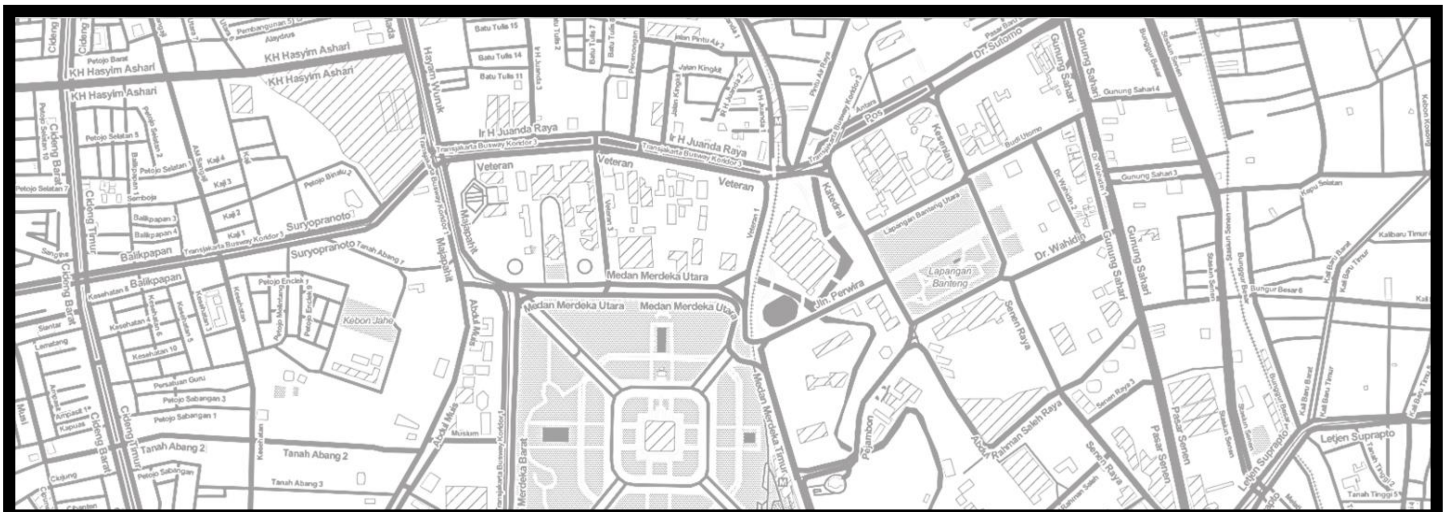

# Volunteered Geographic Information (VGI) for Disaster Management

## A Case Study for Floods in Jakarta

A thesis submitted in partial fulfilment

of the requirements for the Degree of

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by


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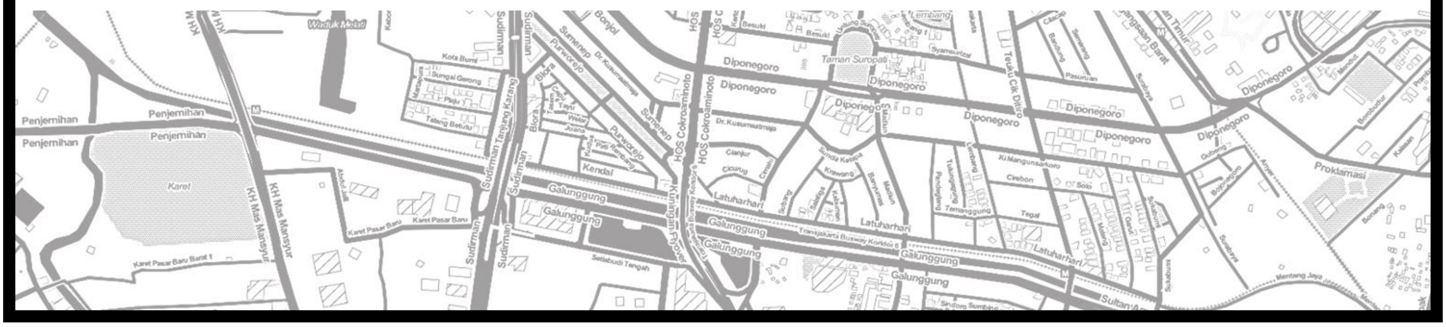

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# Acknowledgements

When I started this thesis, I understood that my journey would be challenging. The monster I was fighting had many heads: dealing with grief, feeling lost, anxious that I'm going to fail, and so on. However, I'm extremely humble and grateful for the great deal of support that I had from others during my thesis journey. Without each and every one mentioned here, this thesis would have been impossible to finish.

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I understand that the completion of this thesis may not be perfect. However, I hope that everyone would learn something useful from it. Additionally, I would appreciate any feedback from everyone, so that I can improve my future work.

# Abstract

Existing studies reveal that Geographic Information Systems (GIS) can be used to enhance disaster management for reducing disaster risks. However, geospatial information acquisition is a key challenge when using GIS for disaster management, particularly in developing countries. A number of studies reveal that Volunteered Geographic Information (VGI) has potential as an alternative method for collecting geospatial information in disaster management. Researchers have called for the development of a framework to account VGI issues.

This thesis presented a framework to improve VGI use in disaster management by using a qualitative case study of VGI use for flood management in Jakarta. Two qualitative techniques were applied for data collection to identify VGI potential, limitations, and opportunities in disaster management: (i) in-depth structured interviews of 13 participants with experience in producing, managing, and using VGI for disaster management in Jakarta, and (ii) a focus group discussion (FGD) with 13 individuals from a local community with experience in conducting VGI activities to reduce flood risks in their local area. Thematic analysis was used to analyse the qualitative data.

Findings from this thesis include how stakeholders in Jakarta are extending the use of VGI in management by using collaborative mapping and geo-located reporting tools. VGI can provide advantages, such as cost-benefit ratios, functionality, and knowledge adding attributes. This thesis also identified that VGI issues comprise legal, credibility, public participation, stakeholder engagement, and interoperability. A key contribution of this thesis is a VGI-disaster management framework which comprises non-technical and technical components. This framework builds a strong foundation to enable VGI proliferation in disaster management for government and non-government.

**Keywords:**

Volunteered Geographic Information (VGI), Geographic Information Systems (GIS), crowdsourcing, disaster management, flood management

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# Acronyms and Abbreviation

| | |
|---|---|
| BIG | : *Badan Informasi Geospasial* (Indonesia's Geospatial Information Agency) |
| BNPB | : *Badan Nasional Penanggulangan Bencana* (Indonesia's Board of Disaster Management) |
| BPBD DKI Jakarta | : *Badan Penanggulangan Bencana Daerah* (Jakarta Province's Disaster Management Agency) |
| DRR | : Disaster Risk Reduction |
| ESRI | : Environmental Systems Research Institute |
| FGD | : Focus Group Discussion |
| GIS | : Geographic Information Systems |
| GPS | : Global Positioning System |
| ICT | : Information and Communication Technology |
| IDP | : Internally Displaced Person |
| NGO | : Non-Government Organisation |
| OSM | : OpenStreetMap |
| RW | : *Rukun Warga* (sub-village administration unit in Indonesia) |
| SDI | : Spatial Data Infrastructure |
| UI | : User Interface |
| UNISDR | : United Nations of International Strategy for Disaster Reduction |
| UX | : User Experience |
| VGI | : Volunteered Geographic Information |

# 1 Introduction

## 1.1 Purpose

A disaster is defined as an event which happens with or without warning and causes serious disruption to the functioning of a community or a society (Teodorescu, 2014). Humans cannot prevent natural disasters, but the risks can be reduced by understanding their differing characteristics (Abbas et al., 2009). The use of Geographic Information Systems (GIS) is considered as one of the most important information and communication technology (ICT) tools for disaster management (Reinhardt, 2014). GIS can enhance the management of disasters and emergencies to reduce risks associated with disaster (van Oosterom et al., 2005). However, there are challenges associated with geospatial data acquisition when using GIS for disaster management as the required data might be difficult to acquire, obsolete or non-existent (ESRI et al., 2000).

Volunteered Geographic Information (VGI) is a phenomenon where a number of untrained people produce geographic data or information voluntarily with various tools (Goodchild, 2007a). VGI is a potential solution to the geospatial data challenge as non-experts can create and provide geographic data or information from Global Positioning Systems (GPS), mapping software, and other technologies (Goodchild, 2009). The characteristics of VGI data are different to authoritative data (valid or trusted data that is recognised by government agencies) because of the diversity of the contributing citizens as data producers and their reasons or aims behind their involvement (Sui et al., 2013). VGI is also closely related to the concept of crowdsourcing (Howe, 2010). VGI activities are supported by the internet technologies to acquire and host the geographic information offered by non-experts (Foody et al., 2013), some examples include:

- OpenStreetMap (OSM)[1] – a collaborative project to create a free editable map of the world.
- Wikimapia[2] – similar with OSM, this project also focuses to create a free editable map of the world.

[1] http://openstreetmap.org

[2] http://wikimapia.org

- Waze[3] – a community-based traffic and navigation, where drivers able to share real-time traffic and road information to other drivers.

Disasters create a time-critical need for geographic information and VGI can fill this need with near real-time information (Goodchild & Glennon, 2010). VGI is widely used during disaster response and recovery, for example, during the 2010 earthquake response in Haiti (Haklay et al., 2014; Meier, 2012), the 2013 typhoon Haiyan in the Philippines (Haklay et al., 2014), and Calgary's 2013 floods in Canada (Schnebele et al., 2014). Geographic information collected through a volunteered process has been useful for immediate emergency response when emergency responders demand up-to-date geographic information to ensure the needs of victims are met and resources are allocated appropriately. Additionally, VGI has been useful for preliminary damage assessment to assist the recovery process during post-disaster events. Beyond the immediate response and recovery stages in disaster management, the application of VGI for the other two stages, that of mitigation and preparedness, is little researched (Haworth & Bruce, 2015).

Using VGI in disaster management is not without issues. Legal issues can include copyright conflicts, specifically when authority wants to use and integrate VGI with authoritative sources (Haklay et al., 2014; Neis & Zielstra, 2014; Scassa, 2013; See et al., 2016). Credibility issues arise because VGI can be produced by anyone, regardless of their expertise (Ballatore & Zipf, 2015; Flanagin & Metzger, 2008; Foody et al., 2013; Goodchild, 2007a; Schnebele et al., 2014). Other possible issues relate to public participation, stakeholder engagement and interoperability (See et al., 2016). As is obvious from these issues, previous studies have called for the development of a framework to improve VGI use in disaster management (Doris et al., 2013; Fazeli et al., 2015; Goodchild & Glennon, 2010; Haworth, 2016). This thesis aims to identify a framework to improve VGI use in disaster management. To achieve this objective, this research employs a qualitative case study of floods in Jakarta.

[3] http://waze.com

## 1.2 Research Questions

Using a case study of floods in Jakarta, this thesis explores the current and potential uses of VGI across all four stages of the disaster management cycle, and develop a framework to improve VGI use for disaster management. Accordingly, this thesis addresses the main research question:

**“What is an appropriate framework to improve VGI use for disaster management using Jakarta flood risk mapping as a case study?”**

Jakarta, the largest city and the capital of Indonesia, has a major flooding problem. Floods occur regularly, especially during the monsoon season, and have a major impact on the city, threatening a population of 10 million (Jakarta, 2014). Floods have displaced thousands of people, paralysed the transportation system, affected social and economic activities and resulted in billion dollar losses in 2002, 2007, 2013, and 2014 (Marfai et al., 2014). Available evidence on application of VGI within a disaster management cycle exists in Jakarta (Chapman, 2012; Haklay et al., 2014; Holderness & Turpin, 2015). This situation makes Jakarta is suitable for the subject of the case study.

To answer the research question above, it is important to identify the current practice of VGI use in disaster management, including its potential, limitations, and opportunities. Additionally, this thesis also addresses the following sub-questions:

1. **What is the current practice (data requirement, collection method, and data use) of VGI at each disaster management stage?**
2. **What are the advantages of the use of VGI at each disaster management stage?**
3. **What are the issues that affect the current use of VGI at each disaster management stage?**
    a. **What are the issues related to legal and policy for the use of VGI in disaster management context?**
    b. **What are the issues related to VGI credibility in a disaster management context?**
    c. **What are the issues related to public participation with VGI use in a disaster management context?**

   d. **What are the issues related to stakeholder engagement of VGI use in a disaster management context?**
   e. **What are the issues related to the VGI interoperability in a disaster management context?**
4. **What is a possible way to overcome the issues of VGI use in disaster management?**

## 1.3 Structure of Thesis

This thesis comprises six chapters. The second chapter (Literature Review) reviews the relevant literature and explores the main concepts of VGI and disaster management, including their definitions. Additionally, the second chapter also covers the case study location. The third chapter (Research Methodology) describes the overall research design and qualitative methodological process. The in-depth interview and focus group processes used for data collection and the thematic process for the analysis are explained. The fourth chapter (Results) describes the results and preliminary findings. The fifth chapter (Discussion) provides a discussion of the interviews and focus group results, and places key findings within the literature. Furthermore, a key contribution of this thesis provides a framework for VGI use in disaster management. Finally, the sixth chapter (Conclusion) concludes the research by outlining key findings and limitations, including the opportunities for further research.

# 2 Literature Review

Many studies have explored the use of Volunteered Geographic Information (VGI) in disaster management. These studies focus on VGI's potential to solve geospatial data acquisition challenges, and some have illustrated the practical use of VGI in disaster management. This chapter provides an overview of these work, including details of the relevant concepts in VGI application for disaster management. First, the concepts of disasters, disaster management (including its cycle), and the role of Geographic Information Systems (GIS) in disaster management, are specified. Next, an overview of VGI is given covering its origin, adoption in authoritative mapping agencies, usage in disaster management (including flood management in Jakarta), and issues (legal, credibility, public participation, stakeholder engagement, and interoperability).

## 2.1 Disasters

A disaster is defined as an event which happens with or without warning and causes serious disruptions to the functioning of a community or a society (Teodorescu, 2014). According to Khan et al. (2008) and Tiwari (2015), disasters only occur when hazards and vulnerability meet (Figure 2-1). For example, if an earthquake happens within an unpopulated area, it may not be labelled as a disaster because people are not vulnerable.

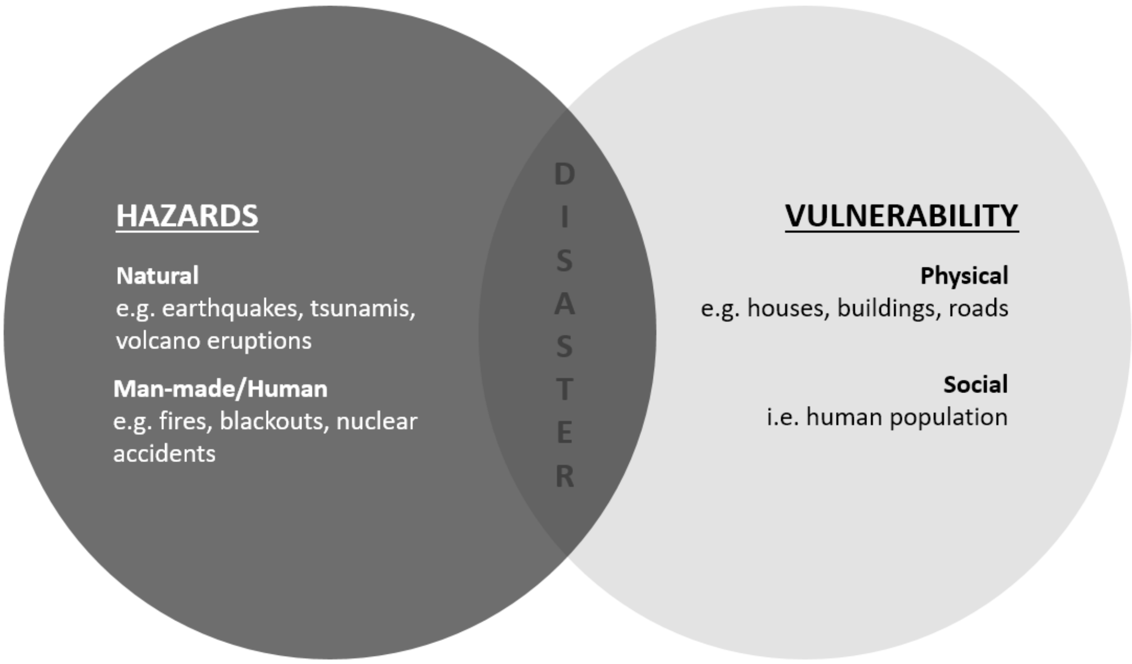


*Figure 2-1. Relationship of hazards and vulnerability in a disaster (author's own)*

Hazards are a condition or event which have the potential to cause harm in a community or a society (Khan et al., 2008; National Research Council, 2006; Tiwari, 2015). There are two types of hazards:

1) Natural hazards which humans cannot prevent (e.g., earthquakes, tsunamis, and volcano eruptions).
2) Man-made hazards which humans are able to prevent (e.g., fires, blackouts, and nuclear accidents). Human activities can cause or increase the intensity of natural hazards (Tiwari, 2015), for example, deforestation can cause flooding.

Vulnerability is the extent to which a community or society in a geographic area is likely to be disrupted by the impact of the hazards (Khan et al., 2008; National Research Council, 2006). Other literature refers to vulnerability as susceptibility (Cardona, 2004) or exposure (InaSAFE, 2015; Tiwari, 2015). According to the National Research Council (2006) there are two categories of vulnerability:

1) Physical vulnerability which represents structures, infrastructures, and natural environment.
2) Social vulnerability which represents the well-being of human populations.

Disasters usually happen on a large scale (Rao et al., 2007). However, it is difficult to label an event as a disaster because of the various dimensions involved, such as legal, political, emotional, human life, social, and economic (Teodorescu, 2014). The declaration of a disaster event always depends on the legal framework by the organisation that responsible for disaster management (e.g., Federal Management Emergency Agency (FEMA) in the United States (US), Civil Defence in New Zealand, National Disaster Management Agency (BNPB) in Indonesia).

## 2.2 Disaster Management

When a disaster happens, the impact can be complex, overwhelming, and disorienting (Rao et al., 2007). A set of programmes to minimise the impact of a disaster, known as disaster management, is necessary for disaster prone areas (Khan et al., 2008; Rao et al., 2007). According to Hollnagel and Masys (2015), disaster management can be grouped according to characteristics based on frequency as shown in Table 2-1 below.

*Table 2-1. Disaster management characteristics based on disaster frequency (Hollnagel 2015, p. 23)*

| | **Regular events (everyday nuisances, incidents, accidents)** | **Irregular events (critical accidents, disasters)** | **Unexpected events (catastrophes)** |
|---|---|---|---|
| **Frequency of occurrence** | High, everyday | Low, but events are imaginable | Rare and mostly unimaginable (until they occur) |
| **Magnitude of consequences** | Low, and in most cases well-known | High, with reason for concern | Extremely high, may exceed the organisation's ability to cope |
| **Relevant data or information** | Statistics, event reports (regular) | Simplified models, shared experience | Hunches, intuition, 'expertise' |
| **Readiness, preparedness to respond** | High, and costs are justifiable | Low, and costs are disputed | No readiness, cost is prohibitive |
| **Presence of resources to respond** | Available and appropriate | In principle available, but never exclusively | Rudimentary or non-existent |
| **Predictability (of occurrence or of development)** | Very high on both accounts | Low on both accounts | Very low, guesswork. May challenge readiness and resources |

Disaster management covers several key activities before, during, and after the disaster event. In the US, disaster management is integrated into a cycle approach with five stages: identification and planning, mitigation, preparedness, response, and recovery (ESRI et al., 2000). Disaster managers in other countries might consolidate the number of stages or use different terms. Most countries (including Indonesia) follow the disaster management cycle as shown in Figure 2-2 below (BNPB, 2008a; Khan et al., 2008; National Research Council, 2006). Each stage of the disaster management cycle can overlap and the length of each stage depends on the disaster's impact (Paul, 2011).

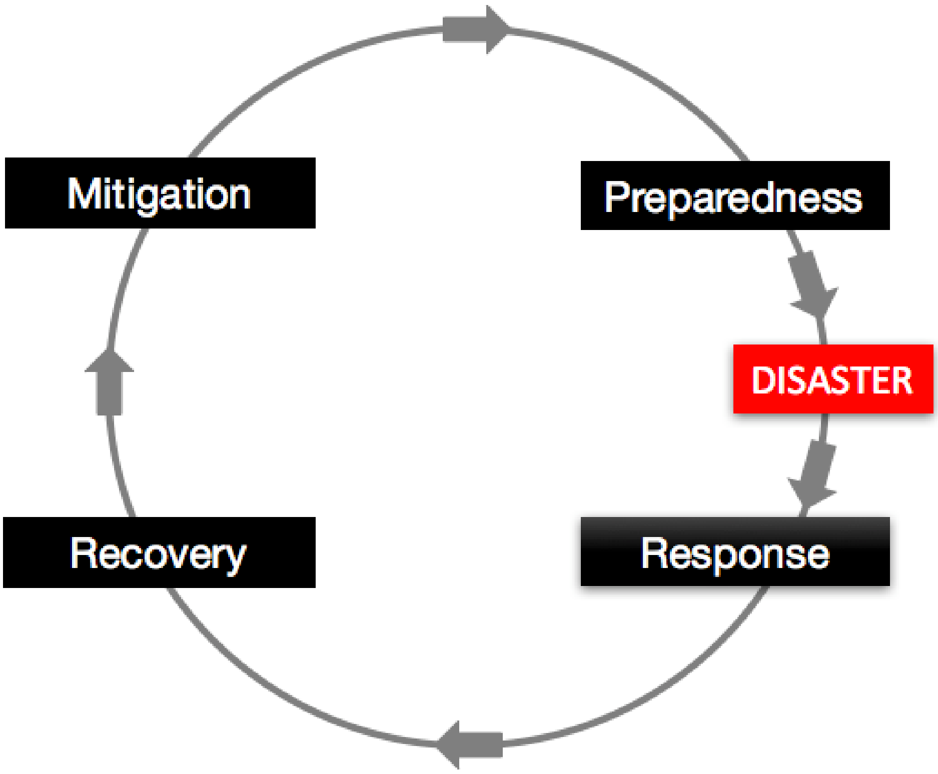


*Figure 2-2. Disaster management cycle (adapted from National Research Council, 2006; Khan et al. 2008; & BNPB 2008a)*

Mitigation is the effort to reduce the physical and social impacts from a disaster (Khan et al., 2008; Rao et al., 2007; Tiwari, 2015). Various methods can be used to mitigate disaster risks depending on the hazard types, such as land use planning and management to mitigate floods, and developing building standards to mitigate earthquakes (Tiwari, 2015). In Indonesia, mitigation actions are determine based on the probability of disaster risks or on the frequency of disasters (e.g., frequent flooding in Jakarta) (BNPB, 2008a).

Preparedness has a similar function to mitigation, but the methods focus on organising available resources for effective response during disaster and recovery during post disaster (Khan et al., 2008; Rao et al., 2007; Tiwari, 2015). The preparedness stage occurs when a disaster is likely to happen. One of the most important instrument used is a contingency plan to describe the responsibility of all stakeholders (e.g., individuals, communities, authorities) (BNPB, 2008a; Mische & Wilkerson, 2016; Tiwari, 2015). Contingency plans should provide disaster risk assessment on a specific type of hazard, based on the worst case scenario (BNPB, 2008a).

Response is the immediate rescue and relief operations during the disaster (Khan et al., 2008; Rao et al., 2007; Tiwari, 2015). At this stage, the response operations should follow the contingency plan from the preparedness stage (BNPB, 2008a). Some examples of response activities include: emergency sheltering or internally displaced person (IDP) camp, search and rescue (SAR), and damage-losses assessment (Tiwari, 2015).

Recovery is carried out after a disaster to return physical and social systems to normal conditions (Khan et al., 2008; Rao et al., 2007). The recovery stage encompasses rehabilitation and reconstruction processes (BNPB, 2008a, 2008b; Khan et al., 2008). Rehabilitation focuses on human aspects (e.g., social-psychological aid, health services), while reconstruction focuses on physical aspects (i.e., rebuilding, repairing, and improving damaged facilities) (BNPB, 2008b). The length of the recovery process depends on the actual impact of the disaster.

