruang Wilayah Provinsi* [RTRWP]). Thus, the lowest unit's spatial plan provides the detailed information for the broader plan at the higher unit. The Director of Disaster Mitigation of BNPB, Herlianto (2020), stated that the national level disaster-prone maps are still relevant for development planning at the national level, although they are small-scale maps. However, at the local level, larger-scale micro zoning disaster maps (i.e., scale of 1:10,000) are required for spatial and infrastructure planning.

Despite the lack of clear regulations on the maps, disaster maps are inevitably important, and other regulations support their production. For example, Law No. 4/2011 on Geospatial Information also describes the essential role of geospatial information in managing both natural resources and disasters (Mardiah et al., 2017). Moreover, the disaster-prone maps should be aligned with spatial plans. Law No. 26/2007 on Spatial Planning states that Indonesia is prone to hazard events, and in order to determine spatial patterns and structures, it is important to consider data and information on disasters (Wijaya et al., 2017). According to this law, areas prone to disasters are classified as protected areas to reduce the negative impact of natural disasters. As a part of disaster mitigation, the law mandates the allocation of infrastructures in the spatial structure plans for mitigation and preparedness measures, such as providing an evacuation system. Moreover, for mainstreaming disaster risk reduction issues in long-term development planning, the law specifies that there should be an introduction, assessment, and monitoring of disaster risks. This condition can be implemented through the production of risk maps with a 1:50,000 scale for regencies and with a 1:25,000 scale for cities, especially for those at a high risk of disasters (Adiyoso, 2018). In 2018, 269 out of 514 regencies and cities in Indonesia were classified as areas with high disaster risks (BNPB, 2018).

Dissemination of spatial information about disasters in Indonesia needs to be in line with policies on spatial data infrastructure and e-government guidelines and regulations. Regarding the spatial data infrastructure, Indonesia's national mapping program was started in 1951 (Sutanta et al., 2013); however, progress occurred after the enactment of Law No. 4/2011. Before that law was enacted, Indonesia’s e-government facility was limited to static maps and there was no integration between websites that have implemented a GIS facility (Ramadhan et al., 2011). After the Geospatial Information Agency (BIG) was formed, the first national geoportal, called Ina-Geoportal, was launched in 2011 (Asseng et al., 2018). Since then, Indonesia has exerted more effort to develop a large-scale National Spatial Data Infrastructure (NSDI) system to build an integrated system of spatial data sharing and assure the government's data quality control.

In 2016, to accelerate data integration and prevent duplication of the same thematic data production by ministries and agencies, the Indonesian government initiated the One Map Policy (available on https://portalksp.ina-sdi.go.id, under the Presidential Regulation No. 9/2016). Through this policy, the government only designates one data custodian for a specific data category (Asseng et al., 2018). While BIG holds the national mapping authority at the local level, no specific agencies function as a decentralized unit. At the local government level, the mandatory geospatial information activity is usually undertaken by agencies related to spatial planning, such as the Local Development Planning Agency (*Badan Perencanaan Pembangunan Daerah* [Bappeda]) or the Public Works and Spatial Planning Agency (*Dinas Pekerjaan Umum dan Penataan Ruang* [DPUPR]).

The national policy on e-government was initially established in 2003 when the Indonesian government issued the Presidential Decree No. 3/2003 on the National Policy and Strategy for the Development of e-Government. This regulation obligates all levels of government to build official domains to accelerate e-government initiatives. In 2006, the Indonesian government first mandated the use of ".go.id" to standardize an official domain name, including local governments, as stipulated in the Regulation of the Ministry of Communication and Information Technology No. 28/PER/M.KOMINFO/9/2006.

1.4.5 Related Guidelines for the Production and Dissemination of Disaster Maps

The Head of BNPB Regulation No. 2/2012 on the Guidelines for Disaster Risk Assessment stipulates risk maps as the basis for formulating a risk assessment document. Within this regulation, risk maps are defined as a visualization of an area's disaster risk level, both spatially and non-spatially, based on a risk assessment of the area. These risk maps are created from overlaying hazard maps, vulnerability maps, and local capacity maps using grid analysis. Three levels of visualization should be used for all types of maps: high, medium, and low. Risk maps are displayed on an A1-sized sheet of paper; hazard, vulnerability, and local capacity maps are displayed on A4-sized sheets papers as part of the risk assessment document supplement. Several guidelines for map presentations are also described in the regulation. **Figure 1.7** shows an example of a risk map produced by a local government after enactment of the Head of BNPB Regulation No. 2/2012.

Maps for risk assessment should be produced for all kinds of hazards that threaten an area. Although not all hazards may threaten an area, in general, there are 13 kinds of hazards in Indonesia that can be used as a reference. These include earthquakes, tsunamis, floods, landslides, volcanic eruptions, surges/extreme waves/tidal waves, extreme weather/typhoons/strong winds, droughts, forest fires and land fires, building and house fires, epidemics, and diseases, technology failures, and social conflicts. Concerning the map scale, at the provincial level, risk maps should be produced with a scale of 1:250,000. In contrast, at the municipal level, risk maps for areas in Sumatra, Kalimantan, and Sulawesi should be produced with a scale of 1:50,000; for areas in Java and Nusa Tenggara, the scale is 1:25,000.

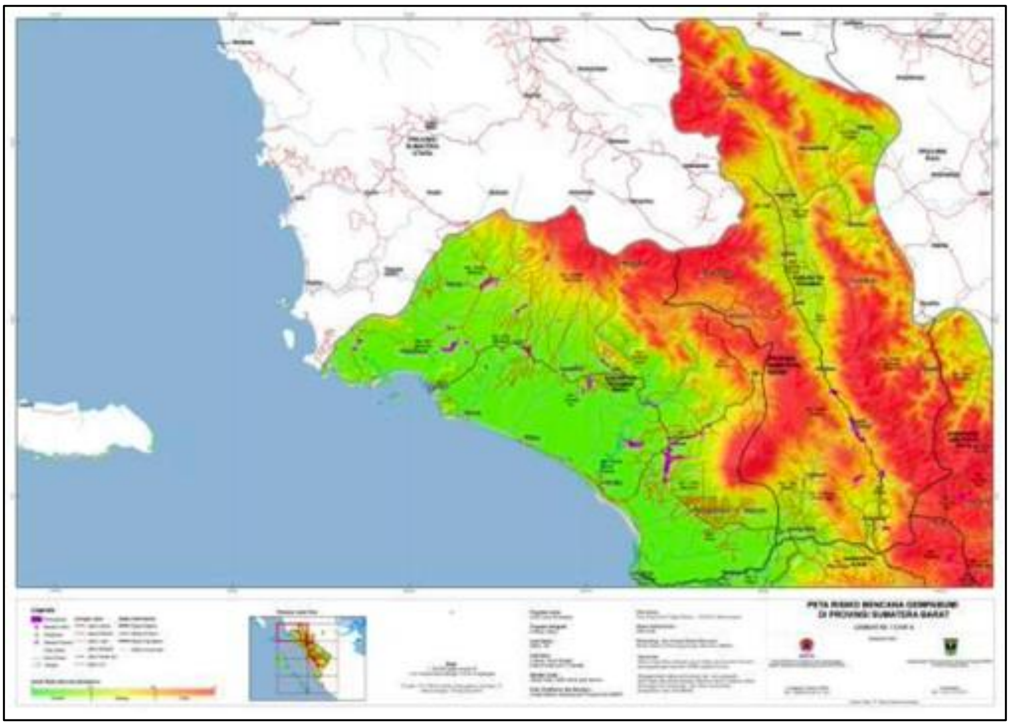

Figure 1.7 Example of a Standardized Presentation for a Risk Map Based on the Head of BNPB Regulation No. 2/2012

Source: The Head of BNPB Regulation No. 2/2012

For the production of hazard maps, the regulation requires the use of standardized hazard maps issued by relevant institutions for earthquakes, landslides, volcanic eruptions, floods, and droughts. For other hazards, such as tsunamis, forest fires, land fires, extreme weather, and tidal wave/ surges, a specific mapping methodology is arranged. A summary of the sources of hazard data for the production of hazard maps is presented in **Table 1.3**.

Table 1.3

Source of Data for the Production of Hazard Maps

Types of Hazards	Sources of Hazard Data
Earthquakes	• Earthquake hazard maps issued by the National Center for Earthquake Studies • The 2017 earthquake zone maps are validated with incident data
Landslides	• Earth movement hazard map produced by the Centre of Volcanology and Geological Hazard Mitigation (*Pusat*

	Vulkanologi dan Mitigasi Bencana Geologi [PVMBG]) is validated with incident data
Volcanic eruptions	• Volcano hazard maps produced by PVMBG
Flooding	• Flooding zone map produced by the Ministry of Public Works validated with incident data
Droughts	• Drought hazard maps produced by the Meteorological, Climatological, and Geophysical Agency (*Badan Meteorologi, Klimatologi dan Geofisika* [BMKG]), and the Ministry of Public Works
Tsunamis	• Tsunami inundation height estimation maps produced by following the tsunami risk assessment guidelines by BNPB
Forest fires and land fires	• Data and guidelines from the Ministry of Environment and Forestry, BMKG, and the Ministry of Agriculture
Extreme weather/typhoons	• Data and guidelines from BMKG
Extreme waves/tidal waves/ surges	• Data and guidelines from BMKG and the Center for Naval Hydrography and Oceanography
Social conflicts	• Historical data on the frequency of social conflict incidents and their impacts
Technology failures	• Industrial zone on spatial pattern map
Epidemics and diseases	• Data and guidelines from the Ministry of Health
Fires (buildings and houses)	• Historical data on the frequency of fire incidents

Source: Translated and compiled by the Author from the Head of BNPB Regulation No. 2/2012 on the Guidelines for Disaster Risk Management

According to the regulation, several components must be included in map presentations. **Figure 1.8** illustrates the suggested layout for a risk map presentation based on the regulation.

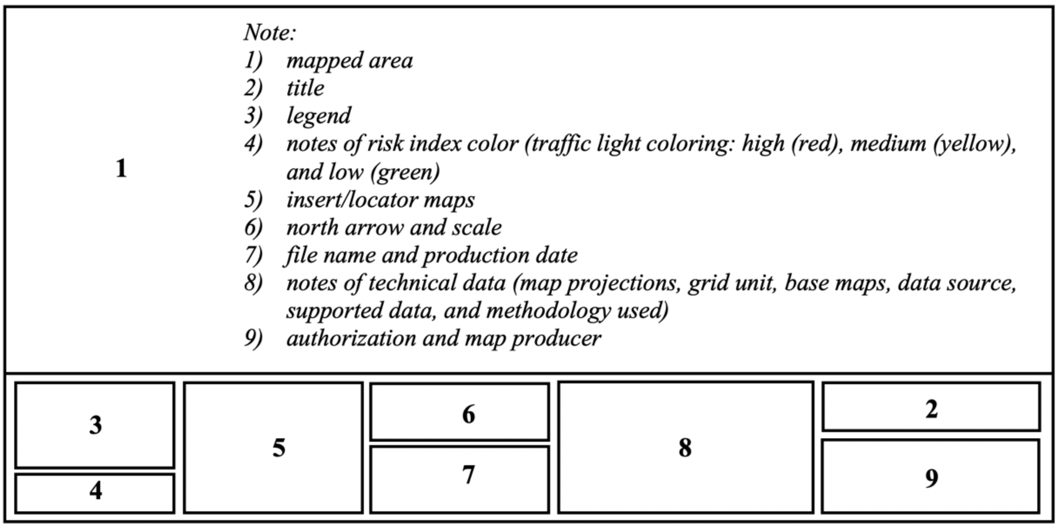

Figure 1.8 Layout Presentation of a Risk Map based on the Head of BNPB's Regulation No. 2/2012

Source: Adapted by the Author from the Head of BNPB Regulation No. 2/2012

1.5 Existing Conditions of Distribution of Spatial Information for Risk Communication in Indonesia

The availability of online maps is an indicator of how spatial information technology has been applied to risk communication. The Internet has redefined how spatial information about disasters is produced and distributed. No longer limited to paper, spatial information about disasters is now broadcast almost instantly and delivered to users as interactive maps. To determine the progress of how spatial information technology has been utilized for risk communication in Indonesia at the study area, the present study conducted online observations on the availability of online disaster maps created and/or disseminated by national and local governments (i.e., provincial and municipal levels).

The collected maps were then classified by type (static or dynamic) and the kinds of hazards they visualized. Static maps, like paper maps, can only be presented in one view (Peterson, 2003), while dynamic maps are interactive and adjustable, allowing users to modify them to their preferences (Roth, 2015). In the present study, dynamic cartographies can be either animated or interactive (Peterson, 2003). If a map could not be identified as either as static or dynamic, it was classified as an unidentified cartographic object: an image that resembles a map in some way but is practically useless (Richmond & Keller, 2003).

The disaster maps uncovered in the present study illustrated single particular hazards or multiple natural hazards. The study focused on ten varieties of natural hazards: flood, flash flood, landslide/sediment-related disasters, extreme weather/storm, drought, earthquake, tsunami, environmental fire (forest and land), volcanic eruption, and tidal waves/surges. Thus, the maps were grouped according to these ten hazards. However, maps with aggregated but unclear hazard visualizations or visualizations of hazards falling outside the ten hazards, we classified their visualization as an "unclear visualized hazard".

1.5.1 Dissemination of Spatial Information about Disasters by the National Government

At the national level, spatial information about disasters was provided mainly by BNPB and other agencies, including the BIG, PVMBG, BMKG, and Ministry of Land and Spatial Planning. Observation of the spatial information about disasters provided by the mentioned agencies revealed that the various information characteristics could be summarized into two broad categories: system and information (content).

Regarding system features, first, most of the information was delivered via dynamic and interactive maps formed as web map applications or geo-portals with location-based features. These online map platforms were developed through collaborative work with other agencies, non-governmental organizations, private sectors, and academic institutions, using primarily free and open-source data and software. The online maps adopted several essential features of visualization, allowing users to perform zooming, panning, and querying functions when accessing spatial information. In addition to being delivered as interactive maps, some of the spatial data were published as downloadable static maps. Despite the maps' interactive features, most of the information was mapped on a small scale, with no further details. Thus, although the maps included zooming tools to enable user interaction, they were largely useless, since zooming in revealed no additional detailed information.

The spatial information about disasters distributed by the national governments mostly described disaster risks and hazards, addressing small-scale or geographical distributions or clusters of compiled disaster events. A few sources also included spatial information on the area affected by a severe disaster event (e.g., Palu, the area affected by the Donggala earthquake and tsunami). There was no information about evacuation plans (e.g., evacuation routes, locations of assembly points, or evacuation shelters). The following paragraph discusses some examples of the spatial information about disasters provided by national government agencies and institutions.

As the leading agency for disseminating data and information about disasters, BNPB used to publish various spatial data and information about disasters on the web platform *Geospasial Badan Nasional Penanggulangan Bencana* (available at http://geospasial.bnpb.go.id). The site offers various features, including a maps gallery with over 1,000 maps related to disasters in Indonesia, presented in PDF format, daily and regularly updated maps, downloadable 1:250,000 topographic maps, Indonesia disaster watches (real-time and daily updated geographical visualizations of disaster events), preparedness and risk reduction WebGIS (including hazard and risk maps), WebGIS for emergency response, and geospatial information map services.

This site also provides links to several interactive mapping services developed by BNPB, such as Disaster Monitoring (*Pantauan Bencana*), “InAWARE” (an Early Warning and Decision Support System, limited to registered users), “InaRisk” (a national map risk portal), “InaSAFE” (free software that produces realistic natural hazard impact scenarios to improve planning, preparedness, and response activities), and “InaMHEWS” (a multi-hazard early warning system portal). As of this writing, *Geospasial* was no longer available. The interactive mapping services were still accessible via their URL.

Currently, the spatial information about disasters provided by BNPB can be accessed mainly via InaRisk, *Geoportal Kebencanaan* Indonesia, and DIBI. InaRisk, which displays national risk maps, is a map portal developed using free software: NodeJS[2], PostgreSQL[3], and D3JS[4]. InaRisk has been accessible via http://inarisk.bnpb.go.id since 2016. It offers three types of base maps as its map background: satellite, terrain, and road. In addition to risk maps, the portal also provides hazard, vulnerability, and capacity maps. Its hazard layer selection includes 11 layers of natural hazards, 1 multi-hazard, and COVID-19 layers. In addition to being available as a web platform, InaRisk’s risk maps are also available on a mobile platform, formed as a mobile application called InaRisk

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[2] Node.js® is a JavaScript runtime built on Chrome’s V8 JavaScript engine. The Node.js package ecosystem, npm, is the largest ecosystem of open-source libraries in the world. As an asynchronous event-driven JavaScript runtime, Node is designed to build scalable network applications.

[3] PostgreSQL is a powerful, open source, object-relational database system. It runs on all major operating systems, including Linux, UNIX (AIX, BSD, HP-UX, SGI IRIX, macOS, Solaris, Tru64), and Windows.

[4] D3.js is a JavaScript library for manipulating documents based on data. D3 helps bring data to life using HTML, SVG, and CSS.

Personal. The application can be downloaded from the Google Play Store (for Android users) and the App Store (for Apple users).

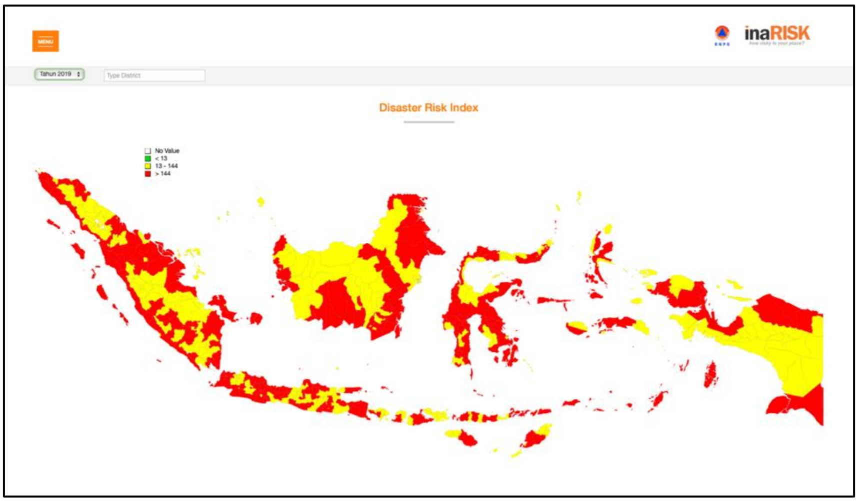


Figure 1.9 The Website Version of InaRisk

Source: http://inarisk.bnpb.go.id/irbi

InaRisk Personal mainly shares spatial data about disasters in the form of a GIS service. This spatial service is expected to be used by all relevant stakeholders, including the community, to design a disaster management plan. InaRisk also serves as a tool for monitoring disaster risk index changes, as it is linked to the implementation of disaster risk reduction programs. Users can see the geographical changes in a municipality’s disaster risk index over five years (2015 to 2019), which indicates the progress of risk reduction at the municipal level.

Likewise, BNPB also provides a portal showing the geographical distribution of disaster events: Geoportal Kebencanaan Indonesia (http://gis.bnpb.go.id). The data used in this geoportal are obtained from BPBD’s reports, and the spatial visualization is dynamic and subject to change based on continuous updates to these data. The geographical distribution of disaster events, including disaster impacts and other related data, can also be obtained from DIBI (http://dibi.bnpb.go.id/DesInventar/), though these data are more user-specified.

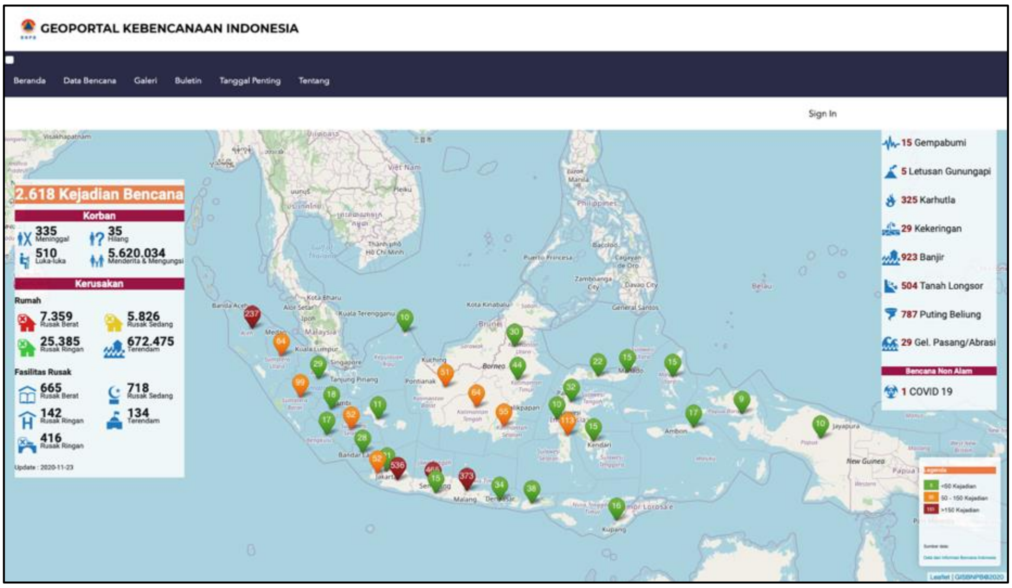


Figure 1.10 Geoportal Kebencanaan Indonesia

Source: http://gis.bnpb.go.id

On the other hand, as the primary agency for producing and disseminating geospatial information in Indonesia, BIG also provides much spatial information about disasters on its National Spatial Data Infrastructure (NSDI) web portal (https://tanahair.indonesia.go.id/portal-web and https://portal.ina-sdi.or.id/portal/home/). This web portal connects spatial data produced by BNPB and local governments (if available) and visualizes these spatial data through its web map application. The web portal also provides downloadable static maps about disasters. These maps, which are produced by BIG and range from the scale of 1:5,000 to the scale of 1:50,000), are limited to six provinces: South Sulawesi, Banten, Central Sulawesi, West Nusa Tenggara, Bali, and North Maluku.

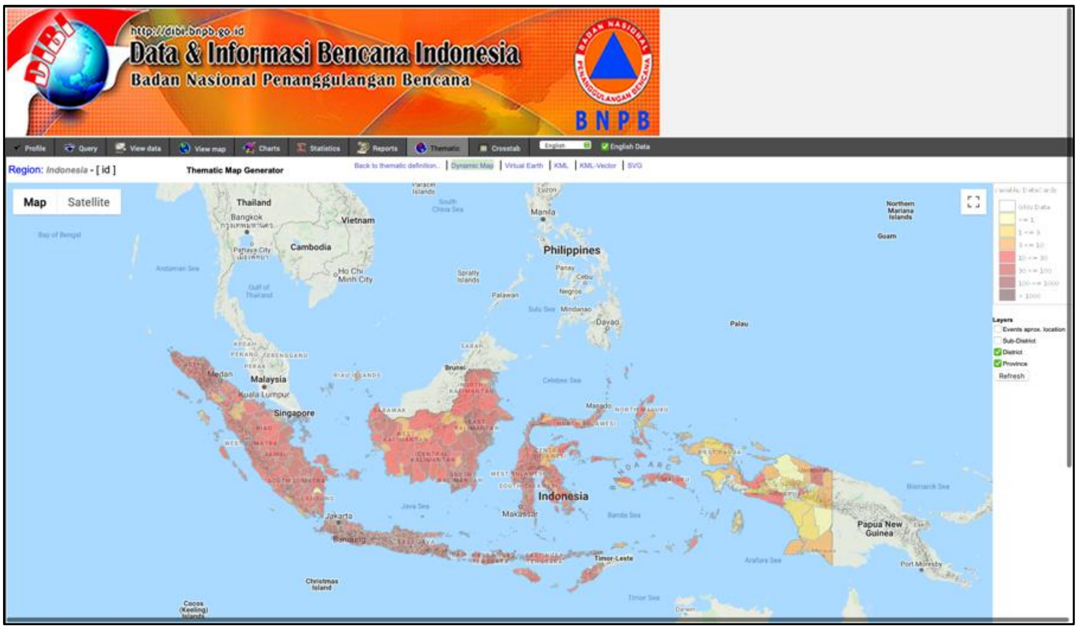


Figure 1.11 Maps on DIBI

Source: http://dibi.bnpb.go.id/DesInventar/

Another institution authorized to produce and disseminate spatial information about disasters is PVMBG. PVMBG is a unit under the Ministry of Energy and Mineral Resources that focuses on the vulcanology and mitigation of geological hazards (landslides, earthquakes, and tsunamis) and is responsible for the production and distribution of volcano and landslide hazard maps. In 2015, a web and mobile platform called MAGMA Indonesia (Multiplatform Application for Geohazard Mitigation and Assessment in Indonesia) was launched to disseminate quasi-real-time information on geohazards. MAGMA Indonesia is also built using open-source software, drawing data from the ESRI ArcGIS online Map server, the Smithsonian Institution, the Global Volcanism Program, BMKG, and the Global Centroid Moment Tensor.

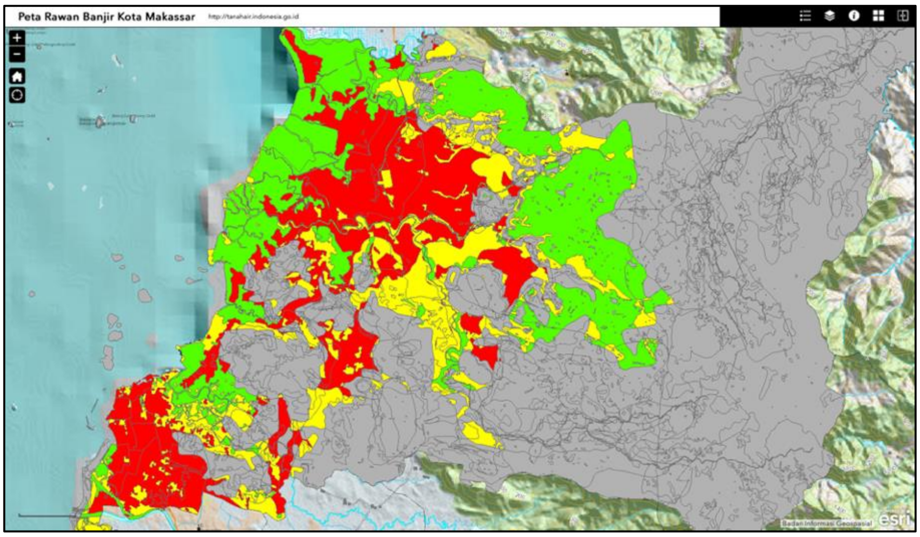


Figure 1.12 Makassar City Flood Prone Map as an Example of Maps about Disasters created by BIG

Source: https://portal.ina-sdi.or.id/portal/apps/webappviewer

Through its official website, BMKG offers various static maps related to disasters, including a map on rainfall projection, a map visualizing the monitoring of consecutive rain days, wind forecasts, wave height forecasts, and satellite images. The geographic distribution of the latest earthquake events can be accessed through BMKG's mobile application, Info BMKG, available on the App Store and Google Play.

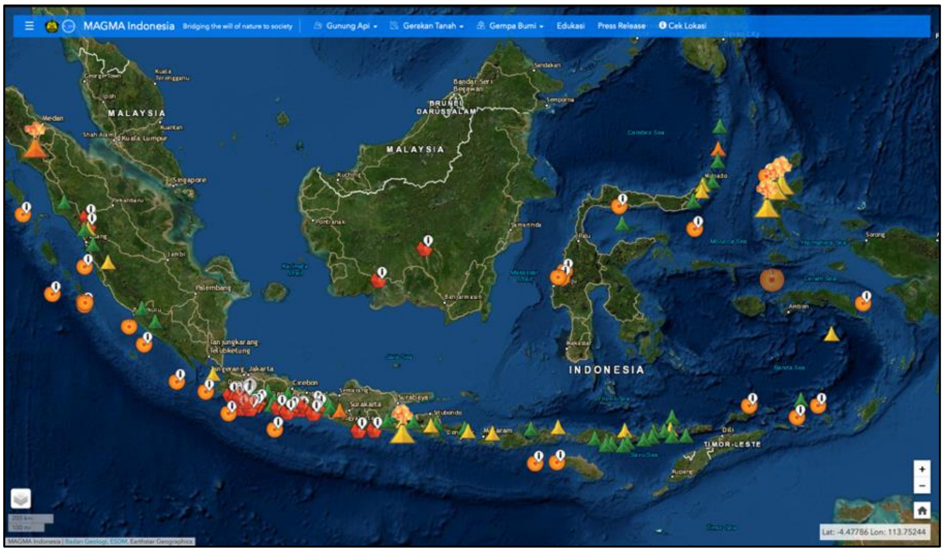


Figure 1.13 MAGMA Indonesia

Source: http://gis.bnpb.go.id

Spatial information about disasters can also be accessed through a portal created by the Ministry of Land and Spatial Planning: GISTARU (https://gistaru.atrbpn.go.id/rtronline/). GISTARU, which stands for the Geographic Information System *Tata Ruang*, is a spatial information system that mainly aims to disseminate multi-level spatial plans and support land use and building permit issuance. This platform shows disaster-related information as part of spatial patterns or zoning.

1.5.2 Dissemination of Spatial Information about Disasters by Local Governments

1. Shortage of Spatial Information about Disasters Developed by Provincial Government

At the provincial level, as of November 24, 2020, all 34 Indonesian provinces had built official websites, including local spatial data infrastructures (i.e., geoportals or web maps) linked to the national spatial data infrastructure portal. Furthermore, 27 of the 34 provincial BPBDs had built official agency websites. However, very few provinces had published their spatial information about disasters online, either on their BPBD websites or via web map services.

Although all Indonesian provinces are vulnerable to disasters, fewer than half (15 provinces) disseminate spatial information about disasters via websites or web maps. Aceh, Riau, Jakarta, and Yogyakarta are among the 15 provinces with various visualized hazards on their online maps. Jakarta and West Nusa Tenggara are the only two provinces that distribute both static and dynamic disaster maps; all others disseminate only one or the other. Where static maps are fixed (i.e., no user adaptations possible), dynamic web maps can be adjusted to users' preferences (Kraak & Brown, 2001).Static maps are highly similar to printed maps (Kraak & Brown, 2001; Peterson, 2003),while dynamic web maps give users the freedom to decide which information to show.

Jakarta was the only province to display various spatial information about disasters. This province built a specific geographic information service for disasters: http://gis.bpbd.jakarta.go.id. The public can use this map portal to access both dynamic and static maps. Since the province is susceptible to flooding, most of the maps describe flooding.

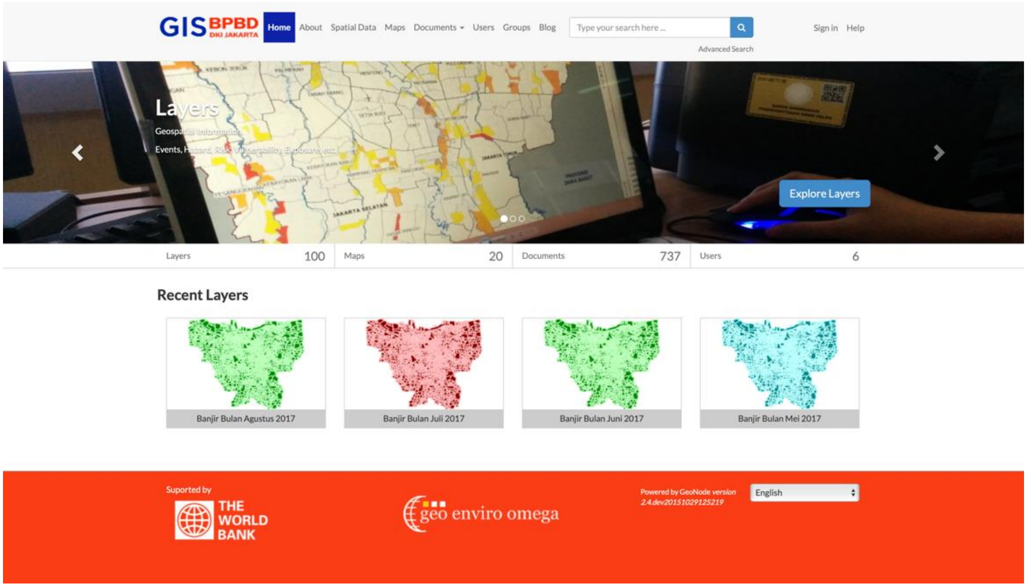


Figure 1.14 GIS BPBD Jakarta

Source: http://gis.bpbd.jakarta.go.id

2. *Lack of Spatial Information about Disasters Distributed Online by Municipal Governments*

At the municipal level, an online search revealed at least one disaster-themed map, either static or dynamic or both, for only 72 of 514 municipalities (14.01%), meaning that publicly available disaster maps could not be found for 442 Indonesian municipalities (85.99%). This figure reflects a considerable shortage of publicly accessible disaster maps in Indonesia. More specifically, this study found that more than half of the available maps were disseminated on BPBD’s websites (43 municipalities: 59.72%). Municipalities with high numbers of available disaster maps tended to be located in Java Island. Sleman

Regency and City of Banda Aceh were the municipalities with the highest quantities of available disaster maps (40 and 36 maps, respectively). Overall, municipalities in Indonesia are not familiar with how to optimize the potential of web maps and information system technologies, as evidenced by how few municipalities (i.e., Magelang Regency, Blitar Regency, Klaten Regency, Sleman Regency, and the City of Semarang) had built their own web map-based disaster information systems at the time of this writing.

Table 1.4
Numbers of Municipalities Facing Specific Hazards vs. Making Relevant Disaster Maps Publicly Accessible

Kinds of Natural Hazards	Number of municipalities at risk of this hazard*	Number of municipalities providing maps about this hazard	Percentage
Floods	480	57	11.88%
Landslides	360	47	13.06%
Extreme Weather	423	30	7.09%
Earthquakes	190	27	14.21%
Droughts	293	26	8.87%
Environmental Fire	190	26	13.68%
Volcanic Eruptions	54	18	33.33%
Surges/Tidal Waves	150	16	10.67%
Tsunamis	50	18	36.00%

* Based on disaster records published in the last 20 years (1999 to 2019) by DIBI BNPB

With regard to content, this study found variations. The identified maps often provided information on levels of danger, risk, susceptibility, warning, or damage. However, none of the maps we found showed situations in real time. Furthermore, a comparison of the maps accessible for each municipality and the kinds of hazards to which each municipality as exposed reveals that, at the local level, there is still a huge dearth of available disaster maps by type of hazard (see **Table 1.4**). In the case of flooding, for instance, there 480 Indonesian municipalities are at risk of flooding, only 57 (11.88%) had disseminated maps about floods. Similarly, while 50 Indonesian municipalities are prone to tsunamis, our study found that only 18 had published tsunami maps.

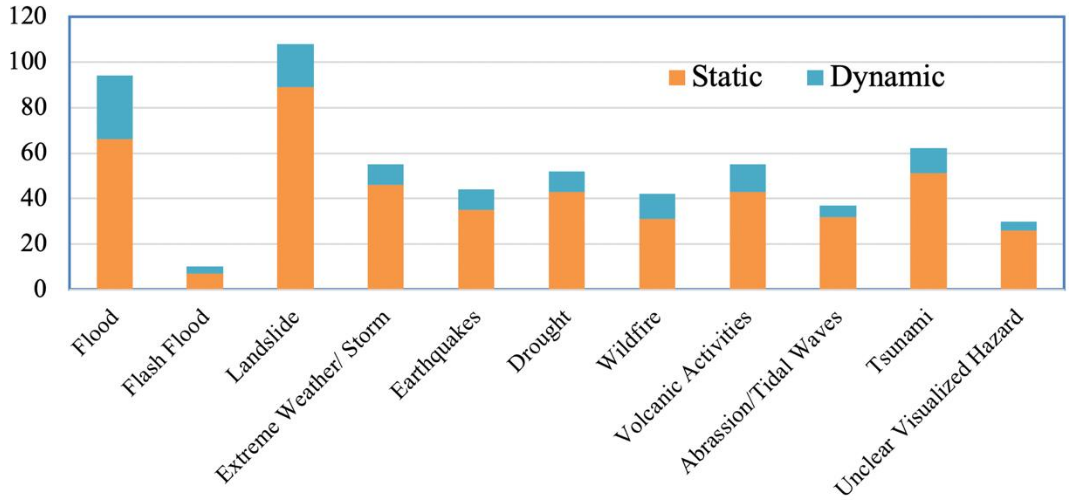


Figure 1.15 Quantitative Overview of Natural Hazard Processes and Their Representation in Static and Dynamic/Interactive Maps

The vast majority of the accessible disaster maps were static maps, which clearly outnumbered dynamic maps (366 vs. 44). Of the dynamic maps, only 11 were part of a geoportal or complex geographic information system; the remaining 33 relied only on a web-mapping service with a range of interactivity features. We found 323 maps illustrating only one hazard and 57 maps visualizing multiple natural hazards. The rest of the maps depicted unclear types of hazards. **Figure 1.15** compares the hazards visualized by both static and dynamic/interactive maps and clearly shows that static maps dominate for all types of hazards. The maps mostly cover landslide (108 maps), flooding (94 maps), and tsunami (66 maps) hazards.