## 2.3 The Role of GIS in Disaster Management

GIS are computer-based systems which facilitate the management, manipulation, analysis, modelling, and visualising of geospatial data. GIS are considered as one of the most important information and communication technology (ICT) tools for disaster management (Reinhardt, 2014). GIS can enhance the management of disasters and emergencies to reduce risks associated with disaster (van Oosterom et al., 2005). Many studies have explored the potential of in disaster management across different stages of disaster management (e.g., Reinhardt, 2014). However, generic models related to the use of GIS in each of the disaster management stage are not available because each model depends on the regions' policy and disaster types.

### 2.3.1 GIS in Mitigation and Preparedness

Hazard modelling is a common GIS method used in the early disaster management stages (mitigation and/or preparedness) (Reinhardt, 2014). Hazard modelling is able to estimate the geographical extent and severity of hazardous events. Each hazard type can be modelled depending on their characteristics. Hazard modelling has been applied to different types of hazard, for example, earthquakes (van Lieshout & Stein, 2012), landslides (Santini et al., 2009), and floods (Yan et al., 2015). The hazard map, which results from the modelling, is an important tool for disaster managers and the community to mitigate the potential hazards (Tran et al., 2009).

Risk modelling is another common GIS method which simulates the likely impact of a hazardous event in a community. GIS tools, such as InaSAFE[4] and Riskscape[5], can be used to calculate disaster risk. According to the United Nations of International Strategy for Disaster Reduction (UNISDR), disaster risk is a combination of hazard and vulnerability (UNISDR, 2009). Similar to hazard modelling, risk modelling has also been used in early disaster management stages. Examples of flood risk modelling can be found in Vojtek and Vojteková (2016) and Aye et al. (2016).

### 2.3.2 GIS in Disaster Response and Recovery

When a disaster occurs, information related to the affected people and infrastructure is critical to minimise the disaster impact. According to Tomaszewski et al. (2015), GIS application in disaster response mostly relates to situation awareness, for example, the location of internally displaced person (IDP), emergency shelters, resources and units, actual impact, and traffic situation. Information is required as soon as possible and updated regularly to provide the most effective response (Ozbek et al., 2015).

In the recovery stage, GIS can be used to assess damage and losses in the affected area (Hashemi & Alesheikh, 2011; Su et al., 2005; Yi et al., 2010) or to monitor the recovery stage to ensure the effectiveness of the recovery process (Contreras et al., 2016). The use of GIS in the recovery stage often overlaps with the mitigation stage as the actual impact information can be used for better planning and coordination in future disaster events.

Implementing GIS in disaster management is not without issues. A key challenge is associated with geospatial data acquisition (such as in a developing country) as the required data might be difficult to acquire, obsolete or non-existent (ESRI et al., 2000). Disaster events are uncertain, so it is important to acquire and use relevant data to deliver information as soon as possible (Roche et al., 2011; Tomaszewski et al., 2015).

## 2.4 VGI Overview

To understand the context of VGI in this research, it is important to identify its overlap with related terms from existing VGI studies, such as web 2.0 and crowdsourcing

[4] http://inasafe.org

[5] http://riskscape.niwa.co.nz

(Capineri, 2016; Goodchild, 2007a, 2007b; Hall et al., 2010; Heipke, 2010; Hudson-Smith et al., 2009; See et al., 2016). This section discusses the background of web.20 and crowdsourcing, and relates these to VGI.

### 2.4.1 Web 2.0 and Crowdsourcing

Web 2.0 is the next generation of technology that has focused on user-generated content on the internet (O'Reilly, 2005). Web 2.0 has played an important role in how knowledge has been produced and disseminated through the internet. It has opened the door for users to generate and publish their own content, supported by a plethora of mobile devices (O'Reilly, 2005). Many user-generated content websites have appeared (e.g., Wordpress, Flickr, YouTube). Web 2.0 has increased the ability to share data and information in efficient ways (Hudson-Smith et al., 2009), enabling the world of crowdsourcing.

Crowdsourcing, coined by Howe (2006), refers to a group of people that take on certain activities online to solve problems. Crowdsourcing has a potential to solve problem more efficiently, compared to a single expert (Howe, 2010). Wikipedia, a free online encyclopaedia is an example of the most popular crowdsourcing website (Giles, 2005).

Crowdsourcing is a broad concept. An extensive number of studies have explored crowdsourcing with a wide range of applications and disciplines, leading to different interpretations of crowdsourcing (e.g., Grier, 2013; Heipke, 2010; Liu, 2014; Wiggins & Crowston, 2011). Estellés-Arolas and González-Ladrón-de-Guevar (2012, pp. 9-10) proposed a comprehensive definition of crowdsourcing as follows:

*"Crowdsourcing is a type of participative online activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task. The undertaking of the task, of variable complexity and modularity, and in which the crowd should participate bringing their work, money, knowledge and/or experience, always entails mutual benefit. The user will receive the satisfaction of a given type of need, be it economic, social recognition, self-esteem, or the development of individual skills, while the crowdsourcer will obtain and utilise to their advantage what the user has brought to the venture, whose form will depend on the type of activity undertaken."*

According to Estellés-Arolas & González-Ladrón-de-Guevar’s definition, a crowdsourcing activity has four key characteristics:

1) The crowdsourcer (an individual or an institution that initiates an activity).
2) The crowd (a group of people that willing to perform the task for the crowdsourcer).
3) The tasks, these are delivered through the internet and they can be anything. The variety of crowdsourcing tasks has led to the variety of crowdsourcing terms (e.g., crowdvoting, crowdfunding).
4) Both crowdsourcer and the crowd gain mutual benefit.

Crowdsourcing is gaining greater prominence within the geoscience fields because of the increasing need for geospatial information, especially in developing countries where access to geospatial information is limited.

### 2.4.2 Introducing VGI

VGI is a phenomenon where a number of untrained people produce geographic data or information voluntarily with various tools (Goodchild, 2007a). Jiang and Thill (2015) defined VGI as user-generated content assorted with geospatial coordinates, which is similar to Goodchild’s (2007a) VGI concept. According to Capineri (2016), VGI has three main components:

1) **Where:** the geographical references (i.e., geospatial references) to represent the information on a map.
2) **What:** the stock of content or data (e.g., texts, numbers, photos, videos) that can be transformed into information.
3) **Who:** the contextual information which comprises the authorship of the information including the time of creation.

VGI usually does not include contributions of professionals, but professionally trained persons may contribute to a VGI project (Goodchild, 2007a). The term *volunteered* indicates that people can choose whether they want to contribute or not. From an ethical perspective, VGI should provide a clear and specific objective for the collection, including the intended use of the collected information (Harvey, 2013).

VGI can be referred to as a form of crowdsourcing to collect geospatial information due to similar key characteristics: VGI involves one or more stakeholders which initiate the activity, VGI requires participation from a group of volunteers to perform the collection of geographic information, VGI is delivered through the internet, and the stakeholders with the volunteers would gain mutual benefit.

Since Goodchild (2007a) introduced the VGI term, many studies have proposed new terms with similar descriptions, for example, Spatial Crowdsourcing (Crampton, 2009), Crowdsourced Geographic Data (CGD) (Rice et al., 2012), Contributed Geographic Information (Harvey, 2013), and Citizen-Contributed Geographic Information (CCGI) (Spyratos & Lutz, 2014). Parker (2014a, p. 11) criticised these variety of terms as a *"…lack of consensus in terminology, leading to multiple authors using various different phrases to describe the same thing."* Sieber and Haklay (2015) also criticised the overemphasis of formal naming instead the study of knowledge by researchers. For consistency, only VGI is used through the rest of this thesis. A more extensive range of VGI concepts and their definitions can be found in See et al. (2016).

## 2.5 VGI Characteristics

Volunteered Geographic Information (VGI) characteristics includes users' role and interaction, the users' motivation, and the type of VGI.

### 2.5.1 Users' Role

Many countries have developed a spatial data infrastructure (SDI) to produce, share, and utilise geospatial data and information. Before Web 2.0 technologies, mapping organisations were responsible for the collection, processing, and distribution of the authoritative geospatial data (Aalders & Moellering, 2001). These mapping organisations can be referred to as Professional Geographic Information (PGI) (Parker, 2014b). Most current SDI users are largely not involved within geographic information supply chain or passive recipients (Budhathoki & Nedovic-Budic, 2008).

With the emergence of Web 2.0 technologies, the public started to produce and supply geographic information over the internet with various tools including Google Maps, Google Earth, Wikimapia, and OpenStreetMap (OSM) (Budhathoki & Nedovic-Budic, 2008; Sui et al., 2013). Previous studies stated that VGI has been transforming geographic data creation (Budhathoki & Nedovic-Budic, 2008; Elwood et al., 2012). In contrast to the traditional top-down authoritative process of geographic information production by government agencies, the public has played an increasingly important role in producing geographic information of all kinds through a bottom-up process (Goodchild, 2007b; Sui et al., 2013).

Recent studies have opened up the idea of incorporating VGI in the next generation of SDI by changing the role of passive SDI users to producer as a part of VGI inclusion within SDI-related process (Budhathoki & Nedovic-Budic, 2008; Elwood et al., 2012; Parker, 2014b), thus blurring the line between the geographic information producer and user (Figure 2-3).

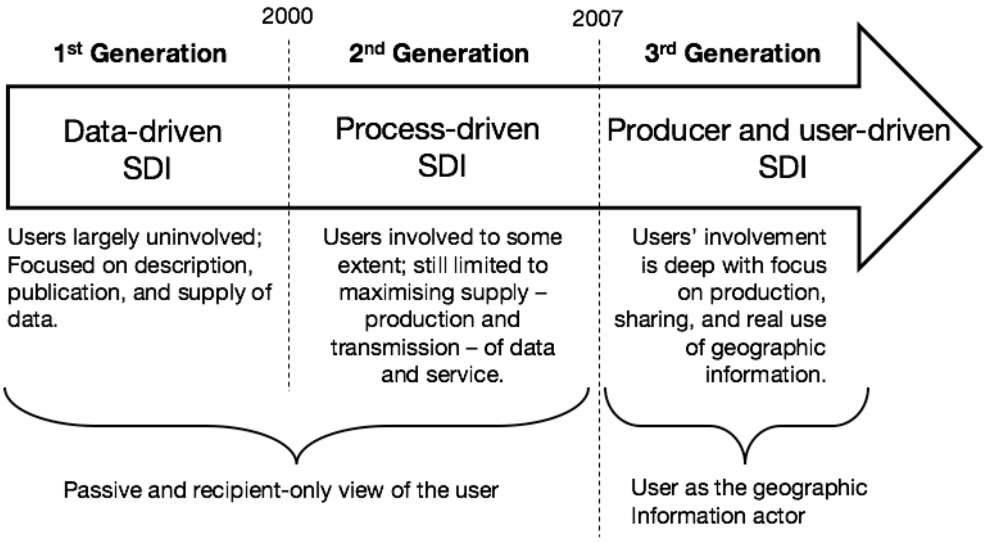


*Figure 2-3. Producer-driven SDI developed from inclusion of VGI within SDI-related process (adapted from Budhathoki & Nedovic-Budic, 2008, p. 159)*

### 2.5.2 Users' Motivations to Contribute

Identifying users' contribution is an important to measure of the success of a VGI project. However, it is also important to identify users' motivations to contribute, an essential condition for capitalising on VGI (Goodchild, 2007a). Users' motivations are the desire or willingness to contribute in a VGI project and might vary across VGI projects, leading to different contribution behaviours (Budhathoki, 2010; Parker, 2014b; Xu & Nyerges, 2016).

Budhathoki (2010) used a psychological approach (incentives theories) to explain the source of motivation. Intrinsic motivation comes from oneself, for example, from personal enrichment, recreation, or the freedom of expression. Extrinsic motivation comes from other people or social forces, for example, career, project goals, and monetary return. Similar to Budhatoki's (2010) approach, Parker (2014d) identified the source of motivation as a multidimensional value which involves aspects, such as emotional, functional, knowledge, legal, moral, price, and social (Table 2-2).

*Table 2-2. VGI values according to users (Parker, 2014d)*

| Values | Examples |
|---|---|
| **Emotional** | • VGI contributors have an emotional connection to subject<br>• Users are concerned about data vandalism |
| **Functional** | • VGI presents the zeitgeist of contributor interest<br>• VGI enables information not found on traditional maps to be utilised<br>• Users perceive VGI as accurate enough for their needs<br>• Users see mapping in regions not covered by authoritative as a strong benefit of VGI<br>• VGI is more up to date than authoritative sources<br>• The ability to customise or personalise maps with VGI is of benefit |
| **Knowledge** | • VGI provides an increase in local knowledge from mapping their own area |
| **Legal** | • Users enjoy freedom to do what they like with the map data |
| **Moral** | • VGI benefits others<br>• Open source VGI fits the ideology of contributors |
| **Price** | • The zero cost to access VGI maps is a large benefit for the interest group |
| **Social** | • An enjoyable community of VGI contributors and developers |

### 2.5.3 VGI Types

Compared to traditional mapping, the information which can be acquired with VGI varies (depending on the VGI themes), provided that a geospatial element is present (i.e., geographic coordinates or contextual location information). Applications, such as OSM and Wikimapia, enable individuals to locate geographical features by drawing in vector format (point, line, or polygon) and including geographical attributes or geographical feature tags. These applications are often referred as collaborative mapping projects

(Bakillah et al., 2013) or feature mapping projects (See et al., 2016). Other applications enable individuals to create a report (textual, graphic, or both of them) with location information attached (geo-located reports). An extensive list of VGI is provided by See et al. (2016), some examples are as follows:

*Table 2-3. VGI examples (adapted from See et al. 2016, pp. 11-12)*

| Themes | Descriptions | Examples |
|---|---|---|
| Communication | Providing information about communication networks (e.g., mobile signal strength, communication tower location) | OpenSignal |
| Disasters | Mapping a natural disaster (e.g., risk mapping, displaced people, evacuation site) | Ushahidi, PetaJakarta, Google Crisis Map, TomNod |
| Environmental Monitoring | Monitoring environmental quality (e.g., water level, air quality) | earth.nullchool.net, OpenWeatherMap |
| Collaborative mapping or feature mapping | Mapping available features on earth (e.g., buildings, roads, land use) | OpenStreetMap (OSM), Google Map Maker, Wikimapia |
| Recreational | Mapping for recreational purposes (e.g., hiking/tramping, traveling, fishing hotspots) | GaiaGPS |

## 2.6 Adoption of VGI in Authoritative Mapping Agencies

Researchers have been studying the possibilities of VGI adoption within authoritative mapping agencies (Haklay et al., 2014; Johnson & Sieber, 2013). There are several practical reasons why authoritative mapping agencies should consider adopting VGI:

1) VGI is able to collect the suitable datasets, where authoritative data is lacking (Haklay et al., 2014).
2) The public holds valuable local knowledge (data richness) (Johnson & Sieber, 2013; Parker, 2014b, 2014d).

3) Cost savings for data collection (Johnson & Sieber, 2013).
4) Data quality is not significantly different from ground-truth and reference data (Chapman, 2012; Haklay, 2010).
5) Increasing collaboration across authorities and public (Johnson & Sieber, 2013).
6) Increasing the positive users' experience, thus increasing users' trust in information from authoritative mapping agencies (Parker, 2014c).

Haklay et al. (2014) identified several examples of VGI use in authoritative mapping agencies, from disaster risk reduction (DRR) in the Philippines and Indonesia to settlement mapping in Kenya and India. Haklay et al. (2014) also identified several key elements which contribute to the success of VGI adoption by governments, which are as follows:

1) Individual, which refers to leaders within public sector organisations. It is important that they are able to support the use of VGI in a mapping authority.
2) Organisational, which refers to structure or procedure when conducting VGI activities (e.g., legal structure, responsibilities to maintain the data).
3) Business model, which refers to costs that might be involved when conducting VGI activities (e.g., communicating to the public, incentives to maintain public interest).
4) Technical, which refers to software and hardware involved.
5) Conceptual factors, where stakeholders need to accept the higher level of uncertainty, heterogeneity, and be able to work closely with diverse communities.

## 2.7 VGI in Disaster Management

In disaster management, VGI has great potential as a data collection tool for most types of disasters. The most notable VGI effort in disaster response is the Haiti 2010 earthquake. During the response stage, an updated map was urgently needed for emergency responders to send help and distribute supplies. However, available geospatial data were poor and last updated in the 1960s (Haklay et al., 2014). The OSM community addressed the issue by crowd-sourcing a detailed and comprehensive base map of downtown Port-au-Prince, allowing emergency responders to work efficiently (Meier, 2012).

A similar example occurred in 2013, when Typhoon Haiyan struck the Philippines and caused massive damage, mainly in Tacloban. The OSM VGI community contributed to nearly five million changes against the existing OSM dataset. The contributed information provided detailed information on the location and extent of pre-event infrastructure for preliminary damage assessment (Haklay et al., 2014).

Another example in flood management context, VGI was applied during flood response in the city of Calgary (Canada) in 2013. A map mashup which combines authoritative and non-authoritative sources (including VGI from geolocated photos and Twitter[6] feed) was used to generate a map of flood extent estimation in real-time, thus promoting situational awareness during the flood event (Schnebele et al., 2014).

As is obvious from these VGI applications, a key benefit of VGI is the potential to fill an information gap during a disaster event. Another key benefit is the ability to provide near real-time information about the disaster (e.g., hazardous extent or location of people who need assistance) to develop situational awareness for decision makers and the public. VGI platforms, such as Ushahidi[7], have enabled people to send out information related to disaster situations (Meier, 2012; Tomaszewski et al., 2015). Social media, such as Twitter, also have a potential to become a VGI platform and deliver information using their geolocation feature (Holderness & Turpin, 2015; Landwehr et al., 2016; Schnebele et al., 2014). A number of studies also found information that is shared through a VGI platform may improve community resilience at local level (Haworth, 2016; Haworth & Bruce, 2015; Haworth et al., 2015). The local community may able to develop their own planning and response procedures for an emergency situation. McCallum et al. (2016) also added that VGI has a potential to deliver user-centric disaster risk assessment effectively with the support of appropriate tools.

[6] https://twitter.com

[7] https://ushahidi.com/

## 2.8 VGI Issues

### 2.8.1 Legal Issues

Legal issues in VGI comprise data license and policy. Data licensing often becomes a problem when people want to use VGI with authoritative sources due to copyright issues (Blatt, 2015; Haklay et al., 2014; Neis & Zielstra, 2014; Scassa, 2013; See et al., 2016). Authoritative sources generally have copyright that requires the users' permission to access and use the information, while VGI sourced information has no such limitation. However, Scassa (2013) suggests that both VGI contributors and users should be aware of the license terms when working with VGI. Similar to authoritative sources, VGI providers also provide documents that govern contributors' and users' rights, which are likely to differ (Table 2-4) (Neis & Zielstra, 2014). Some VGI providers are adopting an open license, such as Creative Commons[8] (CC) or Open Database License[9] (ODbL), which allows anyone to access and use the information without limitation as long users give credit to the VGI provider (Neis & Zielstra, 2014; Scassa, 2013).

*Table 2-4. Comparison of VGI's license (adapted from Neis & Zilestra, p. 79)*

| | **OSM** | **Wikimapia** | **Map Share** | **Waze** | **Here Map** |
|---|---|---|---|---|---|
| **Launched** | 2004 | 2006 | 2007 | 2008 | 2012 |
| **License** | Open | | | Proprietary | |
| **Data downloadable** | Yes | | | No | |

Authorities in many countries have also adopted an open license for their geographic information, allowing VGI inclusion into authoritative sources to some extent (Singleton et al., 2016). Some examples are Land Information New Zealand's (LINZ) data service[10], United Kingdom's (UK) GoGeo service[11], and Indonesia's InaGeoportal service[12]. Adopting an open license potentially mitigates license and copyright issues.

[8] https://creativecommons.org/

[9] https://opendatacommons.org/licenses/odbl/

[10] https://data.linz.govt.nz

[11] http://gogeo.ac.uk

[12] http://tanahair.indonesia.go.id

Legal issues can also relate to policy. A mapping authority may have a policy which restricts the use of VGI for specific datasets. Malaysia, is an example where the authority has banned VGI use for cadastre mapping as it could create a land dispute between the community and the authority (Fox et al., 2006).

### 2.8.2 Credibility Issues

In contrast with authoritative geographic information, users are concerned about VGI credibility because of the nature of public participation which leads to variability of contributions (Goodchild & Li, 2012; Haklay, 2010). Authoritative data is well-known with a high level of credibility because of its known quality assurance processes and often legal standing, which leads to a high level of trust from the public (Ballatore & Zipf, 2015; Goodchild & Li, 2012). In contrast with authoritative sources, trust in VGI is generally low as with other types of user-generated content (Figure 2-4).


*Figure 2-4. Spectrum of trust associated with authoritative and non-authoritative sources (adapted from Schnebele et al. 2014, p. 383)*

According to Flanagin and Metzger (2008), the notion of credibility is closely related to data quality. Bordogna et al. (2014) argue that VGI is a special case where quality can be represented by three different quality indicators: intrinsic, extrinsic, and pragmatic quality.

1. **Intrinsic quality**

   Intrinsic quality is related to validity and representation of the information (Bordogna et al., 2014). Alternatively, intrinsic quality can be referred as 'quality-as-accuracy' (Flanagin & Metzger, 2008) or 'conceptual quality' (Ballatore & Zipf, 2015). Defining intrinsic quality for geographic information is a complex issue as there are different dimensions of it such as: lineage, positional accuracy, attribute accuracy, logical consistency, completeness, semantic accuracy, usage, purpose and constraints, and temporal quality (Elwood et al., 2012; van Oort, 2006). Examples of intrinsic quality assessment for VGI are shown in Haklay (2010). Haklay found that the quality of OSM data, from a spatial accuracy perspective, is reasonably accurate (up to 6 metres). Similar research in Indonesia also found the quality of OSM data was accurate up to 1: 5,000 scale (Aditya, 2012).

2. **Extrinsic quality**

   In contrast with intrinsic quality, extrinsic quality is related to the characteristics of the authors, for example, trust, expertise, and competence of the volunteers (Bordogna et al., 2014).

3. **Pragmatic quality**

   Pragmatic quality refers to the users' need and intended purposes (i.e., usability) that involves all aspects of intrinsic and extrinsic quality (Bordogna et al., 2014).

Many efforts have been made to study VGI quality assessment. Different approaches to assess VGI credibility are as follows:

*Table 2-5. VGI quality assessment approaches and methods (adapted from Hung et al. 2016, p. 39)*

| Approaches | Methods | Descriptions | Limitations |
|---|---|---|---|
| The crowdsource or social approaches | Crowd/social methods (Goodchild & Li, 2012; Hall et al., 2010) | Errors and false information are expected to be edited and corrected by crowd | 1. Crowd might not know or find the existence of errors<br>2. Evaluation of the final results may require a field assessment |
| The geographic approach | Comparison aggregation (Doris et al., 2013) | Comparing (aggregated) VGI based on spatiotemporal characteristics to authoritative information | Availability of authoritative information for comparison is often limited, and it is difficult to have quantitative measurements |
| | Spatial pattern & geo-context analysis | Analysing the geographic context | 1. Available methods are inflexible to identify |

| | | | |
|---|---|---|---|
| | (Craglia et al., 2012; Hung et al., 2016) | and the spatiotemporal proximity of VGI | the factors and impact of variances<br>2. Textual and media contents are excluded |
| Other approaches | Text pattern analysis (Bishr & Mantelas, 2008) | Analysis of the text content of VGI for identifying the features which influence credibility | 1. Further usage is limited as geographic information is absent<br>2. In some cases, contributors might not have any reputation |
| | Source & reputation analysis (Bishr & Mantelas, 2008) | Analysing the source for identifying high reputation contributors | |
| | Linguistic analysis (Bordogna et al., 2014) | Establish a VGI assessment based on the linguistic decision making model | Complex procedure |
| | Generic trust model (Severinsen, 2015) | Establish a trust rating algorithm based on author, spatial, and temporal components | Available algorithm does not include spatial attribute components |

Many researchers agreed that credibility is a key concern when using VGI in disaster management (Doris et al., 2013; Fazeli et al., 2015; Goodchild & Glennon, 2010; Haworth, 2016). However, an appropriate methodology to assess VGI credibility is still debated. Flanagin and Metzger (2008) suggested that VGI should be assessed based on the content of the information rather than the way they were collected. If the information is factual in nature (such as OSM, for instance), both intrinsic and extrinsic aspects should be involved. For information aiming at opinions (e.g., social media), only extrinsic aspects that should be applied. Fazeli et al. (2015) argue that extrinsic aspects are more important because the volunteers' diversity of characteristics (e.g., skills, expertise, and motivation to contribute) potentially affect intrinsic aspects.