3. *Poor Quality of Available Online Spatial Information about Disasters at the Municipal Level*

This study also evaluates the suitability of available maps for risk communication at the municipal level. This evaluation process was divided into two phases. First, the analysis focused on the quantitative assessment of essential map elements, since these can influence the effectiveness of risk communication by affecting the way in which information is transferred to users (Van Alphen et al., 2009).

Since this study examined two types of maps (static and dynamic), we categorized map element completeness according to map type. The elements of static maps are different than those of dynamic or interactive maps. Static maps were examined for the existence of eight map elements: title, inset, credits, cartographic projection, orientation (north arrow), scale, grid, and legend. Meanwhile, dynamic maps were evaluated using criteria developed based on the web cartographic elements identified by Muehlenhaus (2014). A binary scale was applied to assess map element completeness: A value of "1" was assigned for each met criterion, and "0" was assigned for each unmet criterion. For example, if static map met all eight criteria, it received an overall score of eight out of eight (100 percent). The same method was applied to the dynamic maps and their 20 criteria.

The second evaluation sought to determine whether the maps were of sufficiently high quality for public risk communication. To assess map quality, this study adapted a quality evaluation framework with a set of key characteristics used by Henstra et al. (2019) to assess the quality of flood maps for public risk communication in Canada. Since their study focused on more hazards than merely flooding, it also considered international research findings concerning maps for risk communication regarding other types of hazards, including volcanoes, wildfires, sea level rise, and earthquakes.

Due to the limitations of existing scholarship in this area, the evaluation of effective map quality used a summed and unweighted binary scale for all criteria. If a map met all criteria, it received an overall score of 12 out of 12 (100 percent). **Table 1.5** below summarizes the criteria used to evaluate the maps.

Table 1.5

Effective Map Evaluation Criteria for Public Risk Communication at the Community Level

Criterion	Description	Sources
A. Improving Risk Perception		
Personalized experience	Users can find information specific to their property (e.g., the map is searchable by address or postal code).	Cao et al., 2017; Kellens et al., 2009; Thompson et al., 2015
Local setting	Identifiable places or landmarks, such as major and minor street names or local landmarks, help users visualize the likely spatial extent of a disaster event.	Cao et al., 2017; Luke et al., 2018; Meyer et al., 2012; Nave et al., 2010; Retchless, 2014; Van Kerkvoorde et al., 2017
Historical supplement	Depictions and descriptions of past disasters (e.g., photographs, victim testimonials) help users comprehend potential impacts, improving their perception of risk.	De Moel et al., 2009; Dunbar, 2007; Luke et al., 2018
B. Ensuring Information Accessibility		
Legend legibility	A clear legend with clear explanations of lines, symbols, colors, and terminology is provided.	EXCIMAP, 2007; Gaspar-Escribano & Iturrioz, 2011; Luke et al., 2018; Meyer et al., 2012; Spachinger, Dorner, Metzka, Serrhini, & Fuchs, 2008
Risk area legibility	Users can easily distinguish the extent of zones prone to disaster. At-risk areas are clearly visually differentiated from areas not at risk (e.g., areas or properties at risk may be highlighted using strong colors, while background information, such as properties not at risk, is presented in pale colors).	Hagemeier-Klose & Wagner, 2009; Kellens et al., 2009; Lindsay & Robertson, 2018; Marti et al., 2019; Meyer et al., 2012; Nave et al., 2010; Spachinger et al., 2008;

		Thompson et al., 2015; Van Alphen et al., 2009
Proper classification of risk	The different levels of risk for a particular hazard are depicted in a simple way so that users can easily grasp the intensity.	Fuchs et al., 2009; Gaspar-Escribano & Iturrioz, 2011; Meyer et al., 2012; Spachinger et al., 2008; Thompson et al., 2015, 2017
Explanation of scientific and technical terminology	Definitions of terms are understandable to lay users (e.g., in the case of flooding, the description of a *100-year flood zone* is simple and clear).	Hagemeier-Klose & Wagner, 2009; Meyer et al., 2012; Van Kerkvoorde et al., 2017
Transparency about uncertainty and map limitations	Information is provided about different types of hazards or disasters that may not yet be covered or visualized on the maps. Areas that may also be affected in the future are identified.	Haynes et al., 2007; Merz, Thieken, & Gocht, 2007
Comprehensive view	a. Various map scales show the local, regional, and national levels of hazards. b. Multiple particular hazards are depicted. For example, in the case of a volcanic hazard, the map depicts all forms of volcanic activity to which a property may be exposed (e.g., pyroclastic density currents, lava flows, lahars, and tephra fall).	Dransch et al., 2010; Thompson et al., 2017
Versions or production date	Since outdated maps allow for faulty planning decisions that put people and property at risk, the data shown are the most up-to-date information.	Dransch et al., 2010; Henstra et al., 2019; Stevens & Hanschka, 2014
C. Motivating Risk Reduction		
Risk reduction advice	Information is provided on such subjects as actions to take during an emergency, evacuation guidance, property-level protection, and insurance.	Girres, Leone, Péroche, Gustave, & Gherardi, 2018; Meyer et al., 2012; Shidawara, 1999; Van Alphen et al., 2009
Emergency management information	Depictions and explanations are provided of local emergency plans and emergency management information, such as safe areas (in the case of a tsunami), general emergency and temporary shelters, assembly points, evacuation routes, and medical services (e.g., hospitals, clinics).	Bignami, Dragoni, & Menduni, 2018; Fuchs et al., 2009; Girres et al., 2018; Luke et al., 2018; Meyer et al., 2012; Nave et al., 2010; Shidawara, 1999

Source: Adapted by the author from Henstra et al. (2019)

A map is not a map if it lacks basic map features, such as a legend, a scale bar, or a north arrow. This extends to maps of disasters. Therefore, our first evaluation process focused on the completeness of map elements. The static disaster maps, on average, achieved a completeness rate of 87.88%. Of the 366 static maps, 230 had all eight elements (title, inset, credits, cartographic projection, orientation [north arrow], scale, grid, and legend), indicating that most of the static maps met essential cartographic principles. Almost all of the disaster maps the authors found had at least the four most basic map elements: title, legend, orientation (north arrow), and scale (**Figure 1.16)**.

The map element completeness rate for the dynamic or interactive maps was lower: on average, 52.16% (i.e., 10 to 11 out of 20 elements). The most complete maps were found for the City of Makassar, the City of Semarang, and the City of Tangerang. As can be seen in **Figure 1.17**, around 80% of the maps had only a title, panning and zooming tools, symbology, and attribution, while locator maps, media supplements, and transparency controls were rarely present. Panning and zooming interfaces are fundamental to an interactive map, as these features are among those that distinguish an interactive map from a static map. Together, these two interfaces give users the ability to move a portion of visible content. However, the scope to which users can pan and zoom should be limited to prevent confusion. Locator maps, which show where the location of the main mapped area within a broader geographical context, are particularly helpful for large-scale maps (i.e., maps depicting small areas), since people often struggle to reference the location of what they are viewing based on mental maps alone (Muehlenhaus, 2014).

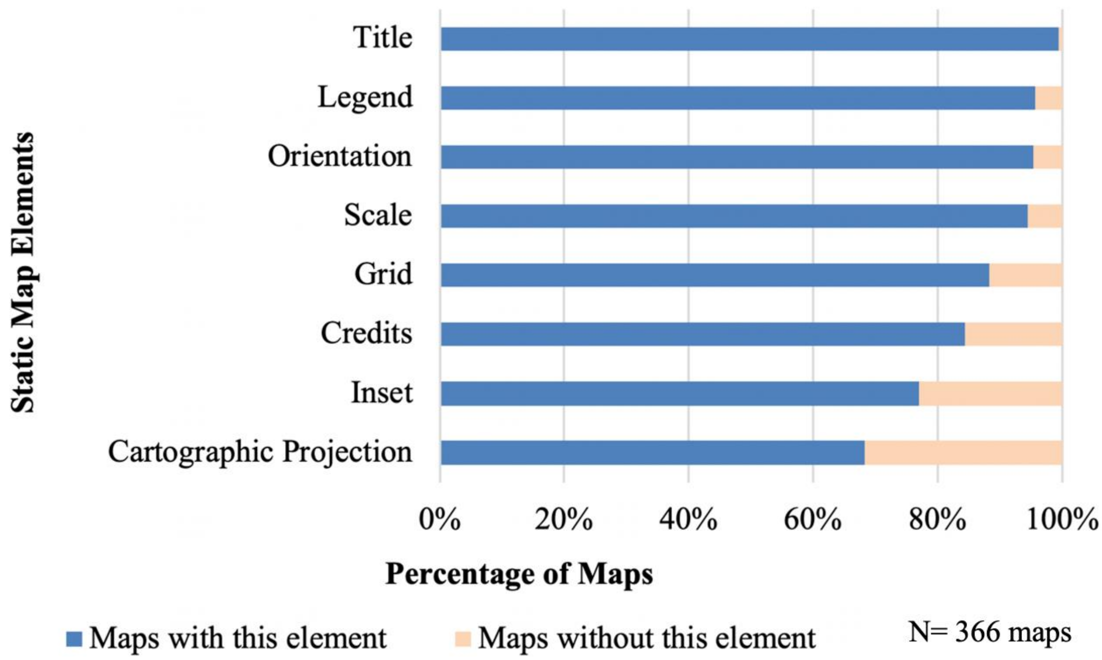


Figure 1.16 Completeness of Map Elements of the Publicly Available Static Disaster Maps

Map query and transparency controlling tools were missing on most of the accessible maps (present on less than 20% of the maps). These two features are essential in allowing users to easily find the area on which they wish to focus. Map queries save users' time by directing them immediately to the maps they need. A lack of transparency control can make overlaid maps hard to read if the shading of hazard visualization is too dense. Another important yet often absent tool is a help menu. Though a help menu may not be necessary for printed maps, it offers additional information for users who are not familiar with or need assistance when using interactive map interfaces.

Next, with regard to the maps' suitability for risk communication, our evaluation found that the vast majority of the disaster maps (97.56%) identified on the website of the 72 municipalities were low in quality (i.e., meeting fewer than 50% of the criteria, or scoring < 6 out of 12) and, therefore, unsuitable for communicating the risks of disasters to public audiences. Only 2.44% of municipalities (10 municipalities) offered access to disaster maps that met or exceeded 6 of the 12 quality criteria. No disaster maps met all of the evaluation criteria; the highest score was 75% (9 out of 12).

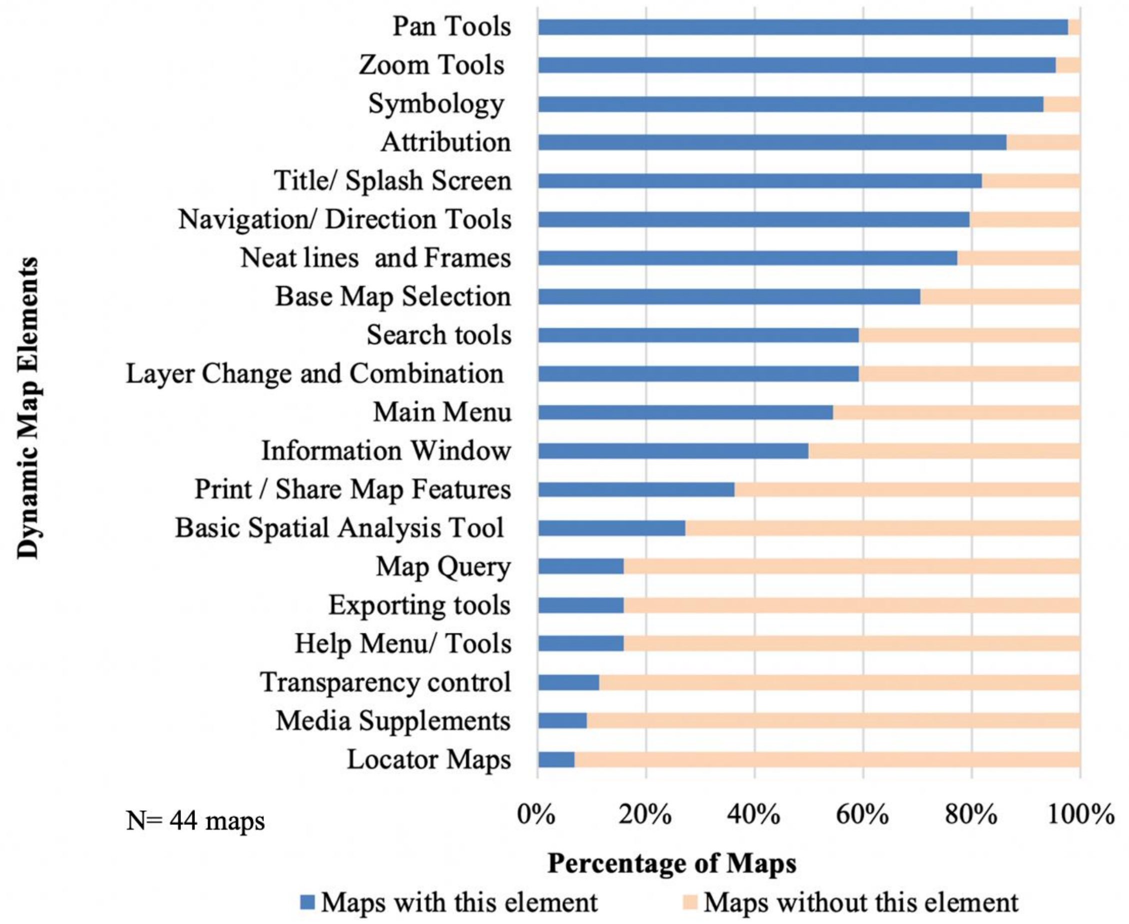


Figure 1.17 Completeness of Map Elements of the Dynamic Disaster Maps Available to Public

In summary, public users in Indonesia can typically access (more than 40% of all identified maps) various municipal-level government-provided disaster maps that include the following: a legible legend; a legible visualization of areas at risk; publicly acceptable risk classifications; and clear information on when the map was created, updated, or uploaded. Most of the maps adopted “traffic light” symbolizations to visualize the uncertainty of hazards (red for high risk, yellow for medium risk, and green for low risk), and the dynamic maps often also included a legend (though this was sometimes only visible as a pop-up window). By contrast, very few maps included the other eight effective map criteria. Furthermore, as shown in Figure 1.6, a very small percentage of the maps (less than 10%) were found to include emergency management information and risk reduction advice: key information to communicate when attempting to encourage protective actions. Without these risk reduction materials, users may struggle to understand which actions to take in the event of a crisis or emergency, implying implies a failure of the identified maps to fulfill one of the primary purposes of map-mediated risk communication.

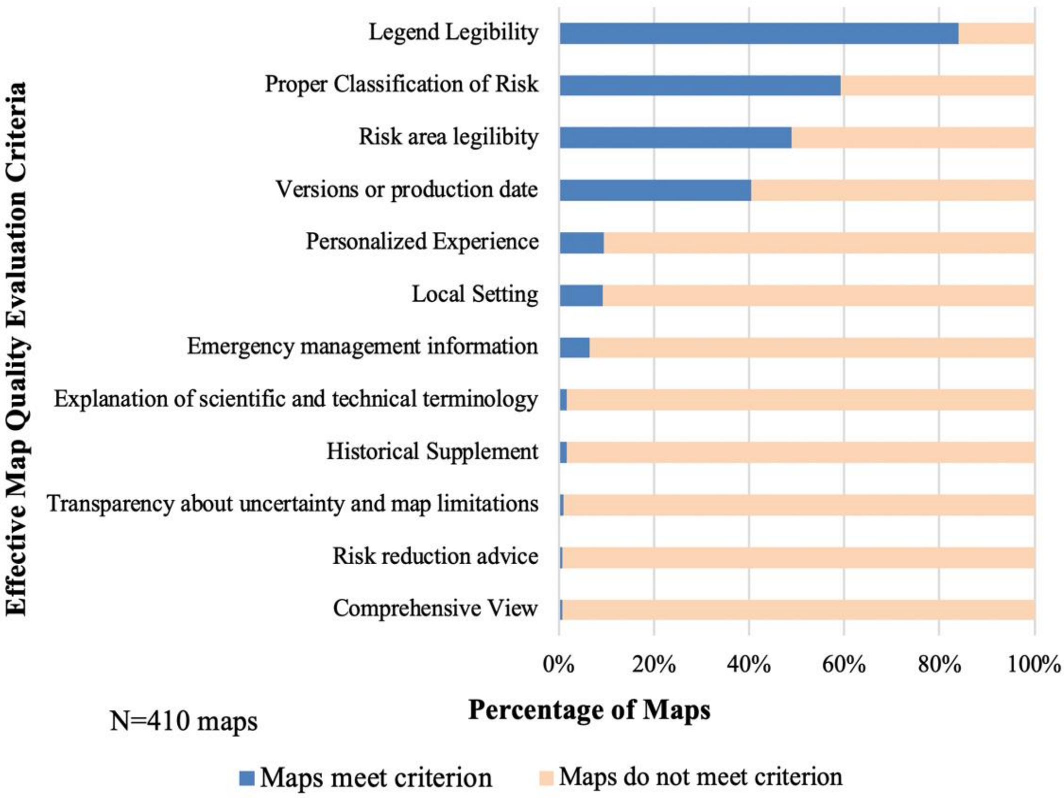


Figure 1.18 Characteristics of Disaster Maps Available to the Public

Historical supplements (e.g., photographs, victim testimonials) are essential to help users comprehend the impacts of past disaster events (Luke et al., 2018) and, in turn, increase their risk understanding. Pictures taken of damage caused by past disaster events offer permanent documentation that may be otherwise erased by cleanup, rehabilitation, and reconstruction projects. Such images can remind people—research scientists and the general public alike—that disaster events are serious and that protecting against their consequences requires precautionary actions (Dunbar, 2007). However, the present study found that only approximately 5% of the accessible maps included this information in ways that could be expected to provoke an emotional response to disasters.

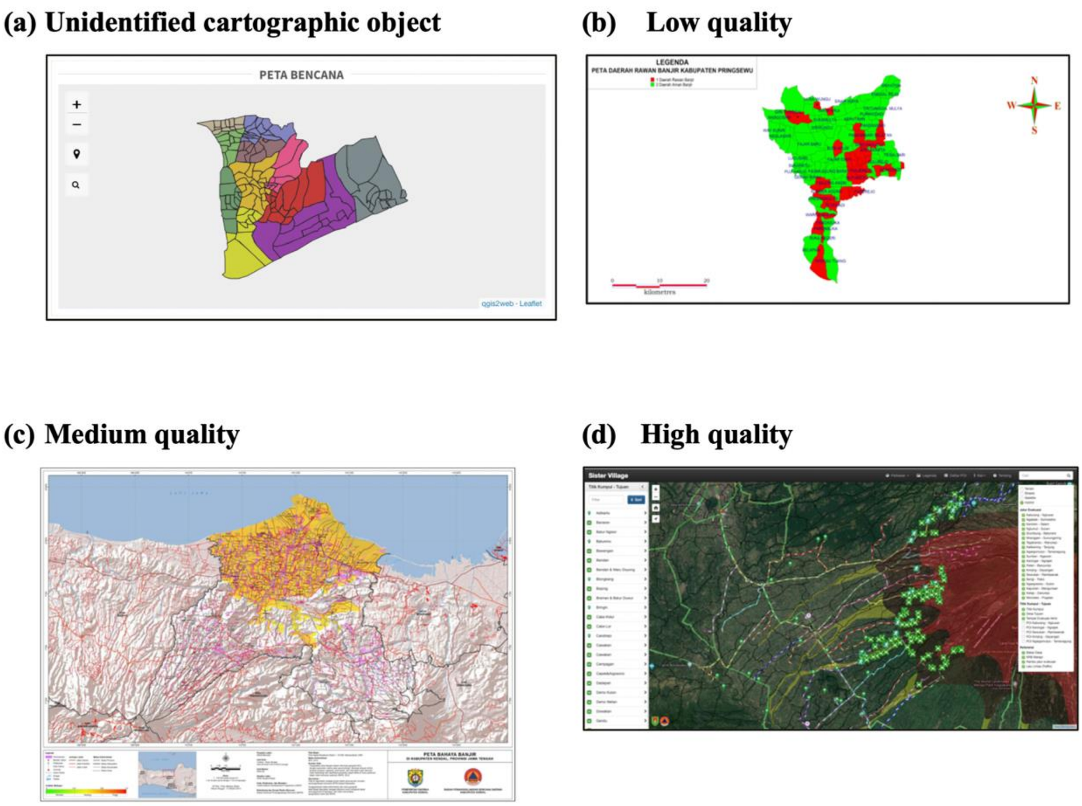


Figure 1.19 Comparison of Disaster Maps and Their Associated Quality Scores

The least common feature was a comprehensive view, or a visualization of multiple hazards. Almost all the maps visualized only the generalized and aggregated risks of a natural hazard(s) and covered only local areas. For instance, none of the volcanic hazard maps showed the whole variety of volcanic hazards, including pyroclastic density currents, lava flows, lahars, and tephra fall; instead, the uncertainty visualization of volcanic activity on the maps was in aggregate. Similarly, with flooding, the observed maps depicted only areas prone to flooding and offered no visualizations of more specific flooding-related hazards, such as whether an area was coastal, riverine, pluvial, or associated with risks from storm water.

Figure 1.19 illustrates how different quality scores were examined, clearly showing the weaknesses of the disaster maps disseminated by local governments. The first picture (a) presents an image about disasters published by Tanah Laut Regency. This image is difficult to classify as a map: Even though it has some dynamic map-like features (e.g., pan and zoom tools), it lacks toponymies and has unclear symbolization, resulting in a score 0% (0 out of 12). Next to this image is (b) a flood map created by Pringsewu Regency. The map is static and has all the basic elements of a map: scale, north arrow, and symbolization (as shown by the use of different colors for the depicted areas). However, in terms of suitability for risk communication, this map is very low in quality: Users may struggle to understand which areas are at high risk of flooding and which are not. Therefore, this map scored 8.33%, having met only one of the effective map criteria: risk classification. The next map, (c) a map published by the local government of Kendal Regency, is also static, but scored higher than the previous static map (33.33%) because it includes a legible legend, legible flood zone (risk area), and risk classification understandable to the general public. However, despite following the risk map guidelines, this map is still largely unsuitable for risk communication. The last map (d) is an interactive map presented as part of a disaster information system produced by Magelang Regency. This map scored highest among the local disaster maps at 66.67% (8 out of 12), since it offers a personalized experience, depicts the local setting, presents historical descriptions and images, identifies legible hazardous areas, offers a clear visualization of each hazard's classes, provides emergency management information (e.g., evacuation routes, evacuation sites, and assembly points), and includes the production date. This map would be much clearer if users were also given an explanation of technical terms. Overall, the highest score was found in three volcanic hazard maps disseminated by Temanggung Regency on Mounts Sundoro, Sumbing, and Dieng (75.00%, 9 out of 12); however, these maps were created by a national agency and then merely published by local governments.

4. *Discussion on the Availability and Accessibility of Spatial Information at the Local Level*

This study's findings show that the availability and suitability of disaster maps for public users at the municipal level in Indonesia are very poor. First, this situation may be related to data deficits, since data related to hazards, such as elevation data, land-use, and aerial photographs, are essential to prepare proper hazard/risk maps. However, these data are not readily available, and generating them is time-consuming. This challenge is compounded in Indonesia due to limited human and financial resource availability (Herold & Sawada, 2012; Osti et al., 2008): a problem proven by our findings, which show that maps are mostly found in municipalities with better data infrastructure (e.g., in the Java Islands).

Mardiah et al. (2017) argued that issues related to maps in disaster risk management are related to the problems of institutional networks and, in terms of data and information integration in disaster risk reduction, to maps and statistics. These problems have hindered the development of appropriate large-scale maps, preventing local governments from obtaining specific hazard maps and internalizing disaster risk reduction in medium-term development planning.

Moreover, Indonesia lacks a central portal through which the public can easily access disaster map information. Instead, maps about disasters are dispersed across many different government websites, all of which are inconsistent. In most of the municipalities, disaster maps are among the spatial planning documents or risk assessment documents located on municipal websites, development planning agency websites, or, sometimes, local disaster management agency websites. Locating the identified maps was not intuitive, and the process varied by local authority. In Jakarta, for example, the provincial government maintained an online portal containing disaster maps published for multiple municipalities; however, these maps were not present on the municipal-level websites.

A few municipalities had built their own local spatial data infrastructures (e.g., geoportals, web map-based disaster information systems, and simple web-mapping menus); nonetheless, they had yet to optimize their infrastructure to distribute maps about disasters. The search tools on these web mapping applications were challenging to navigate, requiring a series of steps potentially beyond the capability of a lay user. Static disaster maps were easier to locate, but they were frequently scattered. To find these maps, users would need to search in every possible menu or search using the query tool: an effort that few users would be likely to expend.

The quality of maps about disasters at the municipal level in Indonesia is also poor. In other countries, the problem with maps is generally that they are more suitable for experts than for lay users. In Indonesia, however, few disaster maps are suited for either user category. Only half the maps the authors observed provided a legible risk area, making the other half practically useless. This issue may be due to the absence of any legalized standards for the design of a public disaster map; in Indonesia, no policies or legislation define what a public disaster map should contain or identify set minimum requirements of information. However, some basic standards should be set by the national government and followed by the municipal levels. For instance, the scale of the maps should be around 1:10,000 or lower so that more detail information can be obtained In addition, areas or properties at risk should be highlighted using strong colors, while background information, such as properties not at risk, should be kept simple and in pale colors. The visualization of maps should be kept as simple as possible, since the average person cannot be expected to be very familiar with map reading. The maps' legends, however, should not be simple; these should provide technical explanations and descriptions of symbology. Self-explanatory legends can significantly aid users' understanding, especially in cases with limited time for map reading, in which case users would not even need to fully recognize the legend to receive important information.

In regard to the map elements, a high proportion of the observed static disaster maps already had the necessary elements. However, the elements contained in the dynamic and interactive maps varied. Though it is not necessary to for these maps to contain every possible element, the dynamic web maps neglected even some basic cartographic principles. All maps should have a well-designed visual hierarchy, emphasizing the relevance of data and map elements for message communication. Compared to static maps, online interactive maps make hazard information local, tangible, and personally relevant. Therefore, converting static disaster maps to interactive online maps could be a promising option, as interactive features allow users to customize hazard maps to suit their needs and interests, facilitating engagement with hazard information.

1.5.3 Engagement in Information and Communication Technology

BNPB and BPBDs are increasingly using information communication technologies, including social media. In addition to these agencies' official websites, Indonesian citizens can collect disaster-related information, data, and updates or news (although the quality might widely vary) through BNPB's and BPBDs' social media accounts (e.g., Instagram, Facebook, YouTube, and Twitter). Disaster management agencies at both the national and local levels have recently created their own social media accounts to more easily disseminate information about disasters to the public. Social media has made it easier for governments to locate disasters (Lestari, 2018).

Table 1.6
Indonesian Disaster Management Agencies Engagement in Social Media and Disaster Applications

		#	Facebook	Twitter	Instagram	YouTube	Built-for-disaster-purpose application
1	Central Government-related Ministries						
	• BNPB		v	v	v	v	InaRisk Personal, i-Tangguh, InaRisk Mobile, InDRA BNPB
	• BMKG		v	v	v	v	InfoBMKG, WRS BMKG, BMKG Real-time Earthquakes
	• PVMBG		v	v	v	v	Magma Indonesia
2	Provincial Government	34	27	26	30	7	6
3	Municipal Government (*Kabupaten/Kota*)	514	330	222	210	41	20

Source: Online search conducted by the authors on October 20, 2020

A number of built-for-disaster-purpose applications have also been developed at the national and local levels. BNPB created national-coverage applications, such as InaRisk Personal, to help increase spatial awareness of risks and provide brief information about the actions necessary before, during, and after disasters. InaRisk Personal complements InfoBMKG, an increasingly popular mobile application created by BMKG with increasingly widespread adoption among Indonesian citizens, who use it for weather updates, early warnings, information about air quality, and notifications of recent earthquakes. At the local level (both provincial and municipal), a few BPBDs have also built their own disaster applications (e.g., the municipally developed SIKK Magelang).

As the number of social media users in Indonesia continues to grow, the government should continue exploring the use of these media to disseminate information about disasters. Social media can be leveraged to spread spatial information about disasters or to provide links to relevant disaster maps.

1.6 Conclusion

A main principle of disaster risk reduction is that to minimize the damages caused by natural hazards, stakeholders and the public must first understand their disaster risks. Since hazards have a strong spatial component, maps are useful for communicating their risks. Governments at every level play an essential role in providing data and information for communicating risks to the public. The Internet and e-government offer the potential for broader and more cost-efficient dissemination of disaster data and information, especially considering the growing trend of the internet users and engagement in online activities in Indonesia.

By reviewing and comparing the availability of spatial data and information, especially at the local level, to the public, this chapter found that the quality of disaster maps at the local level and, especially, at the municipal level is inferior and unsuitable for risk communication purposes. This raises concerns regarding ways to improve spatial information about disasters, particularly at the local level. At the national level, while spatial information about disasters is more varied, maps have insufficient detail and information for public consumption, making them unsuitable for use by laypeople. Such national government-provided information is more appropriate for experts and governments.

Finally, spatial information about disasters in Indonesia is fragmented and compiled in a wide variety of layouts, largely due to the absence of specific regulations or guidelines for information production and dissemination. Existing regulations also fail to clarify the role of each government level in providing this type of information.

Together, these findings suggest that Indonesia must invest greater efforts to build a more comprehensive spatial database. Significant improvements are necessary to ensure effective, map-mediated risk communication.

CHAPTER 2
USER EVALUATION OF SPATIAL INFORMATION FOR RISK COMMUNICATION: FOCUSING ON CHANGES IN RISK PERCEPTIONS, AWARENESS OF HAZARDS, AND READABILITY

2.1 Objectives

The main objective of this chapter is to evaluate the effectiveness of spatial information for risk communication from the user's perspective. Any spatial information visualizing disaster risks should be appropriately disseminated and used effectively; otherwise, it will not impact the public's hazard awareness and preparedness. Prior studies on how maps about disasters have been distributed to the public have focused on a single hazard (i.e., flooding). They have also mostly been conducted in developed countries with advanced human and technological resources (de Moel et al., 2009; Henstra et al., 2019; Shidawara, 1999; Stevens & Hanschka, 2014; Van Alphen et al., 2009). This evaluation is meant to address the need for research on the cognition of geographic information risk communication, as the ways people understand and interpret maps vary; it should thus include people's perceptions and map reading skills in the research (Thomas, 2018).

Nonetheless, an evaluation is distinct from fundamental research, particularly in its purpose (Shaikh, 2016). While fundamental research is solely to advance knowledge, an evaluation is context specific and is concerned with the factors that determine the values of the target practice in a particular setting; the goal of an evaluation is to bring useful insights (Fitzpatrick et al., 2009) that can be used for merit assessments, oversight, compliance, and any other improvements besides sheer knowledge development (Mark et al., 2000).

Coppola and Maloney (2017) argued that risk communication in public preparedness efforts aims to raise awareness of hazard risks and guide public behavior (i.e., preparedness and risk reduction). Thus, the focus on user evaluation for map-mediated risk communication in this chapter refers to how users absorb and process the spatial information delivered both in printed maps and a map-based disaster application, resulting in risk perceptions, changes in hazard risk knowledge, and changes in attitudes (i.e., perceptions of evacuation-related information and disaster risk information), which are the main goals of a risk communication tool. Since the selected areas of study are at risks of a range of hazards, hazard risks in this chapter are also multiple although the main concerns are on flooding, landslides, earthquakes, and volcanic eruptions.

Regarding available modern GISs, such as web maps or map-based applications, this chapter also evaluates the readability of these new maps compared to the conventional practice of map-mediated risk communication tools (i.e., printed maps). The dynamic interactions of a map and its data are the key features of modern GISs. This ranges from basic interactions such as panning and zooming that allow areas of interest to be quickly viewed to interactive querying capabilities and multiple formats of data sharing with disaster management teams (Tomaszewski, 2021). In many cases, features of modern GISs can allow for greater understanding of a situation, swifter interpretation, and better, more informed decision making. Thus, readability of both types of map were also evaluated to find out whether maps displayed on a disaster application offer higher readability or easier to use or to interpret.

Mobile applications, particularly map-based or mobile map services, might be especially practical for individuals to understand the spatial aspect of disaster risks (Dransch et al., 2010). Producing a map-based, public-awareness-building information system is useful for community learning and fostering public awareness about natural disasters (Haimes et al., 2015; Hattori et al., 2006). These applications could enhance resilience to disasters, ensure preparedness, and aid in effective responses (Firdhous & Karuratane, 2018). By integrating them with mapping features, this application could provide safety information, guide users to safer places, and show prediction and visualization of a particularly hazardous area (Nishikawa et al., 2015; Sonwane, 2014).

In the first chapter of this dissertation, it was found that children, especially teenagers, are part of the group with the highest internet penetration and increased numbers of mobile device users. Thus, they can serve as effectively targeted users for disaster learning through a mobile application. These applications can be used as tools of disaster e-learning for children and young people. Digital maps can offer features that rise above and beyond traditional maps in the learning process (Jones et al., 2004). With location-based features provided by a map-based mobile application, they can see their current locations and the maps' related environment in real time and with relatively accurate locations. In the case of disasters, this feature is essential in understanding one's position in areas at risk of natural hazards, especially flooding, landslides, earthquakes, tsunamis, and volcanic eruptions since those are the most frequent and deadliest disasters.

2.2 Changes in Risk Perception, Hazard Risk Awareness, and Attitudes as Indicators of Effective Delivery of Map-Mediated Risk Communication

Risk communication is an approach that can change people's perceptions of risk and influence their actions with respect to disaster preparedness and disaster response (Shaw et al., 2013). Changes in the public's risk reduction and preparedness behaviors are one of the many goals of public risk communication (Coppola & Maloney, 2017;

Covello et al., 1986; Lundgren & McMakin, 2018). In particular, risk perception is one of the antecedents of intended disaster preparedness and protective behaviors (Martin et al., 2009; McNeill et al., 2013; Miceli et al., 2008; Paton, 2003; Paul & Bhuiyan, 2010; D. Xu et al., 2018).

In order to communicate effectively about risks, it is important to examine public perceptions associated with hazards risks (e.g., how severe the risks, the extent of risks in a particular area), which can then be used as the basis for the development of best practices in communicating about risks (Frewer, 2004). After all, effective risk communication requires more than simply conveying accurate information (Fischhoff, 1995). It should raise awareness and understanding (Boholm, 2009) targeting the perceptions, issues, and attitudes of at-risk populations. Effective risk communication, then, should be able to enhance the public's knowledge about risk, encourage shifts in attitudes and behavior, and increase public confidence with risk management agencies (Wachinger et al., 2013). Thus, assessing changes in risk perception as a result of any kind of risk communication is essential to indicating its effectiveness.

Graphic materials are often seen as effective communication tools, and maps in particular are a potentially powerful means of conveying spatial information visually (Stieb et al., 2019). Spatial information about disasters, via either hazard or risk maps, is essential for risk communication. Hazard maps contain information about the probability and/or the magnitude of an event, where risk maps contain additional information about the consequences such as economic damage and affected people (de Moel et al., 2009). They are the most common means of visual risk communication for disasters (Charrière et al., 2012) and have been used in many countries as an official risk communication tool (de Moel et al., 2009; Henstra et al., 2019; Kellens et al., 2014; Shaw et al., 2013; Strathie et al., 2017; Van Kerkvoorde et al., 2018). Besides supporting risk management plans, they can support public risk communication by depicting information on the geographic extent of hazard risks (Meyer et al., 2012). Hazards often cover large areas beyond administrative boundaries, which may be difficult to describe in words. Maps can thus deliver more specific delineation of spatial information concerning hazards and their associated risks (Dransch et al., 2010). They offer a visual, vivid tool to represent complex and localized information and to increase public knowledge and understanding of the possible geographic extent of a hazard's potential impact (Dransch et al., 2010).

With regard to map-mediated risk communication, understanding the influence of maps on disaster risk perception could help improve the quality of risk communication, which in turn enhances the public's willingness to support government policies and take precautionary measures (Houston et al., 2019; Kellens et al., 2013). Moreover, as hazards and disasters are spatial in nature, it is essential to assess spatial risk perceptions and the spatial awareness that results from spatial information-mediated risk communication.

Apart from the potential of spatial information benefits for risk communication, very little is known about how spatial information (maps) directly raises public perceptions of hazard risk. McKay's study may have been one of the first to represent how traditional maps (i.e., paper maps) improved the perception and comprehension of flood risk within a flood-prone community in Australia (Mckay, 1984). This study challenged what Handmer (1980) had found in his study, in that hazard maps were ineffective in influencing the public's perception of flood risks. As maps have evolved into many forms with the advancement of technology (e.g., digital maps), the advantages of interactive hazard and risk maps distributed on the internet, for example, have been confirmed by a study conducted by Hagemeier-Klose and Wagner (2009). However, this particular study did not directly examine the impacts of these maps regarding higher risk awareness and increased personal responsibility; instead, the results focused on the importance of technical explanations of terminology used on the maps.

Studies by Cao et al. (2016), Houston et al. (2019), Retchless (2018), and Strathie et al. (2017) are examples of the most recent studies evaluating risk perception prompted by map-mediated risk communication. Cao et al. (2016) found mixed results regarding the influence of maps about disasters on risk perception. When compared to text messages, maps provided better understanding accuracy and generated a significantly higher score on the people's perception of the likelihood of the risks. However, it was insignificant for the perceptions of risk severity. While Retchless (2018) found that college students who viewed an interactive map of rising sea levels increased their risk perceptions, Houston et al. (2019) found that using a combination of two interactive flood maps heightened spatial flood hazard awareness. Strathie et al. (2017) suggested making alterations to the standard format used to communicate probabilistic flood risk information in order to increase risk understanding and awareness, including the language to communicate the probabilistic information and colors used to visualize the risks. Colors especially should be changed to those that made intuitive sense and good differentiation between shades. These latest studies support the notion that maps may be effective for disaster-related behavioral change.

2.3 Readability and Satisfaction as Indicators of the Usability of Spatial Information (Maps) for Risk Communication

Risk communication can be seen via public awareness initiatives or public education about disasters, which aim to increase the awareness of communities and other stakeholders about risks and protective actions (Susmayadi et al., 2014). Thus, risk communication can also be seen as a way for the public to learn about natural disasters, such as the imminence of one striking in the near future and how severe it may impact the public. In recent years, the field of disaster education and learning has grown substantially due to rapid advancements in information and communication technologies. New technological advancements, such as social media and disaster applications, have opened additional pedagogical space for learning and disseminating information and knowledge (R. Hoffmann & Blecha, 2020).

With regard to modern spatial information, mobile applications with increasing map interactivity have democratized mapping and spatial data for the public. This new type of map has become an integral component of most individuals' daily activities, ranging from use for navigating when traveling or in shopping centers to frequent uses in education. Compared to printed maps, online map services, including their mobile versions, offer advantages such as navigation services, integration with a searching database, satellites, and an "airplane view" (i.e., displaying landscape features from overhead), as well as zooming and panning tools.

A study done by Meltzer et al. (2014) found that hazard maps are the most crucial feature of a disaster application on smartphones in the response phase. Specifically, in the case of respondents between 14–18 years old, they found that information about first aid, information on proper behavior in the case of a natural disaster, GPS tracking, and interactive maps were the most useful functions that a disaster application should fulfill.

Better locational accuracy and dynamic geospatial visualization are two improvements brought about by changes in spatial information (Morita, 2007; Thomas, 2018). This chapter, therefore, also aims to examine whether these features, which are embedded in a map-based disaster application, may affect the readability aspect of this new form of spatial information. It also includes an evaluation of users' satisfaction of the maps both in printed and displayed on a mobile application. Together with readability, satisfaction is another vital aspect in the usability of spatial information (maps) (Çöltekin et al., 2009).

The simple provision of a disaster application does not guarantee that the targeted users will discover the most effective means of using the application for disaster learning. Tan et al., (2020), for instance highlight the importance of user interface aspects of disaster apps for the usability of the apps. Concerns on user interface include graphic interface, user interface input, output, and structure. Aesthetic graphics and subtle animation are examples of graphic interface. While effort minimization and fingertip size controls are some examples of input, concise language, user-centric terminology, and audio output are some examples of the user interface output. In terms of user interface structure, minimal external links and logical path are some of the concerns of this aspect.

Moreover, since the disaster app in this study is a map-based or is built with interactive mapping feature, thus issues on map usability are also essential to take into considerations. Bartels & van Beurden (1998) argued that although maps can be an ideal way to learn about hazards spatially due to their strong visual impact, less proper use of cartographic techniques can lead to inaccurate interpretations of the message. Three basic elements of a map such as the symbology chosen, classes and class boundaries and use of colors are crucial for risk mapping and misuse can easily lead to misinterpretation of the spatial information. This situation indicates that an application needs to be easy to use and understood by the intended users to optimize its utilization.

In the context of maps or spatial information, perceived ease of use can be represented as “map readability.” Map readability is the process of the user’s representation of the information on the map in their mind. This representation can be estimated quantitatively through surrogate measures, including the speed of map comprehension and accuracy of map interpretation. Traditionally, cartographers have been responsible for ensuring the readability of maps. However, because of the digital revolution in cartography, the readability characteristics of many digital maps cannot be longer controlled solely by cartographers. Software developer, graphic designer, and prosumers (map users who are also map producers) (K. Hoffmann, 2013) may also control the readability of recent modern maps since they also take parts in creation of modern maps

Readability is a component of map quality and the antecedent of map usability. Readability assessment is usually reflected in ratings from “easy to read” to “hard to read” (Garmiz et al., 1988). Readability can also be defined as the degree of difficulty in reading a map and the difficulty or ease in obtaining information about objects and phenomena from their cartographic representations (MacEachren et al., 2005). More specifically, Harrie and Stigmar (2009), have defined measurements of map readability, which include: (1) amount of information (i.e., the amount and size of the map objects), (2) spatial distribution (i.e., the density and distribution of the map objects), (3) object complexity (i.e., size and shape of objects on maps). To improve the readability of maps from an online source such as geoportals for example, ones could select layers with appropriate content and resolution and then perform real-time generalization, (Harrie et al., 2015).

Several studies have highlighted the following potential problems associated with readability (Monmonier, 2018):

- A map is less readable when it provides too much information.
- The message supposed to be conveyed by the map is not clear because graphic semiotics rules are not represented.
- Users experience difficulty in determining which cartographic rules should be applied and how to apply them.

This study defines readability as the user's ease (or difficulty), accuracy, and rapidity (speed) of representation (comprehension of content) of the map (MacEachren et al., 2005). Readability is the effectiveness of the functioning of a man-map system or the interaction between map users and the maps itself, which depends on an aggregate of psychological factors and is manifested in the speed and accuracy (freedom of errors) of the performance of specific tasks. Difficulty or ease is an internal and subjective measurement, whereas accuracy and rapidity are objective external indicators of map reading effectiveness. Difficulty or ease is an internal, subjective aspect of the representation process characterized by the degree of effort expended by the user in reading the map. Speed is defined as the time taken to understand cartographic information, which is an objective external indicator of the effectiveness of this process.

Measuring the effectiveness of a map is related to the ways people use a map hierarchically. At the simplest level, they read maps to search, locate, identify, measure, and estimate (Clarke, 2003; Stieb et al., 2019). In regard to disaster maps, at this level, individuals can position themselves on the map and estimate the dangers of hazards based on their position. In the higher level of complexity when using maps, people can analyze them to recognize, reorganize, decode, detect, discriminate, and compare the visualized information (Clarke, 2003; Stieb et al., 2019). At this level, for example, one can recognize the geographic patterns of areas threatened by flood hazards. At the highest level, people can interpret the maps they read and make inferences about spatial relationships (Clarke, 2003; Stieb et al., 2019). For example, one can interpret the relationships between settlements at high risk of flooding based on their distances to the nearest river.

Satisfaction is an element of the standard usability performance metrics of an interactive digital map (Çöltekin et al., 2009). These performance metrics are employed to assess how easy the product or system is to use. Satisfaction refers to a user's attitude or preferences concerning a system and is generally regarded as one of the determinants of information system success (Petter et al., 2008; Xiao & Dasgupta, 2002). Satisfaction in this study is defined as the extent to which users believe that each feature of the application meets their expected satisfaction.

2.4 Designing for User Evaluation

Today's young generation is very familiar with digital technologies. Thus, it is now an excellent time to incorporate maps of various natural hazards in teaching such technology-accustomed youths about certain risks, especially disaster learning. In Indonesia, for example, it is estimated that there were more than 100 million internet users in 2018, with the highest proportion belonging to the group between 15–19 years of age (APJII & Polling Indonesia, 2018). Such numbers point to the importance of considering the targets of internet-mediated risk communication. The population within this age group is also a critical demographic with respect to the development of disaster awareness in a community. It has been widely acknowledged that effective disaster learning, which can later be translated into more engagement in risk reduction activities, should start in the period of youth (Ronan & Johnston, 2003). The Sendai Framework for Disaster Risk Reduction 2015-2030 for example encourages risk reduction activities done by children, especially those aged 10 to 14 (UNISDR, 2015).

Torani et al. (2019) summarizes some benefits of starting a disaster education at a lower age and schools including: (1) long memory of things learned at an early age, (2) children tend to define what they have learned from their parents, (3) earlier onset disaster prevention education makes it easy for children to think about risk reduction from an early age, (4) people familiar with the concepts of hazards and disasters in their childhood can respond better and faster when disaster events occur, and (5) in many countries, most of the population are children. Thus, this study targeted students at senior high schools as respondents.

Data used for the evaluation were obtained from a questionnaire survey with map-reading trials in four schools in West Java, Indonesia: Tasikmalaya 1 Senior High School, Tasikmalaya 2 Senior High School, Garut 1 Senior High School, and Sumedang 3 Senior High School. West Java was selected as the study area for this chapter's study since it is one of the provinces with a high frequency of disasters especially flooding, extreme weather, and landslides, a great impact from volcanic eruptions, a high number of internet users, and a high disaster risk index in Indonesia. These unique characteristics are suitable to conduct study of using online spatial information about disasters for at high-risk community. At the provincial level, Garut Regency ranked as the municipality in West Java Province with the highest disaster risk index (208.63) and ranked 18th at the national level. On the other hand, while Sumedang ranks as the 14th, Tasikmalaya ranked 23rd in West Java Province for its disaster risk index.

Students were selected and gathered with the help of local government officers and teachers from those four senior high schools in February 2020. The schools were selected with consideration of types of local hazards, availability of supporting facilities, faculty willingness, and ease of obtaining permission. Public schools were selected since compared to the private or boarding school they also represent the middle-class population with different religion for instance. Thus, they are more appropriate to represent the whole population due to the mixed socio-economic background. Based on several consultations with teachers and school curricula personnel, participants were selected from the 11^{th} and 12^{th} grades and those enrolled in natural sciences and social sciences.

A total of 362 participants completed this study. Due to missing data, one set of data from a participant was omitted, making the final number of respondents 361. Participants agreed to the experimental procedure, participated voluntarily, and could withdraw freely from the experiment at any time (for example, in Garut, some students withdrew from the experiment due to other tasks given by the school or student meetings). All the participants had normal or corrected-to-normal vision. One participant from Sumedang, who had slight color blindness, could still distinguish colors appropriately on the map. This study was carried out at the schools at the designated time. It was not applicable for students to have the experiment on their own time. The environmental conditions were kept constant for all participants except for the internet connection. Some schools had difficulties in stabilizing their internet connections.

2.4.1 Measurement and Procedure of Evaluation

This part of the research involved several stages. First, students were asked to fill out a set of questions about their demographics and other personal characteristics. Before conducting trials of the application and static map reading, students were given brief explanations about the application and the maps by researchers helped by research assistants, teachers, and support from local government officials. Before testing, participants were instructed that their response times would be recorded and that it would be ideal to perform the tasks in pairs or groups. These response times would further be analyzed as the “efficient” variable, and one of two items was used to measure readability as a whole. Times were calculated in seconds (and milliseconds, if possible).

A set of questionnaires was first distributed to students to assess their background information and demography. This first set initially consisted of 37 questions. All items were measured with a five-point Likert scale, on which “1” represented “strongly disagree,” and “5” represented “strongly agree.” The first eight questions inquired into the students’ demographic information (e.g., educational class, gender, age, and address). The next six questions assessed their perceived familiarity (extensive experience) with maps and perceived map reading ability (understanding of cartographic elements). Subsequently, the next eight questions assessed the students’ perceived familiarity with using the internet, social media, smartphones, and a computer/laptop. The following four questions assessed their perceived ability to use online maps and geographic information technology. Some items, however, were excluded after conducting a factor analysis due to violations of convergent reliability and internal consistency. The last eleven questions were designed to collect data about disaster experiences, including participation in disaster drills, the importance of searching for disaster information, and sources of disaster information.

To use and extract information from a map requires a certain level of ability in map use and some level of map understanding or map literacy (Bayram & Ibrahim, 2005; Koç, 2014). Such tasks entail the ability to understand and use maps in daily life, for working purposes, and in the community (Clarke, 2003). Wakabayashi has argued that the literacy of online maps might be different from that of paper maps (2018). However, since this study used both printed and online maps, map literacy was thus construed as only consisting of the most basic map items, including an understanding of scale, north direction, and a map legend. This level of literacy is essential because if one is not familiar with a map's fundamental elements, they might fail to read a map correctly (Wakabayashi, 2018). Familiarity with maps was included as a respondent characteristic since familiarity with technology was found to be correlated with successful use of such technology (Gula et al., 2009). A certain level of ability to use information and communication technology and a good sense of direction were found to have significantly affected the use of online maps in Japan (Wakabayashi, 2003).

To evaluate the effectiveness of map-mediated risk communication for improving risk perception, hazard risk awareness, and attitudes, a number of questions were asked of the students in the beginning and at the end of map reading tasks and readability assessments. Positive gaps in these variables indicate the effectiveness of risk communication.

To measure the effectiveness of using spatial information as a means of visual risk communication, this study developed some measurements derived from the objectives of risk communication, namely increasing hazard risk awareness and guiding risk reduction and preparedness behavior (Ajzen, 2011; Coppola & Maloney, 2017). Another main indicator is risk perception; thus, changes in risk perception were also gathered as a variable to measure the effectiveness of using spatial information for risk communication.

Awareness of hazard risk was measured by comparing how students perceive what kinds of natural hazards threaten their school. Classification of hazards followed that which BNPB has regulated, including flooding, flash flooding, landslides, extreme weather/strong winds/storms, droughts, earthquakes, tsunamis, wildfires, volcanic eruptions, and tidal waves/surges. For each type of hazard, four levels of risk were presented: high risk, moderate risk, low risk, and no risk. An additional option stating "I do not know" was also given to facilitate whether the students have any idea at all about the hazards that may threaten their school. Initially, this hazard assessment was also applied to the home locations of the respondents. However, since some respondents' houses were out of the printed maps' boundaries, the assessment of respondents' homes was finally eliminated.

The measurements of risk perception in this study were drawn from the psychometric paradigm of Slovic (1987), which is mainly composed of unknown risk and dread risk. Measurement of risk perception was also adapted from prior studies that generally used two indicators: perceived threat likelihood (possibility) and perceived threat severity (e.g., the degree of threat to family or personal properties) (Adiyoso & Kanegae, 2013; Calvello et al., 2016; Houston et al., 2019; McNeill et al., 2013; Terpstra et al., 2009; D. Xu et al., 2018).

Attitudes were measured by two dimensions. The first is related to perceptions of the importance of preparedness and knowing evacuation plans. The second dimension reflects respondents' intentions to seek disaster-related and hazard awareness-related information.

The nonspatial dimensions of disaster risks measured in this study were defined in terms of participants' dread of future disasters and disaster impact concerns (Houston et al., 2019). Risk perception was conceptualized in terms of two components: the likelihood of a hazardous event occurring and the consequences of hazardous activity (Paton et al., 2008). Initially, five items were used to measure this perception with respect to both components. The items were measured with a five-point scale of options (1: Not possible; 2: Probably not; 3: Undecided/neutral; 4: Possibly; 5: Definitely). One item about the possibility of future disaster events was finally excluded due to a lack of reliability. Thus, the last four items could only demonstrate the perceived magnitude of a disaster or perceptions of the consequences of hazards rather than demonstrating the two components.

Perceptions of the importance of knowing evacuation plans and being prepared were rated using a five-point Likert scale indicating the perceived levels of importance for the students (1: Unimportant; 2: Slightly unimportant; 3: Neutral/Moderately Important; 4: Important; 5: Very Important). Respondents' information-seeking intentions were measured with items operationalized using a five-point Likert scale representing levels of agreement (from 1: Strongly disagree to 5: Strongly agree).

After responding to these parts of the questionnaires, students were also asked to self-rate the risks of their school areas with respect to various natural hazards. More specifically, they were asked to answer multiple-choice questions derived from the statement, "My school is at risk…." Various levels of risks (i.e., high, medium, and low) and different kinds of hazards were presented to the students. There were ten hazards, including flooding, flash flooding, landslides, extreme weather, drought, earthquakes, tsunamis, tidal waves/ surges, wildfires, and volcanic eruptions. Each type of hazard was then categorized as “1” if students did not know the answer, “2” if they perceived that their school was not at risk of a particular hazard, “3” if the risk was perceived as low, “4” if the risk was perceived as medium or moderate, and “5” if the risk was perceived as high.

Figure 2.1 Students Examining the Maps and Filling the Questionnaire

Source: Author Documentation from Field Surveys, 2020

While the satisfaction variable was fully measured by items representing users’ subjective perceptions, two approaches—objective and subjective—were used to measure the application's readability. These two approaches are sensible since readability depends on an aggregate of psychological factors and is manifested in the speed and accuracy (freedom of errors) of the performance of specific tasks. Furthermore, while the subjective self-estimate measurement focused on the difficulty or ease of using the application, the objective measurement highlighted the actual accuracy and rapidity of map reading effectiveness. Two map-use tasks—spatial understanding and pattern recognition (Harrie & Stigmar, 2009; Herman et al., 2018) with a focus on accuracy (whether participants can correctly complete the tasks) and the calculation of the completion time (to measure the speed) for analyzing hazards threatening participants’ school—were given during the trial session.

In order to measure readability, participants were asked to identify kinds of hazards that may be threatening to their schools by performing a set of map-use tasks using the application. These map-use tasks were a combination of two tasks that are usually given to measure the performance of a map: spatial understanding and pattern recognition (Çöltekin et al., 2009). Students were given a maximum of 20 minutes (1,200 seconds) for each task. First, students were asked to find the location of their particular school on the map. Once they located their school, students needed to interpret the map and identify the types of natural hazards that may threaten their school by analyzing the patterns and shades of hazards coloring their school area. A table with rows showing ten kinds of hazards and four columns of risk levels (high risk, medium risk, low risk, and no risk) and one additional column stating, "I do not know" were given to respond to the following question: "Based on the application or the maps, my school is at risk of...." The ten different kinds of hazards include flooding, flash flooding, landslides, extreme weather, droughts, earthquakes, tsunamis, wildfire, volcanic eruptions, and tidal waves/surges. Participants had to identify and answer each type of hazard, meaning that all rows had to be checked. Answers given on this table were used to assess the effectiveness or accuracy in analyzing the types of natural hazards threaten their schools.

If students could answer about kinds of hazards with their risk levels correctly, they were labeled 1. They were labeled 0 otherwise. For example, based on the risk map displayed on a map-based disaster application created by BNPB, InaRisk Personal, Garut 1 Senior High School is at a medium risk of earthquakes, a medium risk of flooding, and a low risk of volcanic eruptions. Therefore, students from this school were classified as having given a correct answer if they put a check or marked cells representing those three risks. The other three risks (tsunamis, landslides, and flash flooding) displayed on the application but not applicable to the school should be marked as no risk. Students could either put marks on no risk or “I do not know” for the remaining four hazards since they were not displayed on the application.

Once the application trial had finished, students were asked to answer questions on perceived readability (perceived ease of use of the app or maps) and user satisfaction. These two variables were measured with a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). These procedures were also applied when using printed maps. The whole session was closed after students answered a set of questions about disaster spatial information source preferences. In the final phase, students were asked whether they preferred InaRisk Personal or conventional static maps.

2.4.2 Materials Used for the Evaluation

1. Local Government-Provided Maps

Traditionally, geographic information has been distributed using paper maps, which are costly to produce and difficult to update and distribute to all parties involved (Herold & Sawada, 2012). Schools selected in this part of the study are located in cities and regencies which have not use and distributed spatial information about disasters online. Governments in these municipalities are still using paper maps for distributing spatial information, including disasters.

There were different numbers and types of maps used at each school, depending on the maps’ availability in each municipality. This study only used maps that may be applicable for risk communication and disaster learning. Thus, only maps with disaster-related content were selected. Once the maps were obtained from local government agencies, they were next prepared and printed on A3 papers (a typical size used for map dissemination by local governments in Indonesia). In Tasikmalaya 1 and Tasikmalaya 2 senior high schools, two maps were used for the map reading trial: (1) the Spatial Pattern Map and (2) the Earthquake Hazard Map of Tasikmalaya. These two maps were obtained from the Development Planning Agency (Bappeda) in Tasikmalaya. Two maps were also distributed to students in Garut 1 Senior High School, namely (1) the Spatial Pattern Map and (2) the Disaster-Prone Area Map of Garut. Both maps were collected from the Bappeda of Garut Regency. At Sumedang 3 Senior High School, three maps were given to the participants: (1) Earthquake Hazard Map, (2) Flood Hazard Map, and (3) Disaster-Prone Area Map of Sumedang. These maps were obtained from the Bappeda of Sumedang Regency with a help from a colleague from Bappeda of Garut Regency.

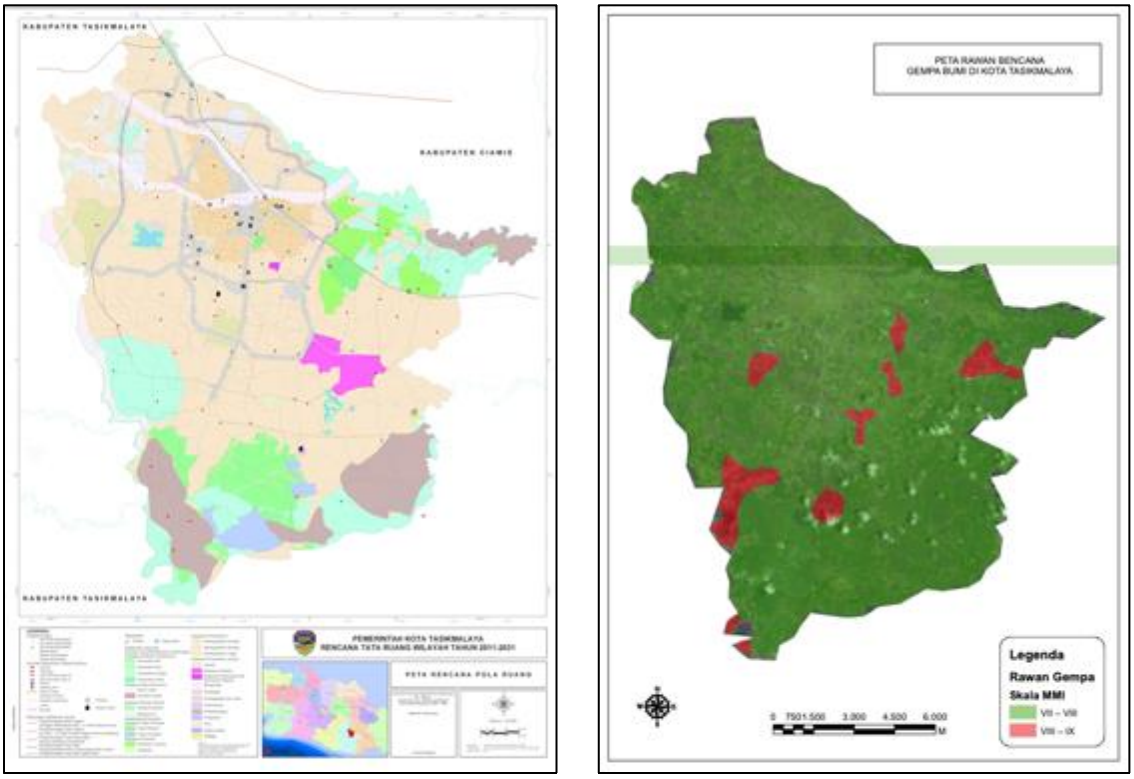
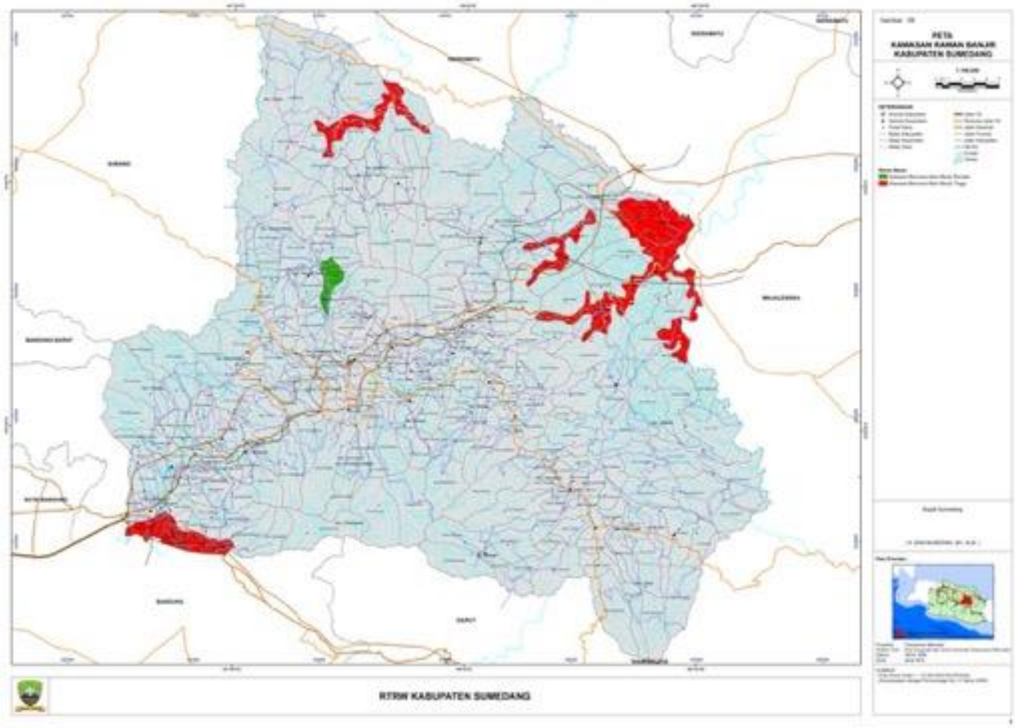
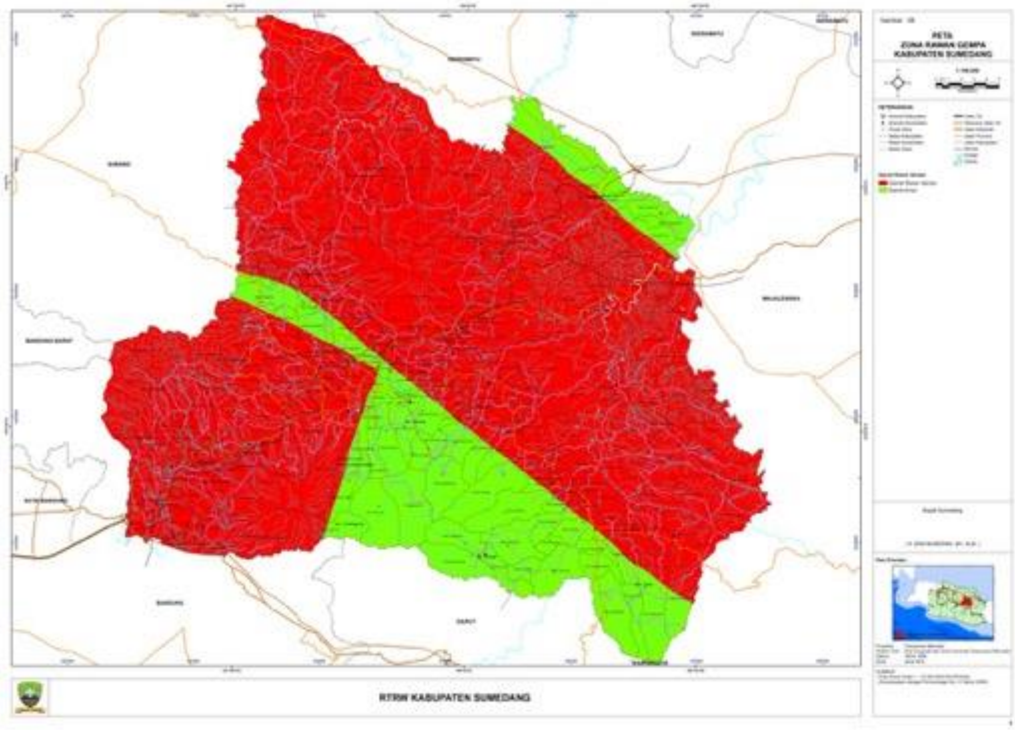


Figure 2.2 Maps Used for Respondents in Tasikmalaya City

Source: Local Development Planning Agency of City of Tasikmalaya, 2020


RTRW KABUPATEN SUMEDANG


RTRW KABUPATEN SUMEDANG

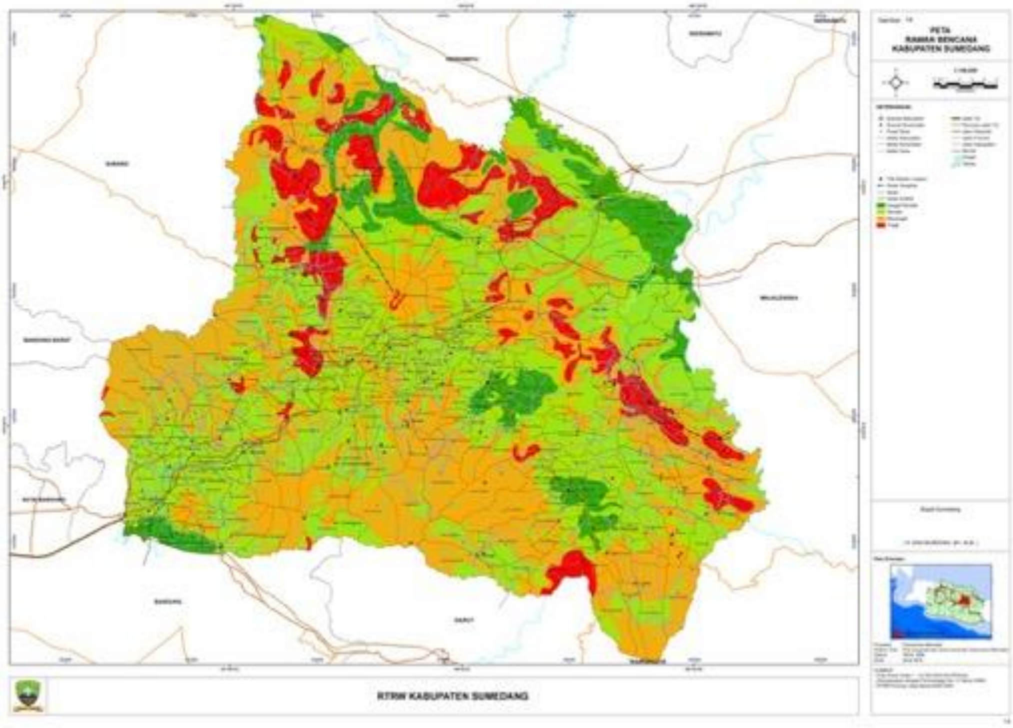


Figure 2.3 Maps Used for Respondents in Sumedang Regency

Source: Local Development Planning Agency of Sumedang Regency, 2020

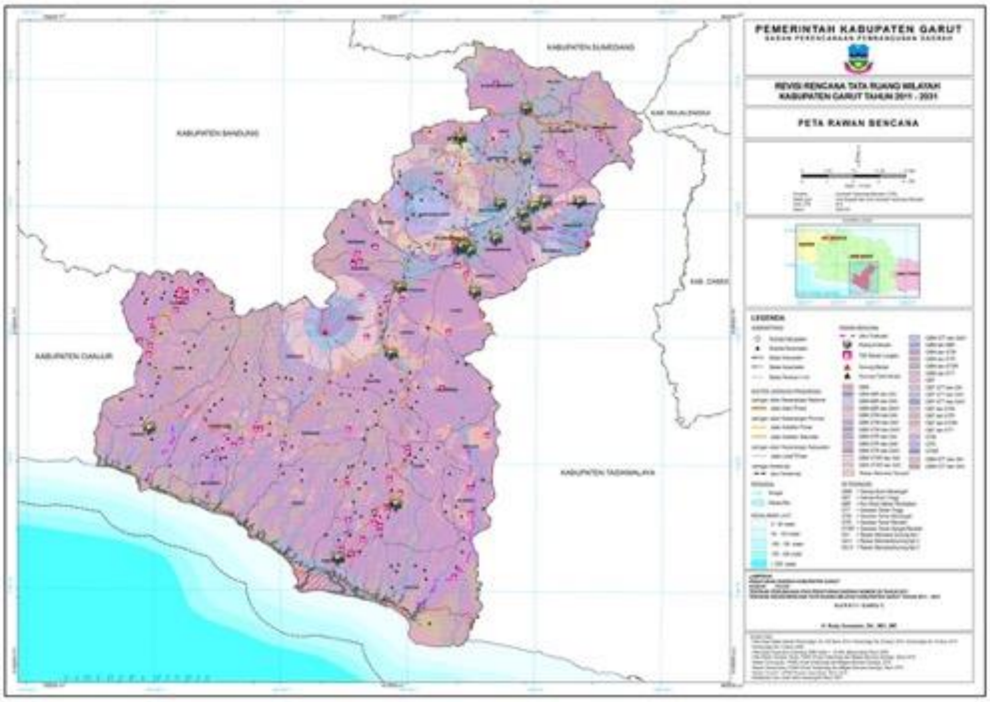


Figure 2.4 Maps Used for Respondents in Garut Regency

Source: Local Development Planning Agency of Garut Regency, 2020

2. *InaRisk Personal: A National Initiative for Informing Personalized Hazard Risk*

BNPB, or the national disaster management agency, has mapped areas prone to disasters in Indonesia up to the scale of 1:50,000 (regency level) and 1:25,000 (city level). These maps can be accessed online through BNPB's website, namely InaRisk (available at http://inarisk.bnpb.go.id). The public can access various data and information, including the spatial distribution of disaster occurrences, specific locations of disasters, and the levels of threat, vulnerability, and capacity. However, this geographical information about disasters has not been widely accessed by the public. This low adoption rate may occur due to the lack of dissemination and limited support facilities (e.g., stable internet connections). Also, the maps are mostly built as web-based and only optimized for a desktop interface. Meanwhile, a high proportion of Indonesian internet users preferred using smartphones or tablets to access the internet (83.44%), according to the Indonesia Internet Service Provider Association's survey in 2017.

To reach broader audiences and make the application more personal, BNPB collaborated with various institutions and developed a more personal disaster learning application, InaRisk Personal. The application aims to help the public spatially understand the risks of various hazards in any location in the country based on its user's real-time position. The application is available in two languages, Bahasa Indonesian and English, and it provides information on what users can do before, during, and after a disaster. Users can select their preferred base maps as either satellite, street map, or terrain. There are also videos about disasters in Indonesia that users can watch to visually understand dangerous events caused by natural hazards. Users can also perform a building assessment to determine how resistant a given building is to earthquakes. The application can display various location-based disaster risk levels. Initially, there were six kinds of hazards on the app: earthquakes, flooding, flash flooding, landslides, volcanic eruptions, and tsunamis. BNPB then added COVID-19 to support risk communication during the pandemic (**Figure 2.5**).

This map-based mobile application is available on Android and iOS platforms. As of July 2020, the application has been downloaded over 100,000 times with a 3.6 rating in Google Play Store.

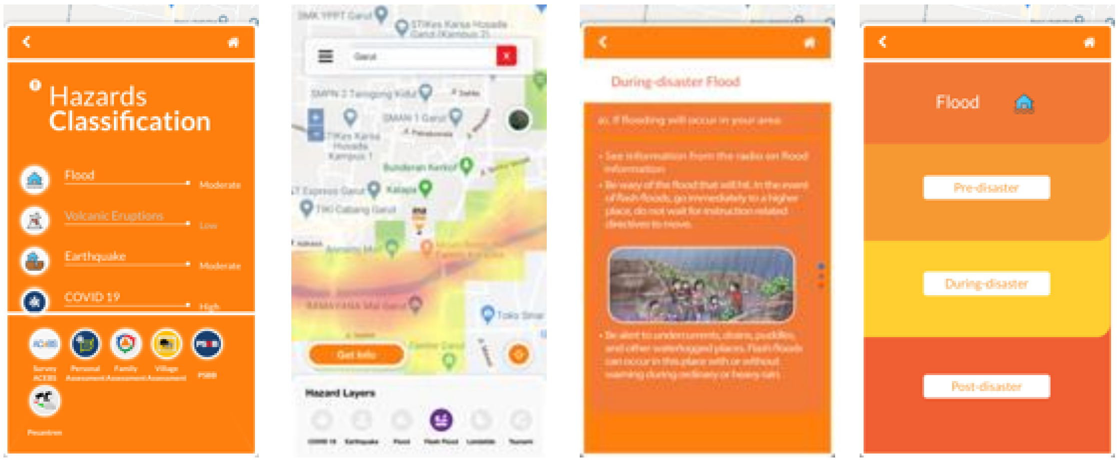


Figure 2.5 Examples of InaRisk Personal Interfaces on iOS

Source: The author's documentation screenshot from InaRisk Personal, 2020

2.4.3 Demography of the Respondents

The initial number of respondents was 362. However, due to missing data, one participant's responses were omitted. The vast majority of the respondents were students enrolled in the 11th grade (83.7%). As seen in **Table 2.1**, the participants were mostly female students. Female respondents outnumbered males (56.0% and 44.0%, respectively). In terms of age, on average, they aged between 16 and 17 years. The age distribution of the students was as follows: 3% were 15 years of age, 39.6% were 16 years of age, 48.8% were 17 years of age, and 8.6% were 18 years of age. Respondents were divided into almost equal numbers across course backgrounds. While 50.7% of the respondents belonged to the natural sciences, 49.3% belonged to the social sciences. Gender distribution among the courses was similar. There were more female students in both courses (57.4% for natural sciences and 54.5% for social sciences).