### 2.8.3 Public Participation

A key success of VGI depends on public participation (Budhathoki, 2010; Haklay et al., 2014; Parker, 2014a; See et al., 2016; Xu & Nyerges, 2016). It is important that the public is aware of the existence of VGI and has a positive attitude towards current VGI activities to maintain public participation. Haworth (2016) reported that disseminating knowledge related to VGI is important to maintain public participation. VGI tools heavily rely on the use of mobile devices and the internet. Particular demographics (e.g., disabled people, senior) may have problems with their lack of familiarity of using mobile devices and the internet, which results in the digital divide. The complex user interface (UI) and user experience (UX) within VGI tools may also contribute to public participation issues (Newman et al, 2010).

Researchers suggested the need for an incentives mechanism to encourage public participation (Haklay et al., 2014; Haworth, 2016; See et al., 2016). According to See et al. (2016), VGI projects have two generic incentives: (i) being part of a good cause and (ii) gaining something tangible from the VGI service (e.g., access to the raw data, access to the information and knowledge). However, the public may not satisfied enough with such generic incentives. Consequently, an additional incentives mechanism may need to be integrated into VGI process. An example is a *gamification*, where participants with a high number of contributions may be included on the leader boards or receive prizes (Haklay et al., 2014; See et al., 2016). However, the choice of incentives needs to be considered carefully, because it may cause bias in the demographics of participants (Hsieh & Kocielnik, 2016).

### 2.8.4 Stakeholder Engagement

Situating VGI adoption in government usually involve a collaboration process (e.g., sharing technology, expertise, and funding) across the various stakeholder, such as government, non-government, private enterprise, and academics (Haklay et al., 2014; Hall et al., 2010; Johnson & Sieber, 2013). The open nature of VGI, where any individual or organisation can be involved, may be responsible for this collaboration. Additionally, the government may have limited resources to initiate VGI activities, and increasing engagement across stakeholders is a practical reason to solve this issue (Hall et al., 2010). This multi-stakeholder engagement may improve VGI in general. However, it may also lead to disparity of VGI technology (Hall et al., 2010). For example, when each stakeholder proposes a different VGI approach to the government.

### 2.8.5 Interoperability

When using VGI as decision-support information, issues related to interoperability need to be accounted. In contrast with authoritative sources, VGI sources are likely to have higher levels of semantic heterogeneity due to contributors' diversity (Bakillah et al., 2013; Bordogna et al., 2016; Sui et al., 2013; Zhang et al., 2014). The public may contribute to a VGI project using different VGI tools, different data formats, different languages, or different contexts of information (terminology and ontology). In a flood context, for example, some people may say a 20-centimetre inundation is a flood, while others may have a higher threshold. This interoperability related issues may prevent the integration of VGI with authoritative sources. Furthermore, there is a need for interoperability standardisation to use VGI in disaster management. Examples of interoperability model for VGI use can be found in Bordogna et al. (2016) and Bakillah et al. (2013), while a specific model for disaster response can be found in Zhang et al. (2014).

## 2.9 Jakarta Flood Case Study

Jakarta suffers from floods because of its low-lying area, flat topography, high precipitation intensity, sea level rise, land subsidence, and rapid population growth (Marfai et al., 2014). The impact of flooding in Jakarta is expected to increase because of a complex combination of physical and socioeconomic drivers (Budiyono et al., 2016; Ward et al., 2010). Physical drivers, such as high precipitation intensity and sea level rise, are expected to increase the flood hazard area because of climate change (Marfai et al., 2014). At the same time, socioeconomic drivers, such as rapid urbanisation and urban sprawl, are expected to increase the exposure to flooding (Marfai et al., 2014). Figure 2-5 below shows flood extent in Jakarta between 2013 to 2015.

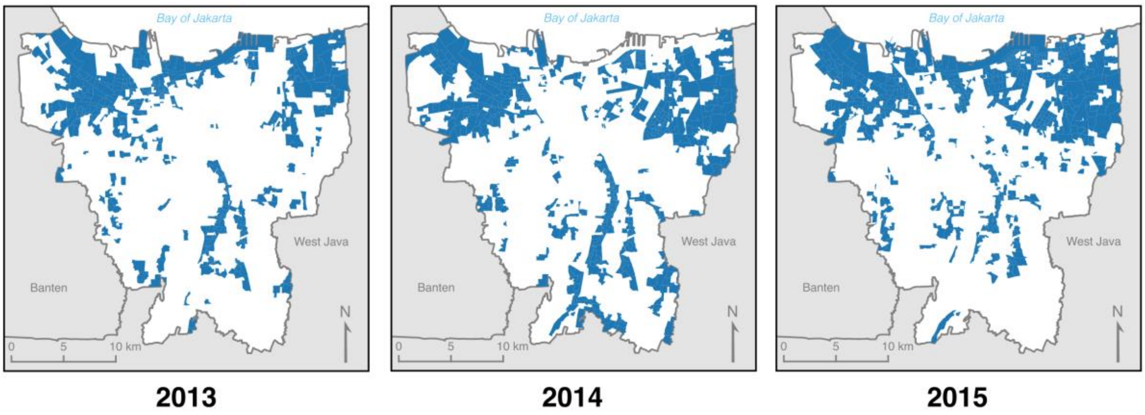


*Figure 2-5. The flood maps (author's own) showing flood extent in sub-village (RW) units. Flood data is based on the annual flood report from the Jakarta Province Disaster Management Agency (BPBD DKI Jakarta)*

A previous study showed that land subsidence will be the largest influence on future flood risk in Jakarta compared to other drivers (Budiyono et al., 2016). Figure 2-6 shows the projected total land subsidence from 2012 to 2025 in Jakarta. An effective disaster management for future floods is urgently required.

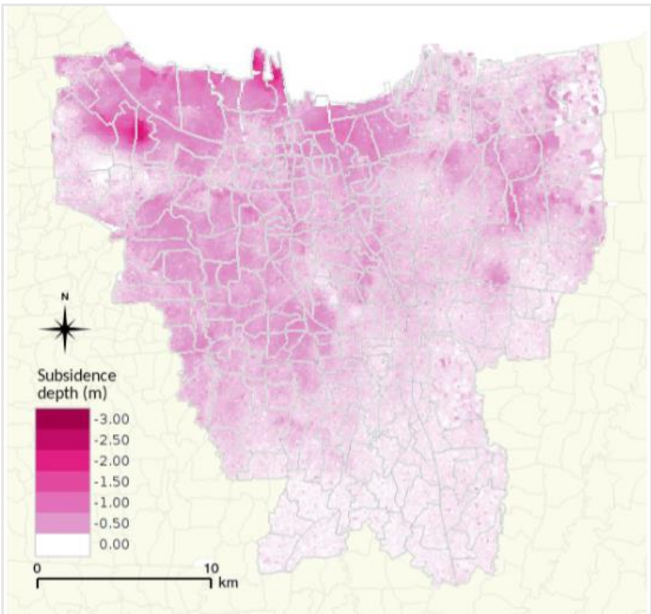


*Figure 2-6. Projected total land subsidence from 2012 to 2025 (Budiyono et al. 2016, p. 760)*

In 2012, the Jakarta Province Disaster Management Agency (BPBD DKI Jakarta) with the assistance of the National Disaster Management Agency (BNPB) hosted a Mapping Jakarta project, involving 500 representatives from Jakarta's government and 70 university students. The project created a base map in Jakarta using the OSM VGI platform. A base map is a general reference to help the user linking the thematic content to the real world for localisation and orientation purposes (Foerster et al., 2012). The project also aimed to collect critical information about key infrastructure elements (e.g., roads, government offices, health facilities, schools) and make it freely and easily available, to support flood contingency planning in Jakarta (Chapman, 2012). OSM data was then used by BPBD DKI Jakarta to develop a detailed scenario to estimate the impact of future floods on people, critical infrastructure, and assets using InaSAFE software. InaSAFE is a GIS-based tool designed to provide natural hazard scenarios and intended to provide ways to combine data from scientists, local governments, and communities. InaSAFE can calculate inundated infrastructure in the event of flooding.

From December 2014 to March 2015, BPBD DKI Jakarta, SMART Infrastructure Facility (University of Wollongong), and Twitter Inc. conducted a pilot study to enable Jakarta's citizens to report the locations of flood events using the social media network (Twitter). The project demonstrated the value of social media within disaster management as an operational tool to provide decision support in the event of disaster (Holderness & Turpin, 2015). Utilising Twitter as a VGI platform makes sense because Jakarta is regarded as an active Twitter city across the world (Semiocast, 2012) and Twitter's user growth is expected to increase along with the growth of mobile internet users in Jakarta (Sconhardt, 2015).

## 2.10 Summary

The literature outlined in this chapter explored the common use of GIS in disaster management to reduce the risks associated with the disaster. However, previous studies related to the use of GIS in disaster management shows a similar consensus where geospatial data acquisition is challenging, specifically in a developing country.

This chapter has also identified VGI as a subset of crowdsourcing to represent where the public is able to contribute geographic data or information using internet-based tools. Previous case studies (e.g., Haklay, et al., 2014; Meier, 2012; Schnebele et al., 2014) have shown the potential of VGI to solve the scarcity of geographic data or information in disaster management; however, they are limited to a specific disaster management stage. Previous studies (e.g., Ballatore & Zipf, 2015; Haklay et al., 2014; See et al., 2016) also found that issues related to legal, credibility, public participation, stakeholder engagement, and interoperability needs to be mitigated when using VGI. Accordingly, there is a common consensus from previous studies (Doris et al., 2013; Fazeli et al., 2015; Goodchild & Glenning, 2010; Haworth, 2016) related to the need for a framework to improve VGI use in disaster management. The framework is important to account VGI issues in disaster management which are described in this chapter. However, research related to the VGI and disaster management framework is very limited.

# 3 Research Methodology

As the literature (Chapter 2) indicates, Volunteered Geographic Information (VGI) for disaster management is a complex issue. To identify a VGI-disaster management framework, it is important to understand the current use of VGI for disaster management including flaws and areas for improvement. A qualitative approach was followed to gather the perspective and experiences of different VGI contributors and stakeholders.

The research workflow of this thesis is provided in Figure 3-1. The initial planning formed a theoretical base for the research. Two qualitative techniques were used for data collection phase: in-depth interviews and focus group discussion (FGD). Ethics approval from the Human Ethics Committee of the University of Canterbury was required and granted (HEC 2016/38) before the data collection process took place. Thematic analysis techniques were used in the analysis phases, following the methodology used by Guest et al. (2012b). Finally, the results are presented as an exploratory approach, providing an insight into the current state of VGI use and identifying a framework to improve VGI use in disaster management. This chapter outlines the research design, methods and the data collection stages, including how the results were analysed.

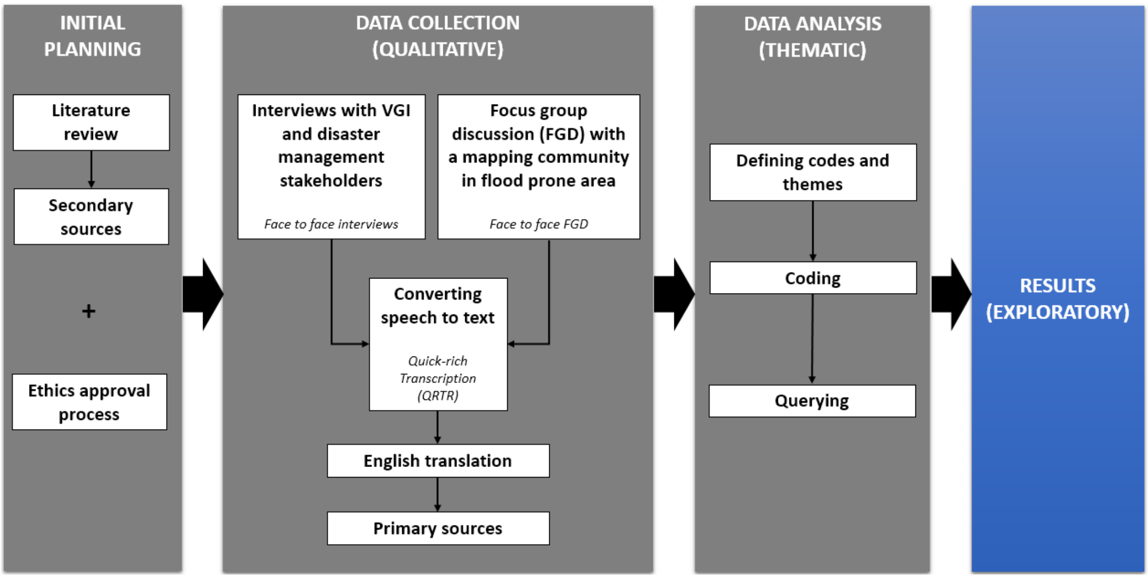


*Figure 3-1. Research workflow*

## 3.1 Data Collection

### 3.1.1 In-Depth Interviews

In-depth interviews are a common qualitative research technique which involves conducting individual interviews with a small number of respondents to explore their perspectives on an idea, program, or situation (Boyce & Neale, 2006). Interviews were conducted face-to-face or in person. Synchronous communication in time and place between interviewer and participants can create a good interview ambience (Opdenakker, 2006), avoid misidentification of an interview participant, and maintain trust between interviewer and participants (King & Horrocks, 2010). The in-depth interviews procedure was as follows:

**1. Identifying and Recruiting Potential Participants**

Participants were identified on the bases of their previous and current experience producing, managing, and using VGI as well their involvement within flood disaster management in Jakarta. Identifying such participants was straightforward as the author of this thesis has worked as a GIS specialist while working with the Humanitarian OpenStreetMap Team (HOT) and the Jakarta Province's Disaster Management Agency (BPBD DKI Jakarta) in several projects using VGI for flood disaster management.

At the beginning of the research, 14 participants were identified and recruited via email with brief information related to the research project, including a consent form that needed to be signed by the participant (Appendix 1). However, only 13 participants were interviewed. Participants were divided into three different categories as follow:

1) *Government*

   Five interviews were conducted with people working in a government organisation, either at local level or national level. At the time of the research, the management of disaster in Jakarta was undertaken by the BPBD DKI Jakarta, which worked under the supervision of the Indonesia's Board of Disaster Management Agency (BNPB). Three employees from BPBD DKI Jakarta and an employee from BNPB were interviewed as they were using VGI in disaster management and were involved in the Jakarta Mapping project in 2012. An additional interview was also conducted with the Indonesia's Geospatial Information Agency (BIG). BIG is responsible for producing, managing, and distributing geospatial information at national level.

*2) Non-Government Organisation (NGO) or Private*

Six interviews were conducted with people working in a Non-Government Organisation (NGO) and related private organisations. NGO refers to non-profit groups that operate independently from the government to deliver resources or tasks. An employee from the Humanitarian OpenStreetMap Team (HOT), an employee from the World Bank, and two employees from the Disaster Management Innovation (DMInnovation) were interviewed. These NGOs have been involved with VGI use in the disaster management sector. An employee from Geo Enviro Omega (GEO), a private organisation, was also interviewed because of VGI use in the organisation.

*3) Academics*

The academic group refers to those who work in an academic institution. In this case, one academic at the University of Indonesia and two academics at SMART Infrastructure Facility (University of Wollongong) were interviewed, primarily because of their involvement in VGI projects in Jakarta.

## 2. Interview Process

A structured interview method was used to gather evidence about the current state, opinions, and future directions of VGI use in disaster management. Compared with semi-structured and unstructured interviewing, structured interviews use an interview schedule which comprises a list of carefully worded and ordered questions to avoid bias (Dunn, 2010). This approach was felt to be most appropriate in helping participants focus on the research topic as both VGI and disaster management are relatively large research domains. Interviews were audio-recorded to ensure the accuracy and accountability of the interview process.

From 13 interviews in total, 9 interviews were conducted in Indonesian language, while 4 interviews in English because subjects were native English speakers. All participants received the same set of interview questions to maintain the consistency of the interview process. The interview questions comprise seven sections (Appendix 2) and each interview was 40 to 60 minutes long.

**3. Confidentiality**

To protect the confidentiality of the participant, all raw data (e.g., audio recordings, interview notes) collected for the study are kept securely and will be destroyed after five years upon completion of this thesis. To maintain participants' confidentiality, a code containing a letter and two digit numbers were assigned to each participant. The letter represents the organisation category to which the participant belongs (Academics, A; Government, G; NGO/private, N), while a two digit number represents the interview order.

**4. Transcription and Translations**

Interviews were transcribed using a Quick-Rich Transcription (QRTR) approach developed by Linguistic Data Consortium (LDC) (Glenn et al., 2010). The audio recording from each interview was divided into three minutes' segments. Each segment was played repeatedly when typing the transcript to ensure that accuracy was maintained. After a segment was completed, the recording was played once more for verification purposes before moving to the next segment.

Transcripts recorded in Indonesian were translated into English using a third-party translator service. To maintain the participants' confidentiality, a confidentiality form was signed by the translator, and any personal identification (e.g., name and occupation of participants) in the transcript documents were removed before they were sent to the translator.

### 3.1.2 FGD

FGD involve a small group of people discussing a topic or issue as defined by a researcher (Cameron, 2010). This method is ideal for investigating what people think, including why they think and behave as they do. FGD are useful for understanding people's beliefs and practices (Barbour, 2008). A small number of respondents were selected from *Rukun Warga (RW)* 07 Marunda, a village in North Jakarta where slums with dense population exist (Figure 3-2). Floods occur regularly in RW 07 Marunda, specifically in the monsoon. Residents of RW 07 Marunda were involved in Marunda Urban Resilience in Action (MURIA) program[13], which VGI activity is included. FGD techniques were more

[13] http://openstreetmap.id/en/muria-membangun-ketangguhan-masyarakat-perkotaan/

appropriate for the flood-affected communities, because such vulnerable groups may not be comfortable talking openly in individual interviews. The FGD aimed to gain knowledge about the characteristics of the user's contribution for VGI, such as trust for VGI-derived information and willingness to participate.

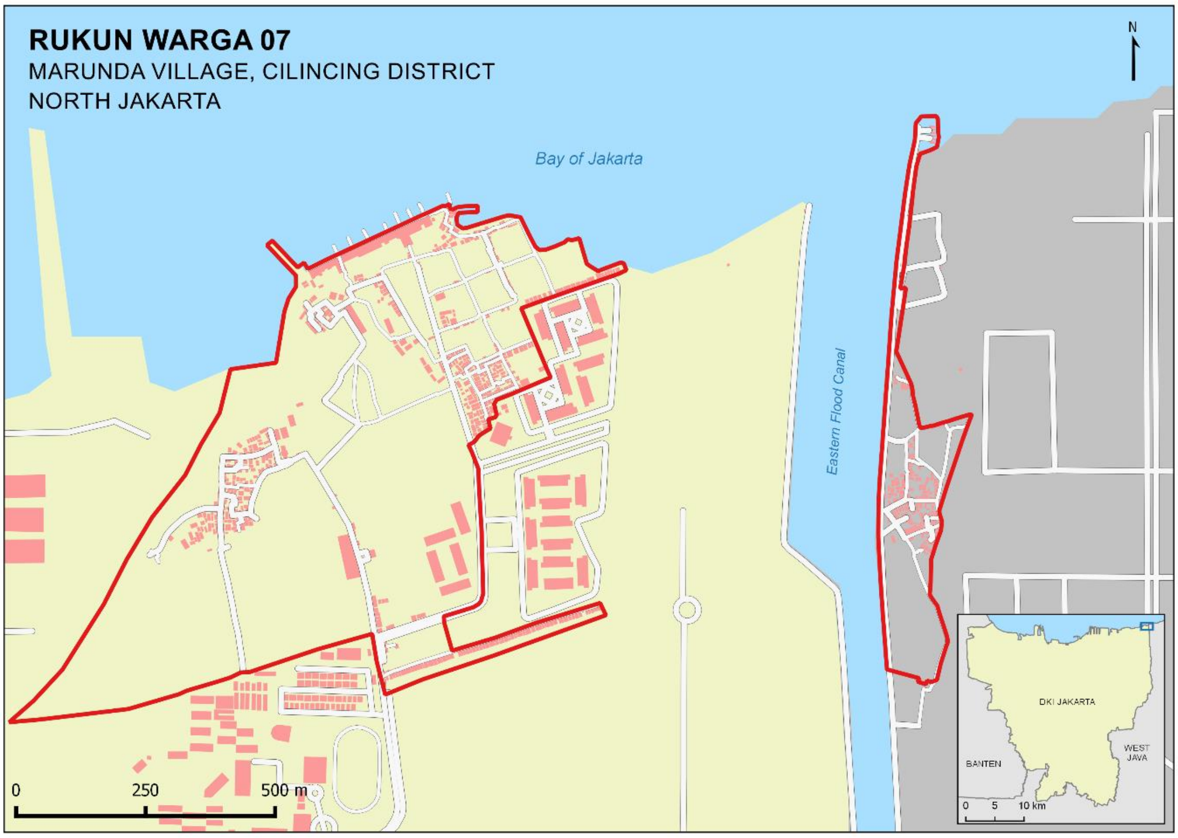


*Figure 3-2. Map showing the location of the community for FGD session (author's own). Map data: OpenStreetMap Contributors and BPBD DKI Jakarta*

The FGD procedure was as follow:

### 1. Identifying and Recruiting Potential Participants

FGD participants were selected based on the criteria listed below:

1) At least 10 Marunda locals who have lived in the village since at least 1996 (when a major flood in Jakarta occurred).
2) Involved in a local community mapping project.
3) At least 20 years old.
4) Maintaining an equal division of male and female participants.

Recruiting process was supported by Bina Swadaya Konsultan (BSK), a local community consultant in Marunda who had gained the trust of the local community. There were 10 participants involved in the FGD session. However, due to unexpected small-scale flooding on the day of the FGD session, all participants were female as potential male participants were helping to clean the streets. An additional FGD with three male participants was held in the following week. Figure 3-3 and Figure 3-4 show the participants' age, gender, and length of residence.

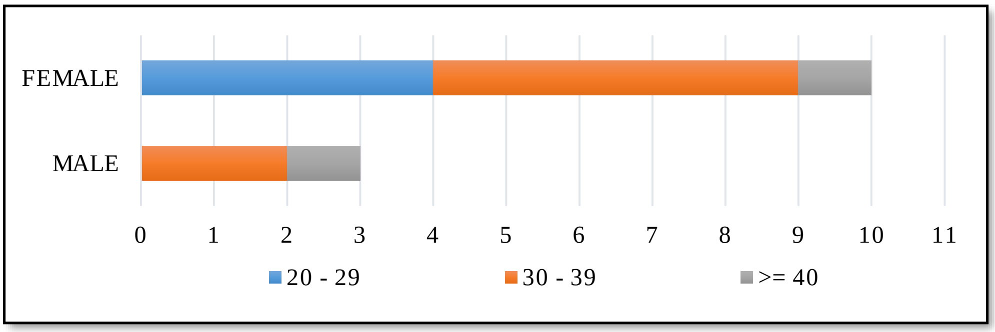


*Figure 3-3. Participants' age and gender*

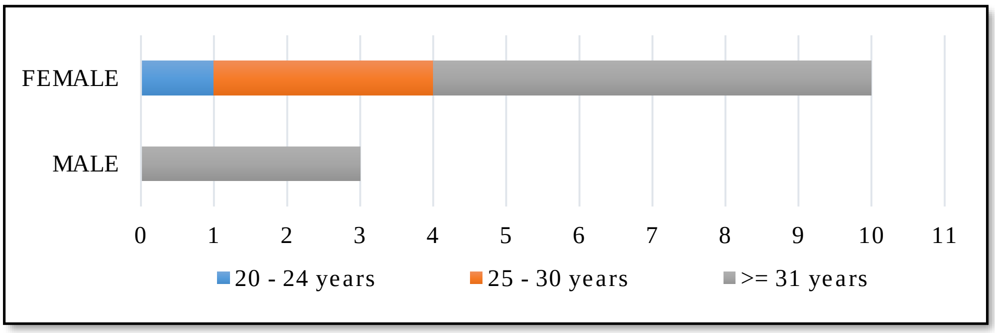


*Figure 3-4. Participants' length of residence*

### 2. FGD Process

The FGD was facilitated and supervised by BSK to ensure all participants felt comfortable. The Indonesian language was used during the FGD. The author of this thesis gave a 10-minute presentation to provide summary of research and FGD process. Participants could ask questions and were asked to sign the consent form (Appendix 3). Next, participants were divided into groups of 3 – 4 (including a designated spokesperson). Participants were given a series of tasks and questions covering two topics: flood events and VGI experiences. Each topic discussion lasted for a maximum of 30 minutes with a 5-minute break between topics. The spokesperson from each group presented the results of the group discussion. Group discussions were not audio-recorded, but an audio recording of the group presentations was made.