Around two-thirds of the students (66.2%) were found to have experienced natural disasters. However, only 11.9% of students reported that they had been victims of disasters, and 3.0% had experienced evacuations. A total of 11.9% of students reported that their homes had been affected at some point by a natural disaster(s), while 10.5% of students indicated that their schools had been affected by disasters.

Table 2.1

Participants' Characteristics (N=361)

Sex	**Female**		**Male**	
	202 (56.0%)		159 (44.0%)	
School	**Tasikmalaya City 1 Senior High School**	**Tasikmalaya City 2 Senior High School**	**Garut Regency 1 Senior High School**	**Sumedang Regency 3 Senior High School**
	53 (14.7%)	64 (17.7%)	120 (33.2%)	124 (34.3%)
Municipality	**Tasikmalaya**		**Garut Regency**	**Sumedang Regency**
	117 (32.4%)		120 (33.2%)	124 (34.3%)
Age	**15 years old**	**16 years old**	**17 years old**	**18 years old**
	11 (3.0%)	143 (39.6%)	176 (48.8%)	31 (8.6%)
Class Grade	**XI**		**XII**	
	302 (83.7%)		59 (16.3%)	
Majors	**Natural sciences**		**Social sciences**	
	183 (50.7%)		178 (49.3%)	
Prior use of InaRisk Personal before the survey	**Yes**		**No**	
	15 (4.2%)		346 (95.8%)	
Experienced disasters	**Yes**		**No**	
	239 (66.2%)		122 (33.8%)	
Participated in socialization about disasters at school	**Yes**		**No**	
	262 (72.6%)		99 (27.4%)	
Joined disaster simulation (s) at school	**Yes**		**No**	
	138 (38.2%)		223 (61.8%)	

This study found that most students had been educated about disasters at school. About 72.6% of students stated that they had participated in socialization about disasters at school, while only 42.1% had received this education from their home neighborhoods. One-third of these students had participated in a disaster drill/training or disaster simulation at school (30.5% and 38.2%, respectively). Despite their different experiences with disasters, almost all students perceived that information about disasters was essential (99.7%). Most of the students mentioned that they had received information about disasters from their teachers, parents, and social media. They also found information about disasters in books.

Table 2.2

Respondents' Characteristics Related to Familiarity with Maps and Engagement with Technology (N = 361)

Variables and Survey Items	Mean	Median	Standard Deviation
A. Self-estimated map reading and spatial ability			
1. I am accustomed to using a map	3.31	3.00	0.79
2. I have a good ability in reading a map	3.13	3.00	0.78
3. I can easily locate an area on a map	**3.65**	**4.00**	0.85
4. I can easily understand the wind direction of a map	2.98	3.00	0.90
5. I understand how to interpret map scale	2.97	3.00	0.91
6. I can easily understand the information shown on a map legend	3.03	3.00	0.93
7. I have a good understanding of the area/geographic conditions of this city	**2.94**	**3.00**	0.81
B. Engagement with technology			
1. I am accustomed to using a computer/laptop	4.02	4.00	0.76
2. I am accustomed to using smartphones	4.58	5.00	0.60
3. I am accustomed to using the internet	4.67	5.00	0.52
4. I am accustomed to using social media (e.g., WhatsApp, Instagram, Twitter, others)	**4.69**	**5.00**	0.54
5. I am a fast learner when it comes to new applications/software	3.83	4.00	0.85
6. The quality of internet connection on my phone is good	3.98	4.00	0.81
7. I have a good internet connection at home	4.13	4.00	0.87
8. I have a good internet connection at school	**3.48**	**4.00**	1.03

C. Familiarity with online maps and GIS applications			
1. I am able to use mapping application software (e.g., ArcMap, QGIS, ArcGIS, or others) without any assistance	**2.73**	**3.00**	0.91
2. I am accustomed to using online maps (e.g., Google Maps, Waze, or others)	**4.01**	**4.00**	0.78
3. I have a good ability to use online maps (e.g., Google Maps, Waze, or others)	3.85	4.00	0.76
4. I can easily understand information depicted on online maps (e.g., Google Maps, Waze, or others)	3.85	4.00	0.84

Note: 1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree

Source: The Author, 2020

Regarding respondents' characteristics related to map reading ability and engagement with technology, the responses were positive overall, as shown by the mean; the median for all indicators was mostly above 3.00, "indicating agree" and "strongly agree" for each statement. This finding suggests that students have a good map reading and spatial ability, are familiar with technology, especially smartphones and the internet, and are accustomed to using online maps. They were likely to have a better internet connection at home than at school.

2.5 Existing Spatial Information as a Risk Communication Tool Has a Minimal Impact on the Perceptions and Awareness of Hazard Risks

This section examines the different effects of using spatial information as a risk communication tool on risk perception and hazard awareness.

2.5.1 Effectiveness of Map-Mediated Risk Communication on Risk Perception

The first hypothesis proposed in this part of study is: The medians for each risk perception indicator are different before and after spatial information about disasters is delivered to the students. Thus, it can be formulated that:

- Null hypothesis (Ho): Med2 - Med1 = 0
- Alternative hypothesis (Ha): Med2 - Med1 ≠ 0
- Med1= Median score of the risk perception indicators before maps are delivered
- Med2= Median score of the risk perception indicators after maps are delivered

The second hypothesis proposed in this part of study is: The mean of the composite value of the students' risk perception is greater after spatial information about disasters is delivered to them. Thus, it can be formulated that:

- Null hypothesis (Ho): $\mu 2 - \mu 1 = 0$
- Alternative hypothesis (Ha): $\mu 2 - \mu 1 \neq 0$
- $\mu 1$= Mean score of the composite value of risk perception before maps are delivered
- $\mu 2$= Mean score of the composite value of risk perception after maps are delivered

Table 2.3 presents a summary of the changes in each risk perception indicator. Three of the five indicators significantly changed after the experiment, indicating that viewing and reading maps about disasters influenced several risk perceptions. It was found that, after the experiment, the students changed their perceptions of the personal impact of disasters, the impact of disasters on their family members, and the impact of disasters on their school.

Table 2.3

Changes in Risk Perception (RP) (N=361)

Items	Before the Experiment		After the Experiment		Related-Samples Wilcoxon Signed-Rank Test	
	Median (Med1)	SD	Median (Med2)	SD	Sig.	Decision
RP 1: It is likely that natural disasters will continue to happen in this city in the future.	4.00	0.69	4.00	0.67	0.895	No significant changes
RP 2: It is likely that I will be hurt or die because of natural disasters.	4.00	0.77	4.00	0.68	0.001	Significant changes
RP 3: It is likely that members of my family will be hurt or die because of natural disasters.	4.00	0.77	4.00	0.70	0.005	Significant changes
RP 4: It is likely that natural disasters will cause damage to my home.	4.00	0.75	4.00	0.64	0.063	No significant changes
RP 5: It is likely that natural disasters will cause damage to my school.	4.00	0.78	4.00	0.72	0.009	Significant changes

Note: 1: Definitely not, 2: Possibly not, 3: Neutral, 4: Possibly, 5: Definitely

Source: The Author, 2020

Table 2.4 shows the composite value of risk perception after performing factor analysis. The composite value of risk perception is the summation of four items (i.e., RP2, RP3, RP4, and RP5). RP1 was omitted to increase the Cronbach's alpha. The Kaiser-Meyer-Olkin (KMO) and Bartlett's test results suggest that all four items passed the communality test since they were reasonably well represented. The internal consistency reliability or composite reliability expressed by Cronbach's alpha for all items was above 0.70. Items with factor loadings higher than 0.70 indicated that they were reliable for the construction of the variables. Thus, they were retained for further analyses. The composite mean of risk perception before the experiment was 3.70; the mean after the experiment was 3.80, indicating a higher risk perception. This increase in risk perception is significant (see **Table 2.5**).

Table 2.4

Composite Value of Risk Perception (RP) after Performing Factor Analysis

Items	Before the Map Reading Experiment			After the Map Reading Experiment		
	CA	FL	Mean	CA	FL	Mean
RP	**0.912**		**3.70**	**0.905**		**3.80**
RP2		0.89	3.67		0.94	3.79
RP3		0.94	3.61		0.93	3.71
RP4		0.73	3.83		0.71	3.91
RP5		0.81	3.69		0.77	3.79

CA: Cronbach's alpha; FL: Factor loadings; (N=361); Source: The Author, 2020

Table 2.5 presents a summary of the changes in risk perception divided by the respondents' characteristics. This table shows that significant changes were found both for female and male students. However, in terms of the school, there were only students from Tasikmalaya City 2 Senior High School and Garut Regency 1 Senior High School found significantly changed their risk perception. Significant changes were also found for students who had never experienced disasters and had never been a victim of disasters.

Table 2.5

Changes in Risk Perception (RP) based on Respondents' Characteristics

	N	Mean Before the Experiment (μ1)	Mean After the Experiment (μ2)	μ2 – μ1	Paired Sample t Test		
					t	df	Sig. (2-tailed)
Total	361	3.70	3.80	0.095	3.134	360	0.002*
Female	202	3.73	3.81	0.085	2.376	201	0.018*
Male	159	3.66	3.77	0.108	2.080	158	0.039*
Tasikmalaya City 1 Senior High School	53	3.78	3.73	-0.047	-0.718	52	0.476

Tasikmalaya City 2 Senior High School	64	3.70	3.88	0.184	2.232	63	0.029*
Garut Regency 1 Senior High School	120	3.67	3.80	0.135	2.999	119	0.003*
Sumedang Regency 3 Senior High School	124	3.71	3.78	0.073	1.259	123	0.211
Had experienced disasters	239	3.78	3.82	0.033	0.934	238	0.351
No disaster experience	122	3.55	3.76	0.217	3.929	121	0.000*
Had experience as a victim	43	3.94	3.87	-0.070	-1.054	42	0.298
Never experienced being a victim	318	3.67	3.79	0.118	3.545	317	0.000*

Source: The Author, 2020

Overall, the findings presented above suggest that the students' risk perception changed after they viewed the maps (i.e., both printed maps and maps via InaRisk application). However, changes in risk perceptions did not apply to the students that had personally experienced a disaster. A similar result was found among those who had been victims of disasters. These findings are consistent with the results reported in studies by Houston et al. (2019) and Retchless (2018), which also found that communicating disaster risks using maps changes risk perception.

2.5.2 Effectiveness of Map-Mediated Risk Communication on the Awareness of Hazard Risks

Although the experiment results for risk perception varied in terms of before and after the map reading activities, maps were found to sufficiently increase the students' spatial risk perceptions at Tasikmalaya City 2 Senior High School and Garut Regency 1 Senior High School. However, the situation is not applicable for students from

Tasikmalaya City 1 Senior High School and Sumedang Regency 3 Senior High School. Some of the students may have already had prior knowledge of the hazards that were spatially threatening their school, so the maps may not have affected their perceptions. However, for the types of hazards that the students may not have been familiar with, the maps may have helped improve their understanding.

The four schools at which this study was conducted had different risks of hazards. Some hazards may not have been a threat to the school (i.e., tsunamis or extreme waves were not dangerous hazards because the school was located far from the coastline, or the city in which the school was located had no coastal landscape). Specifically, Tasikmalaya City 1 Senior High School was at a medium risk of flooding and a medium risk of earthquakes. Tasikmalaya City 2 Senior High School and Sumedang Regency 3 Senior High School were at a low risk of flooding and a medium risk of earthquakes. Garut Regency 1 Senior High School was prone to a medium risk of flooding, a medium risk of earthquakes, and a low risk of volcanic eruptions. However, all hazards, including tsunamis and extreme waves, were still included as options to test the students' general comprehension of natural hazards.

In general, using the McNemar-Bowker test, this study found some significant differences in the awareness of hazard risks after the students viewed the maps for all schools, except for the Tasikmalaya City 1 Senior High School's students. There were no significant differences in the awareness for all hazards in the case of the Tasikmalaya City 1 Senior High School's students, although if looking at the pattern, some changes emerged. For example, before viewing the maps, most of the students at Tasikmalaya City 1 Senior High School perceived that their school was part of an area with a medium risk of drought. However, after they viewed the maps, they were aware that the school had no risk of drought. The students were also likely to change their perception of flooding hazard. After viewing the maps, they tended to perceive that their school was at a medium risk of flooding.

In the case of Tasikmalaya City 2 Senior High School, the map experiment was found to be useful in increasing the students' understand of flooding. Before reading the maps, students were already aware that their school was at risk of flooding, although they tended to overestimate the level of this particular threat. After reading the map, their perception of the significance of flooding was similar to the flood level visualized by the maps. The experiment also changed their perceptions of drought. Previously, the students had overestimated the risk of drought. After reading the maps, they perceived a lower level of risk from drought. Interestingly, in the case of Tasikmalaya City 2 Senior High School, most of the students still perceived that their school was also at risk of hazards that were not visualized by the maps after they viewed them. They still perceived that their school had a low risk of flash flooding, a low risk of landslides, a low risk of extreme weather, and a medium risk of volcanic eruptions. However, based on the maps, the school was only exposed to a low risk of flood and a medium risk of earthquakes. Significant changes in the spatial risk perceptions of the students from this school were seen with respect to their perceptions of flooding, landslides, droughts, and wildfires.

At Garut Regency 1 Senior High School, significant changes in spatial risk perceptions were seen with respect to the students' perceptions of landslides, tsunamis, and volcanic eruptions. The students were also found to have a better understanding of risks after viewing the maps, especially with respect to landslides, tsunamis, and volcanic eruptions. Specifically, concerning volcanic eruptions, this school was located approximately 12 kilometers from the Guntur Volcano. Although the school was located close to the volcano, before reading the maps, most of the students did not know that their school was at risk of volcanic eruptions. This situation may have been due to the volcano's dormancy. Mount Guntur has not erupted for more than 100 years, which may explain the students' lack of awareness of the risk of volcanic eruptions. The post-viewing results showed that the students were perceived that their school was at a low risk of being impacted by a volcanic eruption. This situation indicated that maps were sufficient for increasing the students' understanding of volcanic eruptions.

Finally, for Sumedang Regency 3 Senior High School, significant changes in spatial risk perceptions were seen with respect to the students' awareness of flooding, drought, earthquakes, and volcanic eruptions. This school was at a low risk of flooding and a medium risk of earthquakes. Thus, the maps helped some students who previously underestimated the risk of earthquakes to understand that their school was at a medium level of risk of being impacted by that type of natural disaster.

Table 2.6

Respondents' Perceptions of Multiple Hazard Risk Levels

Pre-Map Reading Risk Perceptions		Hazards	Post-Map Reading Risk Perceptions		Significant Changes in Risk Perceptions/ Hazard Awareness
Mode	**Median**		**Median**	**Mode**	
		Tasikmalaya City 1 SHS (n = 53)			
Low Risk	Low Risk	**Flooding**	Medium Risk	Medium Risk	No
No Risk	No Risk	**Flash Flooding**	No Risk	No Risk	No
No Risk	No Risk	**Landslides**	No Risk	No Risk	No
Low Risk	Low Risk	**Extreme Weather**	No Risk	No Risk	No
Medium Risk	Medium Risk	**Droughts**	No Risk	No Risk	No
Medium Risk	Medium Risk	**Earthquakes**	Medium Risk	Medium Risk	No
No Risk	No Risk	**Tsunamis**	No Risk	No Risk	No
No Risk	No Risk	**Wildfires**	No Risk	No Risk	No

Low Risk	Low Risk	**Volcanic Eruptions**	No Risk	No Risk	No
No Risk	No Risk	**Tidal Waves/ Surges**	No Risk	No Risk	No
		Tasikmalaya City 2 SHS (n = 64)			
Medium Risk	Medium Risk	**Flooding**	Low Risk	Low Risk	Yes***
Low Risk	Low Risk	**Flash Flooding**	Low Risk	Low Risk	No
Medium Risk	Low Risk	**Landslides**	Low Risk	Low Risk	Yes*
Medium Risk	Medium Risk	**Extreme Weather**	Low Risk	Low Risk	No
Medium Risk	Medium Risk	**Droughts**	Low Risk	No Risk	Yes**
Medium Risk	Medium Risk	**Earthquakes**	Medium Risk	Medium Risk	No
No Risk	No Risk	**Tsunamis**	No Risk	No Risk	No
Low Risk	Low Risk	**Wildfires**	No Risk	No Risk	Yes*
Medium Risk	Medium Risk	**Volcanic Eruptions**	Medium Risk	Medium Risk	No
No Risk	No Risk	**Tidal Waves/ Surges**	No Risk	No Risk	No
		Garut Regency 1 SHS (n = 120)			
Medium Risk	Low Risk	**Flooding**	Medium Risk	Medium Risk	No
Do Not Know	Low Risk	**Flash Flooding**	No Risk	No Risk	No
No Risk	No Risk	**Landslides**	No Risk	No Risk	Yes***
Medium Risk	Low to Medium Risk	**Extreme Weather**	No Risk	No Risk	No
Do Not Know	Low Risk	**Droughts**	No Risk	No Risk	No
Medium Risk	Medium Risk	**Earthquakes**	Medium Risk	Medium Risk	No
No Risk	No Risk	**Tsunamis**	No Risk	No Risk	Yes***
No Risk	No Risk	**Wildfires**	No Risk	No Risk	No
Do Not Know	Low Risk	**Volcanic Eruptions**	Low Risk	Low Risk	Yes***
No Risk	No Risk	**Tidal Waves/ Surges**	No Risk	No Risk	No
		Sumedang Regency 3 SHS (n=124)			
Low Risk	Low Risk	**Flooding**	Low Risk	Low Risk	Yes***

No Risk	No Risk	**Flash Flooding**	No Risk	No Risk	No
No Risk	No Risk	**Landslides**	No Risk	No Risk	No
Low Risk	Low Risk	**Extreme Weather**	No Risk	No Risk	No
Medium Risk	Low Risk	**Droughts**	No Risk	No Risk	Yes***
Medium Risk	Low Risk	**Earthquakes**	Medium Risk	Medium Risk	Yes***
No Risk	No Risk	**Tsunamis**	No Risk	No Risk	No
No Risk	No Risk	**Wildfires**	No Risk	No Risk	No
No Risk	No Risk	**Volcanic Eruptions**	No Risk	No Risk	Yes***
No Risk	No Risk	**Tidal Waves/ Surges**	No Risk	No Risk	No

Significance of changes in the perceptions of hazard risks were tested using the McNemar-Bowker test (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Some of these findings are consistent with those reported in previous studies conducted by Mckay (1984), Houston et al. (2019), and Retchless (2018), which argued that maps can increase risk perception and hazard awareness. However, map users should be aware of the limitations and uncertainty of maps, such as limitations on the visualization of hazard risks. The risk information depicted on the maps may also be imperfect because of the limitation of topographical information.

2.5.3 Effectiveness of Map-Mediated Risk Communication on Attitudes Toward the Evacuation Plan and Preparedness

The hypothesis proposed in this part of study is: The medians of each indicator reflecting attitudes toward the evacuation plan and preparedness are different before and after spatial information about disasters is delivered to the students. Thus, it can be formulated that:

- Null hypothesis (Ho): Med2 - Med1 = 0
- Alternative hypothesis (Ha): Med2 – Med1 ≠ 0

- Med1= Median score of attitudes toward the evacuation plan and preparedness indicators before maps are delivered
- Med2= Median score of attitudes toward the evacuation plan and preparedness indicators after maps are delivered

Table 2.7 presents a summary of the changes in each of the items related to attitudes toward the evacuation plan and preparedness. The attitudes associated with three of the five items were found to significantly change after the experiment, indicating that viewing and reading maps about disasters influenced several risk perceptions. It was found that the students significantly changed their attitudes on the importance of knowing evacuation routes, assembly points, and emergency numbers. It was found that having been informed about disaster risks did not influence the students' attitudes on being prepared.

Table 2.7

Changes in Attitudes toward the Evacuation Plan and Preparedness

Items	Before Experiment		After Experiment		Related-Samples Wilcoxon Signed-Rank Test	
	Median	SD	Median	SD	Sig.	Decision
ATEPP1: For me, knowing the evacuation routes for the future emergency situation is…	5.00	0.68	4.00	0.66	0.010	Significant changes
ATEPP2: For me, knowing the assembly points for the future emergency situation is …	5.00	0.70	4.00	0.65	0.035	Significant changes
ATEPP3: For me, knowing the evacuation sites for the future emergency situation is …	4.00	0.70	4.00	0.65	0.348	No Significant changes
ATEPP4: For me, knowing essential emergency dialing numbers is …	5.00	0.67	4.00	0.70	0.000	Significant changes

ATEPP5: For me, preparing a disaster emergency kit is …	4.00	0.72	4.00	0.69	0.191	No Significant changes

Note: 1: Unimportant, 2: Slightly unimportant, 3: Neutral/Moderately Important, 4: Important, 5: Very Important (N=361); Source: The Author, 2020

2.5.4 Effectiveness of Map-Mediated Risk Communication on Risk Information-Seeking

The hypothesis proposed in this part of study is: The medians of each risk information-seeking indicator are different before and after spatial information about disasters is delivered to the students. Thus, it can be formulated that:

- Null hypothesis (Ho): Med2 - Med1 = 0
- Alternative hypothesis (Ha): Med2 – Med1 ≠ 0
- Med1= Median score of the risk information seeking indicators before maps are delivered
- Med2= Median score of the risk information seeking indicators after maps are delivered

Table 2.8

Changes in Risk Information-Seeking Intentions (N=361)

Items	Before the Experiment		After the Experiment		Related-Samples Wilcoxon Signed-Rank Test	
	Median	SD	Median	SD	Sig.	Decision
RIS1: I want to know about the kinds of disasters that frequently occur in this city.	4.00	0.68	4.00	0.62	0.009	Significant changes
RIS2: I want to know about the various hazards threatening my home.	4.00	0.75	4.00	0.64	0.000	Significant changes
RIS3: I want to know about the various hazards threatening my school.	4.00	0.76	4.00	0.64	0.044	Significant changes

RIS4: I want to know about the various hazards threatening any areas in this city.	4.00	0.75	4.00	0.72	0.000	Significant changes
RIS5: I want to participate in disaster drills or disaster simulations.	4.00	0.80	4.00	0.77	0.166	No Significant changes
RIS6: I want to know what I should do prior to, during, and after disasters.	4.00	0.71	4.00	0.69	0.000	Significant changes
RIS7: I want to talk about/discuss disasters with my family.	4.00	0.78	4.00	0.72	0.726	No Significant changes
RIS8: I want to talk about/discuss disasters with my friends.	4.00	0.81	4.00	0.72	0.472	No Significant changes

Note: 1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree

Source: The Author, 2020

Table 2.8 presents a summary of the changes in each risk information-seeking intention. Five of eight items were found to be significantly changed after the experiment, indicating that viewing and reading maps about disasters stimulated intentions to find risk information when concerned about: (1) the kinds of disasters that frequently occur in the city, (2) the hazards threatening one’s home, (3) the hazards threatening the school, (4) the hazards threatening any areas in the city, and (5) the steps to take before, during, and after disasters.

2.6 Low Readability of Local Government-Compiled Static Maps about Disasters

Readability was assessed using two approaches. First, the assessment was based on an objective examination from an experimental session, which included the InaRisk Personal application and map-reading trials. The second approach was a more subjective assessment based on the students’ perceptions.

2.6.1 Measured Readability

The total completion times the students needed to examine the types of natural hazards threatening their school (for students with both correct and incorrect answers) using InaRisk Personal were: a minimum of 1.90 seconds, a maximum of 318.16 seconds, and a mean of 34.68 seconds. The minimum time needed to first locate the school on the InaRisk Personal application was less than 1 second; the maximum was 76.00 seconds. On average, the students needed 3.41 seconds. To analyze the types and level of hazards that threaten their school from the application's map, the students needed a minimum of 1 second and a maximum of 317.16 seconds. On average, the time needed to complete this task of recognizing the types and level of hazards was 31.27 seconds.

When using printed maps, the students needed more time to accomplish the tasks. The minimum total completion time was 21.00 seconds; the maximum time was 631.00 seconds. On average, it took 153.64 seconds to locate the school and examine the hazard that was threatening the school based on the information displayed on the printed maps. See Figure 2.6 to compare the total completion time the students needed to accomplish each task when using the application and when using the printed maps. The data were first normalized by having them logged.

Figure 2.6 shows that the application is more efficient than the printed maps for analyzing hazards, as shown by the shorter time needed to accomplish the tasks. There was clear evidence that by using InaRisk Personal, the students could more quickly locate the school. The results of the paired samples T-test suggested significant differences at a 5% significance level for all pairs of time differences for all tasks: locating the school (t=-35.27, df=360, Sig. (2-tailed< 0.000); analyzing the risk pattern (t=-24.35, df=360, Sig. (2-tailed< 0.000); both tasks (t=-31.98, df=360, Sig. (2-tailed< 0.000).

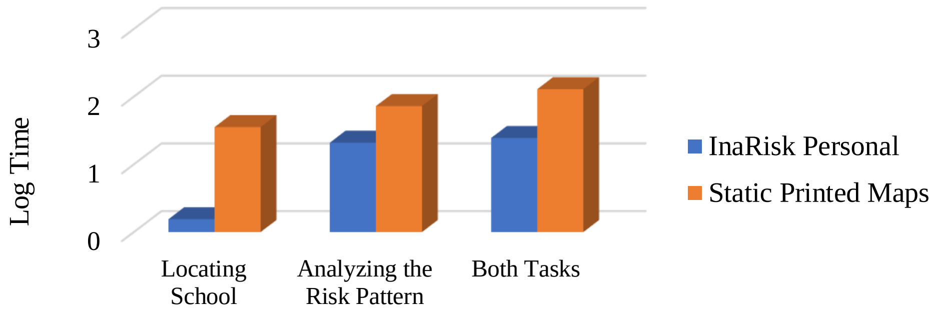


Figure 2.6 Comparison of Normalized Self-Reported Completion Times for Each Task Using InaRisk Personal and Printed Maps (N=361)

Source: The Author, 2020

Table 2.9 shows how the completion time for analyzing hazards using InaRisk Personal differs based on the students' demographics and other characteristics.

Table 2.9

Self-reported Completion Times for Examining Natural Hazards at School using InaRisk Personal based on the Respondents' Characteristics (N=361)

Respondents' Characteristics		**Time to locate the school** (in seconds)		**Time to analyze the risk pattern** (in seconds)		**Total completion time** (in seconds)	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Total		3.41	6.53	31.27	32.54	34.68	34.18
School	Tasikmalaya City 1 Senior High School	**1.19**	2.05	**13.50**	10.03	**14.69**	10.17
	Tasikmalaya City 2 Senior High School	4.67	8.86	23.14	16.62	27.81	19.24
	Garut Regency 1 Senior High School	3.37	7.89	40.39	29.35	43.76	32.88
	Sumedang Regency 3 Senior High School	3.77	4.41	34.23	42.68	37.99	43.03
Sex	Female	**3.31**	6.02	32.26	32.05	35.58	32.59
	Male	3.54	7.14	**30.00**	33.22	**33.54**	36.17
Age	15 years old	**1.02**	0.71	**20.55**	17.44	**21.56**	17.36
	16 years old	3.96	8.69	29.69	27.19	33.65	29.56
	17 years old	3.00	4.58	32.79	35.54	35.78	36.60
	18 years old	4.13	5.09	33.71	40.82	37.84	43.41
Class grades	XI	**3.36**	6.82	**30.01**	27.56	**33.37**	29.62
	XII	3.72	4.81	37.69	50.80	41.40	51.41
Majors	Natural sciences	3.50	6.36	**28.67**	26.41	**32.17**	28.00

Social sciences		**3.33**	6.71	33.93	37.72	37.26	39.46
Experienced disasters	Yes	3.46	7.48	33.24	37.54	36.57	37.67
	No	**3.33**	4.10	**30.26**	29.70	**33.72**	32.30

The results show that the students from Tasikmalaya City 1 Senior High School completed the task faster than the students from the three other senior high schools. Although the female students located the school more quickly than the male students, they needed more time when analyzing the risk pattern. Younger students and those in the natural sciences classes completed the task more quickly than the other students. Lastly, the students with no disaster experiences completed the tasks faster than those with disaster experiences.

This study found that more students could correctly answer the questions about hazards threatening their school when using InaRisk Personal rather than when using the printed maps (**Figure 2.7**). According to InaRisk Personal, Tasikmalaya City 1 Senior High School is at a medium risk of flooding and a medium risk of earthquakes. In contrast, Tasikmalaya City 2 has a low risk of flooding, a low risk of volcanic eruptions, and a medium risk of earthquakes. As displayed on the application, Garut 1 Senior High School is at a medium risk of flooding, a low risk of volcanic eruptions, and a medium risk of earthquakes. Sumedang Regency 3 has a low risk of flooding and a medium risk of earthquakes. A total of 140 students could identify these hazards as those that may affect their school based on the application's maps.

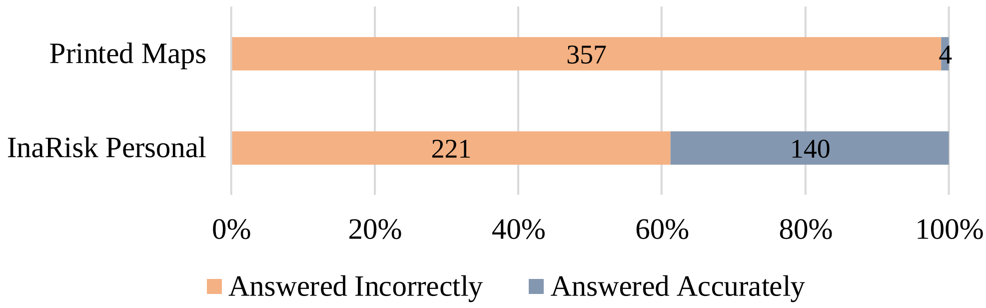


Figure 2.7 Percentages of the Respondents that Correctly and Incorrectly Answered the Questions about Hazards Threatening Schools (N=361)

Source: The Author, 2020

Table 2.10 compares the number and characteristics of the students who can and cannot successfully identify the hazards at schools when using InaRisk Personal. Based on the printed maps, Tasikmalaya City 1 Senior High School is at a medium risk of earthquakes. Tasikmalaya City 2 Senior High School has a low risk of volcanic eruptions as it is located on the path of volcanic lahar, and a medium risk of an earthquake. Garut Regency 1 Senior High School is at a medium risk of earthquakes and a low risk of landslides. Sumedang Regency 3 Senior High School is at a high risk of earthquakes. Only four students could accurately identify the hazards and risks that were presented on the maps. While 129 students correctly answered the questions about the types of hazards threatening their school, their answers for the other types of hazards were incorrect. For example, a student from Tasikmalaya City 1 Senior High School correctly identified that his school was at a medium risk of earthquakes. However, he also verified that his school was at a low risk of landslides and flooding, which was incorrect.

Table 2.10

Comparison of Students with Correct and Incorrect Answers when Identifying Hazards at School using InaRisk Personal based on their Characteristics (N=361)

		#students with correct answers	#students with incorrect answers	#students
Total		140	221	361
School	Tasikmalaya City 1 Senior High School	26	27	53
	Tasikmalaya City 2 Senior High School	7	57	64
	Garut Regency 1 Senior High School	61	59	120
	Sumedang Regency 3 Senior High School	46	78	124
Sex	Female	90	112	202
	Male	50	109	159
Age	15 years old	6	5	11
	16 years old	60	83	113
	17 years old	67	109	176
	18 years old	7	24	31
Class grades	XI	123	179	302
	XII	17	42	59
Majors	Natural sciences	90	93	183
	Social sciences	50	128	178
Experienced disasters	Yes	88	151	239
	No	52	70	122

Source: The Author, 2020

2.6.2 Perceived Readability

Eight items were compared to assess the perceived readability of the InaRisk Personal application and the printed maps (**Table 2.11**). Items with the highest ratings for InaRisk Personal are those related to the ease of locating the school and home and the ease of identifying the risks threatening the school, with mean scores of 4.24, 4.22, and 4.16, respectively. The item with the lowest rating is “I can distinguish areas prone to disasters” (mean=4.06). Similar to the results for InaRisk Personal, for the printed maps, items stating, “I can easily locate my home” and “I can easily find out risks of any hazards threatening my school”, had the highest ratings (mean scores of 3.56 and 3.51, respectively). Moreover, the mean for perceived readability of the printed maps for finding the risks threatening one's home was 3.53. The item with the lowest rating for the printed maps is: "It takes a short time for me to read the maps" (with mean=3.21).

Table 2.11

Comparing the Perceived Readability (PR) of both Tools (N=361)

Items	**Mean (SD)**		**Paired differences (InaRisk Personal – Maps)**				
	Printed Maps	**InaRisk Personal**	**Mean (SD)**	**SE Mean**	**t**	**df**	**Sig. (2-tailed)**
PR 1: It takes a short time for me to read the maps.	3.21 (0.84)	4.10 (0.70)	**0.89 (1.03)**	0.05	16.34	360	0.00
PR 2: I can easily locate my position now.	3.36 (0.91)	4.14 (0.63)	**0.78 (1.01)**	0.05	14.71	360	0.00
PR 3: I can distinguish areas prone to disasters.	3.44 (0.85)	4.06 (0.66)	0.63 (1.01)	0.05	11.76	360	0.00
PR 4: I can easily locate my school.	3.48 (0.89)	**4.24 (0.61)**	**0.76 (0.98)**	0.05	14.60	360	0.00
PR 5: I can easily locate my home.	**3.56 (0.89)**	**4.22 (0.65)**	0.66 (1.03)	0.05	12.14	360	0.00
PR 6: I can easily identify the risks of any hazards threatening my school.	**3.51 (0.81)**	**4.16 (0.60)**	0.65 (0.91)	0.05	13.61	360	0.00
PR 7: I can easily identify the risks of any hazards threatening my home.	**3.53 (0.80)**	4.13 (0.62)	0.61 (0.92)	0.05	12.50	360	0.00
PR 8: I can easily identify the risks of any hazards threatening any areas.	3.43 (0.79)	4.12 (0.62)	0.69 (0.93)	0.05	14.21	360	0.00

Source: The Author, 2020

The paired samples t-test results indicate that there are significant differences at the 1% significance level for all pairs of the perceived readability items. The most significant gap in means was noticed for the statement: "It takes a short time for me to be able to read the maps."

Table 2.12 shows a comparison of how the mean values of the perceived readability items differ based on the respondents' characteristics. The composite value of perceived readability shows that students from Tasikmalaya 1, female students, younger students, those majoring in natural sciences, and those that have experienced disasters are likely to have a higher perceived readability.

Table 2.12

Perceived Readability of InaRisk Personal based on the Respondents' Characteristics (N=361)

Respondents' Characteristics		**Means of the Perceived Readability of the Items**								**PR**
		PR1	**PR2**	**PR3**	**PR4**	**PR5**	**PR6**	**PR7**	**PR8**	
School	Tasikmalaya City 1 Senior High School	**4.32**	**4.36**	4.13	**4.38**	**4.47**	4.26	4.25	4.28	**4.31**
	Tasikmalaya City 2 Senior High School	3.98	4.09	4.08	4.22	4.23	4.17	4.09	4.00	4.11
	Garut Regency 1 Senior High School	4.12	4.11	4.00	4.18	4.10	4.16	4.17	4.16	4.12
	Sumedang Regency 3 Senior High School	4.04	4.10	4.09	4.26	4.21	4.11	4.07	4.07	4.12
Sex	Female	4.13	4.20	4.09	4.29	4.27	4.19	4.18	4.15	**4.19**
	Male	4.05	4.07	4.03	4.18	4.15	4.12	4.08	4.08	4.09
Age	15 years old	4.27	4.45	**4.27**	4.45	4.45	4.45	**4.36**	**4.45**	**4.40**
	16 years old	4.12	4.15	4.03	4.24	4.26	4.13	4.11	4.11	4.14
	17 years old	4.08	4.13	4.09	4.24	4.17	4.18	4.13	4.11	4.14
	18 years old	4.03	4.06	4.03	4.19	4.19	4.10	4.19	4.19	4.11
Class grades	XI	4.12	4.16	4.06	4.24	4.22	4.17	4.13	4.13	**4.15**
	XII	4.00	4.07	4.08	4.25	4.19	4.14	4.15	4.05	4.12
Majors	Natural sciences	4.20	4.22	4.09	4.29	4.27	4.19	4.17	4.16	**4.20**
	Social sciences	3.99	4.06	4.03	4.19	4.16	4.13	4.10	4.07	4.09

Experienced disasters	Yes	4.17	4.21	4.11	4.30	4.30	4.24	4.21	4.18	**4.21**
	No	3.96	4.00	3.97	4.13	4.05	4.01	3.99	4.00	4.01

Source: The Author, 2020

The main questions investigated in this paper regarding the readability and user satisfaction of a map-based disaster application called InaRisk Personal have been addressed. Although more tasks with more comprehensive ranges of users are required to support more reliable results, this study has significantly proven that the application may be practical for learning about disasters, as indicated by the high ratings for readability and satisfaction. The application may improve users' geographical knowledge of hazards.