This small group and spokesperson method was used to encourage involvement from individuals as participants are expected to be more comfortable talking to others within their community rather than in front of the full group. At the end of the FGD, the researcher summarised the discussion. The list of FGD tasks and questions is included in Appendix 4.

**3. Confidentiality**

All raw data (e.g., audio recordings, FGD notes, photos) collected for the study are kept securely and destroyed will be after five years upon the completion of this thesis. To maintain participants' confidentiality, only the research team has access to the raw data.

**4. Transcription and Translations**

Similar to the interviews, a QRTR approach was used to transcribe. To maintain participants' confidentiality, the translation process did not involve a third-party translator.

## 3.2 Analysis Phase

Thematic analysis was used to analyse the data. This method captures the complexities of meanings within textual data sets (Guest et al., 2012a). The analysis process follows (Guest et al., 2012b). Quality checks were conducted to maintain the reliability of analysis results. Because of the difference in the amount of information collected, interview data was analysed using NVivo software while FGD data was analysed using Microsoft Excel software. The thematic analysis comprised of three stages:

**1. Developing Codes and Themes**

The themes and codes were aggregated on the basis of interview and FGD questions. Table 3-1 shows list of themes and codes for the interview, and Table 3-2 shows list of themes and codes for FGD.

*Table 3-1. List of codes and themes which applied for interview analysis*

| THEMES | MAIN CODE | MAIN CODE DESCRIPTION |
|---|---|---|
| Understanding the research scope | VGI | Opinion related to VGI concepts |
| | DM | Acknowledgement of disaster management concepts from the participants |
| | VGI DM AWARE | Participants' awareness of VGI use in disaster management |
| Current practice of VGI use for floods disaster management in Jakarta | VGI FLOOD DM | The use of VGI for floods within the disaster management stages (data requirement, data collection, and the use of data) |
| | PUBLIC PERC | Opinion related to public acceptance of VGI use in disaster management |
| | VGI REDUCE FR | Opinion related to participants' acceptance of VGI potential to reduce the flood risk |
| Advantages and limitation of VGI use for floods disaster management in Jakarta | VGI PRO | The advantages of VGI use |
| | VGI CONS | The limitation of VGI use |
| Improving VGI use in disaster management | VGI DM IMPROVE | Ways to improve VGI use in disaster management |
| | VGI COLLECT | Organisation that should responsible for data collection through VGI |
| | VGI PUB | Organisation that should responsible to publish VGI-derived information |

| | | |
|---|---|---|
| | VGI CRED DEF | The definition of credibility in VGI context |
| | CRED ASSESSMENT | Ways to assess VGI credibility |
| | CRED RESPONSIBILITY | Organisation that should responsible for maintaining VGI credibility |
| | VGI AUTH INT | VGI integration with authoritative sources |

*Table 3-2. List of codes and themes which applied for FGD analysis*

| THEMES | MAIN CODE | MAIN CODE DESCRIPTION |
|---|---|---|
| Understanding Floods in Marunda | FLOOD EXP | Number of floods experienced by the participant between 2007 and 2015 |
| | FLOOD LOC | Participants' knowledge of flood locations around the village |
| | FLOOD DEPTH | Participants' knowledge of flood depth around the village |
| VGI experiences | VGI COLLECT | Types of information collected by the participant at each disaster management stage |
| | VGI LEARNED | Participants' opinion of their experience with VGI |
| | VGI ISSUES | Participants' opinion of VGI issues |
| | VGI IMPROVE | Participants' opinion of ways to improve the VGI process |
| | VGI ACCESS | Participants’ confirmation of access to the information that they have collected through the VGI process |

**2. Coding**

Coding involved reading interview transcripts and grouping their contents into appropriate codes (nodes in NVivo) based on responses, descriptions, or explanations. Poor data (e.g., unclear responses) were also flagged during this process. A quality check was involved to ensure that each response is coded appropriately.

**3. Querying**

Codes were queried and visualised, using bar charts. A quality check was involved to ensure the number of responses were valid.

# 4 Results

This chapter presents the results from all data collection stages. Section 4.1 provides interviews' results and section 4.2 provides focus group discussion's (FGD) results.

## 4.1 Interview Results

This section explores the interview results of the 13 interviews across 4 main themes. The first theme explores participants' knowledge related to the research scope. The second theme explores current practice of Volunteered Geographic Information (VGI) use for flood disaster management in Jakarta. The third theme explores the advantages and issues that arise when using VGI for flood disaster management in Jakarta. The fourth theme explores ways to improve VGI use for flood disaster management in Jakarta.

To protect interview participants' confidentiality, interview statements are presented with a code containing a letter and two digit numbers. The letter represents the organisation to which the participant belongs (Academics, A; Government, G; NGO/private, N), while a two digit number represents interview order (Section 3.1.1).

### 4.1.1 Understanding the Research Scope

A strong understanding of how participants conceptualise VGI and disaster management was important to analyse responses appropriately. At the beginning of the interview, questions about VGI concepts were provided to each participant. Participants were also provided with a brief definition of disaster management and a diagram of the disaster management (Appendix 5).

Each participant defined and used VGI differently, but there was a general consensus: "*VGI is geographic or location information delivered by the public, voluntarily, using a variety of tools.*" Figure 4-1 shows that six participants agreed with Goodchild's (2007a) VGI definition. A further seven participants agreed but identified some issues, for example, a participant stated that:

*"I'm reasonably comfortable with that definition. I think in some cases there are training programs available for the volunteers, but in many cases, volunteers are untrained."*

- Interview Participant N04

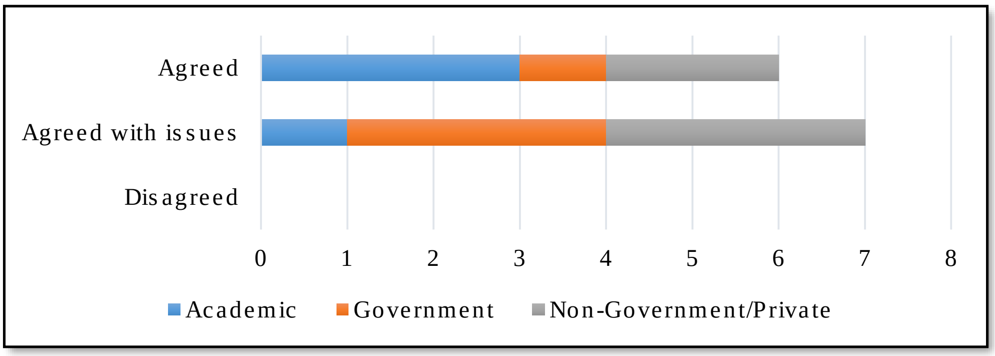


*Figure 4-1. Responses from the interview participants on Goodchild's (2007a) VGI definition*

Each participant also had a good understanding of the disaster management concepts. Participants who work in government and NGO/private sectors specialised in disaster management fields, while participants from academia had experience in disaster management projects.

Figure 4-2 shows that all participants are aware of VGI being used in disaster management because ten of them had experience as a VGI contributor and recognised the available case studies (see Section 2.7 for case studies), while three participants only recognised from the available case studies.

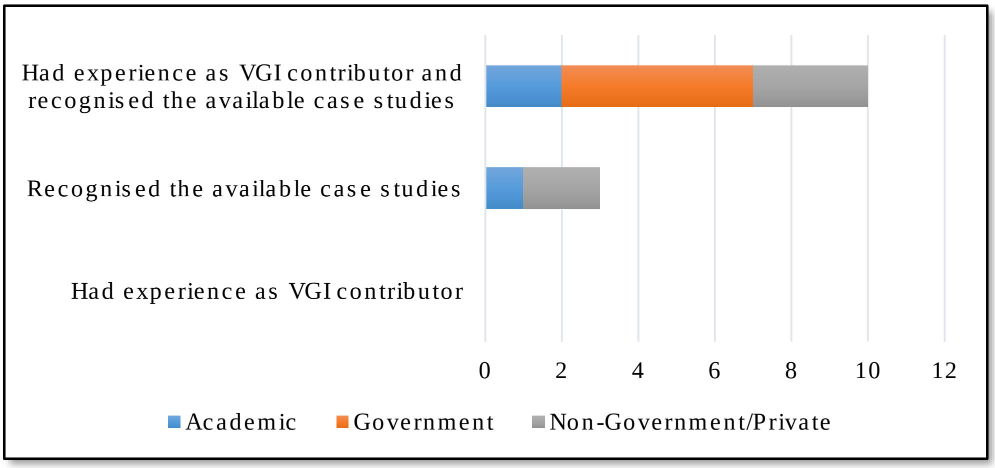


*Figure 4-2. Responses from the interview participants on awareness of VGI use in disaster management*

Overall, it is clear that interview participants were appropriate for inclusion in this research.

### 4.1.2 Current Practice of VGI for Flood Disaster Management in Jakarta

Participants recognised that VGI has the potential to be used in disaster management which comprises a four stage cycle. Participants were asked to give current examples for each stage within which VGI is use.

Twenty-five examples of VGI use in disaster management mentioned by thirteen participants. Examples provided predominantly sit in the preparedness and recovery stages, while six examples sit in the response stage and five in the mitigation stage (Figure 4-3).

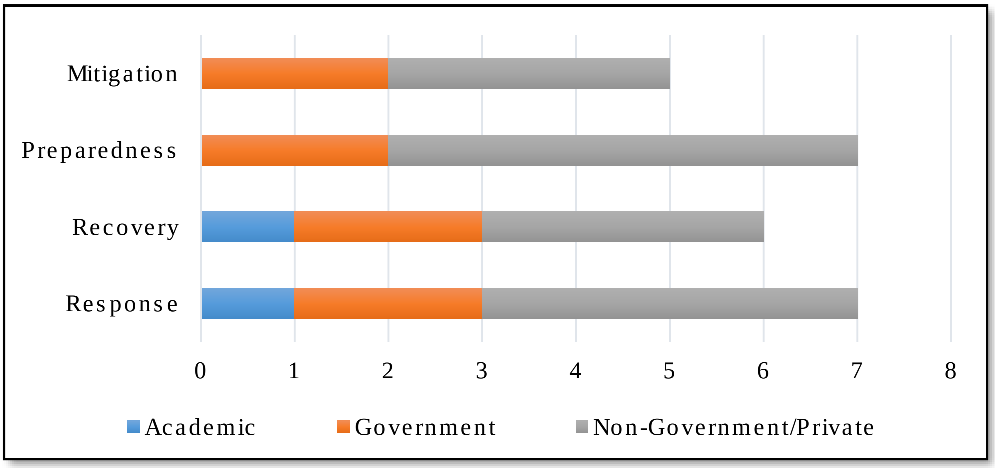


*Figure 4-3. Responses from the interview participants related to VGI use in disaster management's stage*

There was a general consensus from the interviews that each stage of disaster management requires specific datasets. Information related to infrastructure (e.g., buildings, roads, utilities) is important both at mitigation and preparedness stages. Additionally, administration boundaries at the local level need to be collected at mitigation stages.

*"During mitigation and preparedness, we focus more on infrastructure (information), which could potentially help during disaster."*

- Interview Participant N01

A general consensus from the interviews also found that OpenStreetMap (OSM) was predominantly used to collect both infrastructure and local administration boundaries. Later on, OSM was used as the main base map (Figure 4-4). Further, OSM was combined with authoritative sources (e.g., datasets of population, flood models, flood gates) for risk assessment using InaSAFE[14]. The result of this risk assessment was used to develop contingency planning in the preparedness stage (Figure 4-5).

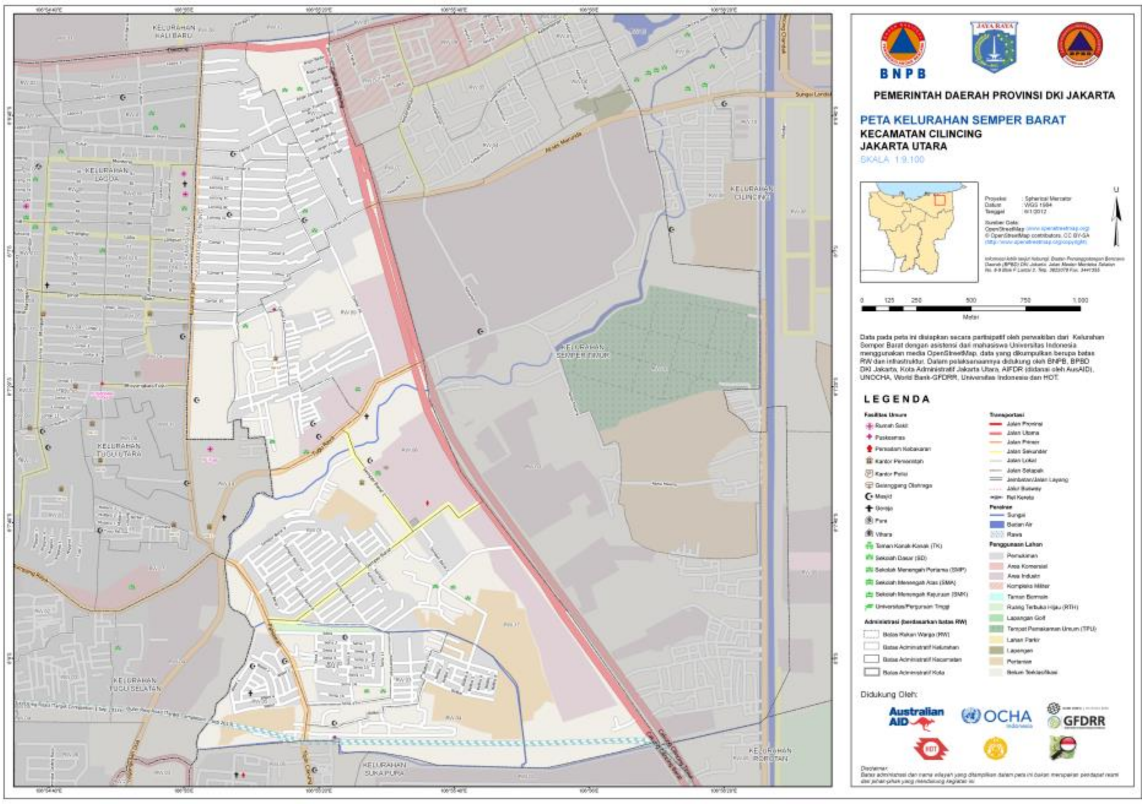


*Figure 4-4. An example of a base map produced with OSM data. Source: Jakarta Province's Disaster Management Agency (BPBD DKI Jakarta)*

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14 http://inasafe.org

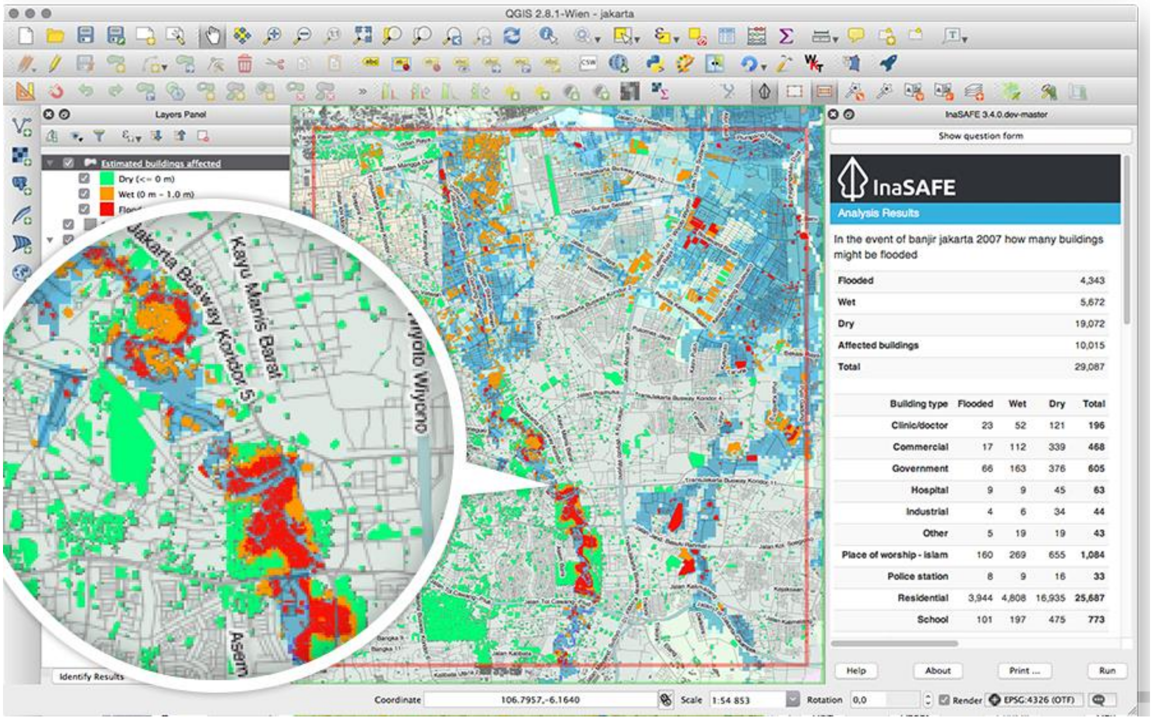


*Figure 4-5. Risk assessment with InaSAFE. Source: inasafe.org*

It is also found from the interviews that in the response stage, information related to flooding situation is important (e.g., current flood locations, flood depth, traffic conditions). Four different geo-located reporting tools were used to collect information related to flooding from the public: Twitter[15] , Qlue[16] , Geo Data Collect[17], and Pasang Mata[18]. Geo-located reports were accessible through the Peta Jakarta website (Figure 4-6). Additionally, the same geo-located reporting tools were used for the recovery stage. The public can send reports of damage and losses to flooding, and this information is published through JakSAFE  website (Figure 4-7).

[15] http://twitter.com

[16] http://qlue.co.id

[17] https://hotosm.org/updates/2016-02-01_geo_data_collect_mobile_data_collection_and_tracking

[18] http://pasangmata.detik.com

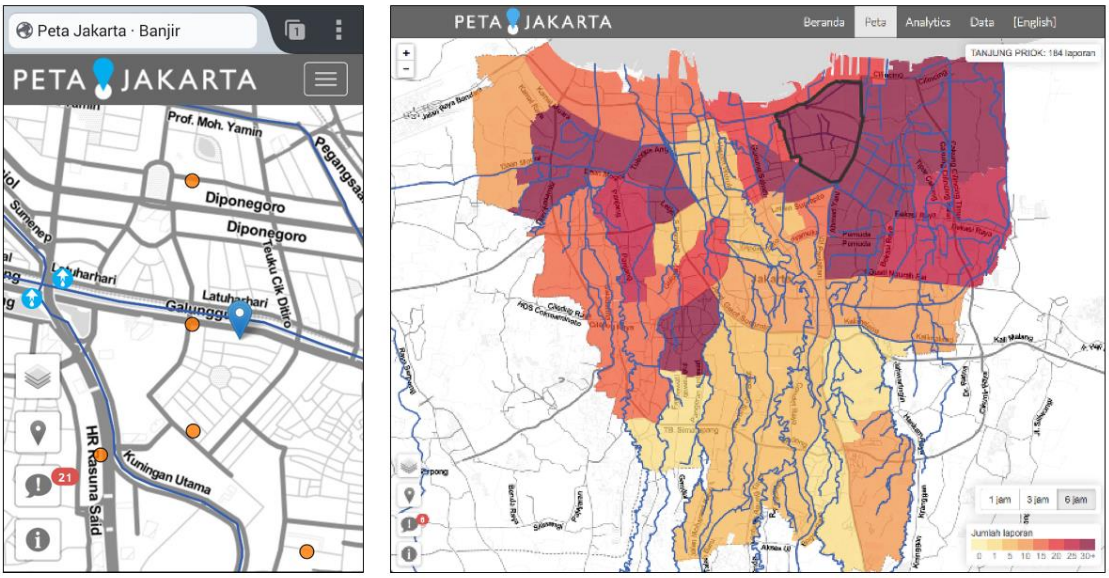


*Figure 4-6. Peta Jakarta user interface on mobile devices (left) and desktop computers (right). Source: petajakarta.org*

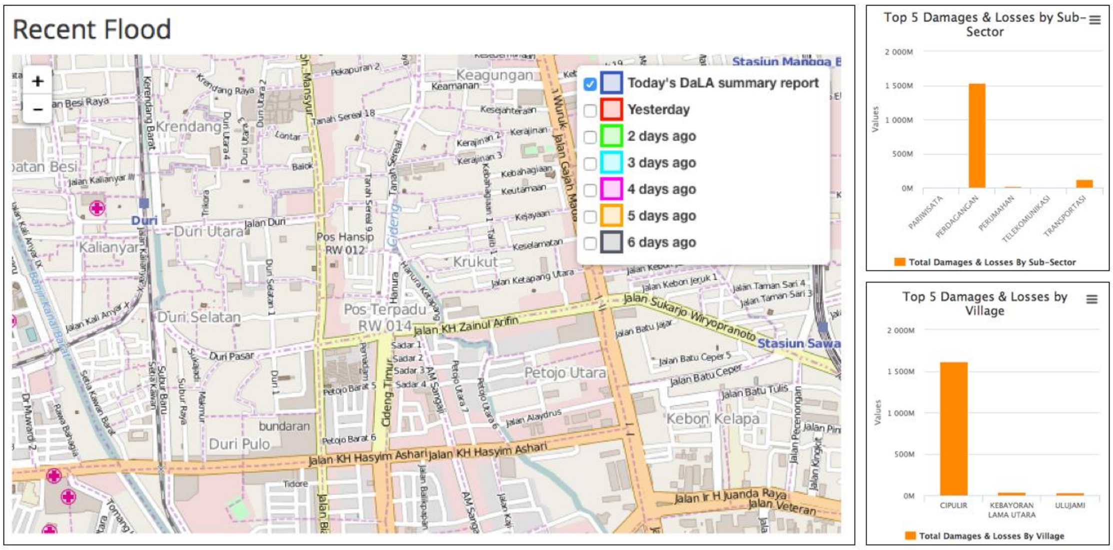


*Figure 4-7. JakSAFE desktop user interface. Source: jaksafe.bpbd.jakarta.go.id*

Table 4-1 summarises the current state of VGI use to reduce flood risk in Jakarta according to the interview results.

*Table 4-1. Summary of the current state of VGI use to reduce flood risk in Jakarta*

<table>
<tr><th rowspan="2">Disaster Management Stage</th><th colspan="2">Data Requirement</th><th rowspan="2">Data Use</th></tr>
<tr><th>VGI</th><th>Authoritative</th></tr>
<tr><td>Mitigation</td><td rowspan="2">• Building polygons<br>• Roads<br>• Important infrastructures (e.g., hospital, school, public building)<br>• Flood hazard polygon<br>• Administration boundaries at the local level</td><td rowspan="2">• Population<br>• Flood gate location<br>• Flood models</td><td>1) Updating the base map<br>2) Intervention form of mitigation process. (e.g., whether it is necessary to build a dyke, excavating sediments, or consider making canals based on infrastructure reports from the public)</td></tr>
<tr><td>Preparedness</td><td>1) Risk analysis for contingency planning<br>2) Increasing community awareness<br>3) Developing an early warning system</td></tr>
<tr><td>Response</td><td>• Location of affected people (including their condition and needs)<br>• Location of evacuation camp<br>• Location of current flood hazard<br>• Traffic conditions</td><td>• Water level status<br>• Rainfall data<br>• Weather forecast</td><td>1) Situational updates for public and response team<br>2) Risk evaluation matrix to validate and update the flood models</td></tr>
<tr><td>Recovery</td><td colspan="2">Damage and losses report</td><td>1) Damage and losses assessment<br>2) Risk assessment validation to update contingency plan</td></tr>
</table>

To maintain VGI credibility, Peta Jakarta has an automated-verification method to provide feedback if contributors did not provide enough information (Figure 4-8). Qlue has a rating system and incentive mechanism that gives virtual credits to the contributor that can be used to buy products or services. OSM currently depends on the crowd or social methods where mistakes are expected to be corrected by other contributors (Section 2.8.2).