The application also provides greater accuracy and efficiency for learning about the geographical distribution of hazards than printed maps. Furthermore, the findings show that students rated the application higher than the printed maps in terms of enjoyment. These findings provide valuable inputs into the readability aspects of a map for specific user groups (i.e., high school students/teenagers).

As demonstrated by this study's results, the application is moderately readable, and it is more readable than printed maps. The students that participated in this study located the school more quickly and interpreted the hazards more correctly when using the application in comparison to the printed map. For the first task, locating the school, when the completion time was compared to the respondents' characteristics, it is likely that female students, younger students, and students from the Social Sciences completed the task more quickly the other students. For the second task, the results show that male students and younger students performed the task more quickly than most of the other students, with the exception of the students from the natural science class, who performed this task more quickly than all the other students. Overall, the total completion time indicated that male students and younger students performed both of the tasks more quickly than all the other students.

This study found that more female students and younger (Class XI) students can accurately interpret the geographical information about hazards. More students from the natural sciences can correctly interpret maps from InaRisk Personal. This is interesting because the Social Science students learn about geography, which is one of their curriculum subjects. These findings matched the results for perceived readability.

It is evident that the application demonstrated significantly higher accuracy and shorter completion times than the printed maps. The data indicated that the hazard pattern recognition task might have been more complicated than the locating task because the participants required more time to solve it. However, it should be noted that a longer duration is not associated with the effort that led students to the correct answers. This result was also found for the subjective examination of readability; for all items, the application had higher ratings or agreements regarding its readability than the locally produced printed maps. The findings suggest that the application is easier to use, the information is easier to understand, and the user needs a shorter amount of time to read the map.

Some issues may be related to the application’s higher readability. First, it is expected that the functional search and location-based features of the application help users navigate the map. Furthermore, the application is equipped with various base maps and zooming-panning tools, helping users locate something more accurately on the map that is displayed on the application. The transparency feature may also help users more quickly understand hazard visualization because it displays quantitative distinctions or differences in importance or intensity. This transparency is often used on data layers to interpret the base map and thematic symbolization (Kunz & Hurni, 2011). Moreover, the application has an option to show the summary of all hazards threatening a point on the map.

This finding may also be biased due to the quality of the printed maps. Users may find it challenging to locate the school on the printed maps because the scale is too small, meaning that they cannot clearly distinguish sufficient labels and annotations do not accompany the buildings on some of the maps. Printed maps with a larger scale, such as a scale of at least 1:5,000 or higher, may deliver more accurate results. Moreover, in Tasikmalaya, the maps are not informative enough since they do not provide sufficient labels and annotations that can help users more easily position themselves on the maps. Furthermore, coloring may also be an issue in understanding the printed maps. For example, in Garut, the disaster-prone area map used a range of different colors than are commonly used on other disaster-prone maps.

On most hazard or risk maps, zones of increasing risk to the hazard are color-coded, commonly using a traffic light color scheme, with red representing a high or unacceptable risk and green indicating an acceptable or low-risk category. However, on the Garut map, different levels (very low, low, medium, and high) of hazards (earthquakes, landslides, and volcanic eruptions), except for the tsunami hazard, are mixed and classified with similar purple-to-pink hues and similar saturation. To help users more accurately interpret a map, the numbers of hues and values should be limited (Muehlenhaus, 2014) because less color variation facilitates better interpretation of the information that is provided. One of the printed maps in Sumedang was created with no apparent hazard. In the maps for Sumedang, areas prone to disasters were colored with a traffic light scheme, although it cannot be assured what kind of hazard was visualized with the colors. To avoid these biases, future research should examine similar information and visualizations with different delivery options (interactive and printed mapping).

2.7 Satisfaction of the Map-based Application

While **Table 2.13** shows the measurements of user satisfaction for InaRisk Personal, **Table 2.14** displays those for the printed disaster maps. Seven items were used to measure user satisfaction in the application (**Table 2.13**). For the printed maps, three items were used to measure user satisfaction (**Table 2.14**). This difference is due to the different contents that each type of map provides to users. In the case of InaRisk Personal, users can watch videos about disasters, earthquake notifications, and brief suggestions of protective actions in addition to the information provided in the common hazard or risk maps. However, the printed maps can only provide geographical information about at-risk areas.

In general, the participants were relatively satisfied with the information given by both the printed maps and the InaRisk Personal application, as seen in the high ratings: the means are all above 3.00. For InaRisk Personal, the three highest ratings were for the information and disaster maps, kinds of hazards displayed on the application, and the protective action suggestions (means 3.96, 3.95, and 3.93, respectively). For the printed maps, the participants gave a high satisfaction rating to the information about areas prone to disasters visualized on the maps.

Table 2.13

User Satisfaction Results for InaRisk Personal (N=361)

Items	SD	D	N	A	SA	Mean (SD)
I am satisfied with the information and suggestions on the actions that should be taken before, during, and after disasters.	-	1.1%	24.7%	54.8%	19.4%	3.93 (0.69)
I am satisfied with the kinds of hazards displayed on InaRisk Personal.	-	0.3%	23.5%	56.8%	19.4%	3.95 (0.66)
I am satisfied with the videos explaining disasters caused by natural hazards on the InaRisk Personal.	-	1.4%	41.8%	42.9%	13.9%	3.69 (0.72)
I am satisfied with the videos explaining how to operate InaRisk Personal.	-	1.9%	40.2%	44.0%	13.9%	3.70 (0.73)
I am satisfied with the earthquake notifications on InaRisk Personal.	-	1.1%	27.7%	51.8%	19.4%	3.89 (0.71)
I am satisfied with the information and disaster maps displayed on InaRisk Personal.	-	0.8%	23.8%	53.5%	21.9%	3.96 (0.70)
I enjoy using InaRisk Personal.	0.3%	1.4%	24.7%	51.2%	22.4%	3.94 (0.74)

Source: The Author, 2020

Because each tool had a different number of items to measure user satisfaction, this study only utilized one item to compare the user satisfaction of both types of maps. The statement representing whether users enjoy using the application and the printed maps was chosen for the evaluation. The findings indicated that the students enjoyed using InaRisk Personal more than the printed maps (means: 3.94 and 3.46, respectively). The paired samples T-test results indicate a significant difference between the InaRisk Personal and the printed maps at a 1% significance level (t: -9.804, df: 360. Sig. (2-tailed): 0.000).

Table 2.14

User Satisfaction Results for the Printed Maps (N=361)

Items	SD	D	N	A	SA	Mean (SD)
I am satisfied with the information about the areas prone to disasters visualized on the maps.	0.6%	6.4%	39.6%	42.1%	11.4%	3.57 (0.80)
I am satisfied with the various kinds of hazards displayed on the maps.	0.8%	7.5%	42.1%	41.8%	7.8%	3.48 (0.78)
I enjoy using the maps.	1.7%	8.0%	41.8%	39.6%	8.9%	3.46 (0.83)

Source: The Author, 2020

In response to the question as to whether the InaRisk Personal application was satisfying, the participants replied: strongly agree and agree. Students gave a high satisfaction rating to the information about disaster maps, suggestions on actions that should be taken before, during, and after disasters, and various kinds of hazards displayed on InaRisk Personal. The students found that using the application was more enjoyable than using the printed maps.

2.8 Preferred Form of Spatial Information

In terms of user preferences for the two different tools, 95.3% (344) of the participants preferred InaRisk Personal to the printed maps for learning about disasters. Most of the participants (95.6%) would recommend the application to their family members and friends, although they faced lag times and encountered bugs in the application during the trial. The participants provided some suggestions for ways to improve the performance of the application:

1. Make the application accessible even without an internet connection.
2. Increase the speed of operation.

3. Use more vivid colors if the colors are too pale.
4. Enable the application to make sound to verbally provide the information (personal audio assistance).
5. Display the percentages of levels of disaster risk; and
6. Add more features, such as weather forecasts and earthquake warning notifications.

A combination of prior findings on readability and user satisfaction is further corroborated by the participants' answers to the final study questions concerning the preferred tool to learn about disasters and what they want to recommend to their family members and friends. Almost all the participants (95.3%) preferred the application to printed maps that are commonly distributed by local governments for learning about disasters. Most of the participants choose the application as the tool they would recommend to their family members and friends.

2.9 Conclusion

The analyses presented in this chapter show that, to some extent, providing spatial information about disasters increases risk perceptions and hazard awareness. While risk perceptions can be different based on variations in the respondents' characteristics, increases in hazard awareness depend on the types of hazards. To some extent, giving spatial information about disasters was found to significantly stimulate changes in the participants' attitudes toward the evacuation plan and the intention to better understand information about the hazards and risks.

In the digital era, mobile technologies have become a valuable learning tool for the public, particularly for young people. With ever-changing technology and the distinct end-user environment, it is necessary to continue to evaluate whether this technology is effective. This chapter has taken the first step towards fulfilling this objective by evaluating the readability and user satisfaction of a map-based application developed by the government as a medium for communicating the risks of hazards and learning about disasters. These two aspects are essential in further evaluating the effective use of the proposed application. It was found that, to some extent, InaRisk Personal is readable and satisfying, indicating that the application might have good potential for learning about disasters, particularly for young people. This segment of the population is highly exposed to the internet; thus, it is reasonable to have them as the application's prioritized targeted users. When the application was compared to the printed maps, it was also found that high school students rated InaRisk Personal as being more preferred, readable, and satisfying for learning about disasters than regular printed maps. Most of the students in this study preferred to learn about disasters through cartographic visualizations on the mobile application with suggestions for improvements, rather than using printed maps. Thus, local governments in the study areas may consider having their own self-developed disaster map-based applications to complement their regular disaster map dissemination.

This study has several limitations. First, the contents provided by the application and the printed maps were different, resulting in some biases on the visualization of hazard prone areas. The biased results of the printed maps may be due to the poor quality of the map design (i.e., selection of colors and absence of labels and annotations). Moreover, some researchers have considered the use of students to be a limitation of a study. However, the present study assumes that students are a representative percentage of the population of internet users.

CHAPTER 3
TOWARD BETTER-PROMOTED ACCESSIBLE, SUITABLE SPATIAL INFORMATION FOR RISK COMMUNICATION IN INDONESIA

3.1 Objective

This chapter aims to identify the factors needed to improve the distribution and utilization of spatial information about disasters in Indonesia, both from the supply and user sides, so that this information can become more accessible and suitable as a medium for risk communication. While the supply-side examination emphasizes the improvements needed for the production and distribution of spatial information, evaluation on the user side highlights factors influencing users' intentions to use spatial information as a source of disaster information.

The chapter begins with a review of how spatial information is distributed in other countries. Japan has been selected as a role model due to its mature disaster management practices. Since existing literature mostly used the United States and European countries, especially the Netherlands and the United Kingdom as focuses of the study, these countries, therefore, have also been selected to provide other perspectives of good practices in non-Asian countries. Some lessons can be learned from the map-mediated risk communication practices of these selected countries, including the need to build a central repository of spatial information about disasters that connects all local government sources, the need for a clear division of roles at each level of government, and the need to issue a standardized format and manual for the content and visualization of the information.

From the user side, this chapter also focuses on identifying the factors influencing users' intentions to use a local, government-developed, map-based disaster application named *Sistem Informasi Kebencanaan Kabupaten* Magelang (SIKK Magelang). The findings in this section are essential for determining whether local governments need to adopt more technological solutions for distributing spatial information about disasters, such as creating their own online maps or applications. For local governments that intend to create their own disaster applications, some considerations are suggested.

3.2 Improving the Delivery of Spatial Information for Risk Communication from the Supply Side

In the first chapter of this dissertation, the method by which spatial information about disasters is distributed to the public as a part of governments' initiatives for disaster risk communication in Indonesia was evaluated, and a number of weaknesses were defined. In this sub-section, selected practices from other countries will be reviewed to obtain insight into how to improve the supply side of spatial information for risk communication in Indonesia.

3.2.1 Lessons Learned from Japan: Hazard Maps as Official Risk Communication Tools

Japan is one of the most prepared countries in the world for potential natural hazards (Matsuura & Sato, 2018). Since the Disaster Countermeasures Basic Act was enacted in 1961 (i.e., Act No. 223 of 1961), the government of Japan has continuously reviewed and revised the act based on the lessons learned from multiple severe disasters, such as the Great Hanshin Awaji Earthquake in 1995 and the Great East Japan Earthquake (GEJE) in 2011.

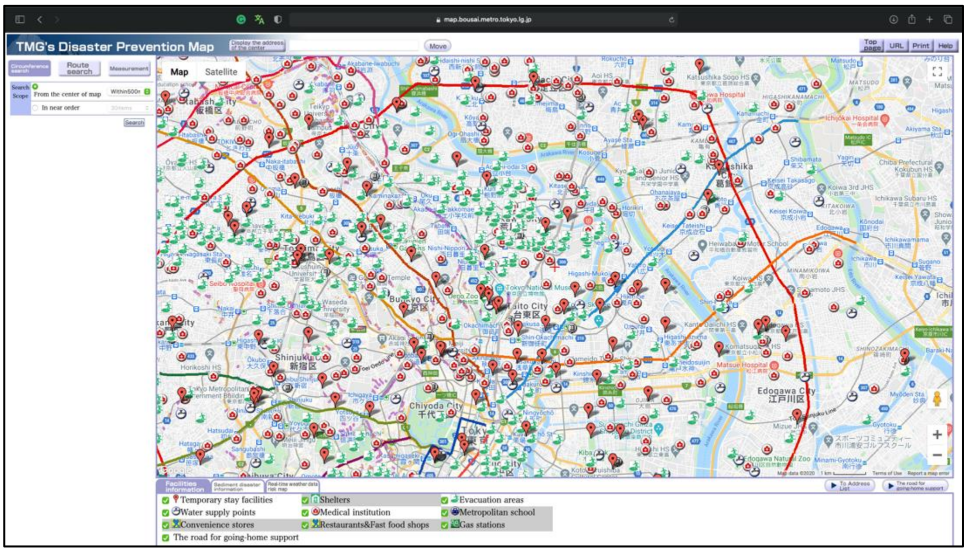
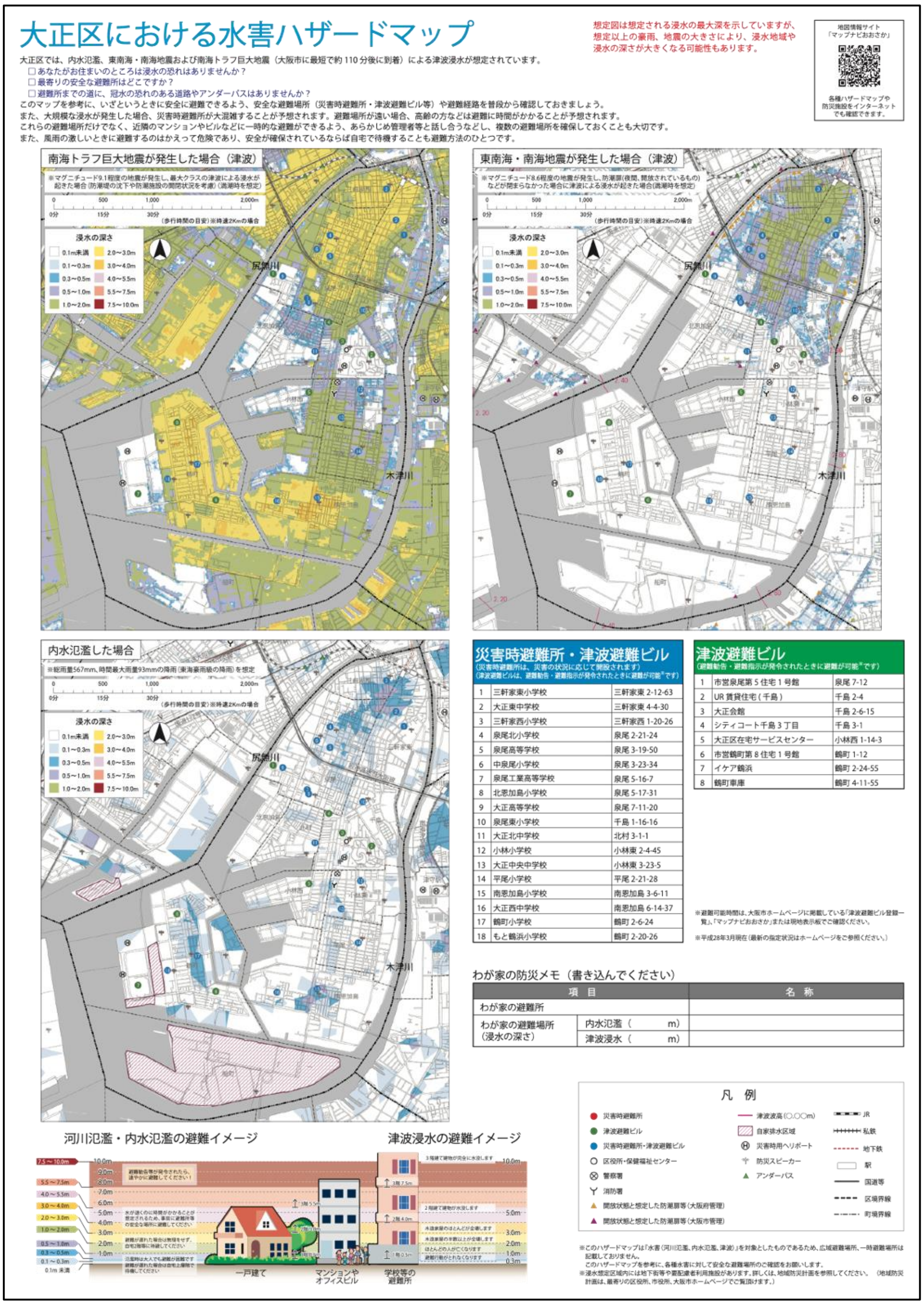


Figure 3.1 An Interactive Disaster Prevention Map Portal Provided by the Tokyo Metropolitan Government

Source: Tokyo Metropolitan Government (n.d.). *TMG's disaster prevention map.* TMG. Retrieved November 26, 2020, from https://map.bousai.metro.tokyo.lg.jp/en/pc/map.html.

As part of the government's effort to communicate the risk of natural hazards, hazard information is regularly produced and disseminated to the public. Information about hazards allows people to estimate the risks associated with disasters before they actually occur. This information also allows people to assess and prepare for potential damage. Since disasters caused by natural hazards are closely tied to specific locations, hazard maps are widely used to disseminate and educate the residents of different regions (Matsuura & Sato, 2018). Hazard maps are official risk communication tools in Japan (Shaw et al., 2013), and their use as a non-structural mitigation measure has been strengthened since 2006 due to the issuance of the Soft Measures Promotion Charter for Safety and Security (国土交通省安全・安心のためのソフト対策推進大綱) by the Ministry of Land, Infrastructure, Transport, and Tourism. Depending on the targeted users and purposes, hazard maps fall into three categories: maps for evacuations, maps for study, and maps for other purposes (Shidawara, 1999). These maps can be static maps (such as PDF files) or interactive web maps (see **Figures 3.1** and **3.2**).

In Japan, hazard maps indicate expected hazard levels and locations, as well as the locations of evacuation centers and routes (Shaw et al., 2013). The scale of municipal hazard maps is recommended to be around 1:10,000, although the scale of published maps may range from 1:5,000 to 1:22,000 (EXCIMAP, 2007; Shidawara, 1999). In terms of flooding, for example, hazard maps not only visualize the predicted inundation depths (indicated by different colors) and nature of the river, but also various other useful items of information (see **Figure 3.2**). They may, for example, include historical records of inundated areas (including photographs, hyetographs, hydrographs, and weather charts of past floods), lead times, information about evacuation shelters and gathering places (including their capacities, phone numbers, and the locations of special shelters for senior citizens, handicapped people, and small children), and telephone numbers for warnings (including the phone numbers of government offices and hospitals (Shaw et al., 2013; Shidawara, 1999). These maps may also include information about the different siren patterns or alarm bell sounds and their meanings, advice for evacuation, and evacuation checklists (Shidawara, 1999).

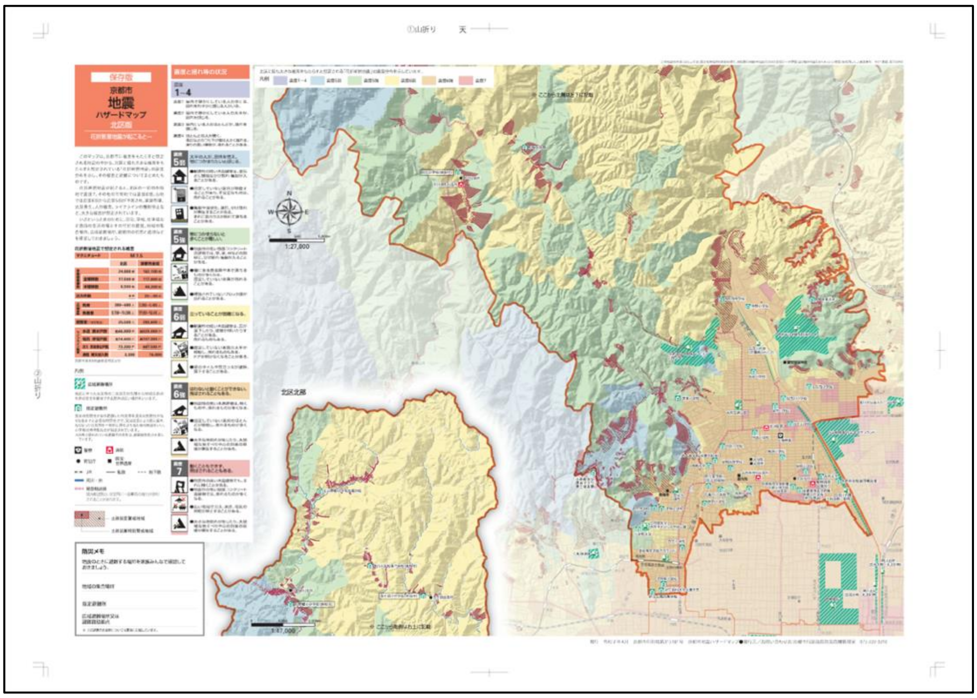


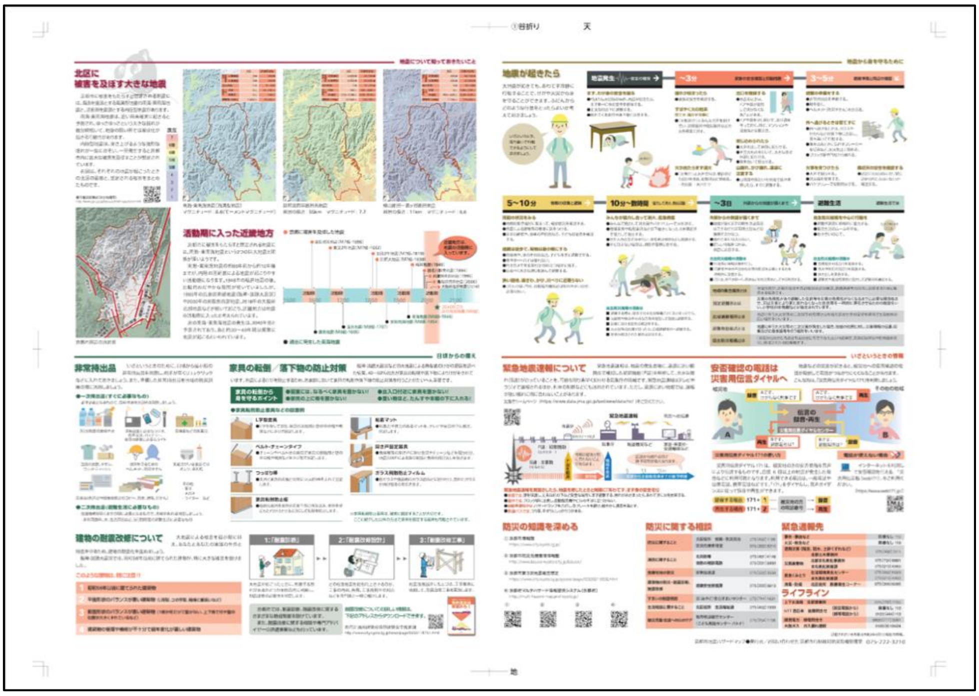
(1) Flood and Inundation Hazard Map Distributed via Osaka City's Government Website

Source: Osaka City (n.d.). Flood and inundation hazard map. *Osaka City.*

Retrieved December 2, 2020, from

https://www.city.osaka.lg.jp/kikikanrishitsu/cmsfiles/contents/0000300/300829/taishoA2.pdf.





(2) Earthquake Hazard Map Distributed on Kyoto City's Government Website

Source: Kyoto City (n.d.). Earthquake hazard map. *Kyoto City*. Retrieved December 2, 2020, from http://www.bousai-kyoto-city.jp/bousai/pdf/dismap/jishin/01jishin-2.pdf.

Figure 3.2 Examples of Hazard Maps Distributed by Local Governments in Japan

In terms of information production, based on an interview with Mr. Osumi (2020), a deputy director in the GSI, the production of spatial information about disasters in Japan depends on the type of hazard and the scope of the designated area. In the case of flooding, the Flood Control Act (Act No. 193 of 1949), which was amended in 2015, requires river administrators, such as the Ministry of Land, Infrastructure, Transport, and Tourism, and prefectural governments to designate river flood inundated areas. The act also requires municipalities to prepare and disseminate flood hazard maps to the residents of the municipalities, which depict the potential river flood inundation areas. Beside requiring the creation of river flood hazard maps, the act also mandates that prefectural governments create hazard maps for flooding from inland waters, storm surges, and tsunamis. The production of earthquake and volcanic hazard maps, on the other hand, are mainly the responsibility of central governments. The National Seismic Hazard Maps, which consist of the Probabilistic Seismic Hazard Maps and the Scenario Earthquake Shaking Maps, are prepared by the Headquarters for Earthquake Research Promotion of the Ministry of Education, Culture, Sports, Science, and Technology (Matsuura & Sato, 2018). Volcanic hazard maps can be accessed on the National Catalogue of Active Volcanoes in Japan (Matsuura & Sato, 2018). Maps depicting sediment disaster prone areas, which include areas prone to debris flow, landslides, slope failures, and other similar disasters, are produced based on land investigations by prefectural and municipal governments.

At the municipal level, hazard maps are usually produced by a committee that comprises the mayor of the city, relevant agencies and departments, engineering experts, and national or prefectural representatives (Shidawara, 1999). Nowadays, to increase the effectiveness of map use by the community, a participatory process of map production is recommended (Shaw et al., 2013).

Osumi (2020) states that while hazard maps can be produced by different levels of government, the distribution of these maps to citizens is mainly the responsibility of municipal governments. Although hazard maps may also be available on some prefectural government websites, for example, there is no responsibility to disseminate hazard maps at the prefectural level. It is municipal leaders who are mandated by laws to share hazard maps with their citizens. Regarding this hazard map dissemination, the role of the national government is mainly to provide laws and regulations offering technical support for the dissemination of hazard maps by municipal governments.

Hazard maps in Japan are available both online and offline. In 2015, for example, more than three quarters of municipalities in Japan (1,310 out of 1,719 municipalities) published printed flood hazard maps, while online hazard maps were published by 1,226 municipalities (Matsuura & Sato, 2018). Online hazard maps can be accessed through municipality websites or via a hazard map portal developed by the Geospatial Information Authority of Japan (GSI). This portal can also show how many municipalities have provided hazard maps by type of hazard (**Figure 3.3**). Meanwhile, offline distribution includes map printing on waterproof paper or the printing of paper maps with plastic cases, to be pinned up or hung on walls or columns (Shidawara, 1999). Another offline method of production includes attaching the maps to booklets. In some places, hazard maps are printed and distributed to all families in a village (Shaw et al., 2013).

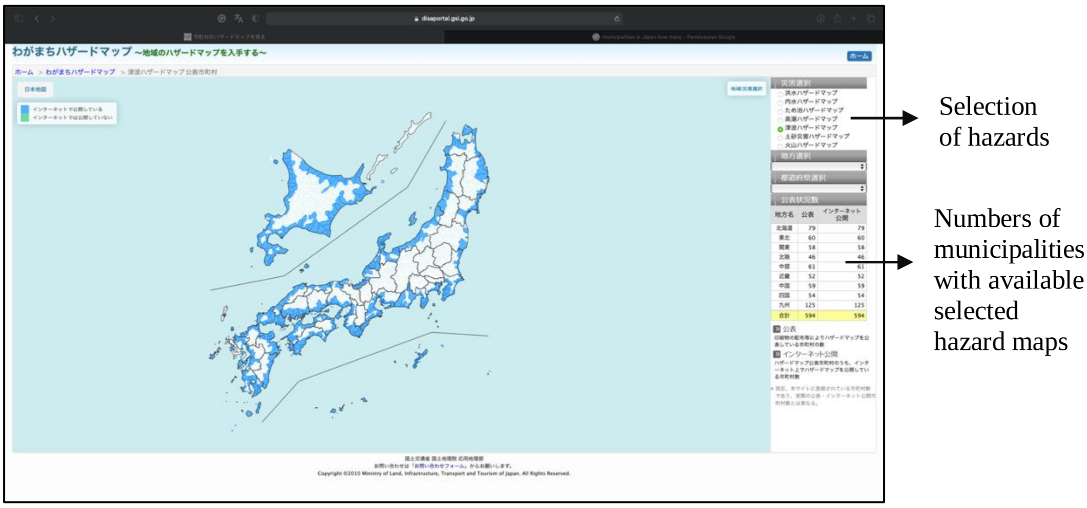
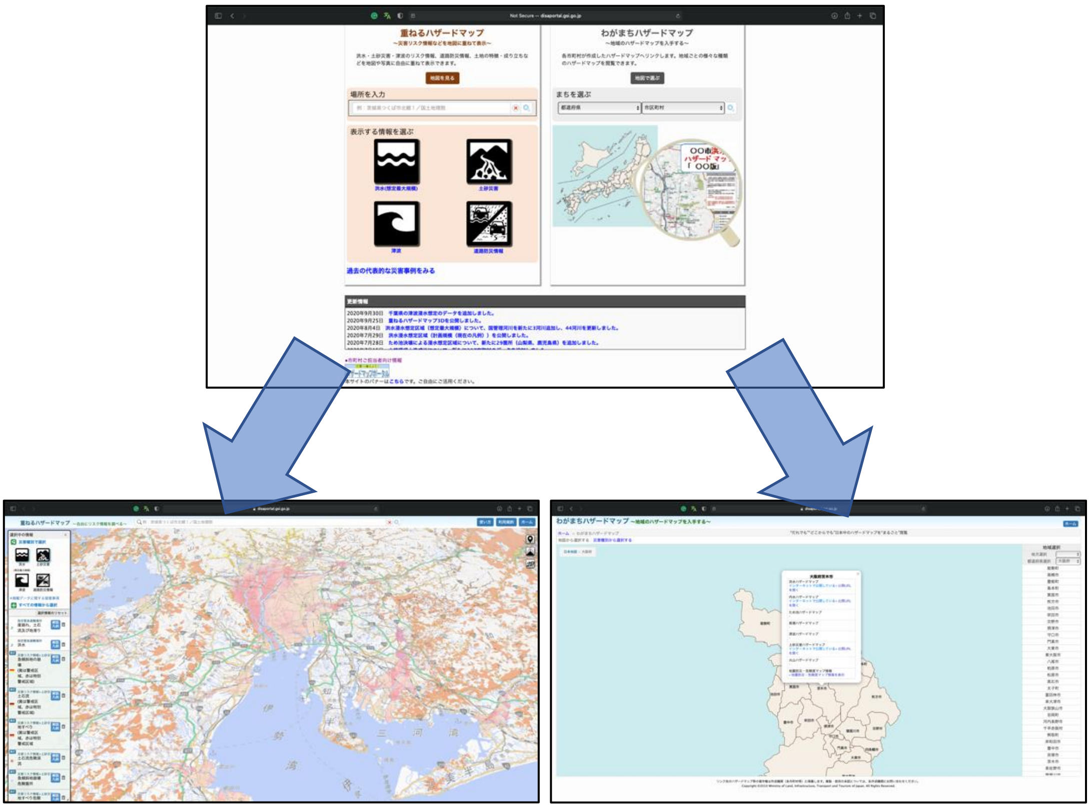


Figure 3.3 Number of Municipalities with Available Hazard Maps, by Type of Hazard

Source: Geospatial Information Authority of Japan, Ministry of Land, Infrastructure, Transport and Tourism of Japan (n.d.). *My Town Hazard Map.* Retrieved November 25, 2020, from http://disaportal.gsi.go.jp/index.html.

Disaster management in Japan is mainly centralized. During ordinary times, there is no regional or local government organization for disaster risk reduction in Japan. However, following the occurrence of a disaster and depending on the scale of the disaster, a National On-Site Disaster Management Headquarters and on-site contact offices will be set up. Thus, hazard maps in Japan are distributed on municipal government websites, instead of on local disaster management agency websites. This situation is different from that in Indonesia since local government organizations for disaster management exist in Indonesia as BPBDs. Consequently, as has been discussed also in chapter one, maps and spatial information about disasters are mostly found on local disaster management agency (BPBD) websites.



By Types of Hazards　　　　By Municipalities

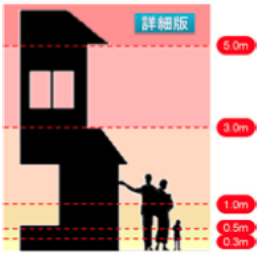
Figure 3.4 Interfaces of Hazard Map Portal Site by the GSI, Ministry of Land, Infrastructure, Transport, and Tourism of Japan

Source: Geospatial Information Authority of Japan, Ministry of Land, Infrastructure, Transport and Tourism of Japan (n.d.). *Hazard Maps Portal.* Retrieved November 25, 2020, from http://disaportal.gsi.go.jp/index.html.

Because each municipality in Japan has a different website layout, which makes the pages on which hazard maps are located differ, in 2007 the GSI developed a hazard maps portal to help citizens find the maps more easily. The map portal can be accessed at https://disaportal.gsi.go.jp/ hazardmap/portal.html. Users can select the maps according to the type of hazard or by location (see Figure 3.2). The menu for accessing the maps by the location is named わがまちハザードマップ (pronounced *Wagamachi Hazaado Mappu*) or *My Town Hazard Map*. The portal basically connects hazard maps from all the municipalities in Japan. According to Mr. Osumi (2020), the GSI, via an assigned private company, asks municipalities to report the links of pages on which hazard maps are displayed on their websites. The company monitors these links and, if the links are not working, will ask the municipalities to send amended links. Any changed or deleted links should be reported by the municipalities.

While hazard maps are seen as useful tools that can help communities understand the risks they face, future disasters may exceed the levels indicated on the maps due to uncertainties on the probability of future disaster events, indicating the need for maps to be updated (Shaw et al., 2013). Nevertheless, according to Mr. Osumi (2020), there is no periodical updating system for hazard maps in Japan; even if the affected areas of a disaster event are different from those that have been projected and visualized on hazard maps, the maps are usually not updated. So far, he argues, the affected areas have usually been consistent with prone areas shown in hazard maps. However, many municipalities are currently updating their hazard maps following revised laws and regulations, as well as updated data on future disasters, such as the prediction of more severe rain in the future or a possible extension of inundated areas, especially after GEJE. The GEJE experience showed that the maps provided residents with a false sense of security. Moreover, the maps were not widely used by the citizens as 55% percent had no idea that the hazard maps existed, and only 20 percent of residents utilized hazard maps for their evacuation (Cabinet Office Government of Japan, 2012; Shaw et al., 2013). Thus, to convey more information, as well as to anticipate underestimated prone areas, it is crucial to have continuous evaluation and updates, as well as clear explanations (from governments and experts) about the limitations of the predicted hazards. The consistency of the content and design details of these maps are also being improved to avoid confusion when interpreting the maps.

浸水深等			詳細版
20m	～		220,122,220
10m	～	20m	242,133,201
5m	～	10m	255,145,145
3m	～	5m	255,183,183
1m	～	3m	255,216,192
0.5m	～	*1m*	248,225,166
0.3m	～	0.5m	247,245,169
	～	*0.3m*	255,255,179



浸水深等			RGB	RGB とα（透過率）	CMYK
20m	～		220,122,220	187,0,187,122	0,45,0,14
10m	～	20m	242,133,201	228,0,142,135	0,45,17,5
5m	～	10m	255,145,145	255,0,0,145	0,43,43,0
3m	～	5m	255,183,183	255,13,13,179	0,28,28,0
1m	～	3m	255,216,192	255,125,45,179	0,15,25,0
0.5m	～	*1m*	248,225,166	236,169,0,166	0,9,33,3
0.3m	～	0.5m	247,245,169	232,226,8,166	0,1,32,3
	～	*0.3m*	255,255,179	255,255,0,179	0,0,30,0

Figure 3.5 Examples of Color Manuals showing Inundation Levels on Flood Hazard Maps in Japan

Source: Ministry of Land, Infrastructure, Transport and Tourism of Japan (n.d.). 洪水浸水想定区域図作成マニュアル(第 4 版). Retrieved November 25, 2020, from https://www.mlit.go.jp/river/shishin_guideline/pdf/manual_kouzuishinsui_1710.pdf.

Although hazard maps published by local and central governments are still seen as the *de facto* instruments for geospatial disaster risk communication and visualization, there is no periodical evaluation of the usage of the maps, nor of their effectiveness from a community perspective. Matsuura and Sato (2018) agree that hazard maps can be effective tools for designing evacuation plans, for promoting risk awareness among the public, and for helping to determine residential and work locations. However, they also mention several drawbacks of hazard maps for risk communication, including the uncertainty of disaster probability, decreases in the value of real estate and other properties in identified high-risk areas, map readability issues, and the possibility of different risk perceptions by different users.

A public opinion survey in 2013 found that hazard maps are the third major source of disaster information, after TV/radio news programs and TV/radio programs on disaster preparedness (Matsuura & Sato, 2018). However, in today’s rapidly changing media era, official government-developed hazard maps may not be considered as the only preferred sources of information, as numerous applications have been released as alternatives.

According to Mr. Osumi, in the case of the online hazard map portal by the GSI, there has not been any usage evaluation. However, according to the author's evaluation of the one-year user statistics (September 2019 – September 2020) from the GSI, the highest rate of access occurred during the Hagibis Typhoon period in 2019 (see Figure 3.6). Several periods of increased access also occurred during the torrential rain in Chiba in 2019, the recent landslides and floods in Kyushu, and the Haisen Typhoon.

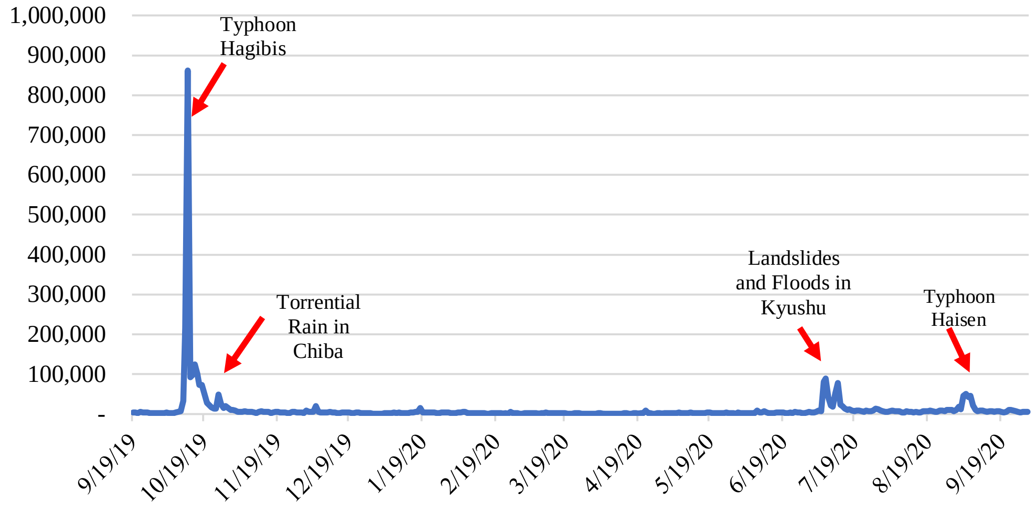


Figure 3.6 GSI Hazard Map Portal User Statistics for September 2019 – September 2020

Source: The Author's Analysis from the Data obtained from Geospatial Information Authority of Japan (2020).

Providing hazard maps in Japan is currently not only the responsibility of governments. Private organizations and non-governmental organizations may also be involved in improving citizens' disaster literacy by releasing hazard maps and other disaster-related spatial information. Supported by the government's open data policy, there are several map-based disaster applications available on the market.

Compared to other non-government-developed disaster apps, NERV is one of the most popular disaster applications in Japan, with very positive reviews. It was released by a company named Gehirn Inc. on September 1, 2019, which is "Disaster Prevention Day" in Japan (Morrissy, 2019). The app's name and design are inspired by NERV, a fictional paramilitary organization that appears in the Neon Genesis Evangelion series, one of the most popular anime in Japan[5]. The free app gives updates about natural disasters such as earthquakes and tsunamis in real time and gives push notifications whenever the danger level in the user's area has increased (Morrissy, 2019).

The app design is not the only thing that makes NERV special, considering that mostly disaster applications built by governments have fewer interesting user interfaces. Those who are really into this anime series can easily be aware of the application from the logo. The app makes use of the Japanese government's open data, but it claims can deliver earthquake and tsunami early warnings faster than any other similar service. The app receives information directly from Japan's Meteorological Agency, including information on atmospheric conditions, typhoons, rain, earthquakes, tsunamis, and volcanic eruptions, as well as notifications from J-Alert (an early warning system for other threats), which it relays faster than almost any other service (*A Look at the New "Nerv" Disaster App*, n.d.). Its users can also browse events that have occurred in the last 72 hours in chronological order. The app is also disability friendly: for users who are blind or have reading difficulties, the app can be set to speak notifications out loud. Figure 3.7 below shows some information displayed on NERV such as recently occurred

[5] ***Neon Genesis Evangelion*** 新世紀エヴァンゲリオン in is a Japanese mecha anime television series produced by Gainax and Tatsunoko Production and broadcasted on TV Tokyo from October 1995 to March 1996. Nowadays, the series are available on Netflix. In the anime, NERV is describe as a special agency that has been tasked by the United Nations to defend the planet.

geographical distribution of earthquake magnitudes, wind pattern, and weather-related information such temperature, humidity and rain prediction.

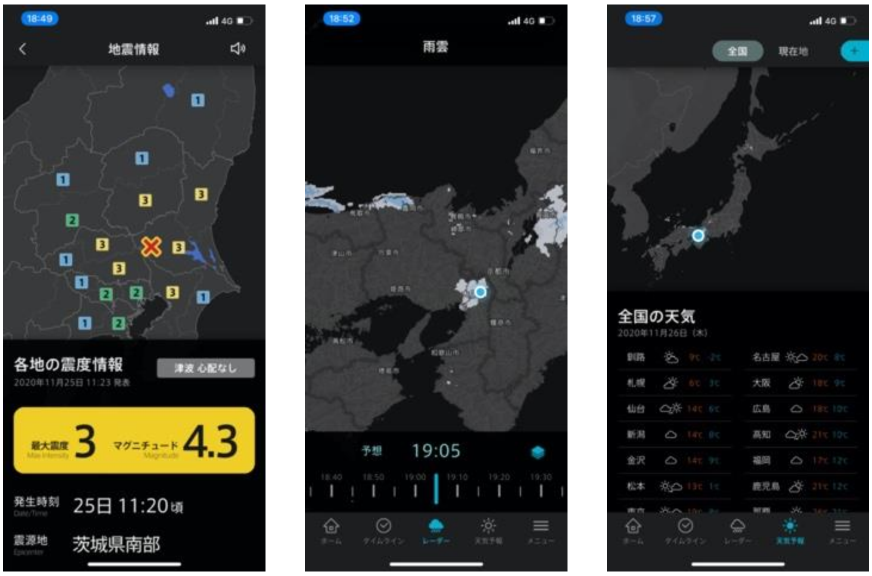


Figure 3.7 Examples of Information Displayed on NERV

Source: The Author screenshot from downloaded NERV mobile application (2020).

Another example of a non-governmental disaster application that provides spatial information about disasters is CMAP. It is the world's first website and application for predicting the number of buildings affected by natural disaster in real time for a given location by municipality released in June 2019 (Fudeyasu, 2020). CMAP is available as both a web platform and a mobile application in dual languages (Japanese and English). It was a joint product of industry-academia research among Aioi Nissay Dowa Insurance Co. Ltd., Aon Benfield Japan Ltd. (now Aon Group Japan Ltd.), and Yokohama National University (Fudeyasu, 2020). On its websites, CMAP mentioned that the map uses open data from various organizations, both governmental and non-governmental. It uses open spatial data from the GSI, including flood zones, landslide warnings, and risk areas. It covers weather (heavy rain and typhoons) and earthquakes.

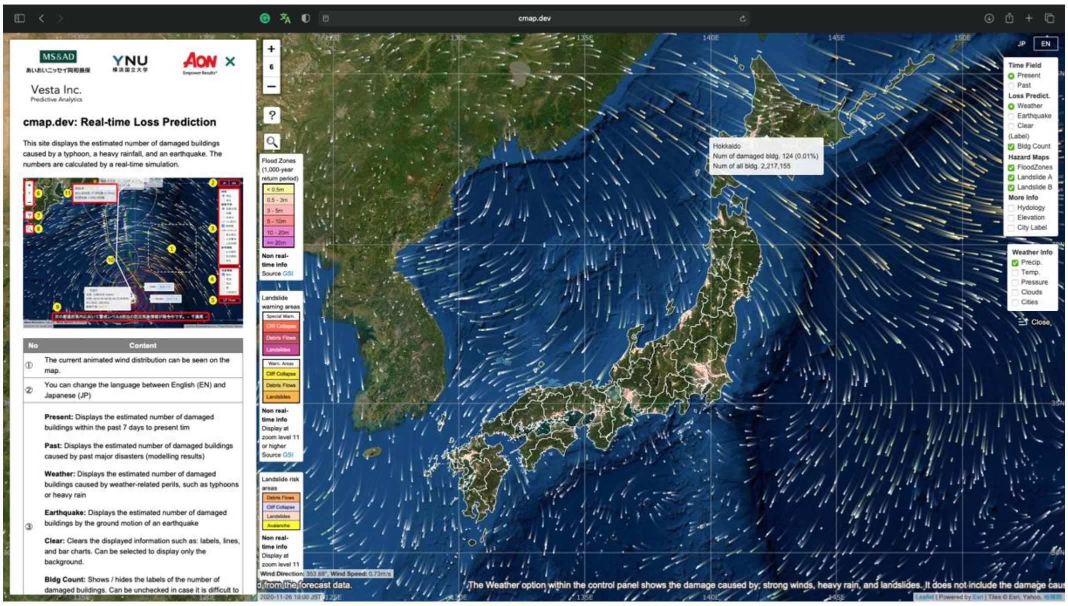


Figure 3.8 Information Visualized on CMAP

Source: Retrieved November 25, 2020, from https://cmap.dev/#6/37.753/132.979.

CMAP provides a number of spatial information and simulations which can help users to have advance knowledge of the extent of damages, particularly those caused by flooding, landslides, and typhoon. Thus, users can understand the scale and affected areas of disaster and aid in rescue activities. Local governments can make use of the information for planning evacuation information and shelters. Its real-time damage prediction can predict the number of building that heavy rainfall and winds, or an earthquake will damage in a given municipality and disclose predictive data in real time when disasters strike (Fudeyasu, 2020). CMAP provides specific damage prediction information relevant to users, for instance predicting buildings will be damaged in the town they live (Fudeyasu, 2020). It also has a simulation function that predict building damage for past typhoons with hypothetical scenarios.

In the near future, following the Society 5.0 initiative (the Imagination Society or the Super Smart Society),[6] communities will not only be given information about hazards and evacuations through hazard maps. Spatial information about disasters will be provided more personally. Each and every person will be provided with information via individual smartphones and other devices, based on disaster conditions, and will be moved safely to the nearest shelter.

To sum up, several lessons can be learned from Japanese hazard map practices, as follows:

1. Spatial information-mediated risk communication uses hazard maps in the form of either static or interactive online or offline maps.
2. The role of local governments in providing spatial information about disasters is significant and is supported by higher-level governments. While local governments should focus more on the dissemination of hazard maps, maps can also be compiled by prefectural and national governments.
3. The information shown by hazard maps is rich (i.e., includes evacuation plans and any other relevant information necessary during emergency situations), is provided on a large scale and on an easy-to-follow background, and uses consistent color visualization due to clear guidelines on how maps should be produced, including manuals on map layout.
4. Information about disasters is also delivered by other non-government organizations, private companies, and academia using the government's open data.

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[6] Society 5.0 was proposed in the 5th Science and Technology Basic Plan in 2016 as a future society that Japan should aspire to. Big Data collected by the Internet of Things (IoT) will be converted into a new type of intelligence by Artificial Intelligence (AI) and will reach every corner of society. (The Government of Japan. (n.d.). *JapanGov news.* JapanGov. Retrieved November 26, 2020, from www.japan.go.jp.)

5. To help the public access the maps more easily, the national government via the GSI has developed a hazard map portal that collects all the hazard map links shown on municipality websites. The portal can also be used for evaluating the availability of maps in each municipality in Japan.
6. Spatial information about disasters is highly accessed by the public during severe disaster events.

3.2.2 Examples of Risk and Hazard Map Practices from Other Countries

In European countries such as the Netherlands, the United Kingdom, and Germany flood-related information, for example, is shared through flood maps (mainly flood extent maps) and flood hazard maps (depth or depth–velocity combinations) that are some of them have already available on the internet as interactive map systems (EXCIMAP, 2007). Flood hazard maps, however, are the maps used for risk communication to the public. Flood hazard maps in a number of European countries such as Austria, Denmark, Estonia, Germany, Norway, the Netherlands, and the United Kingdom are mostly characterized with visualizations of flooded area either with or without water depth (Nones, 2017). Flood hazard maps in Italy are examples of those with runoff direction. Risk maps are intended for use by insurance companies, government emergency services, and development managers (EXCIMAP, 2007). The maps are prepared following European Exchange Circle on Flood Mapping (EXCIMAP) guidelines (Van Alphen et al., 2009). There are two main cartographic aspects of flood maps based on EXCIMAP map production guidelines: the map content (e.g., the extent of the flood, the probability of flooding, flood hazards, potential damage, and evacuation maps) and layout issues and GIS approaches (e.g., background mapping, color palettes, and symbols). While hazard maps in Japan include various information, including information related to emergency situations, in European countries, evacuation schemes are depicted separately on emergency maps.

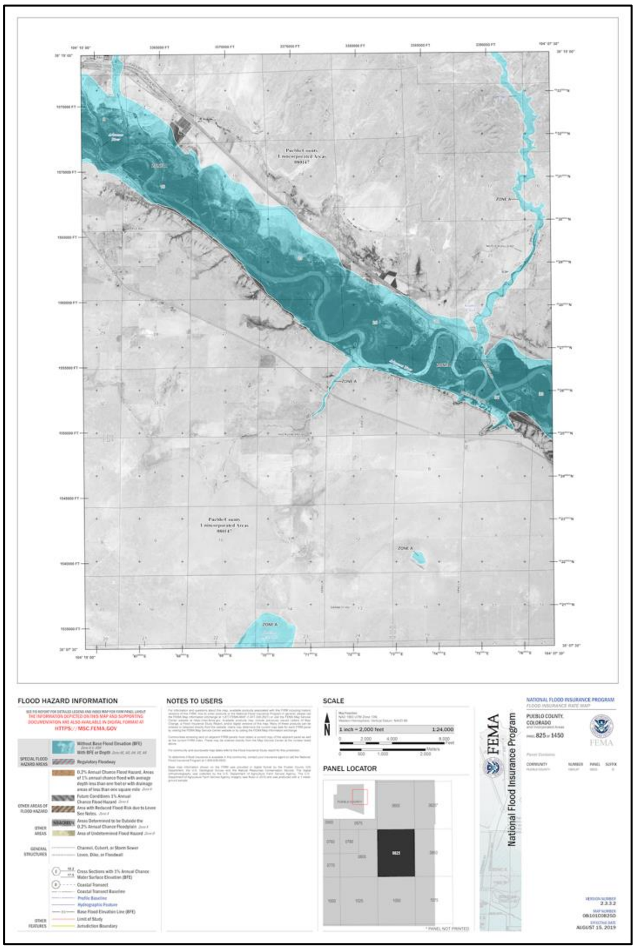


Figure 3.9 Flood Hazard Maps Created by FEMA as Part of the National Flood Insurance Program available on FEMA NFHL

Source: FEMA NFHL (n.d.). *National Flood Hazard Layer*. Retrieved November 25, 2020, from https://www.fema.gov/flood-maps/products-tools/national-flood-hazard-layer

In the United States, hazard maps are distributed via an online map portal developed by the Federal Emergency Management Agency (FEMA). In the case of flooding, flood hazard maps are distributed through FEMA's National Flood Hazard Layer (NFHL). **Figure 3.9** is an example of a flood hazard map available online in the United States. Compared to the flood hazard maps in Japan, the example from the United

States shows less information and does not provide any evacuation-related information. **Figure 3.10** depicts the visualization on the National Risk Index Map in the US, which is quite similar to that of Indonesia (i.e., InaRisk).

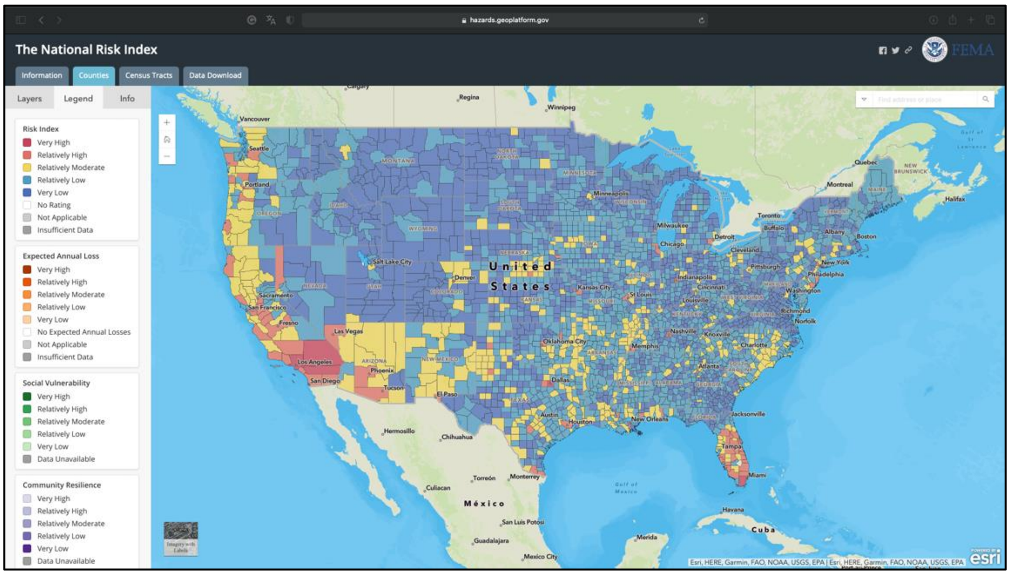


Figure 3.10 The National Risk Index Map in the US

Source: FEMA (n.d.). *Hazards geoplatform.* FEMA. Retrieved December 2, 2020, from https://hazards.geoplatform.gov/portal/apps/MapSeries/index.html?appid=ddf915a24fb24dc8863eed96bc3345f8.

A study conducted by Henstra et al. (2019) evaluated spatial information about flooding in Canada and found that flood maps in most municipalities are less suitable for risk communication. **Figure 3.11** below provides an example of a flood hazard map from Alberta, Canada. The map is presented as an interactive map; however, it has less information compared to the flood hazard maps from municipalities in Japan.

Comparing these maps to the Japanese case study presented in the previous sub-section, it can be said that Japanese maps share more of the comprehensive spatial information necessary for raising awareness and promoting protective behavior.

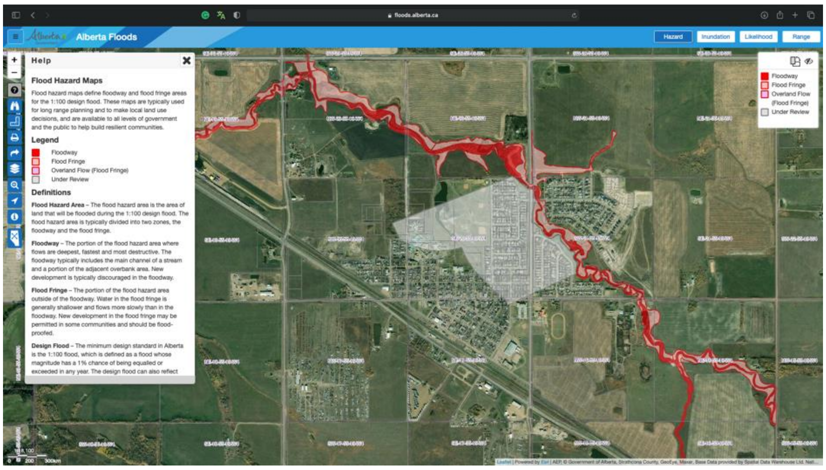


Figure 3.11 Example of Flood Hazard Map in Alberta, Canada

Source: Alberta Government. (n.d.). *Alberta floods.* Alberta Government. Retrieved November 26, 2020, from https://floods.alberta.ca.

3.2.3 Recommendations for Improving the Delivery of Spatial Information for Risk Communication from the Supply Side in Indonesia

Advancements in geospatial, information, and communication technologies, including the invention of web cartography and mobile-based mapping technologies, have led to spatial information becoming more ubiquitous (Morita, 2007; Muehlenhaus, 2014). Geo-visualization has also become more dynamic (Morita, 2007), allowing more interaction between maps and users facilitated by more interactive tools (Muehlenhaus, 2014). Numerous free and open-source geospatial technologies have made it more possible for governments to use technology more affordably, especially in developing countries where human resources and budgets are limited (Herold & Sawada, 2012; Tomaszewski, 2021). Such conditions are expected to encourage more utilization of spatial information, including in disaster management and disaster risk communication.

Despite the significant "spatial" nature of hazards and disasters, the use of maps has not yet become an everyday communication approach for improving risk understanding and for warning the public of forthcoming emergencies. In the first chapter of this dissertation, it was found that governments in Indonesia, especially at the local level, appear reluctant to employ map-based approaches using recently available technologies for delivering spatial information about disasters. This situation indicates the lower utilization of spatial information for risk communication at the local level, despite the fact that local governments play a crucial role in risk management. It was also found that spatial information about disasters is fragmented. There is no clear connection between the information produced and disseminated by local governments and that produced and disseminated by higher levels of government. The author expects that this condition is due to the absence of clear regulations for how spatial information should be produced and disseminated, including the role of each level of government in these issues. Most of the available information was also found to be of very poor quality, decreasing its potential usefulness for increasing hazard awareness and risk perception, as examined in the second chapter. In the second chapter of this study, it was found that the existing maps and map-based disaster applications have minimal impact in improving risk perception and hazard awareness.

Learning from some practices in other countries, especially Japan, some points are suggested for improving the distribution of spatial information about disasters in Indonesia, as follows:

1. To increase hazard awareness and risk perception, spatial information-mediated risk communication using hazard maps, such as those used in Japan and European countries, is better than that using risk maps.
2. These hazard maps can be delivered in the form of either static or interactive maps and either online or offline, as long as effective map criteria for public risk

communication purposes are kept. To support more universal layout and content, it is suggested that the national level of government should compile clear guidelines and manuals for map production, such as those created by the national government in Japan and by EXCIMAP for European countries.

3. The role of local governments in providing spatial information about disasters is significant and should be supported by higher-level governments. Local governments should be encouraged to produce more suitable spatial information about disasters (both risk maps and hazard maps) as decentralized disaster management is applied in Indonesia. Local governments should also be supported in promoting the availability of this spatial information more actively, making use of all means of communication, including social media.
4. Information about disasters can also be delivered through collaborative work with non-government organizations, private companies, and academia using the government's open data.
5. To help the public access the maps more easily, the national government of Indonesia can adapt the system implemented in Japan by developing a hazard map portal to collect all hazard map links shown on municipality websites. The portal could also be used for evaluating the availability of maps in each municipality in Indonesia.

3.3 Improving the Utilization of Spatial Information for Risk Communication from the User Side: The Case of SIKK Magelang

This sub-chapter provides an example of how free and open-source geospatial information technology was adopted by a local government in Indonesia for developing a map-based disaster application. As a city threatened by multiple hazards, mainly volcanic hazards from the Merapi Volcano, the local government of Magelang Regency sees disaster risk reduction efforts as crucial, especially considering the severe volcanic eruption of Merapi in 2010. To improve disaster data and information management, as well as to provide more accessible disaster information to the public, since 2017, the local government of Magelang Regency has started utilizing geospatial information technology by developing the *Sistem Informasi Kebencanaan Kabupaten Magelang* (SIKK Magelang) or Disaster Information System of Magelang Regency. By examining this case study, the author tries to examine how this local government has made use of better technology for risk communication and to understand what factors should be considered to improve the use of this type of spatial information from the user side.

3.3.1 Disasters in Magelang Regency

Magelang Regency, or *Kabupaten Magelang*, is a municipality located in the Central Jawa Province in the Java Islands, Indonesia. Jawa is the most populous region with rapid urbanization in Indonesia, which also makes it the region most vulnerable to disasters caused by natural hazards. The region is at risk of multiple natural hazards, including flooding, landslides, volcanic eruptions, earthquakes, and tsunamis. Of the 129 active volcanoes in Indonesia, one third (43 volcanoes) are located in Jawa.

Magelang Regency is geographically situated between 110^0 01’ 51” - 110^0 26’ 28” East and 7^0 19’ 13” - 7^0 42’ 16” South. According to data from Magelang Regency in 2018 (BPS Kabupaten Magelang, 2019), the Regency comprises 24 sub-districts (*kecamatan*), 372 villages (*desa/kelurahan*), and 2,841 sub-villages (*dusun*). The three sub-districts with the largest areas are Kajoran, Grabag, and Salaman. The area covers around 110,385 hectares with various topographic conditions. Most of the area in Magelang is steep, which makes it highly prone to landslides. Topographically, Magelang is a basin and a largely agriculture-based area, with volcanic mountains surrounding its administrative borders. There are five mountains surrounding the city from east to west: Merapi, Merbabu, Andong, Telomoyo, and Sumbing. Two main rivers flow to the center of Magelang: the Progo River and the Elo River. In its southern region lies the Menoreh ridge.

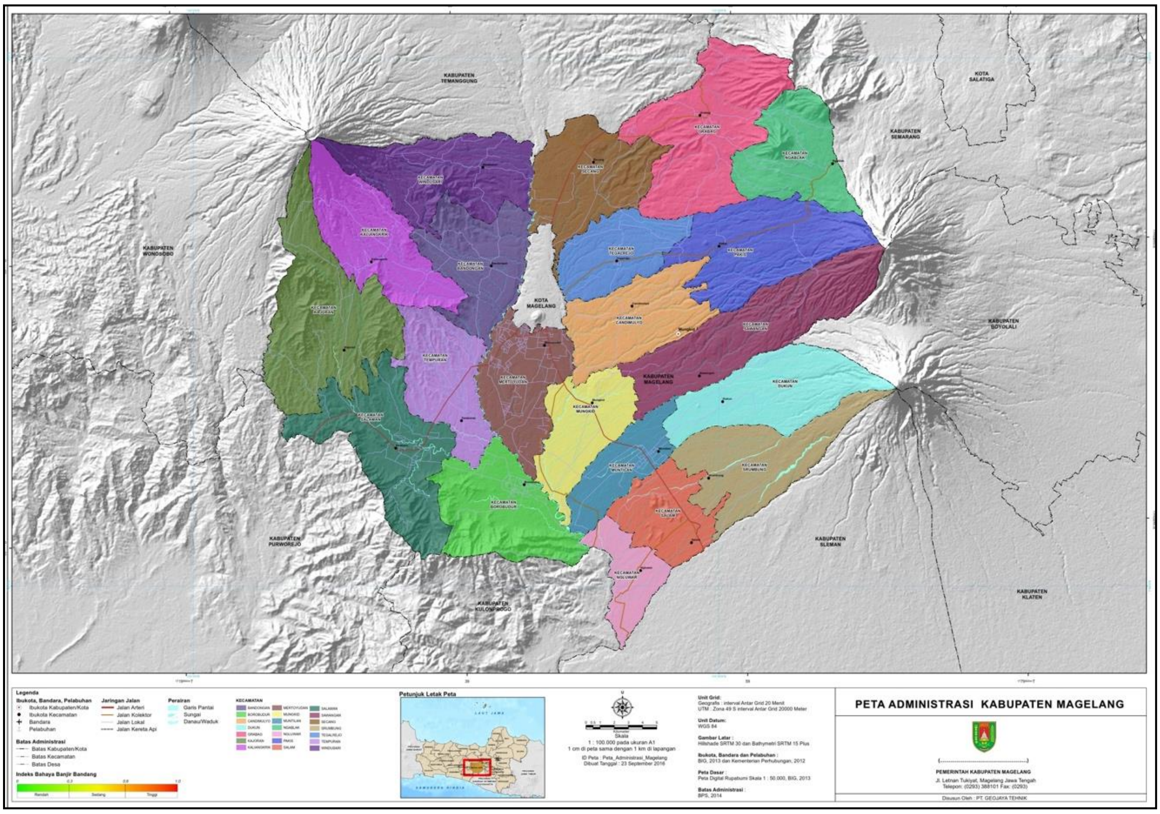


Figure 3.12 Administrative Boundary of Magelang Regency

Source: Disaster Risk Assessment Document of Magelang Regency (2017-2021); BPBD of Magelang Regency (2019).

Magelang Regency’s economy mainly depends on mining, farming, and tourism activities, with a growing contribution from trade and services. A study conducted by Rizki et al. (2019) found mining to be the most significant contributor to Magelang Regency’s economy. Mining activities in Magelang Regency are dominated by Merapi volcano sand and stone mining. Merapi’s volcanic sand is well known for its quality, and the 2010 Merapi eruption, followed by its cold lava events, produced an additional abundance of sand resources. The second most significant contributor to Magelang's economy is farming, which also makes the highest proportion use of land in the area. Magelang's economy is also supported by tourism activities, especially due to the presence of Borobudur Temple, a UNESCO designated world cultural heritage site that has been the main tourist attraction. The trade and service sector has grown recently, since Magelang lies strategically in the corridor between two busiest cities in the central area of Java Island, Semarang City, the capital of Central Java, and Yogyakarta, which makes it a potential development hub (Cho et al., 2016). There has been significant growth in commercial activity in this corridor, including shopping centers and hotels.

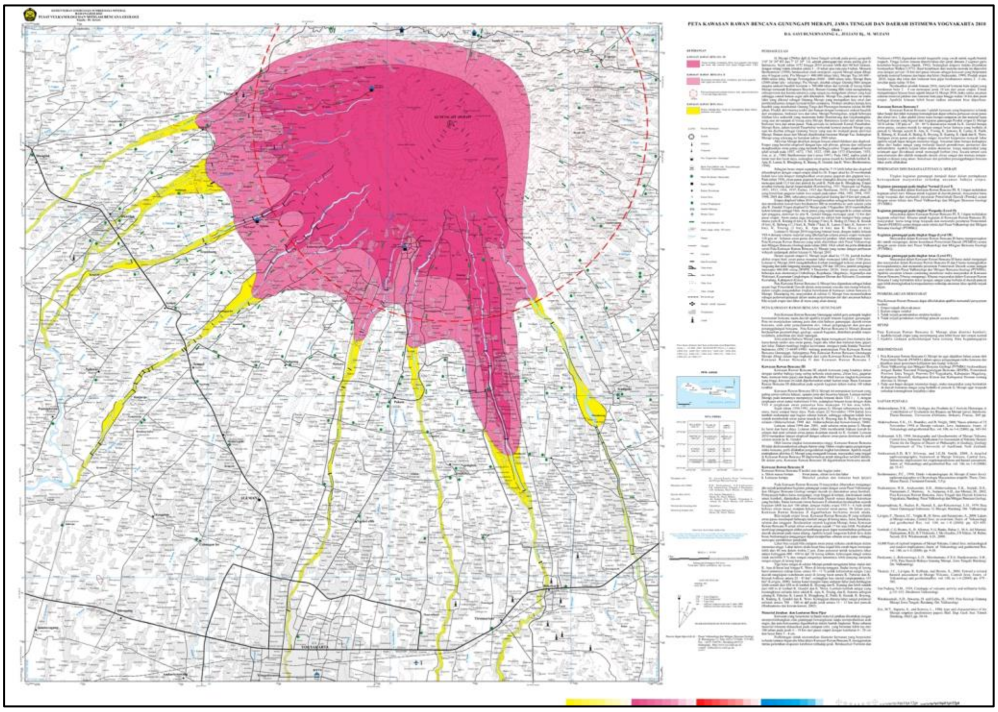


Figure 3.13 Merapi Volcano Hazard Map

Source: Sayudi et al. (2010). Peta Kawasan Rawan Bencana Gunungapi Merapi, Jawa Tengah dan Daerah Istimewa Yogyakarta, retrieved 25 November 2020 from https://magma.vsi.esdm.go.id/img/krb/ga/jpg/KRB_Merapi.jpg.

Magelang Regency is at high risk of volcanic eruptions from several active volcanoes, but Mt. Merapi is the most hazardous to Magelang. Mount Merapi is a strato-type volcano that is also reputed to be one of the most active volcanoes in the world. Due to its changing eruption characteristics and the density of the population around the volcano, it is predicted that the catastrophic impacts of Merapi Volcano will increase in the future. Since 1900, Merapi has had a typical recurrence interval of 4–6 years, with lava dome generation that collapses to generate pyroclastic flows and lahars. In 2010, the volcano erupted explosively, with the main explosive events occurring on October 26, 29, and 31 and November 1, 3, and 4. The eruption of Mt. Merapi in 2010 was a once-in-a-hundred-year event that does not compare in magnitude with previous eruptions and that has cost the lives of almost 400 people. According to various reports on the 2010 explosion during the critical phases, pyroclastic flows reached 12 km. Such pyroclastic flows were particularly detrimental to Dukun and Srumbung, areas within a 15 km distance of the volcano.

Besides being prone to volcanic eruptions, according to the Disaster Risk Assessment document (BPBD of Magelang Regency, 2017), Magelang is also threatened by several natural hazards, including landslides, extreme weather (storms, heavy rain, etc.), earthquakes, drought, forest and land fires, flooding, and flash flooding. In the last two decades, between 1999 and 2019, the most frequently recorded disasters were landslides, extreme weather, and flooding. The total disaster occurrence in Magelang from 1999 to 2019 was around 7,000 incidences, causing around 3,000 fatalities, more than 30,000 injuries, and the displacement of around 4 million people.

Based on the General Spatial Planning document of Magelang Regency (*Rencana Tata Ruang Wilayah* (RTRW) *Kabupaten Magelang*), areas prone to disasters include:

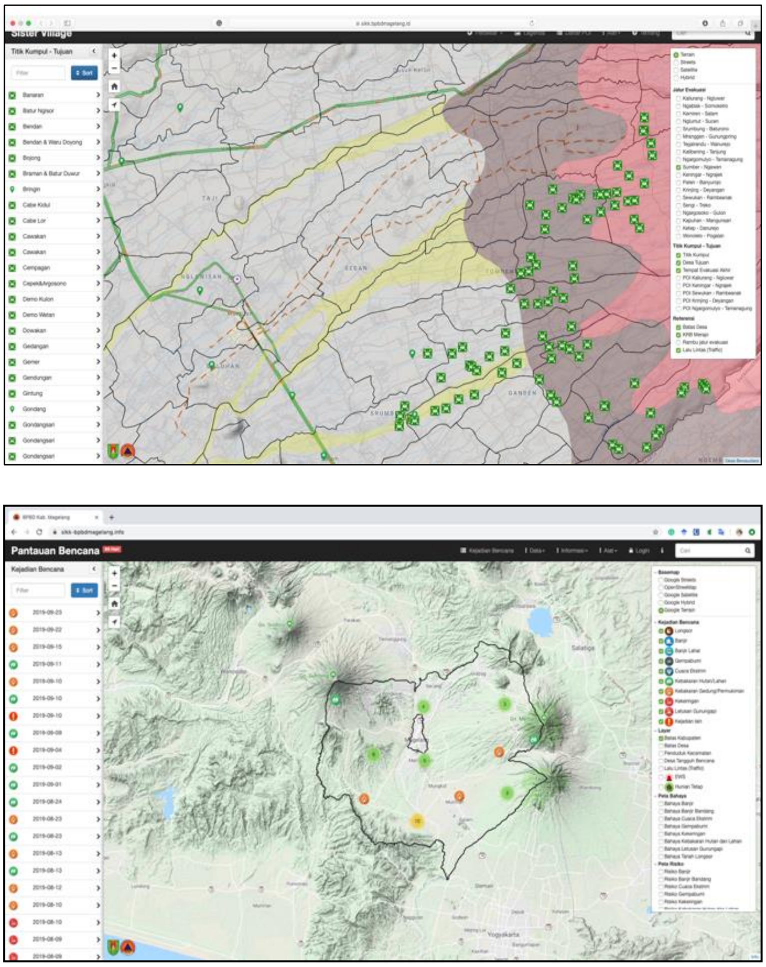
1. Areas prone to Merapi Volcano eruption activities: Kecamatan Srumbung Dukun, Muntilan, Salam, Sawangan, Ngluwar, and Mungkid.
2. Areas prone to Sumbing Volcano eruption activities: Kecamatan Kajoran, Kaliangkrik, and Windusari.
3. Areas prone to earthquakes: the whole area of Magelang Regency.
4. Areas prone to landslides, divided as follows:
   a. High risk: Kecamatan Kajoran, Kaliangkrik, Windusari, Tempuran, Borobudur, Salaman, Grabag, Ngablak, Pakis, Sawangan, Bandongan, and Secang.
   b. Medium risk: Kecamatan Kajoran, Windusari, Tempuran, Borobudur, Salaman, Grabag, Ngablak, Pakis, Sawangan, Dukun, Srumbung, Bandongan, Tegalrejo, and Candimulyo dan Secang.
   c. Low risk: Kecamatan Borobudur, Ngablak, Sawangan, Dukun, Srumbung, Mungkid, Muntilan, Salam, and Ngluwar.
   d. Very low risk: Kecamatan Borobudur, Mungkid, Mertoyudan, and Secang.