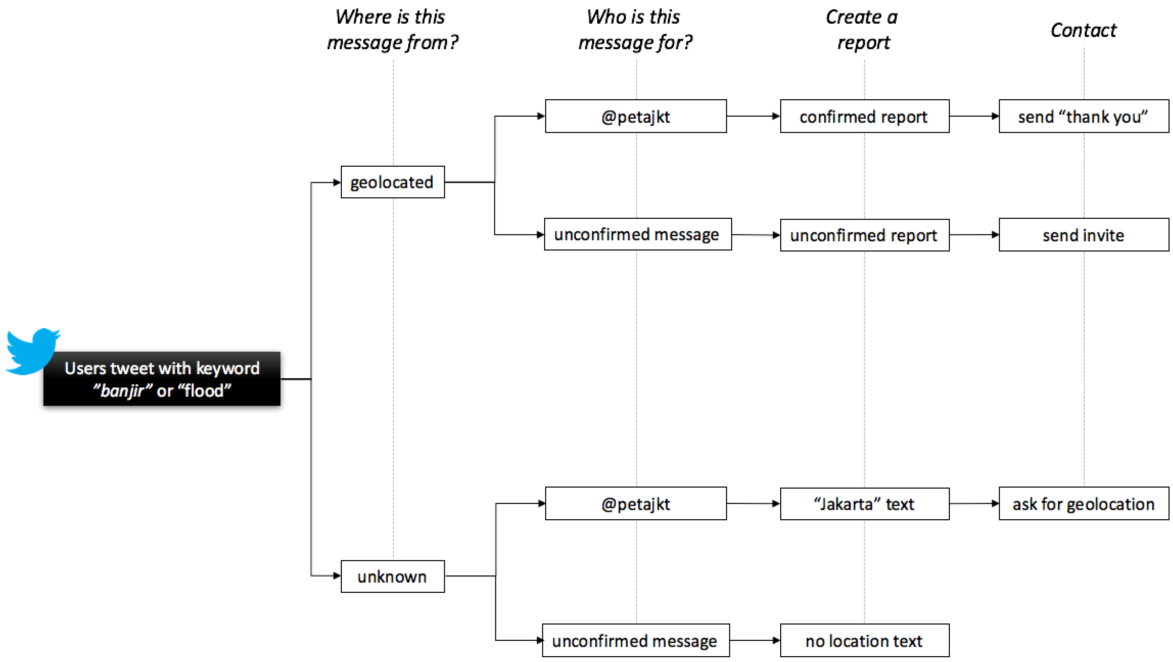


*Figure 4-8. Credibility assessment in Peta Jakarta (adapted from Holderness & Turpin, 2015)*

VGI heavily relies upon public participation to collect the required information. Accordingly, it is important to understand the participant's views of public acceptance of the current VGI practice for flood disaster management in Jakarta. Figure 4-9 shows that eight participants were confident that the public would accept VGI use positively.

*"The public welcomes VGI positively, especially NGOs. They are welcome positively because this is for humanitarian (purposes) in which information should be open; the information should be available as wide as possible. So far there is no problem."*

- Interview Participant G03

Five of the participants did not provide a clear answer. For example, a participant stated:

*"If they (public) are aware or have geographic knowledge or at least (access to an) information system, they are positive about this. If they don't (have knowledge), maybe they would have various perceptions."*

- Interview Participant G06

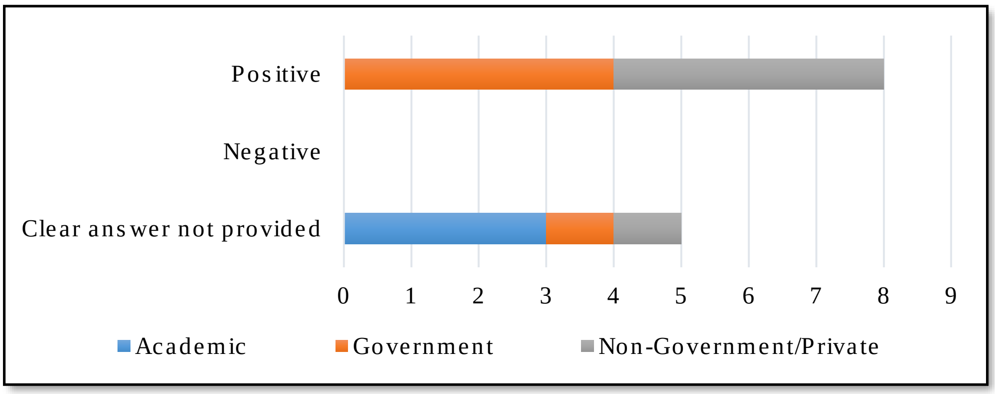


*Figure 4-9. Participants' opinion of public perception on the current VGI use in disaster management in Jakarta*

Furthermore, participants were also asked whether they thought the current VGI practice would be able to reduce the future flood risk in Jakarta. Figure 4-10 shows that the majority of participants (they were ten in total participants) were confident that VGI may be able to achieve a flood risk reduction.

*"Certainly, if a good process to collect and use data could be managed, I think it could significantly reduce the risk of flood. Depends on the management at that period, if the management make a good use of it, I think it could."*

- Interview Participant G03

*"(Yes), on the condition that it (VGI) is used according to a logic co-management, which makes the user generated information in its aggregate form. Asking people to volunteer and share, particular types of information, in our opinion, works best if they are the ones who benefit from the aggregation. If that was the case in this context, I would say yes, VGI has a positive role to play."*

- Interview Participant A03

Three of the participants did not provide a clear answer. For example, a participant stated:

*"Whether or not it could directly reduce the risk of disaster is still being debated."*

- Interview Participant N01

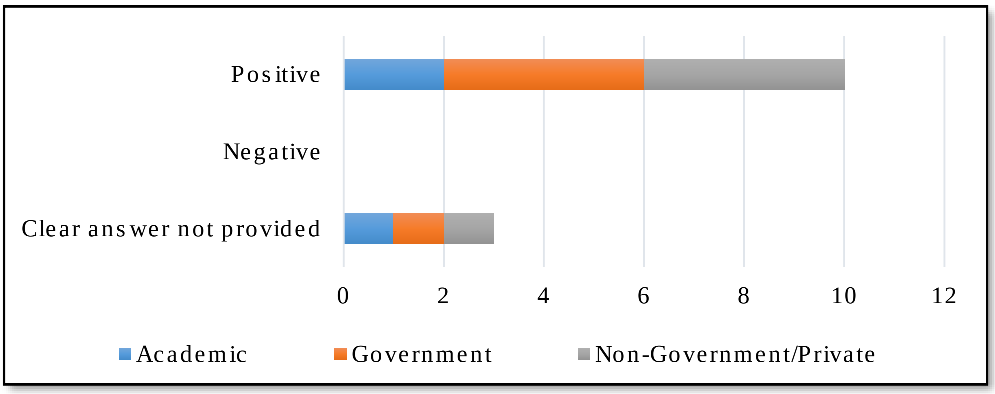


*Figure 4-10. Participant responses related to whether VGI use within each stage of disaster management cycle could reduce the flood risk in Jakarta effectively*

### 4.1.3. Advantages and Limitations of VGI Use for Flood Disaster Management in Jakarta

Figure 4-11 shows that the majority of participants (they were five in total participants) mentioned that VGI is able to enrich authoritative data. Other advantages mentioned were: being cheap and time efficient, establishing community knowledge, increasing community awareness, and promoting open data.

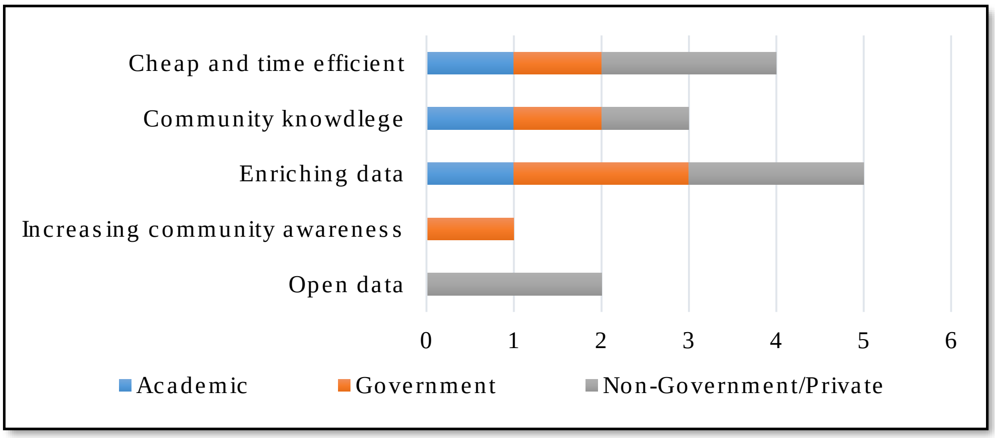


*Figure 4-11. Advantages of VGI mentioned by participants during interviews*

*"… first it (VGI) would be more massive than doing it ourselves."*

- Interview Participant G03

*"We are all connected by mobile devices now and it's a big sensors network effectively."*

- Interview Participant A03

Using VGI is not without issues (Section 2.8). The participants have identified four issues based on their experiences: completeness, credibility, participation, and stakeholders. Interestingly, all participants were concerned about credibility related issues (Figure 4-12).

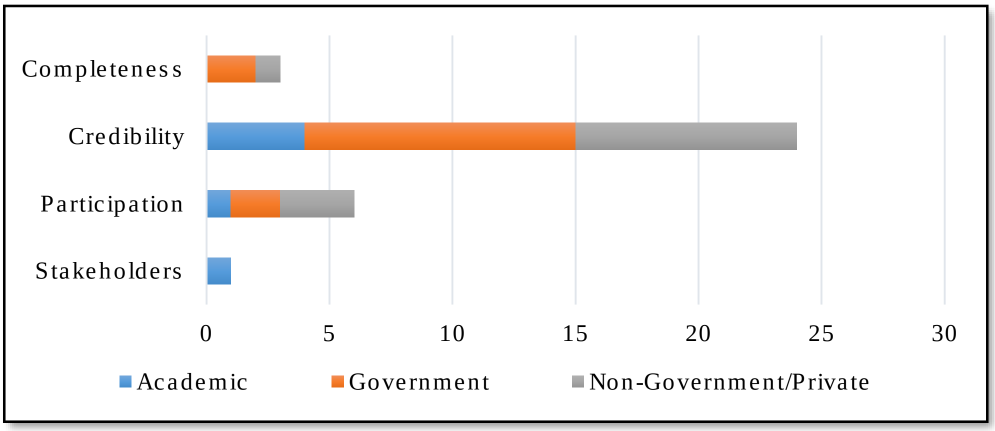


*Figure 4-12. Disadvantages of VGI mentioned by participants during interviews*

*"The challenge for VGI data is checking its credibility."*

- Interview Participant A01

*"When using data from sources that could not be trusted, the filtering process is not well implemented, and the verification process is not well structured; (thus) it would have bias."*

- Interview Participant G03

*"The biggest challenge is the moderator or the compiler. At the time, VGI is compiled to produce information, used to make decisions, it should include a validation process and formalisation. If such a process was implemented, it could be stated as "official map for planning". Without a validation process, the risk is that we could (end up) making decisions based on information that does not have any credibility."*

- Interview Participant N05

### 4.1.4 Improving VGI Use for Flood Disaster Management in Jakarta

Participants have identified five possible ways to improve VGI use in disaster management: improving community outreach, establishing a verification agency, improving user interface (UI) and user experience (UX) of VGI tools, interoperability standardisation, and integrating VGI with authoritative sources (Figure 4-13).

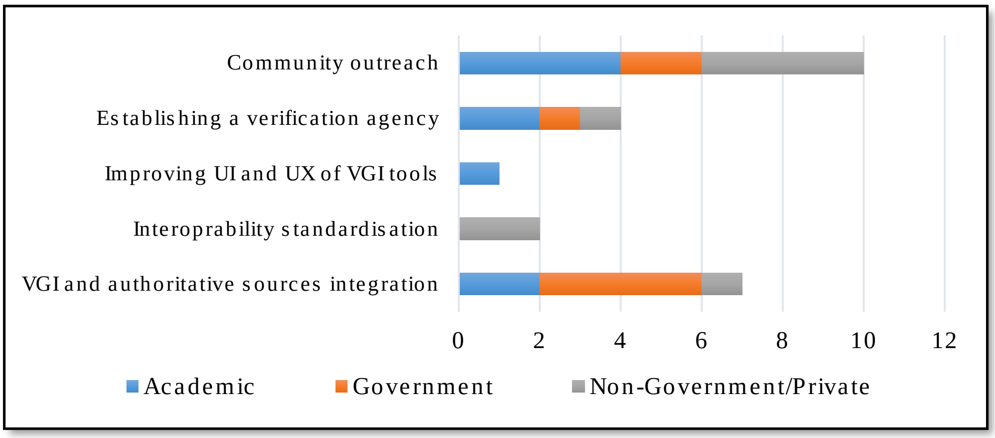


*Figure 4-13. Ways to improve VGI use in disaster management*

Although only one participant mentioned a stakeholder related issue, it is important to identify the roles of each stakeholder when using VGI in disaster management. Participants were asked their opinion about which organisation should be responsible for VGI, from data collection to the publication of VGI-derived information. Correspondingly, the majority of participants responded that government should be responsible for collecting the required dataset through VGI (Figure 4-14). The majority of participants (they were eight in total participants) also suggested that government should be responsible for publishing VGI-derived information (Figure 4-15).

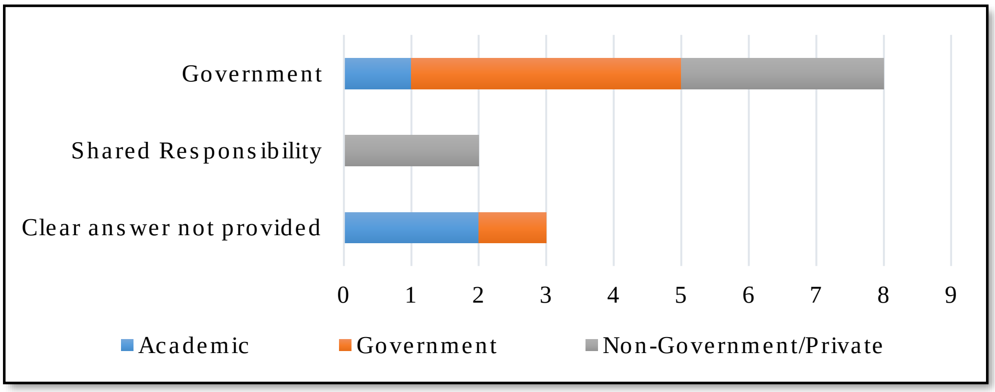


*Figure 4-14. Participant' opinions on the organisation that should responsible for collecting VGI datasets*

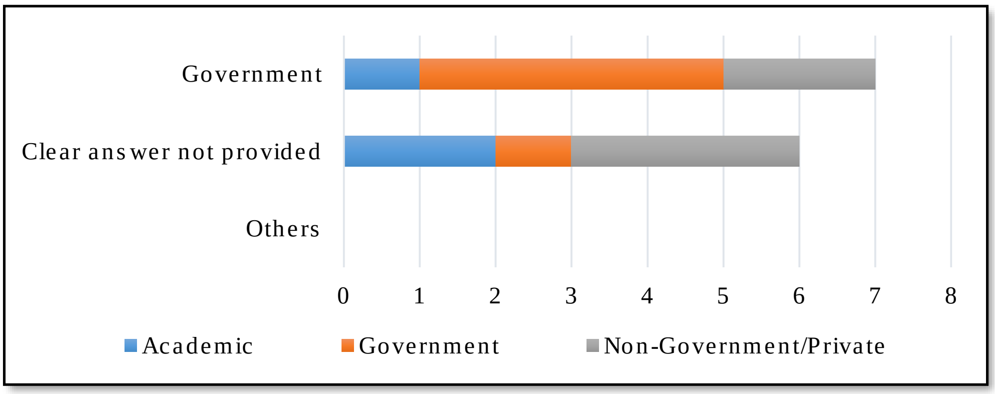


*Figure 4-15. Participants' opinions on the organisations that should responsible for publishing VGI-derived information*

*"(The) Indonesian government should be very clear about which data they want to use to make decisions and to facilitate mapping that is accessible to people."*

- Interview Participant N03

Credibility is a key issue that could restrict VGI use in disaster management (Section 2.8.2). Credibility related issues in VGI were discussed with participants to gather a consensus of what credibility mean, including the assessment methods to mitigate credibility related issues in VGI. Most participants (they were nine in total participants) defined VGI credibility as related to an extrinsic quality or authorship (Figure 4-16).

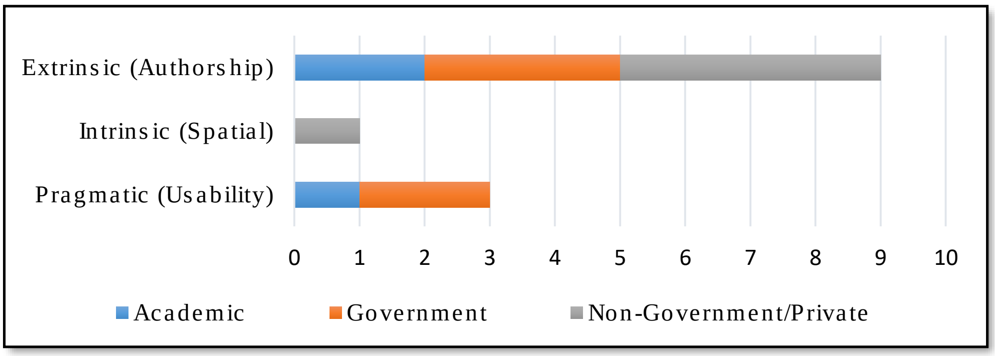


*Figure 4-16. Participants' opinions on credibility definition in VGI*

Below are three different assessment methods that identified by participants during interviews:

1) **Author validation**: each contributor needs to be identified and information that comes from verified contributors is more likely to be credible.

2) **Field validation**: each contributed information needs to be verified by a field survey.
3) **Statistical validation**: information is more likely to be credible if there are a number of different contributors who provide similar information at similar times and location.

Most participants (they were four in total participants) suggested that a statistical validation should be applied to assess VGI credibility (Figure 4-17). However, four participants did not provide a clear answer, arguing that VGI credibility assessment should depend on the type of information acquired.

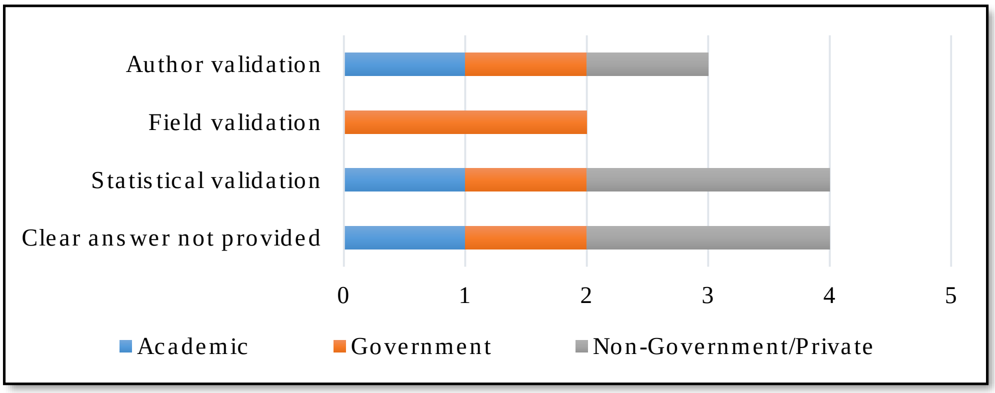


*Figure 4-17. Participants' opinion on VGI credibility assessment methods*

When participants were asked about which organisation should be responsible for maintaining VGI credibility, six participants did not provide a clear answer. For example, one participant stated:

*"The responsibility should go back to those with the competence in such a field. However, it would also be difficult to take them into account, because it does not always mean that they are the ones who produce the data."*

- Interview Participant N01

Two participants suggested that VGI credibility assessment should be a shared responsibility. Four participants suggested the government should be responsible, but one participant suggested the community (Figure 4-18).

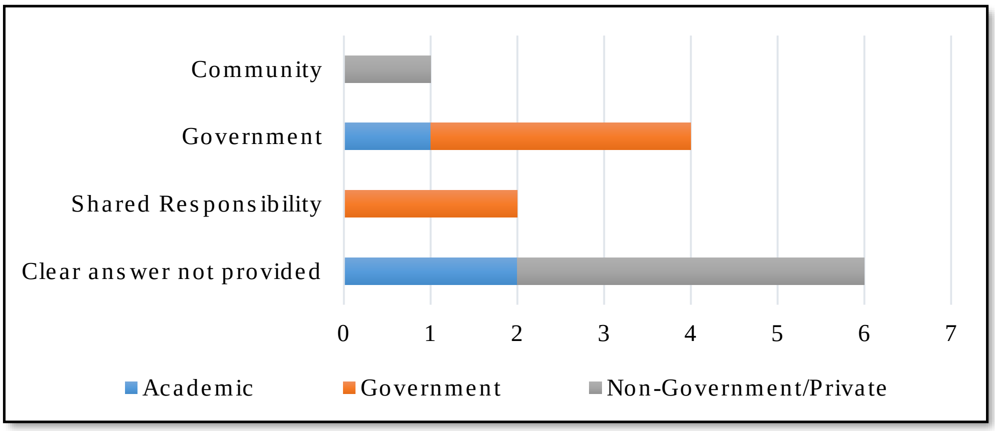


*Figure 4-18. Participants' opinions on the institution responsible for VGI credibility*

Since VGI sources fill an information gap in disaster management, they should to be integrated with authoritative sources. Previously, seven participants argued that the integration of VGI and authoritative sources may improve VGI use (Figure 4-13). However, the integration process can be difficult. Below are challenges of VGI-authoritative sources integration that identified by the participants during interviews:

1) **Temporal representation:** authoritative sources have a specific timeline to update their information, while VGI sources tend to be more dynamic and updates can be near real-time.
2) **Spatial representation:** in contrast to authoritative sources, VGI sources may have different accuracy levels.
3) **License conflict:** authoritative sources tend to have a proprietary license, while VGI sources are adopting open licenses.
4) **Interoperability:** authoritative sources comply with different standards compared to VGI sources.

As shown in Figure 4-19, the majority of the participants (they were six in total participants) argue that spatial representation is the main challenge when integrating VGI and authoritative sources.

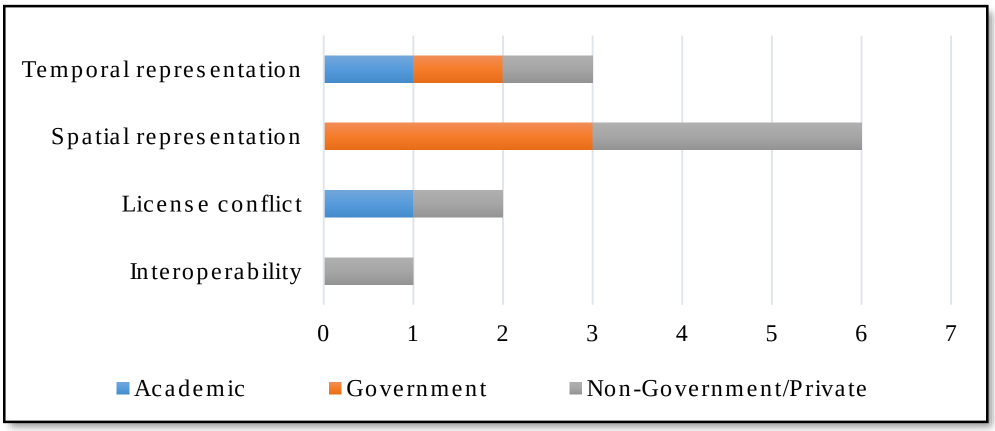


*Figure 4-19. Challenges related to the integration of VGI and authoritative sources*

## 4.2 FGD Results

This section provides the results from the community FGD, which comprises two main themes: understanding the flood in Marunda and current practice of VGI use in the local community. The results explore the participants' knowledge and opinions related on flooding and local community experiences with VGI use in RW 07 Marunda.