3.3.2 SIKK Magelang: From an Internal Disaster Database and Reporting Tool to a Public Information Portal and Map-Based Disaster Application

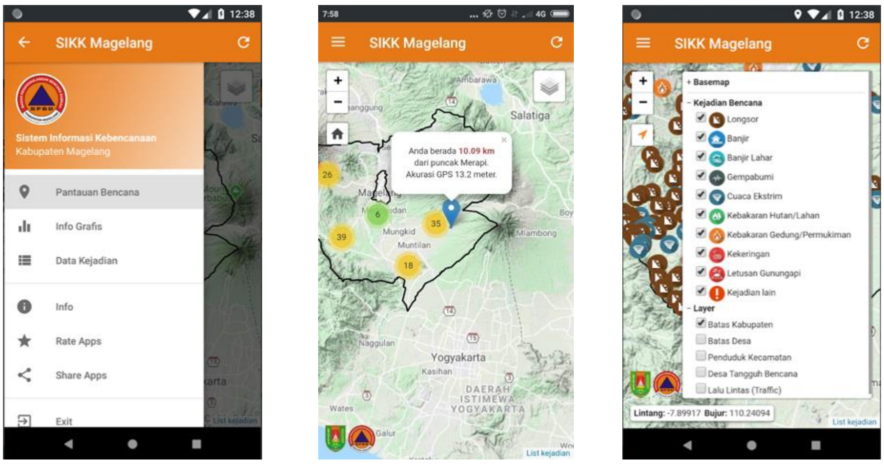
SIKK Magelang is an information system built by the BPBD of Magelang Regency in 2017 that aims to collect, manage, and disseminate information about disasters to the public and other relevant stakeholders. It comprises various information about disasters, ranging from disaster-related maps (risk, hazard, and capacity maps and evacuation plan maps) to non-geographical and geographical disaster-related databases and a list of disaster occurrences in Magelang Regency, which includes several graphics and photographs. This disaster information system can be accessed via most web browsers, including Mozilla Firefox, Opera, Internet Explorer, Google Chrome, and

Apple Safari. Previously, it was accessible as a web-map platform at http://sikk.bpbdmagelang.id (previously, the URL was https://sikk-bpbdmagelang.info/). In 2019, the BPBD of Magelang Regency extended SIKK Magelang as a mobile phone application, making it one of few map-based disaster applications in Indonesia. The mobile version, however, is still limited to Android users. **Figure 3.14** below shows the interfaces of SIKK Magelang in both the web and mobile versions.

SIKK Magelang was initially developed as an internal disaster database and reporting platform used only by the central data and operation monitoring division (Pusdalops) of the BPBD of Magelang Regency. As an online reporting tool, it allows registered users, such as heads of villages, sub-district officials, or volunteers, to immediately report disaster events from the field to Pusdalops. The report includes geolocation of the occurrences and photographs showing the damage. Once the report is verified, it will be displayed on SIKK Magelang and included in the database. Thus, the database in SIKK Magelang is more or less similar to those of DIBI and EM-DAT but with more detailed information. Recognizing that such information would also be valuable to the public, the BPBD of Magelang Regency later decided to make it publicly accessible. The link was then announced on the BPBD of Magelang Regency's official website. On several occasions, such as in meetings with village officials and volunteers, SIKK Magelang was also promoted. To increase awareness of its presence, it has also been included as a part of the BPBD's WhatsApp broadcasted message signature.



(a). Displays of the desktop version of SIKK Magelang.



(b). Interfaces of the mobile version of SIKK Magelang.

Figure 3.14 Examples of SIKK Magelang Interfaces in Both Versions

SIKK Magelang has since been transformed into one of the disaster learning tools used in Magelang Regency. Disaster volunteers, who are well positioned to interact with the local community and usually take part in disaster simulations or public campaigns, may use it as a medium to geographically inform the public about hazards. The public in general may also use it as a disaster self-learning tool, since they can individually access SIKK Magelang to learn about disasters threatening their home area. Those who live in villages at high risk from Merapi Volcano may use it to better understand the locational aspects of evacuation plans (i.e., evacuation routes, evacuation shelters, and assembly points) for severe eruptions. SIKK Magelang may also be valuable to local government agencies, donors, and other relevant parties in deciding the areas to prioritize for disaster relief distribution.

Mostly, using geospatial information technology is expensive, requiring a considerable investment in spatial data, computer software/hardware, and human resources (training and education), which has hindered its utilization for disaster management in developing nations (Herold & Sawada, 2012). In many cases, disaster management responsibilities and duties are decentralized to local governments without being accompanied by the necessary funding (Montoya & Masser, 2005). In other cases, budgeting issues may also be related to the absence of obligatory regulations and a lack of focus on the budget for responsive actions as opposed to preventive and risk management activities (Mardiah et al., 2017). Furthermore, considering that local governments have to provide many essential public services (e.g., education, health, and infrastructure and utilities), they are often not predisposed to purchase commercial GIS software due to other demands on funding (Renyi & Nan, 2002), especially for areas with budgetary constraints (e.g., disadvantaged regencies). The cost of the software alone can prevent it from being used at the local level in developing countries (Renyi & Nan, 2002).

SIKK Magelang is an example of how a local government in a developing country, in collaboration with a local consultant, can make optimum use of free and open-source geographic information software for disaster management, thereby lowering the cost. Although faced with a limited budget, the local government of Magelang can still provide spatially informative data to the public. One of the problems with disaster management in Indonesia is the limited budget for disaster management at both the national and local levels. Disaster management budgets, in most cases, are allocated less than one percent of the total budget. Many local governments do not consider it necessary to allocate a budget for disaster management, which may lead to chronic and systemic problems (Mardiah et al., 2017). SIKK Magelang, which was initiated by Mrs. Muflichah Roychani (the Secretary of the BPBD of Magelang Regency) in collaboration with SinauGIS, a local individual consultant with GIS expertise, could avoid this bottleneck. While in other cases it may cost more than 500 million IDR to build an online information system, the BPBD of Magelang Regency only spent around 50 million IDR when initially developing SIKK Magelang.

SIKK Magelang was created by making use of free and open-source GIS software and standards. The Leaflet JavaScript engine and other free and open-source programming software and mapping library tools were employed to develop the webGIS interface. Leaflet and JavaScript APIs are similar to Google Maps APIs, which are able to operate mashups. Data visualized on the Sister Village menu, for example, were collected through field tracking using an Android application called Open Camera, resulting in .gpx format files. These data were then converted into shapefiles (.shp) for editing, before being finally transformed into the GeoJSON format for loading and visualization through the Leaflet JavaScript engine.

Meanwhile, for building the online disaster database, SIKK Magelang uses PHP (a Hypertext Preprocessor) and MySQL to store and prepare the disaster occurrence data for display on its webGIS interface (BPBD Kabupaten Magelang, 2019). PHP is a widely used general-purpose scripting language for web development and can be embedded into HTML. MySQL is an open-source relational database management system that offers multi-user access to a number of databases. The use of PHP and MySQL involves three steps: creating a table in MySQL, settling the table from an external Excel or spreadsheet into the MySQL database, and outputting XML or HTML with PHP. In the case of SIKK Magelang, the data set is collected initially through the online registration process (limited to the operators only) and transformed into the XML file format. After the occurrences are input to the application, the results can be visualized cartographically on the map container so that users can easily view their spatial distribution. Displaying a large number of locations or markers often causes both visual overload and sluggish interaction with the map. Therefore, SIKK Magelang has adopted a clustering feature on its system. Clustering techniques simplify the data visualization by consolidating markers that are very close to each other on the map in an aggregate form.

At the initial launch of the web page, icons for disaster occurrences are displayed within the map container as clusters. This gives users a clear view of where most of the disasters that have occurred in Magelang Regency in the last 90 days were concentrated. The most recent events are marked with red, blinking dots. There are four base maps from Google (Google Streets, Google Satellite, Google Hybrid, and Google Terrain) and one base map from OpenStreetMap loaded into the map container. Meanwhile, for the Sister

Village interface, only base maps from Google can be selected by users. In order to provide the user with some interaction with the map, a few standard mapping controls have been added, such as pan and zoom controls, map scale controls, and base-map type controls.

The sidebar on the left side contains a list of the same disaster incidences marked on the map. Interestingly, since the sidebar and the map are linked, disasters shown on the left sidebar will follow the number of disasters visualized on the map container. If users are interested in a particular event, for example, but do not know where it is, this sidebar catalogue lets them go straight there without having to hunt around the map for it. On the right top, beside the menu tab, there is a search function. However, it does not function well, since users cannot easily make queries from this menu. On the right side, there is another sidebar showing the map legend that provides information about the ten types of disaster shown on the map. This feature provides users with a clear understanding of the disaster occurrences they are looking at. Users can click on any icon to get more specific information from a pop-up information window about the incidents, including the date, location, and a brief description of the incident, the causes of the incident, the number of affected people, any damage, and pictures. Users can customize the cartographic display by turning on or off the various thematic overlays and layers (different maps or symbols) from the map legend. Thus, information shown on the map container is only that preferred by the users.

SIKK Magelang is also able to display various disaster maps (hazard maps, risk maps, vulnerability maps, and capacity maps) according to the type of hazard (flood, flash flood, earthquake, drought, extreme weather, forest, or land fire, volcanic eruption, or landslide). Those disaster maps were produced with support from the national-level disaster management agency, the *Badan Nasional Penanggulangan Bencana* (BNPB), in 2015.

Compared to other disaster information systems, Magelang perhaps has a wider range of maps. However, there are still two issues with these maps. First, there is no explanation provided for the colors used: it is not clear what each color means, nor whether any particular color refers to a specific level of hazard or risk. When users turn on the “flood hazard” (*bahaya banjir*) layer, for example, which is located under the hazard map layer group, the map will show some areas colored by green, yellow, or red polygons. It may be easier for those who are already familiar with the different levels of hazard on a hazard or risk map to presume or to understand what flood level is referred to by the color. For instance, green usually indicates a low level of hazard, yellow usually reflects a medium level, and red usually represents a high level of hazard exposure. Nevertheless, for users who are not familiar with this color code, it may be more difficult to understand. Second, the colors used for each hazard are different. On the flood hazard map again, for instance, users may spot some areas colored with green, yellow, and red shades. However, when they turn on the landslide hazard map, for example, the map displays yellow, orange, and red, still without any explanation. This may cause users confusion, as they are not given further details about the hazard coloring.

What makes SIKK Magelang different from other online disaster map services built by local governments in Indonesia is that it has a menu displaying evacuation scenarios (including visualizations of evacuation routes, assembly points, and final evacuation sites) based on a program called Sister Village, or *Desa Bersaudara* in the Indonesian language. SIKK Magelang depicts this program more clearly, making it easier to locate the evacuation sites, for example, and to follow roads as the route for evacuation.

This program matches 19 villages at high risk of volcanic eruptions with one or two safer villages located outside of the risky radius. The evacuation routes are drawn connecting these pairs of villages, starting from the locations of assembly points or village offices and meeting halls and ending at the evacuation site's location. Detailed information about the evacuation site, such as photographs, coordinates, and the site's capacity, is shown in a pop-up window.

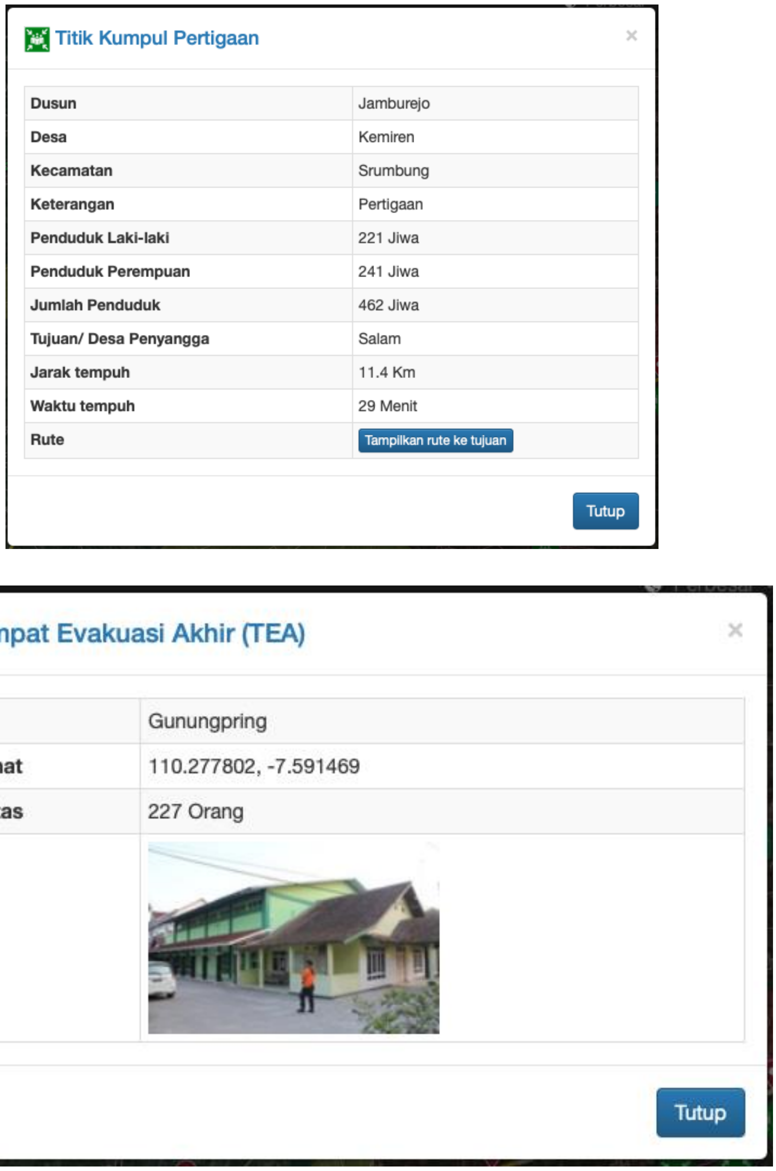


Figure 3.15 Pop-Up Information about Assembly Points on the Sister Village Menu

3.3.3 Lack-of-Use Challenges

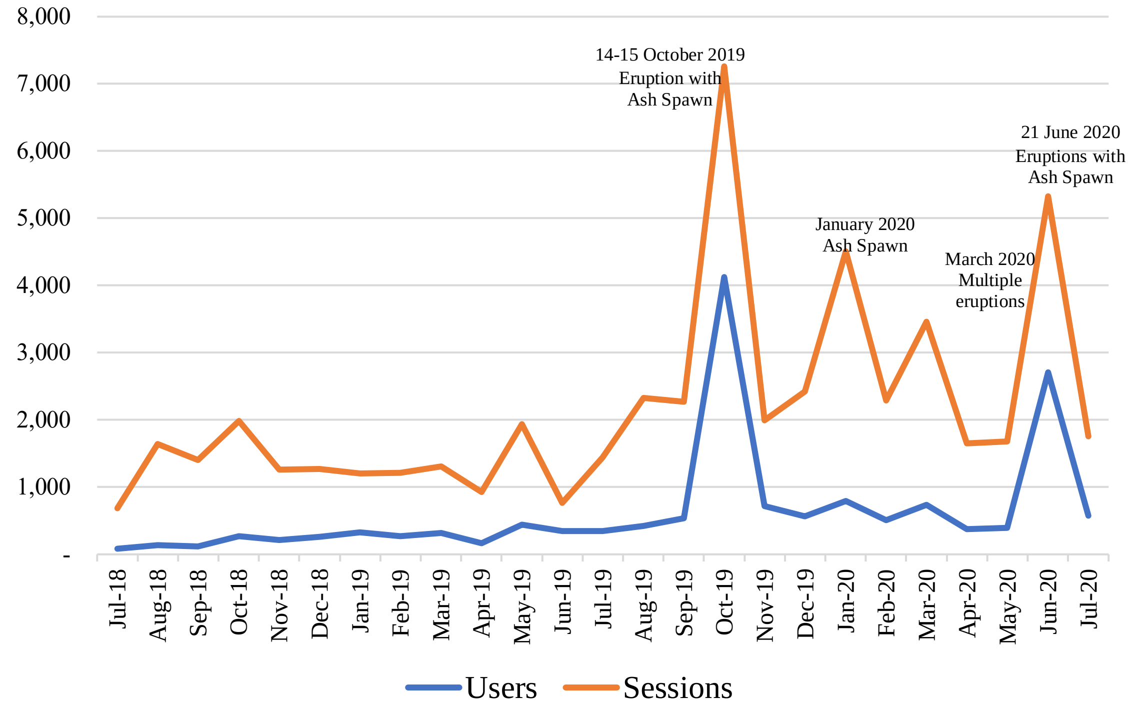


Figure 3.16 SIKK Magelang' User Statistics by Month (July 2018 – July 2020)

Source: Data analyzed from Google Web Analytics, BPBD of Magelang Regency (2020).

Despite its useful features, as with many e-government services in Indonesia, SIKK Magelang suffers from a low adoption rate, as indicated by the low and stagnant usage statistics for the desktop version and the small number of downloads of the mobile app. Based on records obtained from Google Web Analytics from July 2018 to July 2020, the average number of users per month was 631, with 2,160 sessions. These numbers indicate that, on average, each user only accesses it around three times per month. Usage statistics prior to conducting this study were even lower (247 users/month). With only around 600 users per month (compared to the population of Magelang Regency itself, which includes the main targeted users), the number of monthly users is less than 0.1%

of the population, not including non-resident users. Interestingly, two usage peaks occurred in October 2019 and June 2020. During these months, considerable eruptions of Merapi were recorded. Therefore, while during the normal time access have been noticeably low, it has more accesses when a severe disaster event occurs, such as frequent eruptions or considerable eruption activities happened. This pattern is similar to the user statistics of Wagamachi Hazard Map which were explained in the previous section.

3.3.4 Perceptions of SIKK Magelang from the Perspectives of Local Risk Managers, Disaster Volunteers and Public Users

1. Study Design of the Perception Assessment

Awareness of innovation is an initial step in the innovation-decision period, during which an individual adopts or rejects an innovation (E. M. Rogers, 1995). Existing literature argued that awareness of the availability of an online service is related to the use of the service (Abdullah & Gibb, 2006; Sipior et al., 2013). Moreover, the adoption of an information system is also influenced by users' perceptions of the quality of information and system(W. H. DeLone & McLean, 1992; W. DeLone & McLean, 2003).

Information quality refers to the desirable characteristics of the system output (Petter et al., 2008). Information quality has proven to be strongly associated with the use or intentions of future use and has been a critical factor in measuring the success of an information system (W. DeLone & McLean, 2003). Quality of information in the context of an information system use is mostly measured in terms of completeness, ease of understanding, personalization, relevance, accuracy, timeliness, consistency, or security. In this study, information quality was measured on whether the maps and information about disasters provided on SIKK Magelang were useful, easy to understand, interesting, complete, and reliable, and trusted. "Up-to-date" was added when assessing local risk managers' and volunteers' perceptions of the information quality since their works urgently need up-to-date information on disasters.

System quality refers to the desirable characteristics of an information system (Petter et al., 2008). System quality is measured by several dimensions, such as ease of use, functionality, adaptability, availability, reliability, response time, importance, and usability (W. DeLone & McLean, 2003). For the case of local risk managers, system quality was measured by thirteen items reflected the adaptability and usability of SIKK Magelang by the participants. Meanwhile, for public users, there are eight items to measure this system quality, which mainly reflected adaptability, reliability, and usability.

This study prefers to measure intentions to use rather than to measure the actual use because it was found from the usage statistics of SIKK Magelang that during the last two years, there have been very low usages of this system. Thus, it was predicted that the usage trial during the survey would be the participants' first use. Intention to use was measured by participants' willingness to use the system in the future and desire to recommend the system to others.

Data were obtained from two field surveys comprised of a semi-workshop and questionnaire distribution by using close-ended multiple-choice questions held in Magelang Regency in June 2019 (local risk managers and volunteers) and December 2019-January 2020 (general public and community at risk) (see **Table 3.1**). Some survey items and operationalization may be different despite referring to the same variables or sub-variables. For the public survey, the questions and survey items were simplified (**Table 3.2**). The analysis is descriptive.

Local risk managers are those who fulfill a risk management function on a local level, such as emergency managers, spatial planners, heads of villages, and sub-district officials. These individuals work as local administrations and are responsible for technical protection or risk management in general. Disaster volunteers are a person or group of people who have the ability and concern to work voluntarily and sincerely in disaster management efforts. Based on the database of disaster volunteers of BPBD Kabupaten Magelang, in 2017, there were 3,976 disaster relief volunteers from 94 volunteer organizations in Magelang. Finally, public users refer to laypeople who potentially use SIKK Magelang: they can either reside or not reside in Magelang Regency. Those who reside in Magelang can be a community at high risk of a group of hazards or one living in a safer place.

Of the total 265 respondents, 58.5% were male, and 41.5% were female. The majority of respondents were those aged between 31 – 40 years old (32.1%). On the education level, the respondents are mostly graduated from senior high school. These situations are also applicable to each type of respondent (see **Table 3.1**).

Table 3.1

Research Methodology and Demography of Respondents from each Survey

	Local risk managers and volunteers	**Public audiences**
Date of the study (month/year)	28 June 2019 with around one-month follow-up (waiting for the post-questionnaire filling)	December 2019 – January 2020
Study location	The meeting hall of BPBD *Kabupaten* Magelang	1. Sumber Village, Magelang (representing a community at high risk of volcanic hazards) 2. *Alun-Alun* (the city plaza) of Magelang Regency 3. Villages close to the Borobudur temple
Data collection method	A semi-workshop meeting with pre- and post-questionnaire distribution and SIKK Magelang usage trial, which initially invited 150 local risk managers, were conducted in collaboration with the BPBD *Kabupaten* Magelang. There were only 112 persons attended. One hundred seven respondents were willing to fill pre-questionnaire, but only 45	A questionnaire distribution was conducted with the SIKK Magelang usage trial.

	respondents filled both pre- and post-questionnaire.	
Number of respondents	45 respondents	220 respondents
Demography of surveyed people	• Sex: 13.3% Female, 86.7% Male • Age: dominated by 31-40 years old (42.2%) • Education background: Senior High School (71.1%)	• Sex: 47.3% Female, 52.7% Male • Age: dominated by 31-40 years old (30.0%) • Education background: Senior High School (51.8%)

2. *Low Awareness of Targeted Users on the Existence of SIKK Magelang*

This study shows that respondents in the majority were not familiar with the disaster information system. It is shown by very few respondents that have ever heard or use SIKK Magelang before this study survey. Two-third of our respondents who are coming from local risk managers and volunteers (31 respondents or 68.9%) said that they have ever heard or used the system before the survey. On the other hand, less than eight percent (16 respondents) of our public respondents were aware of the availability of this disaster information system.

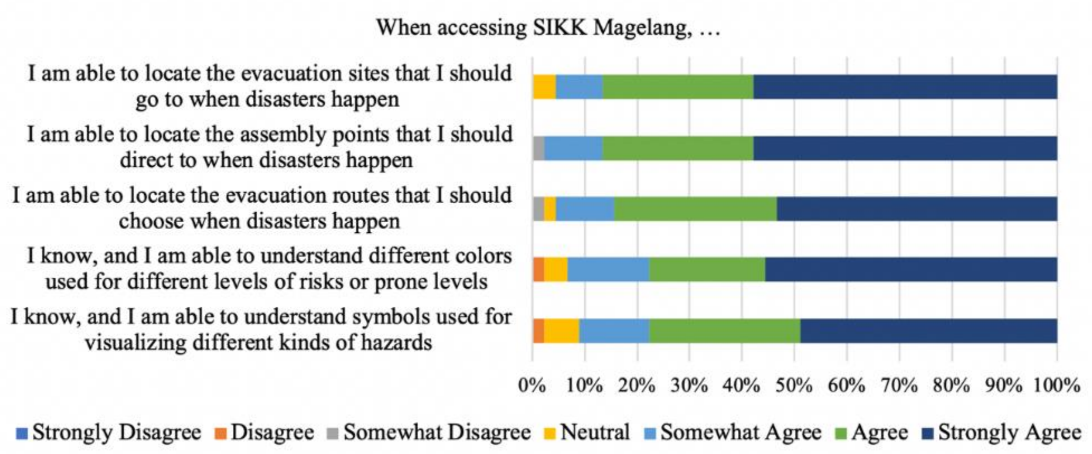
Local risk managers and volunteers first knew the presence of SIKK Magelang in the last one month (55.6%). Most of them received information about SIKK Magelang for the first time from their friends, family members, and colleagues (53.3%) and social media (42.2%). They were found more aware of the availability of SIKK Magelang, perhaps because they are more actively involved in disaster management activities. Besides, they may also get the information more quickly and directly from BPBD.

Less awareness of public respondents indicates that BPBD needs more efforts to spread the awareness of the information system or to promote the use of SIKK Magelang more frequently. These efforts should also include manual training or a demonstration so that potential users can learn how to use it properly and get the maximum benefits provided by SIKK Magelang.

3. *Positive Perceptions of SIKK Magelang after Trying the Application with Explanations*

In general, this study found that both local risk managers and disaster volunteers and public users expressed positive perceptions on the system and information quality of SIKK Magelang after trying the application accompanied by the author and BPBD of Magelang Regency, although, in the previous section, their awareness of the presence of this information was quite low.

For the case of local risk managers and disaster volunteers, findings indicated that our respondents expressed high agreement on the system quality of the information system (**Figure 3.17**). Almost all respondents agreed that when they were accessing SIKK Magelang, they are able to locate the evacuation sites, assembly points, and evacuation routes, which are essential for the emergency situation. They also agreed that they were able to understand colors and symbols used for the visualization of hazards from the maps on SIKK Magelang.



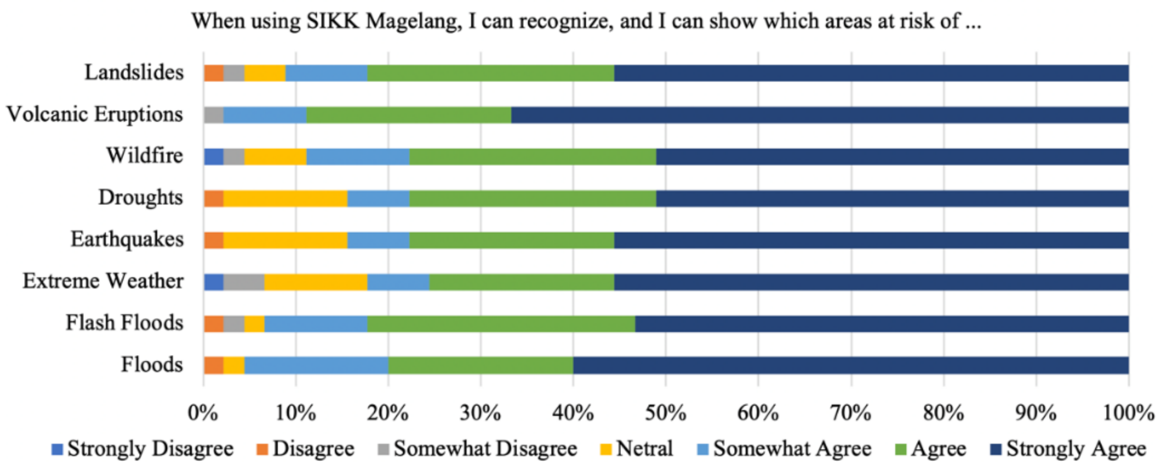


Figure 3.17 Perceptions of Local Risk Managers and Disaster Volunteers on the System Quality of SIKK Magelang

Public users also showed high agreement on the system quality of SIKK Magelang (**Figure 3.18**). More than 60% of the respondents agreed and strongly agreed that SIKK Magelang is reliable as a source for knowing evacuation sites, evacuation routes, and assembly points. Around two-thirds of the respondents also agreed and strongly agreed that SIKK Magelang is reliable as a source of disaster maps. More than half of the public respondents perceived that SIKK Magelang is easy to operate, easy to access anytime and anywhere. More than 60% of the respondents also agreed that SIKK Magelang is easily accessible through any device. Both types of respondents also showed high agreement on the information quality of SIKK Magelang. Overall, most of the respondents agreed that maps and information provided on SIKK Magelang are useful, easy to understand, interesting, reliable, complete, and up-to-date. Public user respondents also agreed that the information on SIKK Magelang is trusted (**Table 3.2**).

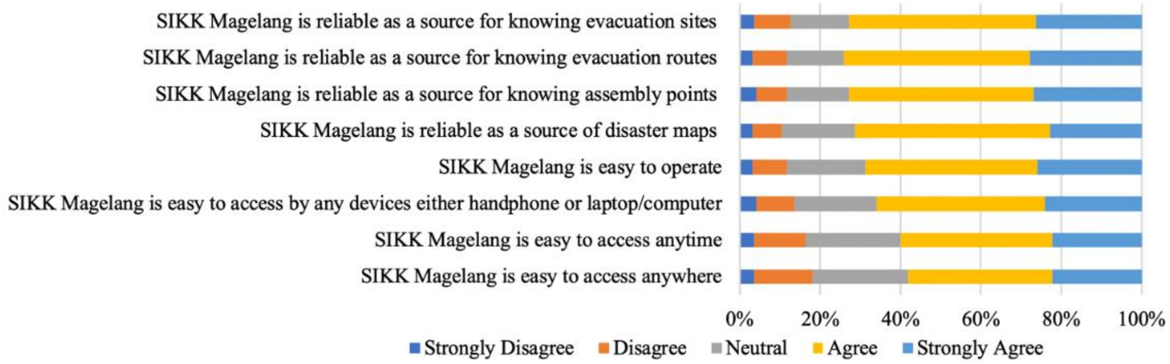


Figure 3.18 Perceptions of Public User Respondents on the System Quality of SIKK Magelang

4. Intentions to Use of SIKK Magelang after Trying the Application with Explanations

Interestingly, this study found that although respondents were not familiar with the system, once they tried using SIKK Magelang, they are willing to use the system in the future, shown by the high percentage of respondents agree to use SIKK Magelang as a source of information system. Almost all respondents from local risk managers and disaster volunteers showed favorable agreements (somewhat agree, agree, strongly agree) for all the statements representing their intention to use SIKK Magelang. They were also willing to recommend SIKK Magelang to their family, friend, and colleagues. The same findings also expressed by public respondents. More than 70% of our public respondents agreed to use SIKK Magelang as a source of disaster information and as a supporting tool for decision-making. Most of this group of respondents also agreed to recommend the information system to their family and friends.

Table 3.2

Perceptions of the Quality of Information displayed on SIKK Magelang

	Mean and Standard Deviation of Perceived Information Quality							
	Useful	**Easy to Understand**	**Interesting**	**Reliable**	**Complete**	**Up to date**	**Trusted**	**Composite**
A. Local Risk Managers and Volunteers - Seven-point Likert Scale (7 = strongly agree, and 1 = strongly disagree)								
1. Maps showing areas prone to disasters	6.67 (0.56)	6.49 (0.73)	6.49 (0.76)	6.16 (1.02)	6.36 (0.91)	6.31 (0.67)	n/a	6.42 (0.62)
2. Maps visualizing the spatial distribution of disaster occurrences	6.62 (0.54)	6.33 (0.74)	6.47 (0.69)	6.36 (0.74)	6.40 (0.54)	6.36 (0.68)	n/a	6.42 (0.57)
3. The visualization of evacuation routes	6.62 (0.61)	6.42 (0.84)	6.53 (0.66)	6.38 (0.68)	6.29 (0.76)	6.33 (0.77)	n/a	6.43 (0.61)
4. The visualization of assembly points	6.60 (0.65)	6.40 (0.81)	6.47 (0.66)	6.24 (0.80)	6.22 (0.82)	6.31 (0.76)	n/a	6.37 (0.66)
5. The visualization of evacuation sites	6.58 (0.69)	6.36 (0.77)	6.42 (0.78)	6.40 (0.78)	6.33 (0.71)	6.27 (0.72)	n/a	6.40 (0.67)
6. The visualization of evacuation signages	6.56 (0.73)	6.40 (0.75)	6.38 (0.83)	6.24 (0.83)	6.31 (0.79)	6.24 (0.83)	n/a	6.36 (0.73)
B. Publics - Five-point Likert Scale (5 = strongly agree, and 1 = strongly disagree)								
Disaster's information and maps shown on SIKK Magelang	4.05 (0.88)	3.88 (0.90)	3.90 (0.90)	n/a	3.81 (0.91)	n/a	3.95 (0.91)	

5. Relationship between Awareness and Intention to Use: The Need of Promotion

This study found that public users' intention to use SIKK Magelang as a source of disaster information is positively correlated to awareness. This relationship, however, was insignificant for users from local risk managers and volunteers. This may indicate that in the case of public users, as they are getting more aware of the availability of SIKK Magelang, the more they intend to use SIKK Magelang as a source of information. Therefore, if SIKK Magelang is prioritizing public users as its audience, awareness of the availability of this system should further be concerned because lack awareness of the availability of SIKK Magelang by its potential users will lead to lack of usage.

If the government of Magelang Regency would like to increase the use of the applications by its citizens some actions can be taken such promotions and endorsement through Facebook, Twitter, Instagram, or any social media that highly used by the community. In the first chapter of this study, for example, most of Indonesian people love to use Facebook, WhatsApp, and YouTube. These platforms can be used for promoting the application.

Meanwhile, if the application is expected be more acknowledged by local risk managers and disaster volunteers, the application can be endorsed through the most popular online communication of these groups, especially considering that they preferred local government sources to national government services. This study found that regarding online sources of data and information about disasters, in general, local risk managers and disaster volunteers in Magelang Regency (N=112) preferred WhatsApp groups, such as volunteers' or village officials' WhatsApp groups, for getting information about disasters. The BPBD of Magelang Regency's social media – including its Instagram page, Facebook page, and YouTube channel – were chosen by 41.1% (N=112) of the respondents, making it the second most popular online source, followed by the agency's official website (28.0%). Only one respondent chose DIBI. The official websites and social networking services (SNSs) of BMKG and *Badan Penyelidikan dan Pengembangan Teknologi Kebencanaan Geologi* (BPPTKG) were among the most popular non-local government sources for disaster data and information (22.4% and 24.3%, respectively).

3.3.5 Factors Affecting Public Users' Intention to Use SIKK Magelang: An Information System Success Approach

A government-initiated map-based disaster app is a blend of e-government services, a built-for-disaster-purpose app, and a map service. Thus, this study assumed that factors influencing the users' intention to use SIKK Magelang are composed of the determinants of adopting e-government services (especially mobile e-government), disaster apps, and factors influencing map usability.

To understand factor influencing targeted users' intention to use this study proposed an adoption model. To test the research model, a questionnaire survey was conducted. The constructs used for developing the model were adapted from previous literature to ensure survey content validity. A pretest was used to validate and evaluate the interpretability and clarity of the instrument. The measurement of the constructs involved using multi-item reflective scales, which enhanced confidence that the measurements were consistent.

This part of study used data that were collected from the questionnaire survey, which was conducted from December 2019 to January 2020. The 220 respondents of this study were all citizens of Magelang Regency who lived in both at-risk and safe areas.

The average respondent age was 34 years old (the youngest was 13 years old, while the oldest was 65 years old), with men accounting for 52.7% of the sample and women for 47.3%. Over half of the respondents had finished senior high school (51.8%), and 40.9% had monthly incomes of around 2.1 to 5 million rupiah. All respondents had experienced disasters, and 90.9% had been victims of disasters, including evacuation during the 2010 Merapi eruption. Concerning the Merapi volcano risk areas, while 24.5% of the respondents lived in non-volcano risk areas, the rest (75.5%) did live in volcano-risk areas. The vast majority of the respondents owned smartphones (92.3%). Only 7.27% (16 people) had used SIKK Magelang before the survey, which means that almost all respondents were potential adopters, not actual users of SIKK Magelang.

1. Identifying the Factors and their Relationships by Extending the Information System Success Model

A government-initiated map-based disaster app is a blend of e-government services, a built-for-disaster-purpose app, and a map service. Thus, this study assumed that factors influencing the adoption of this type of app are composed of the determinants of adopting e-government services (especially mobile e-government), disaster apps, and factors influencing map usability.

Among the prominent technology adoption models used in the context of e-government and mobile apps, the IS success model (W. H. DeLone & McLean, 1992; W. DeLone & McLean, 2003) was used, particularly its extended version developed by Rana et al. (2014), as the main base theory. The IS success model, which allows for the modification of constructs, was built exclusively for understanding the use of information technology (Urbach & Müller, 2012). It was selected for the following reasons. First, the model applies “intention to use” instead of “use” as the dependent variable, which suits the context of this study, which focused on examining a service or an information system from the perspective of potential adopters (not actual users) who have been exposed to how the system works and its benefits. Second, the model excludes the service quality construct, which also suits this study’s focus on a specific app. Service quality is concerned with measuring the quality of a service obtained by an IT department rather than the service of specific IT applications. Finally, the model includes perceived usefulness. The inclusion of perceived usefulness in this extended IS success model was based on Seddon and Kiew's (1996), and Seddon's (1997) criticism of the original IS success model of DeLone and McLean, which included perceived usefulness as an IS measure that influences user satisfaction. They conjectured that the underlying information system success construct is usefulness, not use. This notion is equivalent to the construct called perceived usefulness from the Technology Acceptance Model (TAM) (Davis, 1989). This construct posits that the user's behavioral intention is the single best predictor of actual system use determined by two particular beliefs: perceived usefulness and ease of use.

The extended version of the IS success model was developed from three constructs (perceived usefulness, information quality, and system quality) to examine two dependent variables (intention to use and user satisfaction) with eight hypotheses. These variables and hypotheses were first adapted to the context. Intention to use is defined as the degree to which people are likely to use SIKK Magelang. User satisfaction represents the feelings and attitudes that emerge after aggregating all the benefits that a person expects to receive from the app. User satisfaction is the citizens' ability to use the app to get the information they require and to address their concerns (Wirtz & Kurtz, 2016). System quality is concerned with whether there are "bugs" in SIKK Magelang, the user interface's consistency, ease of use, and sometimes the program code's quality and maintainability. In contrast, information quality is concerned with users' expectations regarding information relevance, timeliness, completeness, trustworthiness, accuracy, understanding, and significance.

Following TAM (Davis, 1989), perceived usefulness is a perceptual indicator of the degree to which one believes that using a particular system or service has enhanced their job performance. In this study, perceived usefulness is defined as the degree to which users believe that SIKK Magelang would enhance their knowledge of hazards and evacuation plans and inform about disaster events in the Magelang Regency. A great deal of prior research on e-government has supported the positive relationship between perceived usefulness and behavioral intention to use. For the context of mobile map services adoption, perceived usefulness was also found significant as a driver of intention to use (E. Park & Ohm, 2014). Based on this primary foundation model, the following is hypothesized:

H1: *System quality will have a significant and positive relationship with the perceived usefulness of SIKK Magelang.*

H2: *System quality will have a significant and positive relationship with the intention to use SIKK Magelang.*

H3: *System quality will have a significant and positive relationship with user satisfaction with SIKK Magelang.*

H4: *Information quality will have a significant and positive relationship with the perceived usefulness of SIKK Magelang.*

H5: *Information quality will have a significant and positive relationship with the intention to use SIKK Magelang.*

H6: *Information quality will have a significant and positive relationship with user satisfaction with SIKK Magelang.*

H7: *Perceived usefulness will have a significant and positive relationship with the intention to use SIKK Magelang.*

H8: *Perceived usefulness will have a significant and positive relationship with user satisfaction with SIKK Magelang.*

Several prior studies have reported a generally positive relationship between users' perceived satisfaction and usability of e-government services, information systems, and mobile technologies (e.g., Alawneh, Al-Refai, & Batiha, 2013; E. Park & Ohm, 2014; Wirtz & Kurtz, 2016). Therefore, a ninth hypothesis was added:

H9: *User satisfaction will have a significant and positive relationship with the intention to use SIKK Magelang.*

Many studies have empirically suggested the influence of Internet connection on the acceptance of e-services (e.g., Pikkarainen, Pikkarainen, Karjaluoto, & Pahnila; 2004; Rallis, Chatzoudes, Symeonidis, Aggelidis, & Chatzoglou, 2019; Sathye, 1999; Shareef, Kumar, Kumar, & Dwivedi, 2011). In the case of geographic information, poor Internet connection limits the import and uploading of the data and hinders geo-informatic training via distance learning (Teeuw et al., 2013). Thus, the Internet connection quality is also a vital driving force for the adoption of online maps. Accordingly, the following hypothesis is also added:

H10: *Quality of the internet connection will have a significant effect on the intention to use SIKK Magelang.*

Among the pronounced challenges that e-government faces are its lower suitability for poor, illiterate, and rural people due to this population's lack of resources and technological literacy (Murenzi & Olivier, 2017; Shareef et al., 2011). Such challenges are evident in developing countries, where resources such as electricity, computers, the Internet, and government support (e.g., via call-centers, resource-centers, or cyber-cafés) are scarce (Shareef et al., 2011). Hence, facilitating conditions are considered important and crucial. Facilitating conditions are defined as users' perceptions of the resources and support available to help them perform a behavior (Venkatesh et al., 2012). Facilitating conditions are measured by the perception of access to the required resources and knowledge and the necessary support needed to use a service (Al-Shafi & Weerakkody, 2010). The effect of facilitating conditions on the acceptance of e-services in prior literature has been mixed. Several studies have shown that facilitating conditions are insignificant as drivers of usage intention (e.g., Venkatesh, Morris, Davis, & Davis, 2003); however, other studies have shown the opposite (e.g., Dwivedi et al., 2017; Lallmahomed, Lallmahomed, & Lallmahomed, 2017; Verkijika & De Wet, 2018).

Facilitating conditions may also have an impact on perceived usefulness. In the e-learning system context, the information technology infrastructure significantly impacts perceived usefulness (Alsabawy et al., 2016). Thus, assuming the infrastructure is part of facilitating conditions, it can be predicted that facilitating conditions may correlate with perceived usefulness. Thus, the following is hypothesized:

H11: *Facilitating conditions will have a positive and significant effect on the perceived usefulness of SIKK Magelang.*

H12: *Facilitating conditions will have a positive and significant effect on the intention to use SIKK Magelang.*

Risk perception may also be significant as a predictor of usage intention (Fischer et al., 2019). This finding is supported by prior research done by H. Park and Lee (2018), which showed that risk perception, directly and indirectly, influenced one's intention to use an application for risk communication purposes and that risk-related perceptions (including perceived severity, perceived susceptibility, and response efficacy) are antecedents of risk-related information-seeking behavior and subsequently influence whether an individual accepts a new app for risk management developed by the government. Hence:

H13: Risk perception will have a significant influence on the intention to use SIKK Magelang.

H14: Risk perception will have a significant influence on information-seeking behavior.

H15: Information-seeking behavior will have a significant effect on the intention to use SIKK Magelang.

Users' familiarity with similar technology is also crucial when proposing a new technology for disaster-related purposes. Cheng and Mitomo (2017) found that the perceived usefulness of using smart wearable devices for disaster apps was influenced by the perceived usefulness of smart wearable devices (similar technology). In the context of map usability in an e-government app, Bishop, Haggerty, and Richardson (2015) found that although the app was well-understood (practical) and satisfying in its completion of various tasks, users had some issues regarding the efficiency of the app, including users' unfamiliarity with its functionality and features. Therefore:

H16: Familiarity with online maps will positively and significantly affect the perceived usefulness of SIKK Magelang.

H17: Familiarity with online maps will positively and significantly affect the intention to use SIKK Magelang.

Based on the literature review, a model was proposed to explain the adoption of the app (**Figure 3.19**)

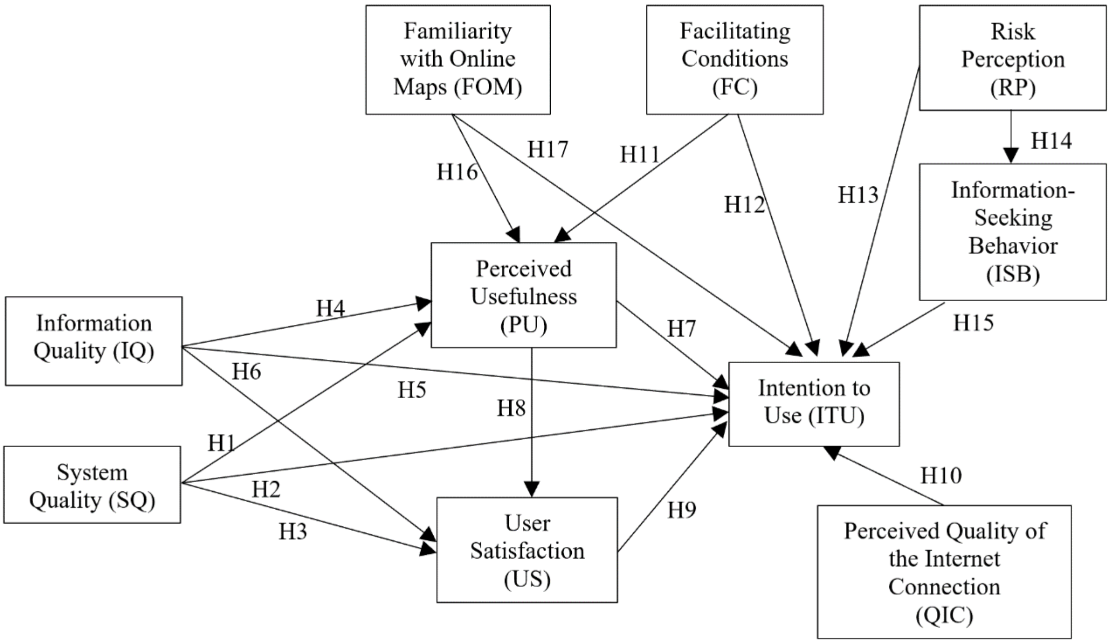


Figure 3.19 Proposed Research Model

2. Measurements of the Factors

To test the research model, a questionnaire survey was conducted. The constructs were adapted from previous literature to ensure survey content validity. A pretest was used to validate and evaluate the interpretability and clarity of the instrument. The measurement of the constructs involved using multi-item reflective scales, which enhanced confidence that the measurements were consistent.

The key factors related to intention to use SIKK Magelang were captured by information quality, system quality, facilitating conditions, familiarity with online maps, perceived quality of the Internet connection, perceived usefulness, user satisfaction, risk perception, and information-seeking behavior. Each construct was comprised of several items to measure a scale. All measures except the risk perception and information-seeking behavior constructs were assessed via a five-point Likert scale ranging from "1 = strongly disagree" to "5 = strongly agree." Risk perception items were assessed by a five-point scale from “1,” representing “not probable,” to “5,” representing “very probable.” Information-seeking behavior items were assessed by a five-point Likert scale ranging from “1 = never” to “5 = every time.” Thirty-five items measured ten latent variables in addition to several items to gather background information for the data analysis and model validation (see **Table 3.3**). Nine independent variables were proposed as the antecedents of intention to use a map-based disaster application, including information quality, system quality, familiarity with online maps, perceived usefulness, user satisfaction, facilitating conditions, risk perceptions, information-seeking behavior, and perceived quality of the Internet connection. Information-seeking behavior was also predicted to be influenced by risk perception.

Table 3.3

Constructs and Items Used in the Model

No.	Constructs	Items	
1.	**Intention to Use (ITU)**	ITU2	I am willing to use SIKK Magelang for decision making.
		ITU3	I recommend using SIKK Magelang as a source of disaster information to my family members and my friends.
2.	**User Satisfaction (US)**	US1	I am satisfied with the information and records about disaster occurrences on SIKK Magelang.
		US3	I am satisfied with the assembly points visualization on SIKK Magelang.
		US4	I am satisfied with information about evacuation routes visualization on SIKK Magelang.
3.	**Perceived Usefulness (PU)**	PU1	I now understand which areas in Magelang Regency frequently see natural disasters.
		PU3	I am now aware of what hazards may threaten the place where I work.
		PU4	I am now aware of what hazards may threaten other places in Magelang Regency.

		PU5	I now understand which nearby assembly points to go to during an emergency.
		PU7	I understand what actions to take during an emergency.
4.	**Information Quality (IQ)**	IQ1	The disaster information and maps on SIKK Magelang are useful.
		IQ3	The disaster information and maps on SIKK Magelang are interesting.
		IQ4	The disaster information and maps on SIKK Magelang are complete/comprehensive.
		IQ5	The disaster information and maps on SIKK Magelang are trustworthy.
5.	**System Quality (SQ)**	SQ1	SIKK Magelang is easy to access anywhere.
		SQ3	SIKK Magelang is easy to access via any device, including a cellphone or laptop.
		SQ5	SIKK Magelang is reliable as a source of disaster maps.
		SQ8	SIKK Magelang is reliable as a source of evacuation sites.
		SQ9	SIKK Magelang makes it is easier for me to access necessary disaster information.
6.	**Perceived Quality of the Internet Connection**	QIC1	Internet connection and network in this area is good.
		QIC2	Internet connection quality on my devices is good.
7.	**Facilitating Conditions (FC)**	FC1	My devices (cellphone/laptop) are compatible with SIKK Magelang.
		FC2	I use the Internet often.
		FC3	I often look up information via the Internet.
		FC4	I am able to and often communicate using SNSs like WhatsApp/Facebook/Instagram.
8.	**Familiarity with Online Maps (FOM)**	FOM2	It is very easy for me to find locations using online maps (e.g., Google Maps).
		FOM3	I use online maps (e.g., Google Maps) often.

9.	**Risk Perception (RP)**	RP2	It is likely that I will die or be injured by natural disasters (either volcanic eruptions, landslides, or any others).
		RP3	It is likely that my family members will die or be injured by natural disasters (either volcanic eruptions, landslides, or any others).
		RP4	It is probable that my house or properties will be damaged because of natural disasters (either volcanic eruptions, landslides, or any others).
10.	**Information-Seeking Behavior (ISB)**	ISB1	I frequently discuss natural disasters and their impacts with my family.
		ISB2	I often discuss natural disasters and their impacts with others (e.g., neighbors).

3. Analysis of the Measurement Model and Hypotheses Testing

Both convergent and discriminant validities were assessed to test the measurement model. Convergent validity was supported after examining item loadings, Cronbach's alpha, composite reliabilities, and average variance extracted (AVE). **Table 3.4** summarizes the results of the convergent validity and discriminant validity test of the variables used in this study. First, each measurement item should significantly load on its latent construct (Gefen et al., 2000). The resulting factor loadings ranged from 0.774 to 0.975, all of which exceeded the cut-off value of 0.5 recommended by Straub (1989).

The measurement model's internal reliability was tested using Cronbach's alpha (Fornell & Larcker, 1981). Cronbach's alpha should be greater than 0.70 to indicate strong reliability of questionnaire content (Nunnally & Bernstein, 1994). The Cronbach's alpha values of all nine variables were found to be higher than 0.70. The smallest was 0.796 for risk perception, indicating the strong reliability of the questionnaire content.

Table 3.4

Results of Convergent and Discriminant Validity (N=220)

Constructs (Latent Variables)	#items	Loadings	α	CR	AVE
Facilitating Conditions (FC)	4	0.833 – 0.901	0.898	0.929	0.765
Familiarity with Online Maps (FOM)	2	0.944 – 0.962	0.900	0.952	0.908
Information Quality (IQ)	4	0.909 – 0.935	0.943	0.959	0.855
Information-Seeking Behavior (ISB)	2	0.890 – 0.956	0.836	0.921	0.854
Intention to Use (ITU)	2	0.963 – 0.965	0.925	0.964	0.930
Perceived Usefulness (PU)	5	0.877 – 0.923	0.946	0.959	0.823
Perceived Quality of the Internet Connection (QIC)	2	0.962 – 0.975	0.934	0.968	0.938
Risk Perception (RP)	3	0.774 – 0.899	0.796	0.858	0.669
System Quality (SQ)	5	0.863 – 0.928	0.939	0.953	0.803
User Satisfaction (US)	3	0.928 – 0.953	0.936	0.959	0.887

α: Cronbach's Alpha, CR: Composite Reliability, AVE: Average Variance Extracted,

Afterward, the convergent validity of the proposed model was assessed by examining the AVE and the composites' reliability. For composite reliability, 0.6 is the recommended cut-off value (Bagozzi & Yi, 1988). In this study, all composite reliability values exceeded this threshold, ranging from 0.858 (risk perception) to 0.968 (perceived quality of the internet connection) and demonstrating composite reliability. According to several scholars (e.g., Hair Jr., Black, Babin, & Anderson, 2010), AVE values should be greater than 0.5 to validate convergent validity. As shown in **Table 3.4**, all AVE values exceeded the recommended threshold value of 0.5, ranging from 0.669 (risk perception) to 0.938 (perceived quality of the internet connection), again demonstrating convergent validity, which means the measures of latent variables are valid. Fornell and Larcker (1981) stated that AVE's square root needs to be higher for this construct than its correlation with other constructs to establish the construct discriminant validity. **Table 3.5** shows the square root of the variance shared between the construct. Its items were greater than the correlations between the construct and any other construct in the model, satisfying the discriminant validity criteria. All diagonal values exceeded the inter-construct correlations, and the results confirmed that the instrument had satisfactory construct validity.

Table 3.5

Correlation Matrix

	FC	FOM	IQ	ISB	ITU	PU	QIC	RP	SQ	US
FC	**0.875**									
FOM	0.705	**0.953**								
IQ	0.602	0.622	**0.924**							
ISB	0.03	0.077	0.059	**0.924**						
ITU	0.573	0.588	0.827	0.07	**0.964**					
PU	0.649	0.629	0.873	0.046	0.844	**0.907**				
QIC	0.502	0.492	0.514	0.164	0.504	0.456	**0.968**			
RP	0.329	0.194	0.247	0.159	0.191	0.296	0.16	**0.818**		
SQ	0.691	0.718	0.841	0.076	0.77	0.799	0.618	0.245	**0.896**	
US	0.586	0.588	0.891	0.042	0.836	0.847	0.503	0.232	0.784	**0.942**

Notes: The bold values on the diagonal represent the square root of the AVE. Other entries represent intercorrelations of the constructs.

Table 3.6 summarizes the parameter estimates, significance levels, and hypotheses test results, while **Figure 3.20** illustrates the relationships between the hypothesized variables. Six of the 17 constructs were significantly supported by the results. Perceived information quality positively influenced perceived usefulness (H4) and user satisfaction (H6). Facilitating conditions positively influenced perceived usefulness (H11). In turn, perceived usefulness positively influenced intention to use (H7) and user satisfaction (H8). Finally, user satisfaction positively influenced intention to use (H9). This study failed to significantly support the new proposed constructs (i.e., risk perception and familiarity with maps) as drivers of intention to use. While H8 was found significant at $p < 0.01$, the other five hypotheses were found significant at levels of p <

0.001. Overall, a substantial amount of variance is explained in the dependent variable, i.e., the intention to use SIKK Magelang. Its R^2 value of 0.779 indicates that the nine independent factors predicted a substantial proportion of variance as the larger the R^2, the more the framework's predictive power (Hair Jr. et al., 2010).

Table 3.6

Hypotheses Testing Results

H#	**Hypothesis**	**Path coefficient**	**t-value**	**p-value**	**Hypothesis status**
H1	SQ → PU	0.112	1.648	0.100	Not supported
H2	SQ → ITU	0.101	1.501	0.134	Not supported
H3	SQ → US	0.060	0.816	0.415	Not supported
H4	**IQ → PU**	**0.675**	**11.207**	**0.000**	**Supported**
H5	IQ → ITU	0.081	0.800	0.424	Not supported
H6	**IQ → US**	**0.602**	**7.692**	**0.000**	**Supported**
H7	**PU → ITU**	**0.421**	**4.244**	**0.000**	**Supported**
H8	**PU → US**	**0.273**	**3.369**	**0.001**	**Supported**
H9	**US → ITU**	**0.319**	**3.751**	**0.000**	**Supported**
H10	QIC → ITU	0.061	1.447	0.149	Not supported
H11	**FC → PU**	**0.147**	**3.663**	**0.000**	**Supported**
H12	FC → ITU	-0.023	0.549	0.583	Not supported
H13	RP → ITU	-0.059	1.476	0.140	Not supported
H14	RP → ISB	0.159	1.660	0.098	Not supported
H15	ISB → ITU	0.024	0.653	0.514	Not supported
H16	FOM → PU	0.025	0.545	0.586	Not supported
H17	FOM → ITU	0.009	0.186	0.852	Not supported

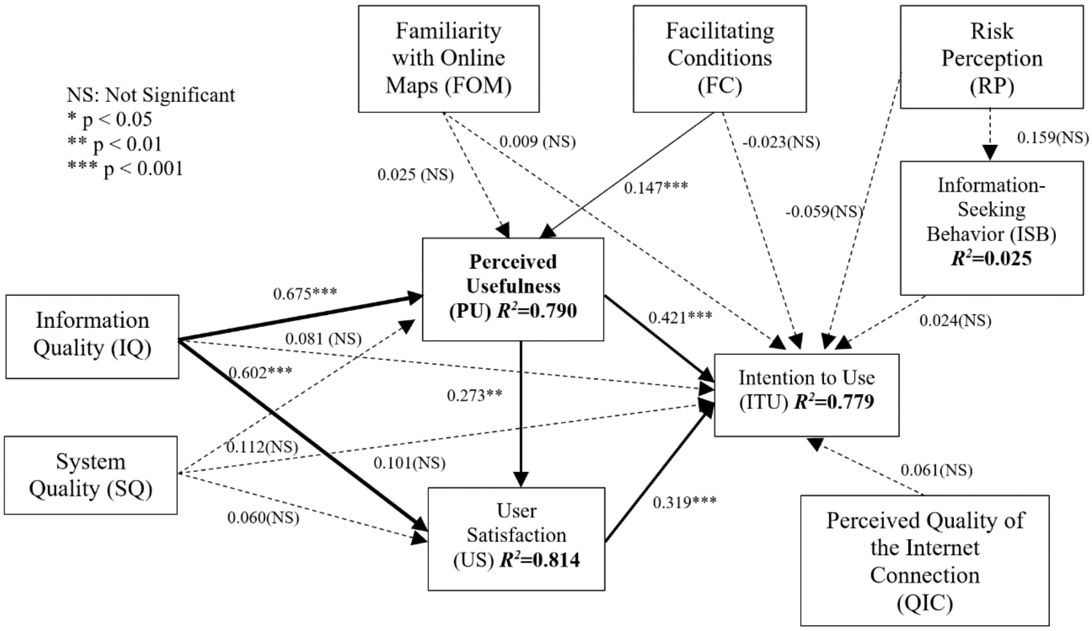


Figure 3.20 The Validated Model Visualizing Factors Influencing Users' Intention to Use SIKK Magelang

4. *Significant Factors Directly Affecting Intention to Use SIKK Magelang: Perceived Usefulness and Satisfaction*

The extended IS success model (Rana et al., 2014) that was adopted as the main foundation of this study hypothesizes that intention to use is directly influenced by information quality, perceived usefulness, and system quality. However, this study could only significantly prove the direct influence of perceived usefulness on usage intention. While system quality had no significant effect, direct or indirect, on the intention to use, information quality indirectly influenced intention to use via perceived usefulness, user satisfaction, and both (IQ → PU → ITU was significant at $p < 0.001$, IQ → US → ITU was significant at $p < 0.01$, and IQ → PU → US → ITU was significant at $p < 0.001$).

The correlation between perceived usefulness and intention to use was relatively strong, as indicated by the path coefficient value (0.421). It is also evident from the analysis that the app's perceived usefulness led respondents more toward their intention to use it rather than toward being satisfied (as shown by the path coefficients). This finding supports perhaps the most basic notion of technology acceptance; namely, perceived usefulness is the main determinant of technology adoption. This finding also aligns with the many articles that have discussed perceived usefulness as a dimension of disaster risk management technology (e.g., Aloudat et al., 2014; Meechang et al., 2020). When technology makes a task easier for an individual, dependency on the technology will likely take place, and thus usage will be prolonged. This important aspect of perceived usefulness suggests emergency managers should emphasize the usefulness of a disaster app, such as by allowing citizens, especially those who live in high-risk areas, to participate in the app's development and share ideas regarding what information should be included.

When comparing respondents' demography (i.e., gender, age, level of education, and experiences as disaster victims) by performing a multi-group analysis (PLS-MGA), it was found that the relationship between perceived usefulness and intention to use was not sensitive to respondents' characteristics. First, regarding the sex of the respondents, the path coefficient value for females is 0.423, while for males, it is 0.359, indicating the more substantial relationship of PU to ITU for female respondents. Nevertheless, the result of the PLS-MGA showed that these differences were insignificant ($p = 0.735$). Regarding the respondents' educational background, the path coefficient for those who finished elementary school and no formal education cannot be generated. The path coefficient value for those with a degree is 0.503, while for those who only finished junior and senior high school is 0.374 and 0.328, respectively. These figures indicate that those who have higher education than only finishing high school tend to have a more decisive influence of intention to use from perceived usefulness; however, the results of the PLS-MGA showed that these differences were insignificant (p values > 0.10). For age, respondents were regrouped into three groups: < 20 years old, 20-50 years old, and >50 years old. The path coefficient value for the youngest group is 0.470, for those aged 20-50 years old it is 0.292, and for the oldest group it is 0.368, indicating that the influence of perceived usefulness on the intention to use is biggest for teenagers; however, after performing the PLS-MGA, these differences were not significant. Finally, regarding their experience as victims of disasters, disaster victims' path coefficient is higher than those who were not (0.451 and 0.318, respectively); however, these different coefficients are not significant.

In addition to perceived usefulness, the model also indicates that user satisfaction enhances the intention to use SIKK Magelang. This finding is relevant to the study of E. Park and Ohm (2014), which showed that satisfaction and perceived usefulness are the most significant antecedents of users' intention to use mobile map services. A significant correlation between satisfaction and usage intention has been identified in numerous prior studies on e-government (e.g., Alawneh et al., 2013; Wirtz & Kurtz, 2016) and has been a focus in the improvement of public administrations. User satisfaction is crucial for an e-service developed by governments; to guarantee the adoption and continued usage of e-government, governments must ensure citizens have higher satisfaction levels.

User satisfaction and perceived usefulness were found to be significantly correlated with information quality, a finding that has also been supported by prior literature (e.g., E. Park & Ohm, 2014; Petter, DeLone, & McLean, 2008; Rana et al., 2014; Rana, Dwivedi, & Williams, 2013). Thus, an improvement in the information quality of SIKK Magelang is likely to increase user satisfaction and perceptions of the app's usefulness. The user satisfaction of SIKK Magelang was also influenced by perceived usefulness. This finding is consistent with the base theories and models (Rana et al., 2013, 2014; P. B. Seddon, 1997) and much other literature (e.g., Almarashdeh, 2016; Xu & Du, 2018).

While facilitating conditions are believed to be a direct determinant of the user behavior of adopting new technology (Venkatesh et al., 2012), this study showed that facilitating conditions did not directly contribute to intention to use SIKK Magelang. This finding is nonetheless consistent with Venkatesh et al. (2003). Facilitating conditions had a significant and positive correlation with perceived usefulness. An indirect effect of facilitating conditions on intention was also found. Facilitating conditions affected perceived usefulness before influencing intention to use (FC → PU → ITU was significant at $p < 0.05$). Thus, if a country lacks the skills and resources to make e-government available to all citizens equally, the government should not expect the same aptitude from all citizens in adopting the system. In other words, if the digital divide is not reduced first, the adoption of e-government is unlikely to be successful.

While prior literature has suggested a positive correlation between the quality of the Internet connection and intention to use (Pikkarainen et al., 2004; Rallis et al., 2019), an insignificant relationship between these constructs was found. In addition, users' experience with using online maps, such as Google Maps, or their ability to use online maps in general (e.g., to locate themselves) was not significantly correlated with intention to use SIKK Magelang.

3.4 Conclusion

To conclude this chapter to some extent could prove some of the propositions toward better distribution and use of spatial information about disasters for risk communication in Indonesia. From the user context this chapter have provided some factors that need to be considered if local governments in Indonesia would like to apply using a map-based disaster application for communicating disaster risks to their community, especially in the context of people who are living in areas similar to Magelang Regency.

In the beginning of this dissertation, it was found that governments in Indonesia, especially at the local level, appear reluctant to employ map-based approaches using recently available technologies for delivering spatial information about disasters which indicates the lower utilization of spatial information for risk communication at the local level. The first chapter of this dissertation also found that spatial information about disasters is fragmented. In this chapter the Author have provided some best practice examples from other countries, especially Japan that can be useful for improving more accessible and suitable spatial information disasters for public risk communication in Indonesia. Some important points for the supply side can be summarized including (1) the selection of hazard maps if the purposes of risk communication is about to increase hazard risk awareness of the community, (2) strengthening the role of each level government in Indonesia, especially each level of disaster management agency in the production and distribution of the spatial information by formulating clear and more specific regulations and guidelines, and (3) to build a central repository for connecting all sources of spatial disaster information from all municipalities to make public easier and more convenient accessing the information.

Meanwhile for evaluating the user side of the utilization of spatial information about disasters, this chapter brought an example of a local government initiative of using free and open-source geospatial information technology for developing a map-based disaster application, namely SIKK Magelang for public risk communication purposes. The use of this technology has made the cost cheaper and the maps become more interactive rather than using a conventional method of printed maps. However, this study found that this application has not been familiarized by its targeted users indicated by the low awareness and lack of usage. This study has proven that lack of awareness is associated with intention to use the application.

The problems of low usage and low awareness maybe related to the less promotion and then absence of proper manual for using the application. It is because based on findings from the experiment, after respondents were given chance to try the application after received explanation about the application, they show a high intention of to use SIKK Magelang as a source of disaster information. Thus, clear manuals are inevitable after better promotion.

Problems of low adoption and low usage were further examined by assessing factors influencing intention to use by using a path analysis. Since the number of local risk managers and disaster volunteers are not sufficient to perform the statistical analysis, only public users that were further analyzed. Using the PLS-SEM approach, this research has identified several factors that influence the intention to use SIKK Magelang. The findings of this study indicated that intention to use was significantly affected by perceived usefulness and user satisfaction. Perceived information quality was the only factor that significantly influenced perceived usefulness and user satisfaction.

CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

This final dissertation chapter concludes overall research findings. The chapter also presents this study's contributions and recommends issues need to be addressed in future research.

A. Conclusion

One of the main principles of disaster risk reduction is that stakeholders and the public must first understand their disaster risks as a prerequisite in minimizing damages caused by natural hazards. Since hazards have a strong spatial component, spatial information about disasters, mostly formed as maps, therefore, are promising to communicate risks of natural hazards to increase public awareness on the surrounding hazard risks.

This dissertation has provided knowledge on the way spatial information is utilized in a developing country for public risk communication purposes by using two approaches both from the supply side (i.e., governments as the information providers) and the user side (i.e., public and relevant users) which has been rare in the literature as has been stated by Thomas (2018). This study met the three objectives presented in the beginning of the dissertation as follow:

1. To examine the existing situation in Indonesia regarding the way spatial information (maps) about disasters is disseminated to the public for risk communication purposes (**RO1**).

2. To assess the effectiveness of using spatial information for risk communication (**RO2**).
3. To identify factors needed for improvements of dissemination and adoption of spatial information about disasters for risk communication (**RO3**).

The first chapter of this dissertation has been able to answer the first two research questions related to the achievement of the first objective as follow.

- **RQ1.1**: How is spatial information about disasters disseminated to the public for risk communication purposes in Indonesia?
    - This study found that spatial information about disasters in Indonesia is fragmented and compiled in a wide variety of layouts, largely due to the absence of specific regulations or guidelines for information production and dissemination. Existing regulations also fail to clarify the role of each government level in providing this type of information.
    - Thus, the first hypothesis **RH1.1**: Spatial information about disasters is not widely available online and the way it is produced by different levels of government vary **is accepted.**
- **RQ1.2**: How suitable is the available information for communicating the spatial aspect of disaster risks?
    - By reviewing and comparing the availability of spatial data and information, especially at the local level, to the public, this study found that the quality of disaster maps at the local level and, especially, at the municipal level is inferior and unsuitable for risk communication purposes. This raises concerns regarding ways to improve spatial information about disasters, particularly at the local level. At the national level, while spatial information about disasters

is more varied, maps have insufficient detail and information for public consumption, making them unsuitable for use by laypeople. Such national government-provided information is more appropriate for experts and governments.

- Thus, the second hypothesis **RH1.2**: Based on an evaluation using effective map criteria, the available information is not suitable for risk communication **is accepted.**

The second chapter of this dissertation has been able to answer the next two research questions related to the achievement of the second objective as follow.

- **RQ2.1:** To what extent does currently available spatial information about disasters can affect one's spatial awareness hazards and risk perception?
  - This study found that to some extent, providing spatial information about disasters increases risk perceptions and hazard awareness. While risk perceptions can be different based on variations in the respondents' characteristics, increases in hazard awareness depend on the types of hazards. To some extent, giving spatial information about disasters was found to significantly stimulate changes in the participants' attitudes toward the evacuation plan and the intention to better understand information about the hazards and risks.
  - Thus, to conclude, the third hypothesis **RH2.1**: Spatial information to some extent can affect one's spatial awareness of hazards and risk perception **is partially accepted.**

- **RQ2.2:** How readable are both printed maps and map-based disaster applications as sources of the spatial information about disasters?
  - This study found that, to some extent, InaRisk Personal is readable and satisfying, indicating that the application might have good potential for learning about disasters, particularly for young people. This segment of the population is highly exposed to the internet; thus, it is reasonable to have them as the application's prioritized targeted users. When the application was compared to the printed maps, it was also found that high school students rated InaRisk Personal as being more preferred, readable, and satisfying for learning about disasters than regular printed maps. Most of the students in this study preferred to learn about disasters through cartographic visualizations on the mobile application with suggestions for improvements, rather than using printed maps. Thus, local governments in the study areas may consider having their own self-developed disaster map-based applications to complement their regular disaster map dissemination.
  - Thus, the third hypothesis **RH2.2**: Compared to printed maps, map-based disaster applications are more readable **is accepted.**

The third chapter of this dissertation has been able to answer the final two research questions related to the achievement of the third objective as follow.

- **RQ3.1:** What aspects should be improved for better spatial information-mediated risk communication?
  - In the third chapter, the Author have provided some best practice examples from other countries, especially Japan that can be useful for improving more

accessible and suitable spatial information disasters for public risk communication in Indonesia. Some important points for the supply side can be summarized including (1) the selection of hazard maps if the purposes of risk communication is about to increase hazard risk awareness of the community, (2) strengthening the role of each level government in Indonesia, especially each level of disaster management agency in the production and distribution of the spatial information by formulating clear and more specific regulations and guidelines, and (3) to build a central repository for connecting all sources of spatial disaster information from all municipalities to make public easier and more convenient accessing the information.

- Thus, the fifth research hypothesis **RH3.1** Based on the evaluation of recent conditions and learning from best practices from other countries, visualization aspects and use of proper technology are among the important aspects for the improvement **is partially accepted.**

- **RQ3.2:** What factors influence individuals' intention to use spatial information about disasters?
    - In chapter three, problems of low adoption and low usage were further examined by assessing factors influencing intention to use by using a path analysis. Since the number of local risk managers and disaster volunteers are not sufficient to perform the statistical analysis, only public users that were further analyzed. Using the PLS-SEM approach, this research has identified several factors that influence the intention to use SIKK Magelang. The findings of this study indicated that intention to use was significantly affected by perceived usefulness and user satisfaction. Perceived information quality was

the only factor that significantly influenced perceived usefulness and user satisfaction.

- Thus, the last hypothesis of this dissertation study **RH3.2**: Information quality, system quality or ease of use, user satisfaction, perceived usefulness, map-related factors, risk perceptions, and facilitating conditions (e.g., available resources and internet connection quality) significantly influence intention to use **is partially accepted.**

B. Research Contributions

By extending the information system success model, this research has tried to develop a model for explaining factors affecting intention to use a map-based disaster application, although some proposed factors in the validated model were not significant in influencing users' intention to use a map-based disaster application. Models and factors explaining intention to use a disaster application have been rare in existing literature

The model shows that map-related efficacy, risk perception-related, and technology-related factor was insignificant in influencing ones' intention to use the application. Based on this study, perceived usefulness and satisfaction were found as the most relevant factors. These two factors can be considered by other scholars as a start of future development of the model or similar studies that also aim to find out factors that affect use of a disaster application or a map-based application that recently their existence has been growing in the market.

The most important one, this research has contributed to literature on how technology, especially spatial information technology has made some implication to disaster risk communication.

By drawing cases in Indonesia, this research has contributed on the findings on the use of spatial information for risk communication from the perspective a developing country, which still faces a limited technology adoption, but has a rapidly growing internet users as the potential target of technology users.

C. Recommendations for Future Research

1. As this study only provides a model for explaining factors affecting intention to use a digital map, future studies should also include a comparison with the model for conventional type of maps (i.e., printed maps) with similar contents.
2. In regard to readability, the contents provided by the application and the printed maps were different and may be resulting in some biases on the visualization of hazard prone areas. The biased results of the printed maps may be due to the poor quality of the map design (i.e., selection of colors and absence of labels and annotations). Thus, future studies should more carefully use exactly similar spatial information but with different tools to analyze more on this readability issue.
3. Future studies should also include a comparison with developed countries that has advanced technology and with a similar developing or less developed countries to more comprehensively understand the impact of spatial changing phenomena to risk communication.

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