### 4.2.1 Understanding the Floods in RW 07 Marunda

Figure 4-20 shows the location of flooding, marked by blue polygons, in RW 07 Marunda, according to the FGD participants. The darker blue colour represents more flooding incidences.

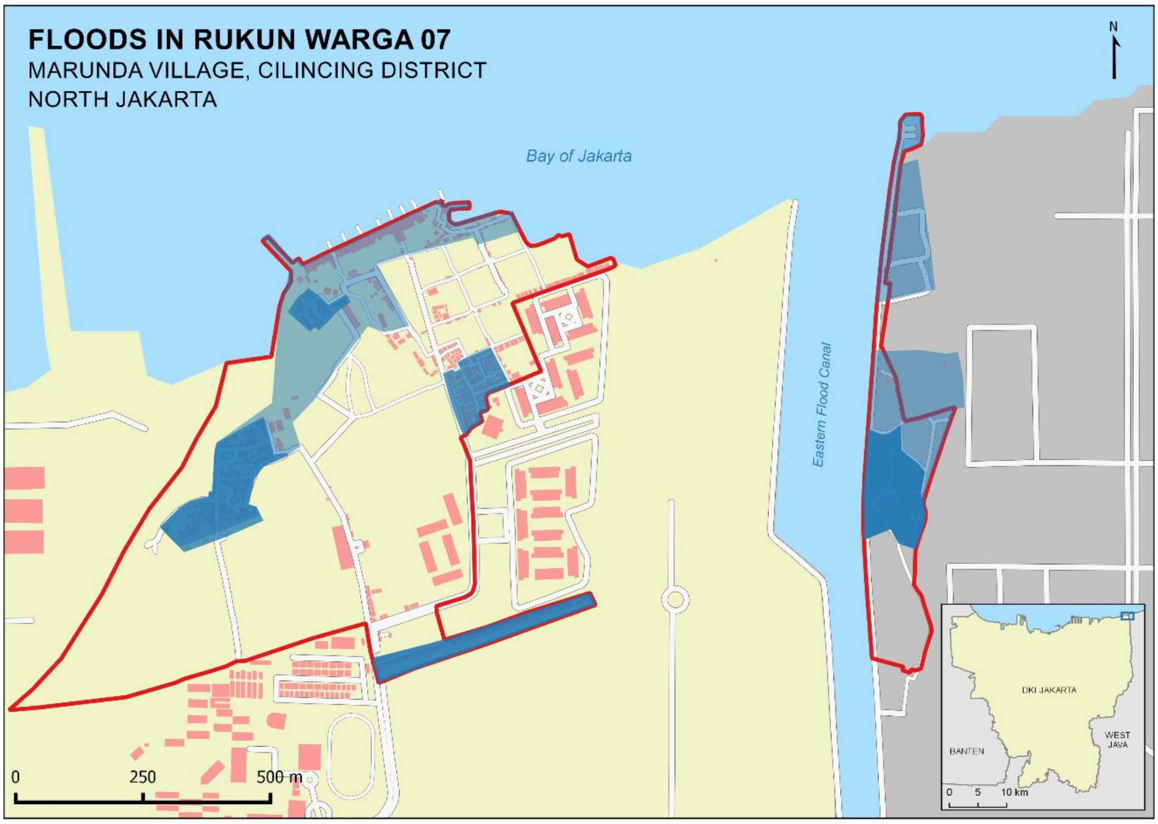


*Figure 4-20. Map showing the location of floods in RW 07 Marunda based on FGD results (author's own). Map data: Community FGD in RW 07 Marunda (June, 2016), OpenStreetMap Contributors, and BPBD DKI Jakarta*

From the FGD, it is found that flooding occurred many times in RW 07 Marunda. The FGD participants were unable to mention a specific number of flood occurrence. However, they agreed that the largest floods occurred in 2007 and 2012, then a mix of small to medium flood events occurred from 2013 to 2015, specifically during the monsoon season. A general consensus found that major floods usually occurred in five year cycles (e.g., 2002, 2007, and 2012). Some FGD participants were also aware of causal factors, such as land subsidence and sea level rise.

*"Yes, the small scale (flood) happens very often. The big one (flash flood) happens in a five years' cycle."*

- Focus Group Participant 01

Figure 4-21 shows the average water depth during the flood as perceived by the FGD participants. The majority of participants (they were four in total) estimated water depth in most flood events are between 26-50 centimetres. However, all focus group participants agreed that no matter the scale, each flood needs to be managed seriously. The FGD participants also expressed concern related to the post-flood events which can be overwhelming and pose health threats to the community, for example:

1) Trash or other sedimentation which is brought by the flood can contaminate water sources.
2) Increased mosquito breeding which can cause malaria or a dengue endemic.

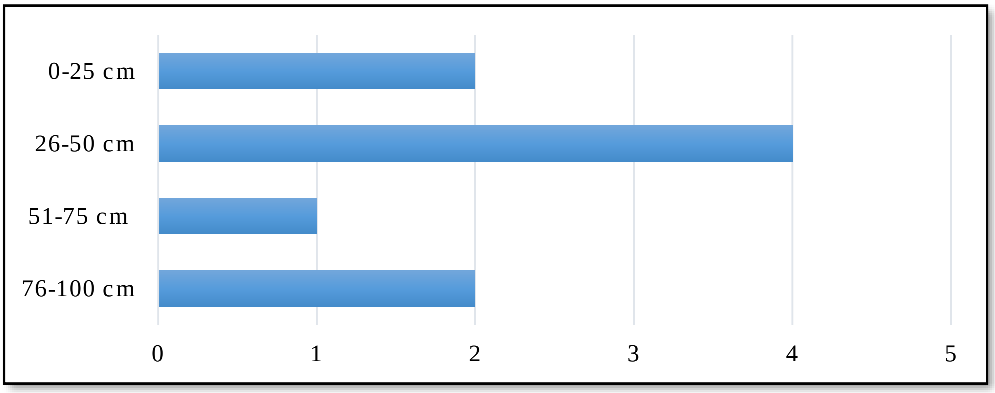


*Figure 4-21. Average estimated water depth during the flood mentioned by the local community during FGD session*

### 4.2.2 Current VGI Use in the Local Community

In 2015, people of RW 07 Marunda, together with a local community consultant, held Marunda Urban Resilience in Action (MURIA)[19] to improve local resilience. One of the main activities was the community mapping program, which involved the use of VGI. It was important to discuss this community's experiences related to VGI use.

There was a general consensus from the FGD participants that the community mapping effort in RW 07 Marunda is similar to scale mapping like Mapping Jakarta in 2012, but they were more focused towards the local. Participants were trained by HOT[20] to use OSM and Ushahidi[21]. Using OSM, participants collect information using field survey methods with mobile devices or FieldPapers[22]. The collected information includes

[19] http://openstreetmap.id/en/muria-membangun-ketangguhan-masyarakat-perkotaan/

[20] http://hotosm.org

[21] https://www.ushahidi.com

[22] http://fieldpapers.org

infrastructure (e.g., roads, buildings, houses), local community boundaries, evacuation routes, evacuation points, the location of the vulnerable groups, and the flood extent needed for the preparedness stage. Additionally, Ushahidi enables participants to send reports about flood incidents (Figure 4-22).

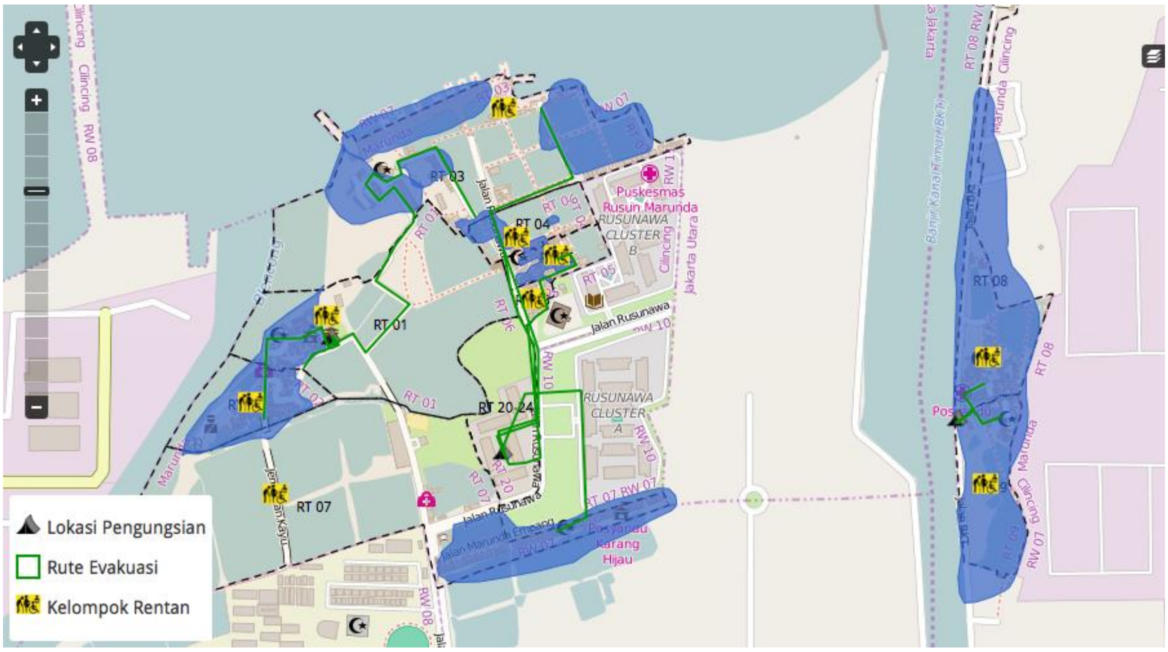


*Figure 4-22. Map showing information related to flood preparedness.*
*Source: http://openstreetmap.id/muria/*

According to the FGD results, the community mapping in RW 07 Marunda is also used to support local development through, for example, mapping social, economic, and cultural activities. The information is accessible online (Figure 4-23) and also available printed (Figure 4-24).

*"We have an idea (of how) to use the application for more than just floods. The youth want Ushahidi applied to other things. For example, when there is a new born baby, the local government would notice that from Ushahidi and automatically create a birth certificate for that baby. So parents could pick up the birth certificate directly from the governmental office."*

- Focus Group Participant 02

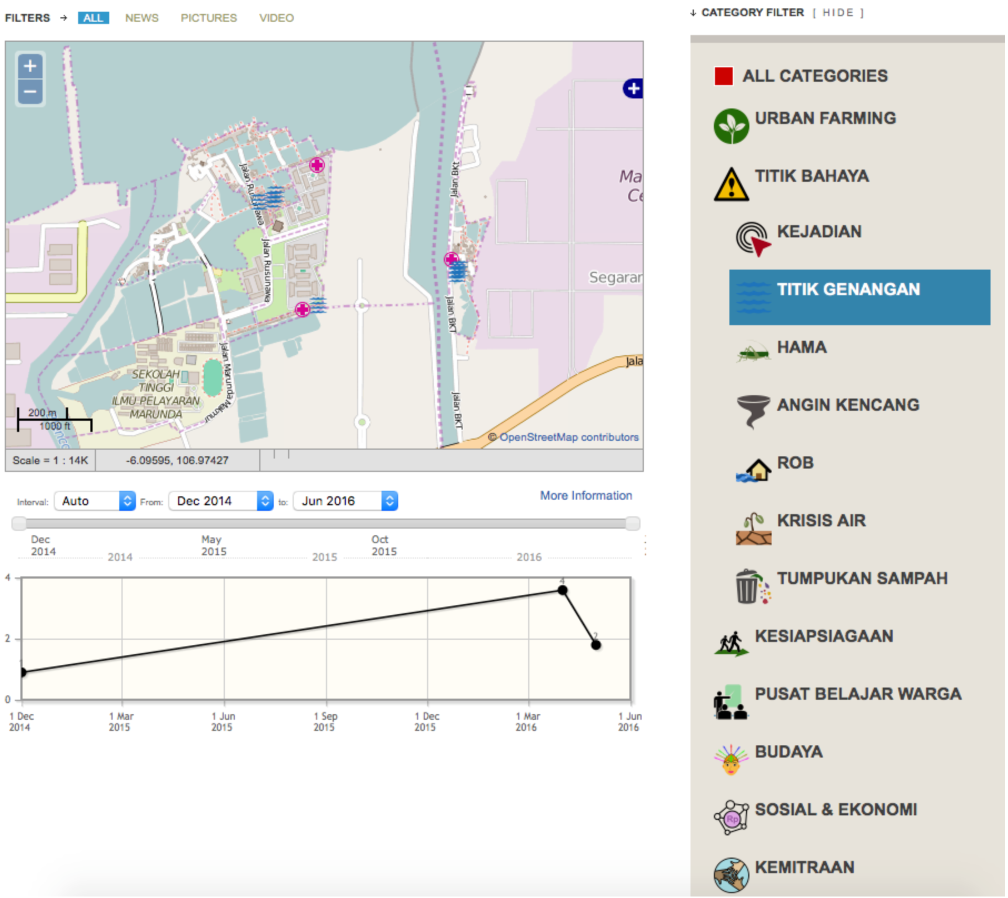


*Figure 4-23. Different types of information on Ushahidi's platform for community mapping in RW 07 Marunda. Source: http://openstreetmap.id/muria/*

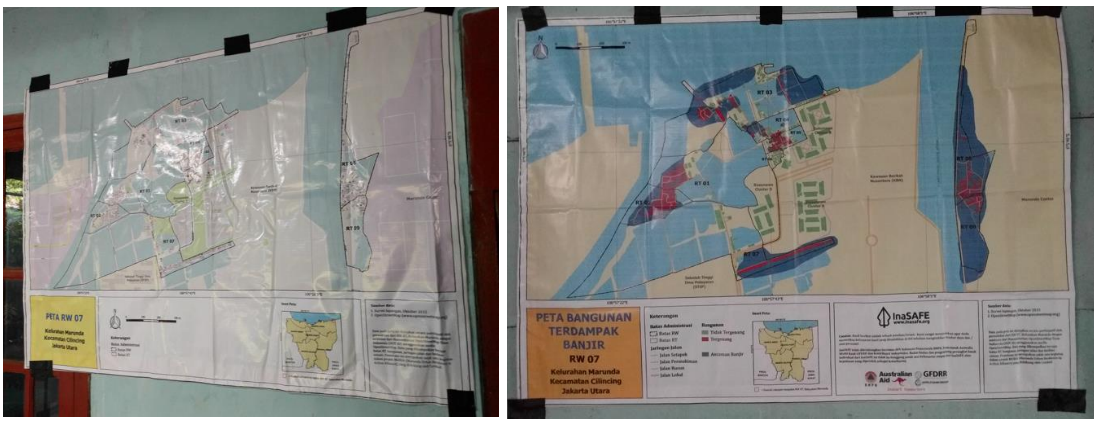


*Figure 4-24. Examples of printed maps. The maps are waterproof to improve their usability during flood season (author's documentation)*

At the end of FGD session, the use of VGI in their mapping process was found positive by the FGD participants. Empowering the local community, improving spatial awareness, and increasing flood awareness are the primary impacts. An example of resulting public benefits is where the local community was able to practice community-based flood management simulation effectively because of maps they have produced.

Finally, the FGD participants expressed concern related to the VGI mapping process. The first issue is the use of the mapping software: not everyone familiar with computers or mobile devices. The second issue is spatial literacy: some people have a problem understanding the context of information on the map, for example, people may have problems locating themselves on the map. The third issue is sustainability: the program could stop without any future direction or follow-up. The last issue is support related: participants request adequate tools to deliver more accurate information, including possible incentives for their contribution time.

*"I think this (community mapping) activity needs to be sustainable. If this only happened once, it's going to be useless. In the other hand, it also needs support."*

- Focus Group Participant 03

## 4.3 Summary

There is a diversity of opinion across the participants interviewed. However, a general consensus of interview participants implied that incorporating VGI in disaster management is important, primarily to fill in gaps in authoritative sources. Current VGI practices in reducing flood risk in Jakarta has generated significant concern amongst participants because of VGI issues, such as completeness, credibility, participation, and stakeholders. Accordingly, participants have identified several ways that may improve VGI use related to improvement of community outreach, establishment of verification agency, improvement of UI and UX of VGI tools, interoperability standardisation, and integration of VGI-authoritative sources.

The FGD process in RW 07 Marunda reflects VGI use in disaster management from local viewpoints. A general consensus from FGD participants implied that VGI is important to reduce flood risk and to support development at the local level. However, the local community requests adequate support from other stakeholders, both education and material.

# 5 Discussion

The current practice of Volunteered Geographic Information (VGI) for each disaster management stage in Jakarta is explored in the first section. The second section focuses on VGI advantages in disaster management. The third section focuses on the key issue of VGI use in disaster management to analyse areas of improvement for the framework development. A key contribution of this thesis is a framework to improve VGI use in disaster management, which is presented in the fourth section. The chapter concludes with a summary of the discussion, answering each research questions of this thesis.

## 5.1 The State of VGI: Towards Better Flood Risk Management in Jakarta

VGI is generally viewed by interview participants as geographic information provided voluntarily by the public (Section 4.1.1). A key finding of this case study is that VGI as an alternative geospatial data acquisition method has widespread support across government, Non-Government Organisations (NGOs)/private, academic, and community participation in Jakarta. Stakeholders rely VGI to fill gaps in authoritative sources where such datasets are lacking or obsolete (Section 4.1.2 and 4.1.3). This practical reason for VGI adoption is beneficial for disaster management (Goodchild & Glennon, 2010), and also for more general use in government (Haklay et al., 2014; Johnson & Sieber, 2013).

In contrast with pervious case studies, where VGI use in the disaster management only focuses on response and recovery stages (Section 2.7), Jakarta case study shows VGI's potential to be used at each disaster management stage (Figure 5-1). Collaborative or feature mapping is most important before the disaster (mitigation and preparedness), while geo-located reporting tools are more important during and after the disaster (response and recovery).

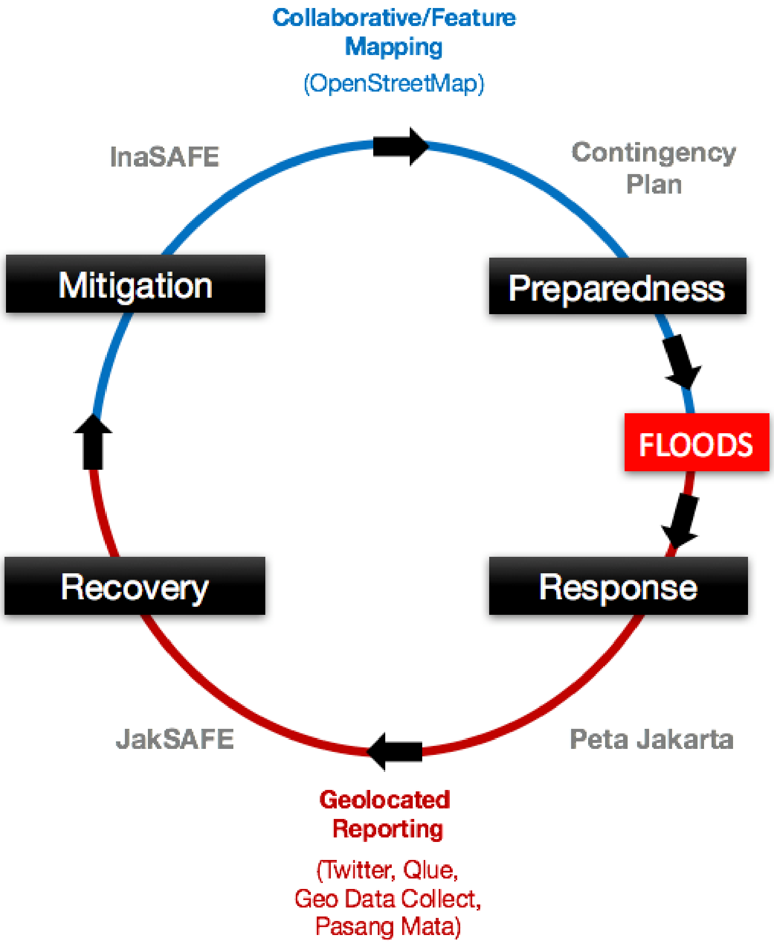


*Figure 5-1. VGI use according to each disaster management stage for floods in Jakarta (author's own)*

There is a general consensus that the data requirements for the mitigation and preparedness stage are similar, although with different uses. Collaborative or feature mapping tools, specifically OpenStreetMap (OSM), are valuable in providing a detailed local base map during mitigation stage. Later, in the preparedness stage, the base map is combined with authoritative sources (e.g., flood models, population data) to produce a Geographic Information Systems (GIS)-based risk assessment using InaSAFE[23] software. The risk assessment can be used to develop contingency plans.

The results found the use of geo-located reporting tools for the response stage is familiar amongst interview participants (Section 4.1.2). Public geo-located reporting tools, such as Twitter, provide information related to flooding in near real-time. The flood

[23] http://inasafe.org

information is aggregated and visualised through Peta Jakarta[24]. In the recovery stage, the JakSAFE[25] tool is used to aggregate damage and loss reports related to the flooding. This mashup technique is similar to Calgary's case study in 2013 (Schenebele et al., 2013). However, there was no consensus on how the information collected at each disaster management stage will be stored and could be used later.

Most interview participants (they were eight in total participants) commented VGI has been positively perceived by the public (Section 4.1.2, Figure 4-9). The rise of mobile internet users in Jakarta can support VGI collection and use. Goodchild's (2007a) "citizens as sensors" concept is also familiar amongst interviewed participants. However, three interview participants did not provide a clear answer about the public's perception of VGI. These participants reasoned that a number of community members may not be aware of VGI existence in Jakarta. Additionally, a lack of research into public perceptions of VGI, specifically in Jakarta, may also lead to this unclear answer.

## 5.2 Advantages of VGI Use in Disaster Management

The results chapter (Chapter 4) show a general consensus from interview and focus group discussion (FGD) participants that using VGI at each disaster management stage can reduce the flood risk. The reasons are linked to the following VGI advantages.

### 5.2.1 The Cost and Efficiency of VGI

Most VGI sources are provided without cost which fits VGI's price value (Parker, 2014d). It is not surprising that interview participants encourage VGI use to reduce the cost of geographic information production (Section 4.1.3, Figure 4-11). Interview participants recognised that access to VGI sources may be free. However, there may be setup costs to integrate VGI within an SDI, such as for maintenance, public outreach, and training programs.

Another VGI advantage is time efficiency. VGI can deliver a high quantity of information in a relatively short time period. This advantage is a functional value of VGI (Parker, 2014d). Figure 5-2 shows that the number of OSM features (buildings and roads) in

[24] http://petajakarta.org

[25] http://jaksafe.bpbd.jakarta.go.id

Jakarta has improved over the past five years. Possible reasons of this improvement may be because OSM gains more attention from the public since the Jakarta Mapping project and a high level of proliferation of internet use in Jakarta (Section 2.9). Less populated area or an area with low internet penetration may require different approach to achieve this VGI advantage.

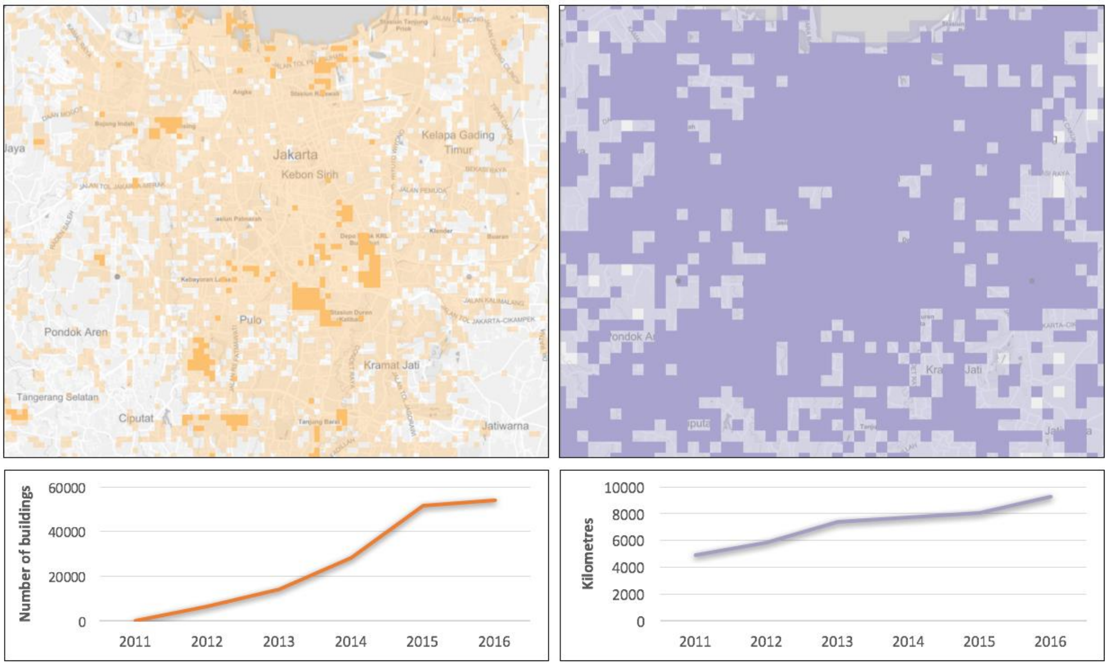


*Figure 5-2. (Left) Building density and number of buildings mapped in Jakarta on OSM. (Right) Roads density and length of roads (in kilometres) in Jakarta on OSM. Source: osm-analytics.org*

### 5.2.2 Harnessing Local Knowledge

VGI harnesses local knowledge which offers more value compared to traditional forms of data collection (e.g., survey, government census). The value of local knowledge is also acknowledged by Parker (2014d). Through VGI contribution, the local community often reveal additional information which potentially delivers better results in disaster management. One interview participant commented that the best knowledge during a disaster is often local knowledge. This advantage is also reported in a number of studies (Haklay et al., 2014; Haworth, 2016; Haworth & Bruce, 2015; Johnson & Sieber, 2013).

Harnessing the local knowledge may create a potential issue for data collection because views within local community and government can differ. For example, Figure 5-3 shows different views between the local community and the government when understanding community boundary. The area around the red line denotes an administration boundary at a community level, mapped by the community in OSM in 2012. The yellow background is the Jakarta province administration area issued by the local authority. As pictured in the map, part of the community (as identified by the local community) is located outside of the Jakarta province administration area (West Java province).

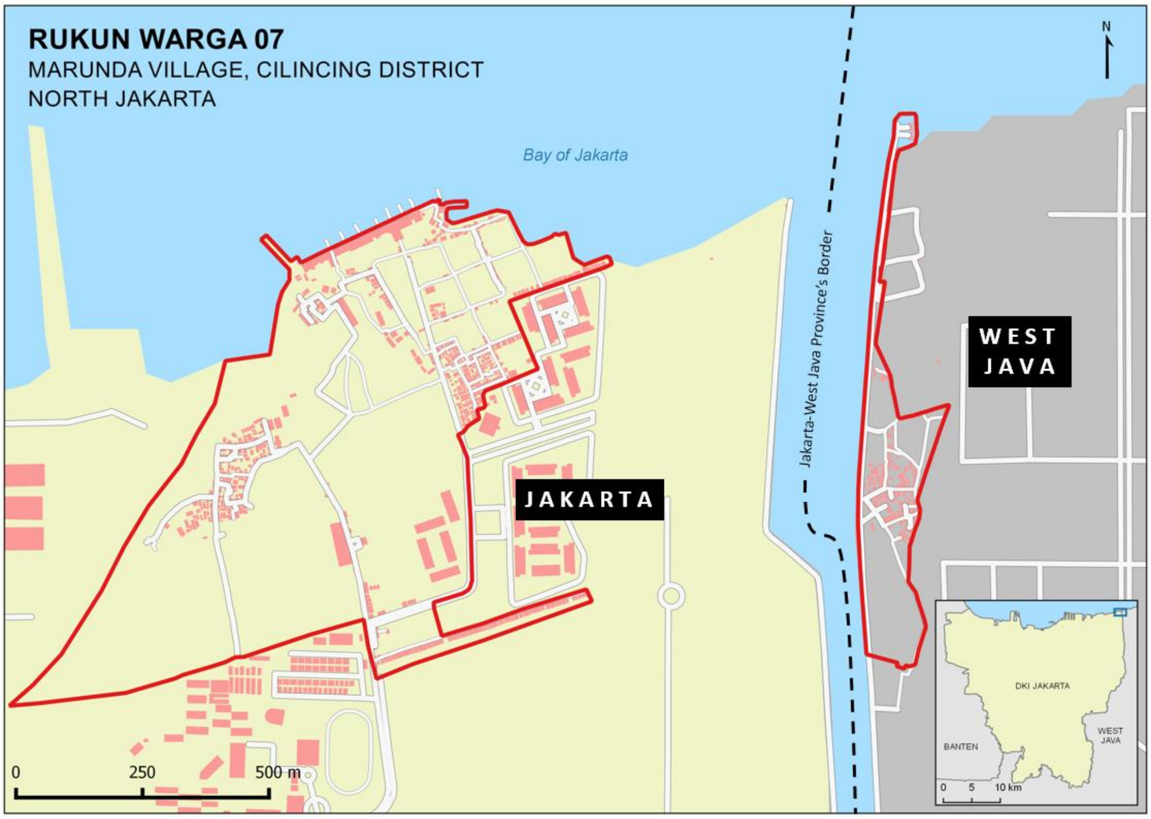


*Figure 5-3. Map showing an issue where views within local community and government can differ (author's own)*

### 5.2.3 Enriching Data

Enriching data was the most commonly mentioned advantage (Section 4.1.3, Figure 4-11). This advantage is not surprising because most interview participants have been dealing with data scarcity. Similar to cost and efficiency, this advantages is also a function value of VGI (Parker, 2014d).

Stakeholders must not assume VGI will answer data scarcity problems. Some data types still require expert's input and the government has a responsibility for geographic data production. Additionally, infrastructure disruptions, such as power outages or communication outages, may occur during a disaster, reducing the public's ability to contribute. Furthermore, the extent to which VGI can enrich authoritative sources needs to be identified.

### 5.2.4 Increasing Community Awareness in Disaster Management Context

A government participant mentioned that community awareness of flood risk may increase if the public contributes to a VGI project. Additionally, with the ease of information access, a community member could make their own decision such as whether they need to evacuate or not. This advantage is also acknowledged by the FGD participants. According to FGD results, VGI increases spatial awareness related to flood risk, which can improve community resilience (Section 4.2.2). This finding is in-line with previous research (e.g., Haworth, 2016; Haworth & Bruce, 2015; Haworth et al., 2015; McCallum et al., 2016).

Previous studies reported that VGI not only supports community resilience in disaster management, but also local empowerment (Haklay et al., 2014; Haworth, 2016). These studies fit the Jakarta case study where the local community also uses VGI to support social, economic, and cultural activities.

### 5.2.5 Promoting the Value of Open Data

Two interview participants stated that open data would enable anyone interested to use the data for any purpose and transform that data into useful information (Section 4.1.3, Figure 4-11). Most VGI platforms allow anyone to access data. Ideally, the data collected from the public should be given back to the public and remains open (i.e., public domain), and this aligns with Parker's (2014d) VGI moral value. The use of VGI also may encourage other stakeholders to publish their data openly in Indonesia.

## 5.3 VGI Issues in Disaster Management

Both interview and FGD participants concerned a number of issues that affect VGI use in disaster management. VGI issues in disaster management are related to legal, credibility, public participation, stakeholder engagement, and interoperability.

### 5.3.1 Legal

The Jakarta case study found conflicting data licenses still occur when integrating VGI sources with authoritative sources (Section 4.1.4, Figure 4-19). This finding is surprising because Indonesia currently has an Open Data Policy (Indonesia Regulation No. 14/2008) to encourage authorities for publishing their data to the public. Some authorities may have difficulty understanding the context of open data and still hesitate to publish their data with an open license. This study suggests a need for outreach in authorities to enforce the Open Data Policy.

Legal issues also related to country's policy where authority may restrict VGI (Section 2.8.1). For the context of Jakarta case study, Indonesian geospatial policy states that only the government, specifically the Indonesia's Geospatial Information Agency (BIG), which has the authority to create and update the base map (Indonesia Regulation No.4/2011, Article 22). Additionally, the policy also stated that a base map comprises datasets, such as coastline, hypsography, hydrology, topographical names, administration boundaries, transportation and utility, buildings and public facilities, and land cover. This policy may threaten future VGI use as such datasets are also being created by public through a VGI process (Section 5.1). Interestingly, apart from data licenses, this policy issue was not mentioned during the interviews. The immediacy of a natural disaster may be responsible, where local disaster managers cannot wait for updated geospatial data from the BIG.

### 5.3.2 VGI Credibility

Having a large pool of VGI contributions can be both useful and problematic. It is useful to enrich authoritative data. However, assessing the credibility from each contribution can be overwhelming. Issues related to VGI credibility were mentioned 24 times during the interviews (Section 4.1.3, Figure 4-12). The extrinsic aspect of credibility (authorship) is the primary concern when using VGI for disaster management (Section 4.1.4, Figure 4-16). All interview participants suggest VGI sources need to be verified to ensure credibility. This finding is not surprising as most studies also stated that stakeholders may hesitate to use VGI for disaster management because of credibility issues (Doris et al., 2013; Fazeli et al., 2015; Goodchild & Glennon, 2010; Haworth, 2016).

The Jakarta case study shows that the biggest concern about VGI credibility comes from central government. Central Government has national standards for geographic information. When producing geographic information, authorities including local government should follow the national standard. However, local government may not have the capacity to do so.

### 5.3.3 Public Participation

Various studies mentioned that public participation is a key success of VGI (Budhathoki, 2010; Haklay et al., 2014; Parker, 2014a; See et al., 2016; Xu & Nyerges, 2016). The Jakarta case study indicates the need for public participation improvement, to increase the data quantity (Section 4.1.3, Figure 4-12). For example, Figure 5-4 shows that Twitter contribution during the 2014-2015 monsoon increased to 541,754 contributions. However, this number is only about 3.61% of Jakarta's daytime population or 5.41% at night.

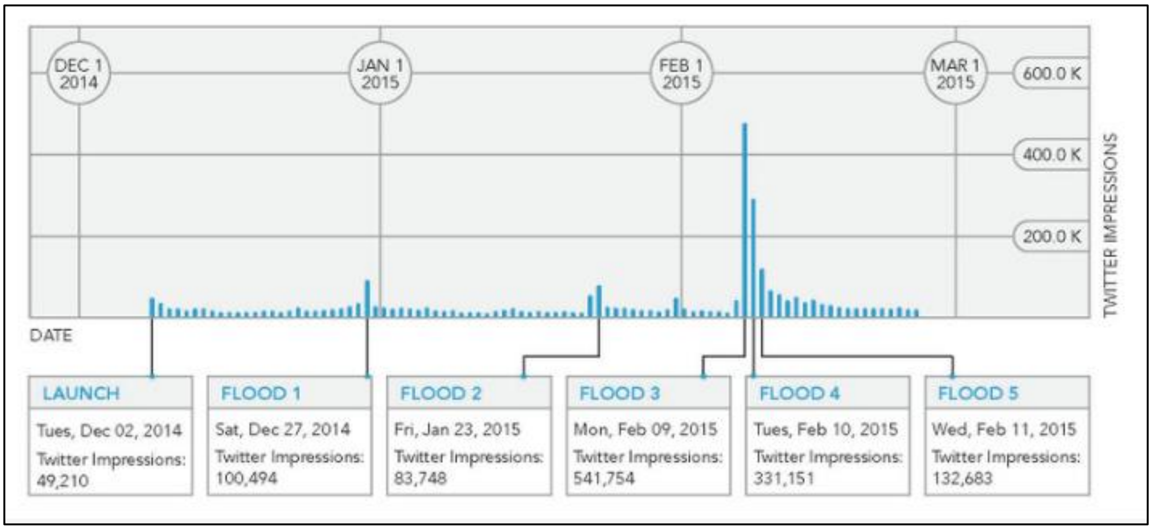


*Figure 5-4. Number of tweets related to flood events in Jakarta during 2014-2015 monsoon (Holderness and Turpin, 2015)*

There is no consensus from the interview results on how much public participation improvement is needed. Interview participants also have concerns about the importance of maintaining participation (Section 4.1.3, Figure 4-12), because it may decrease in the future as public lose interest.

To maintain VGI participation in disaster management, it is also important to prioritise the number of contributors and their geographic distribution, to ensure data completeness (Section 4.1.3, Figure 4-12). Information provided by the public may lack details or does not cover the entire area of interest. For example, not every building in Jakarta is mapped by OSM contributors (Figure 5-5). Having a better geographical spread of contributors is important to ensure that each community, especially in flood-prone areas, will receive assistance when a flood occurs.

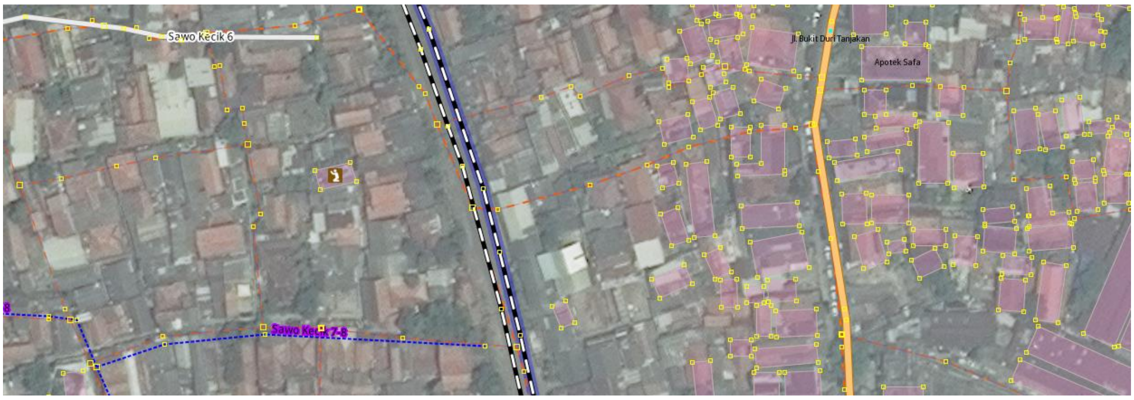


*Figure 5-5. OSM building coverage in a Jakarta's village. Source: OSM contributors, Bing imagery*

### 5.3.4 Stakeholder Engagement

VGI at each stage of disaster management in Jakarta is initiated by the government, specifically the Jakarta province's disaster manager (BPBD DKI Jakarta). A number of stakeholders are also engaged in the process (Section 2.9). Internationally, multi-stakeholder engagement is also common when implementing VGI in the government (Section 2.8.4).

Multi-stakeholder engagement may improve VGI use in disaster management, but may cause disparity of VGI technology (Section 2.8.4), which leads to interoperability issues. Additionally, the results also identified that a multi-stakeholder engagement could trigger conflicts that may restrict VGI use (Section 4.1.3, Figure 4-12). For example, when a stakeholder collects particular information driven by their own needs rather than by the disaster risk manager.

### 5.3.5 Interoperability

Interoperability issue was mentioned in the literature review (Section 2.8.5) and during interviews (Section 4.1.4, Figure 4-13 and 4-19). VGI sources are more meaningful if they are integrated within authoritative sources. The process of VGI integration in authoritative sources can be daunting due to the semantic heterogeneity of VGI sources. Interestingly, from Jakarta case study, semantic heterogeneity comes from authoritative sources as well as VGI. The integration process is also more complicated because some interview participants also complained that some agencies published their data in a non-spatial format (e.g., JPEG, PDF).

## 5.4 Developing a Framework for Improving VGI Use in Disaster Management

The purpose of this study is to develop a framework to improve VGI use in disaster management. Key findings from the literature review (Chapter 2) and the results of Jakarta case study (Chapter 4) show that VGI use in disaster management requires both non-technical and technical components to improve VGI use in disaster management. Based on the Jakarta case study and issues identified in the literature, this study proposes the following framework for VGI use in disaster management (Figure 5-6). The framework has been informed by the Jakarta participants but is intended for wider applications. Non-technical components comprise legal and policy support, organisational practice, verification agency development, better community outreach, and incentive mechanisms. Technical components comprise improving user interface (UI) and user experience (UX) of VGI tools, credibility assessment methods, VGI and authoritative sources integration, and interoperability standards.

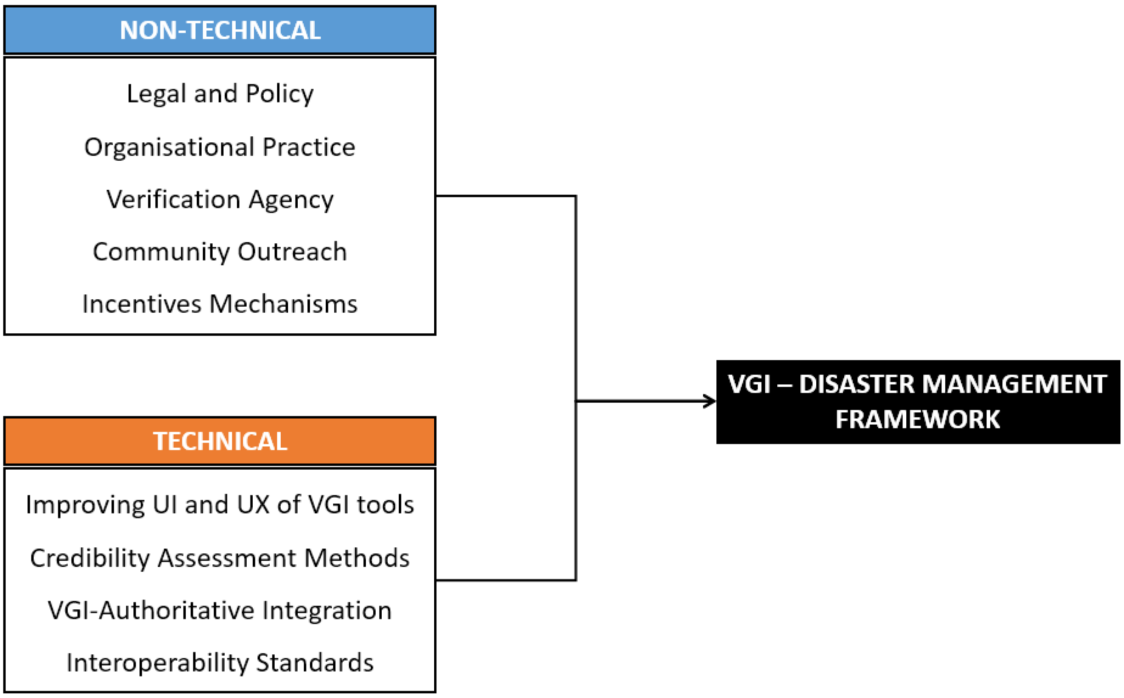


*Figure 5-6. Key contribution of this thesis: a framework of VGI-disaster management (author's own)*

### 5.4.1 Non-Technical Components

**1. Resolving Legal Issues to Support VGI Activities**

The Jakarta case study suggest that stakeholders need to resolve legal issues that may restrict VGI use in disaster management (Section 5.3.1). In Jakarta, Indonesia Regulation No. 4/2011 may need to be clarified because the regulation statement may threaten future VGI use in the future. Further, enforcing Indonesia Regulation No. 14/2008 is also necessary to resolve data license conflicts and support VGI sources integration with authoritative sources.

More generally, a country's legal and policy will need to be reviewed to support VGI use in disaster management. As mentioned in the literature review (Section 2.8.1), disaster managers should be aware of the VGI source licenses and resolve any copyright issues that may arise. Enforcing open data policy may resolve copyright issues and allow the inclusion of VGI sources at a national or local spatial data infrastructure (SDI). Additionally, any policy and regulation that may restrict VGI should be clarified. However, further work related to policy or regulation issues is needed as little has been written on this area.

**2. Developing a Better Organisational Practices to Improve Stakeholder Engagement**

As stakeholder engagement is common in a VGI initiative (Section 2.8.4), developing appropriate organisational practices is important to improve VGI use as suggested by Haklay et al. (2014). This study proposes the following organisational practices (Figure 5-7).

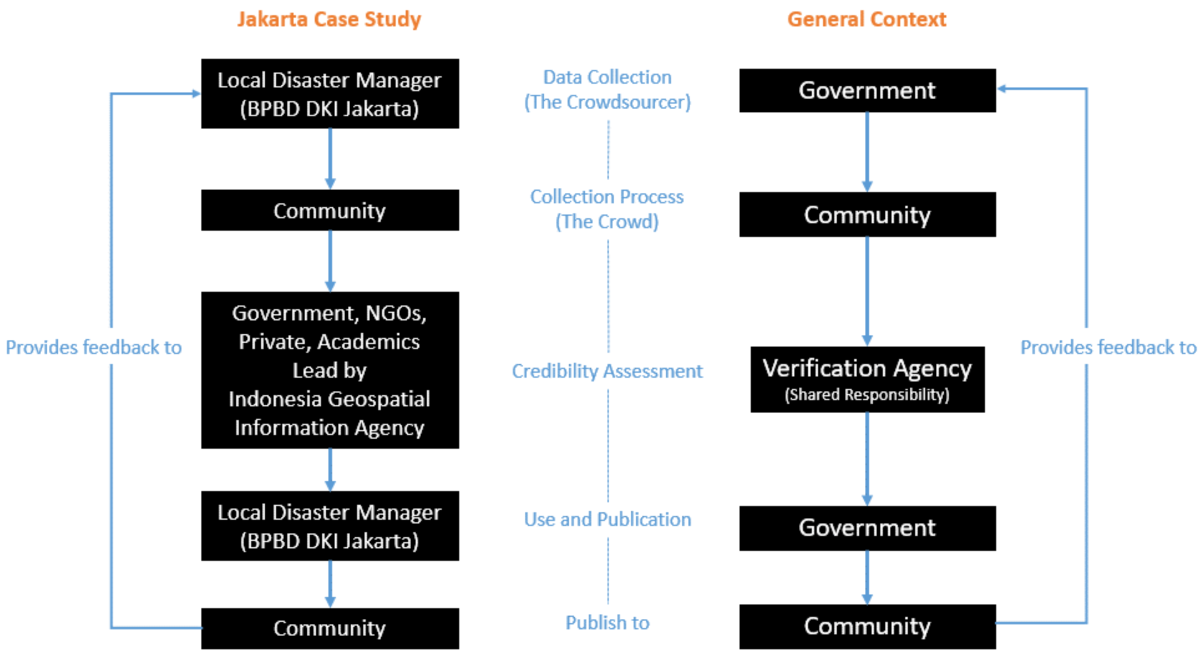


*Figure 5-7. An example of organisational practice model to improve VGI use in disaster management (author's own)*

The government is ideally responsible for collecting VGI and should take a lead as the crowdsourcer to:

1) Define the types of required datasets (data models), including an interoperability model.
2) Facilitate appropriate method and tools to collect the data, including an open SDI to store the data.
3) Promote and educate community about VGI initiatives through an outreach program.
4) Provide an incentives mechanism for contributors.

While the proposed role for government is large, other stakeholders may assist in specific tasks. For example, an academic institution may assist in outreach program and NGO/private may assist in developing appropriate methods and tools for data collection. However, each stakeholders' role needs to be clear and transparent to minimise conflicts (e.g., unnecessary duplication of VGI datasets). This could be achieved by encouraging stakeholders (such as international NGOs) to register their intentions before taking part in VGI initiatives.

In situations where the government is incapable of taking the role as crowdsourcer (e.g., during overwhelming disaster events), non-government stakeholders may be able to take up this role. For example, in Haiti's and the Philippines' case study (Section 2.7), the international OSM community took the initiative as a crowdsourcer for collecting geospatial data through OSM.

Each community contribution should be assessed by a verification agency that may comprise various stakeholders to ensure that community contributions are credible before use. The government should also be responsible for publishing VGI-derived information to the community. Finally, the community should be able to provide feedback related to the VGI process and VGI-derived information to the government.

**3. Establishing a Verification Agency to Improve VGI Credibility**

A verification agency is necessary to overcome credibility issues through working as a clearing house to verify VGI. One interview participant proposed that a verification agency could be an open initiative, so anyone who interested can join the agency. A verification agency may need to be supervised by the government at a national level (i.e., national mapping authority) to ensure that each contribution follows national standards. A verification agency is expected to define the methodology to assess VGI credibility and assist the VGI-authoritative integration process.

**4. Developing a Better Community Outreach to Increase Public Participation**

As VGI success depends on public participation (Budhathoki, 2010; Haklay et al., 2014; Parker, 2014a; See et al., 2016; Xu & Nyerges, 2016), it is important to address public participation issues. In Jakarta, interviews and focus group participants suggested to developing community outreach programs (Section 4.1.4 and 4.2.2).

More generally, community outreach programs should be able to educate peoples about VGI, including benefit of VGI for disaster management. Such efforts would encourage people to contribute appropriately. The community also needs to be educated to respond to information provided from various sources to keep themselves safe during disasters, (e.g., when and where to evacuate). Community outreach would maximise the information dissemination, minimise digital divide, and should improve VGI credibility because people understand what needs to be contributed and how to do so (Haworth, 2016). Examples of community outreach activities are community workshops, media advertisements, and public seminars.

**5. Developing an Incentive Mechanisms as an Additional Benefit for Contributors to Increase Public Participation**

In Jakarta, the FGD participants requested incentives for their VGI contribution. Interview participants also mentioned that the community can be suspicious because they spent money (for mobile data or internet service) to provide information with no significant benefit. Consequently, small incentives may be required to retain motivation for VGI contributions.

In broader context, similar studies also suggested developing incentive mechanisms for increasing public participation in VGI (Haklay et al., 2014; Haworth, 2016; See et al., 2016). When developing an incentive mechanism, it is important to keep costs to a minimum to maintain VGI's low-cost advantage.

Consensus associated with incentive types is not covered in this study. However, incentive types can be small merchandise, virtual credits that can be exchanged for products or services, or mobile internet credits. Additionally, while incentive mechanisms may improve public participation, a number of concerns exist, such as:

1) The number of invalid contributions may increase because contributors' motivation may primarily focus on the incentives. To overcome this limitation, VGI stakeholders need to clarify that incentives are given to the valid contribution.
2) Disaster risk may increase if the incentive becomes a primary motivation amongst contributors, especially if high-value. Contributors may risk their safety to collect data.
3) The choice of incentive mechanism also may cause bias in the demographics of participants (Section 2.8.3). A specific type of demographics may not be attracted to a product or service offered as the incentive.

### 5.4.2 Technical Components

**1. Developing a Better UI and UX of VGI Tools to Improve Public Participation**

One interview participant also suggested the improvement of UI and UX for VGI collection tools (Section 4.1.4, Figure 4-13). UI relates to the ways are user interacts with the application, while UX relates to the usability of the application. VGI activity is delivered through an internet-based application (Section 2.4.2). VGI tools should be intuitive, easy to understand and deliver better usability for users (e.g., provide help menu, offline support for users, minimise mobile data use, and low power consumption). This interview participant also added that by improving both UI and UX of VGI tools, public participation and VGI credibility may be improved. An example of guidelines to improve UI and UX for VGI can be found in Newman et al. (2010).

**2. Developing a Methodology to Assess VGI Credibility**

The Jakarta case study showed that each VGI tool has their own assessment method (Section 4.1.2). Most interview participants (they were nine in total participants) mentioned that the notion of credibility in VGI context is related to the extrinsic quality of the data (Section 4.1.4, Figure 4-16). Similarly, Fazeli et al. (2015) also relates VGI credibility to extrinsic aspects. These findings indicate that the methodology to assess VGI credibility should primarily be based on data authorship. However, it seems logical that author-based credibility assessment may raise privacy issues if the author's identity is included. It is important that the assessment process is limited to author quality only. An example of author-based credibility assessment can be found in Bishr and Mantelas (2008).

Most interview participants (they were four in total participants) suggested a statistical approach to assess VGI credibility (Section 4.1.4, Figure 4-17). This approach is similar to generic trust model or VGTrust (Severinsen, 2015), where spatial and temporal component are included in the model. Additionally, the VGTrust model seems more appropriate because an author component is also included, while author’s confidentiality is maintained.

Two interview participants also suggested that field surveys should be used to assess VGI credibility, which may increase the cost of VGI. However, this method could be an alternative if both author and statistical methods fail to deliver the expected degree of credibility.

**3. Integrating VGI and Authoritative Sources to Improve Credibility**

When using VGI in disaster management, VGI sources are often used alongside authoritative sources (Section 2.7). The Jakarta case study shows similar mashup processes in a number of applications, such as InaSAFE, Peta Jakarta, and JakSAFE (Section 4.1.2). Interview participants suggested that VGI and authoritative sources need to be integrated (Section 4.1.4, Figure 4-13). Integration of VGI with authoritative sources will improve the analysis, and useful to cross-validate the information.

Generally, integration processes may follow the concept of next generation SDI (Section 2.5.1). Ideally, the government should provide an open SDI platform to store geospatial data from various sources, including VGI sources. This open SDI ideally should be accessible for anyone to use the geospatial data. Figure 5-8 shows an example of VGI-authoritative sources integration workflow in disaster management that identified from this study.

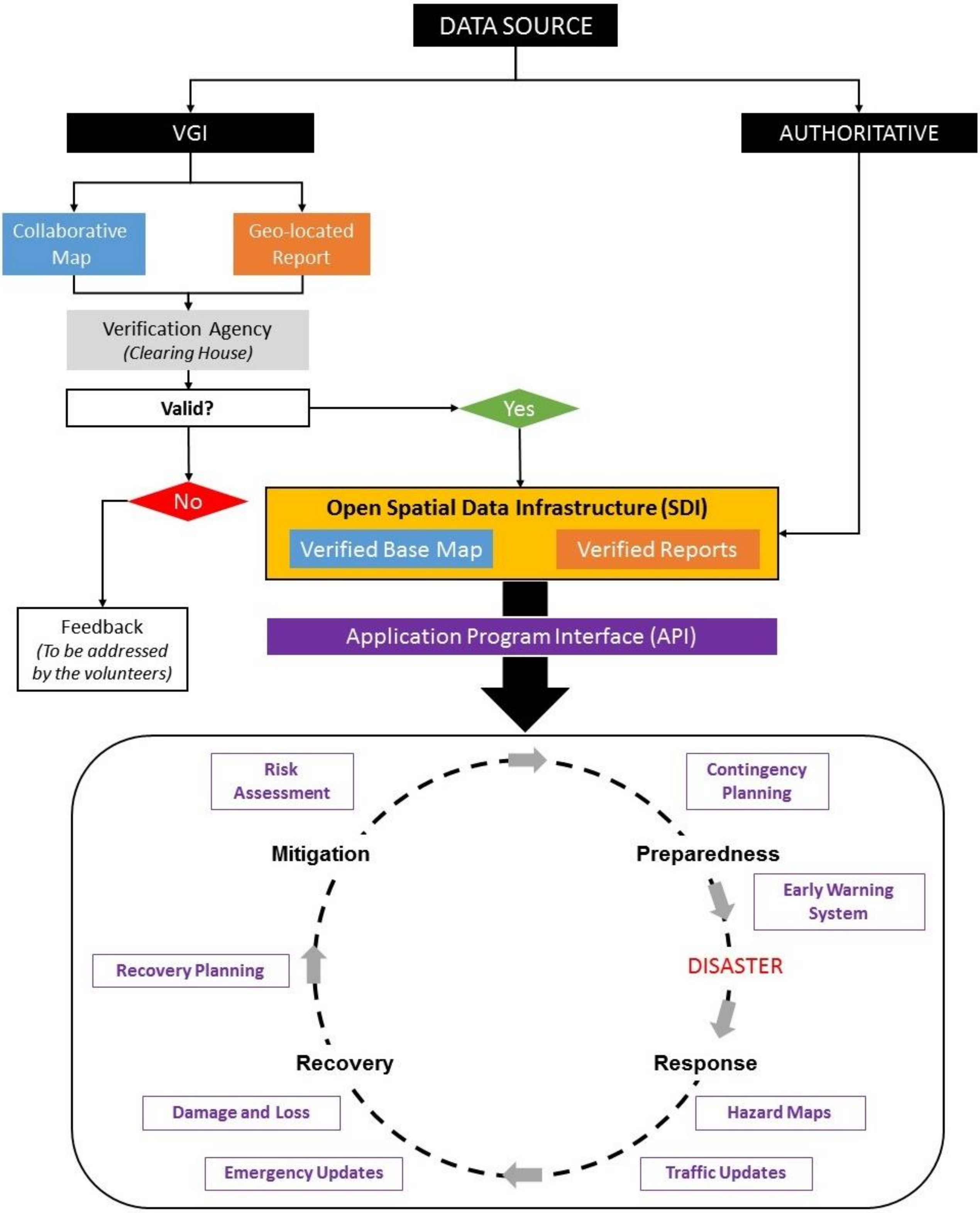


*Figure 5-8. An example of VGI-authoritative sources integration workflow (author's own)*

From Figure 5-8 authoritative sources should be included in the open SDI, assuming the sources are valid, have followed the interoperability standards, and classified information is excluded. VGI sources (both feature map and geolocated reports) need to be verified for their credibility by the verification agency before they can be included in the open SDI. Only valid data are included in the open SDI. Invalid data should be returned to the contributor with feedback, so they can improve their contribution. The open SDI should be updated regularly, while providing archives from previous updates. For example, disaster manager may want to have a daily archive for flood extent reports. Finally, the open SDI will provide the required geospatial data for each application according to the disaster management stages.

**4. Developing an Interoperability Standard to Support VGI and Authoritative Sources Integration Process**

Some interview participants concerned that the integration process comprises issues, primarily due to the lack of interoperability standard amongst VGI and authoritative sources, leading to data heterogeneity. This concern is relevant and supported by previous studies (Bakillah et al., 2013; Bordogna et al., 2016; Sui et al., 2013; Zhang et al., 2014). While examples of an interoperability model for VGI use exist (Section 2.8.5), further study may be required to develop such model to fits Jakarta's needs.

## 5.5 Answering the Research Questions

Volunteered Geographic Information (VGI), a subset of crowdsourcing where the public is able to contribute geographic data using internet-based tools, has the potential to improve geographic data acquisition in each disaster management stage. Previous studies have called for the development of a framework to account issues related to VGI (Doris et al., 2013; Fazeli et al., 2015; Goodchild & Glennon, 2010; Haworth, 2016). Accordingly, this thesis proposed a VGI-disaster management developed based on a case study of VGI use in Jakarta. This thesis addressed the main research questions:

**"What is an appropriate framework to improve VGI use for disaster management using Jakarta flood risk mapping as a case study?"**

From the literature review and the analysis results, this study found that a framework to improve VGI use for disaster management comprises:

1) **Non-technical components** including legal and policy, organisational practice, verification agency, community outreach, and incentive mechanism.
2) **Technical components** including improving UI and UX of VGI tools, credibility assessment methods, VGI and authoritative sources integration, and interoperability standards.

This thesis also examined four supplementary questions:

1. **What is the current practice (data requirement, collection method, and data use) of VGI at each disaster management stage?**
   This research found collaborative or feature mapping is most important before the disaster (mitigation and preparedness stages) by collecting exposure and hazard information to develop a contingency plan, while geo-located reporting tools are more important during response and recovery stages (Section 5.1).

2. **What are the advantages of the current practice of VGI at each disaster management stage?**
   This research found that disaster managers in Jakarta extends the use of VGI in disaster management and VGI is valuable because of its cost-benefit ratio, functionality, and knowledge-adding attributes (Section 5.2).

3. **What are the issues of the current practice of VGI at each disaster management stage?**
   a. **What are the issues related to legal and policy for the use of VGI in disaster management context?**
      Legal issues in VGI reflect data copyright and regulation conflicts (Section 5.3.1).
   b. **What are the issues related to VGI credibility in a disaster management context?**
      VGI credibility is most related to extrinsic quality (authorship) because of the heterogeneity of contributors, leading to different contributions behaviours (Section 5.3.2).

c. **What are the issues related to public participation of VGI use in a disaster management context?**

   Public participation issues are most related to how to improve and maintain the number of contributors, including their geographic distribution to ensure data completeness for area of interest (Section 5.3.3).

d. **What are the issues related to stakeholders' engagement of VGI use in a disaster management context?**

   Stakeholder engagement issues (e.g., disparity of VGI technology, conflict of interests) usually occur if a number of stakeholders are engaged in a VGI initiatives (Section 5.3.4).

e. **What are the issues related to the VGI interoperability in a disaster management context?**

   VGI interoperability issues usually occur when integrating VGI with authoritative sources due to the semantic heterogeneity of data (Section 5.3.5).

4. **What is a possible way overcome the issues of VGI use in disaster management?**

   To overcome issues on VGI use in disaster management, this study proposes an appropriate framework of VGI-disaster management (Section 5.4).

# 6 Conclusion

Geographic Information Systems (GIS) have an important role to reduce disaster risks. GIS can be used to support corresponding activities in each of disaster management stage such as implementing hazard or risk modelling in the mitigation and preparedness stages, developing situation awareness in the response stage, and assessing damage-losses in the recovery stage. However, acquiring near real-time and accurate information for disaster management can be challenging in a developing country as the required data might be difficult to acquire, obsolete or non-existent.

Volunteered Geographic Information (VGI) is a subset of crowdsourcing where public is able to contribute geographic data using internet-based tools. VGI has the potential to improve geographic data acquisition in each disaster management stage. A number of case studies of VGI use in disaster management shows that VGI can potentially fill-in an information gap during a disaster event, providing near real-time information related to the disaster, for decision makers and the public (Section 2.7). However, researchers have called for the development of a framework to account issues related to VGI (Section 2.8).

This study presented a framework to improve VGI use in disaster management. This framework is developed using a qualitative case study of VGI use for flood management in Jakarta to identify VGI potential, limitations, and opportunities in disaster management. Two qualitative techniques were applied for data collection: (i) in-depth structured interviews with 13 participants with experience in producing, managing, and using VGI for disaster management in Jakarta, and (ii) a focus group discussion (FGD) with 13 individuals from a local community with experience in conducting VGI activities to reduce flood risks in their local area.

Thematic analysis was used to analyse the qualitative data (e.g., interview transcripts, notes) by grouping their contents into codes and themes. Finally, the results are presented as an exploratory research, providing an insight into the current VGI use and identifying VGI-disaster management framework (Chapter 3).

In contrast with previous studies where VGI is only used in a specific disaster management stage (Section 2.7), this study found that disaster managers in Jakarta are extending VGI use for all disaster management stages. VGI methods are include: (i) collaborative or feature mapping tools, which are mostly important before the disaster (mitigation and preparedness) to collect exposure and hazard information for developing a contingency plan, and (ii) geo-located reporting tools, which are more important to assist during response and recovery processes (Section 5.1).

This study also found the advantages of VGI in disaster management (cost-benefit ratios, functionality, and knowledge-adding attributes) largely in-line with previous research findings (Section 5.2). Similarly, the VGI issues (legal, credibility, public participation, stakeholder engagement, and interoperability) also matches with previous studies (Section 5.3).

Based on key findings from the literature review and the results of Jakarta case study, VGI-disaster management framework comprises: (i) non-technical components, such as legal and policy support, organisational practices, a verification agency, community outreach, and incentive mechanisms, and (ii) technical aspects, such as user interface (UI) and user experience (UX) of VGI tools, credibility assessment methods, integration of VGI sources and authoritative sources, and interoperability standards (Section 5.4). Although the framework has been informed by the Jakarta participants, it is intended for wider applications.

## 6.1 Future Research Directions

While this thesis proposes a framework of VGI-disaster management, this framework was developed based on a single case study in Jakarta province and only flood disaster was covered. However, the framework could be extended beyond the limitations of the case study and the theoretical foundation in this thesis. It would be valuable to observe how this framework would apply to other locations (e.g., less populated areas or areas with low internet penetration) and with different types of disasters or hazards (e.g., earthquakes, tsunamis, landslides).

The study of VGI data models in disaster management is also an important domain for future research. Ideally, each type of disaster or hazard should have their own data models (e.g., data requirements, types or formats of the data, collection and assessment methods, usage purposes), including semantic considerations to minimise interoperability related issues when integrating VGI with authoritative sources.

Furthermore, incentive-based VGI contribution is also a potential domain for future research. It would be valuable to explore suitable incentive mechanisms and observe their impact on VGI initiatives particularly in disaster management (e.g., whether incentive-based VGI could increase participation or improve credibility).

## 6.2 Concluding Statement

Previous studies have focused on examining VGI use at one particular disaster management stage. These studies similarly concluded that a framework is compulsory to improve VGI use in disaster management, accounting particular issues in VGI such as legal and policy, credibility, public participation, stakeholder engagement, and interoperability. This research is proposed a means to develop a framework to improve VGI use in disaster management on the basis of a case study in Jakarta, addressing the following research question:

**“What is an appropriate framework to improve VGI use for disaster management using Jakarta flood risk mapping as a case study?”**

Through the facilitated case study, this thesis has captured principles of VGI use in disaster management, both in theory and practice. The proposed VGI-disaster management framework as part of this thesis has combined non-technical and technical components, which can affect VGI use in disaster management, into one holistic framework. The in-depth interviews and FGD methods that applied in this study provides a strong coverage of VGI involvement in disaster management across sectors (government, non-government, private, academia, and local community). The novelty of the followed approach on this study also differs from previous studies, where VGI use in disaster management is not only focused in a specific disaster management stage, but for all stages (mitigation, preparedness, response, and recovery). The proposed VGI-disaster management framework builds a strong foundation to enable VGI proliferation in disaster management for government and non-government.

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# Appendix 1: Consent Form (Interview)

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

## Consent Form for Participants

Department of Geography
Telephone: +64 221887496
Email: emir.hartato@pg.canterbury.ac.nz

**Project Title**

### Volunteered Geographic Information (VGI) for Disaster Management (DM): A Case Study for Floods in Jakarta

Include a statement regarding each of the following:

- I have been given a full explanation of this project and have had the opportunity to ask questions.
- I understand what is required of me if I agree to take part in the research.
- I understand that participation is voluntary and I may withdraw at any time without penalty prior to the analysis of results on 1 July 2016. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.
- I understand that any information or opinions I provide will be kept confidential to the researcher, his research assistant, his translator, and his supervisors. Any published or reported results will not identify the participants but may identify the institution. I understand that a thesis is a public document and will be available through the University of Canterbury library.
- I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after five years.
- I understand the risks associated with taking part in this thesis and how they will be managed.
- I understand that I am able to receive a report on the findings of the study by contacting the researcher at the conclusion of the project.
- I understand that I can contact the researcher (**Emir Hartato**, emir.hartato@pg.canterbury.ac.nz) or his supervisors **Dr. Ioannis Delikostidis** (ioannis.delikostidis@canterbury.ac.nz) and **Dr. Mairead de Roiste** (mairead.deroiste@vuw.ac.nz) for further information. If I have any complaints, I can contact Badan Pelayanan Terbuka Satu Pintu (BPTSP) DKI Jakarta (bptsp.pengaduan@jakarta.go.id) or the Chair of the University of Canterbury Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)

☐ I would like a summary of the results of the project.

☐ By signing below, I agree to participate in this research project.

Name: ________________________ Signed: ______________________ Date: ______________

Email address: ______________________________________________

*Please return this consent form to emir.hartato@pg.canterbury.ac.nz or at the start of the interview*

# Appendix 2: Interview Questions

1. **Introduction and consent**
   - Introducing researcher's name and institution to participants
   - Providing a brief summary of the research purpose to participants
   - Receiving informed consent from participants

2. **Understanding the participant**
   - Please introduce yourself with your name, institution, and your role

3. **Understanding Volunteered Geographic Information (VGI)**
   - In your opinion, what is VGI?
   - Do you currently use VGI in your organisation? (Yes/No/Unsure)
     - o If Yes: In what ways does your organisation currently use VGI?
     - o If No: (move to the next question)
     - o If Unsure: (move to the next question)
   - Here is Goodchild's (2007a) definition of VGI:
     *"VGI is a phenomenon where a number of untrained people produce geographic data or information voluntarily with various tools."*
     Is this similar with what you think VGI is? (Yes/No/Somewhat)
     - o If Yes: given this definition, briefly describe the ways your organisation uses VGI
     - o No (a): How would your definition, differ?
     - o No (b): Given your own definition, briefly describe the ways your organisation uses VGI

4. **Understanding disaster management**
   - Here is a definition of disaster management and a diagram of the disaster management cycle (Appendix 3). In what parts of the disaster management stage, does your organisation currently operate? Please mark your organisation's areas of operation on the diagram.

5. **Understanding Volunteerd Geographic Information (VGI) in a disaster management context**

- Within your organisation, which activities involving the use of VGI are carried out? Please mark those activities on the diagram.
- Are you aware of the current VGI use in disaster management context globally or do you just work on a solution designed by your organisation? Please provide a brief explanation of your approach.
- In your opinion, would using VGI within each part disaster management cycle be able to reduce the flood risk effectively? (Yes/No/Somewhat) Please explain why.

**5.1 Data acquisition and requirement**

- What VGI data are required for each stage of the disaster management cycle?
- Who is responsible for data collection for each stage?
- How are VGI collected for each stage of the disaster management cycle?
- What are the advantages of collecting VGI during each stage of the disaster management cycle?
- What are the disadvantages or issues of collecting VGI during each stage of the disaster management cycle?
- What might be possible ways to overcome the issues you have identified?

**5.2 Data use and distribution**

- How are VGI data being used during each stage of the disaster management cycle?
- Who is responsible for the use or analysis of the data and for publishing any derived information to the public?
- Are you using authoritative data (e.g., from Indonesian Geospatial Information Agency) as well as VGI? (Yes/No)
    - If Yes: How do you use VGI along with authoritative data?
    - If No: Why not?
- What are the advantages of using VGI data?
- What are the disadvantages or issues of using VGI data?
- What might be possible ways to overcome the issues you identified?

**6. Credibility**

- In your opinion, what is credibility in a VGI context?
- According to Flanagin and Metzger (2008), the notion of credibility is closely related to data quality. Is this similar with what you think VGI credibility is? (Yes/No/Somewhat)
    - If Yes: (move to the next question)

  - If No/Somewhat: Please explain briefly your own definition or how your understanding is different
- Are there issues with the credibility of VGI in the context of disaster management?
  - If Yes: What are these issues?
  - If No: (move to the next question)
- How can VGI credibility for disaster management be assessed?
- What type of metrics, if any, do you currently use to measure VGI credibility?
- How do you maintain VGI credibility in the context of disaster management?
- Who is responsible for maintaining VGI in your organisation?
- What are the current issues in maintaining VGI data in your organisation?
- What are the possible ways to overcome the issues you have identified?

**7. Public participation and perception**

- What are the current issues related to public awareness and perceptions of VGI derived-information?
- What might be possible ways to overcome the issues you have identified?

# Appendix 3: Consent Form (Focus Group Discussion)

## Consent Form for Participants

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Department of Geography
Telephone: +64 221887496
Email: emir.hartato@pg.canterbury.ac.nz

**Project Title**

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Include a statement regarding each of the following:

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- I understand that any information or opinions I provide will be kept confidential to the researcher, his research assistant, his translator, and his supervisors. Any published or reported results will not identify the participants but may identify the institution. I understand that a thesis is a public document and will be available through the University of Canterbury library.
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☐ I give permission for the researcher to use my photo for any published or reported results of this project (in printed form and on the web)

☐ I would like a summary of the results of the project.

☐ By signing below, I agree to participate in this research project.

Name: ________________________ Signed: _____________________ Date: _____________

Email address: ______________________________________________

*Please return this consent form to emir.hartato@pg.canterbury.ac.nz or at the start of the focus group session.*

# Appendix 4: Focus Group Discussion (FGD) Session

**1. Introduction Session (Approximately 10 Minutes)**

- Welcoming the participants
- Introducing the researcher's name and institution
- Providing a summary of research purpose
- Question and answer session about the research
- Receiving informed consent from participants
- Participants' introduction
- Explaining the focus group process
- Question and answer session about the process

**2. Session 1 – Flooding Experiences (Approximately 20 Minutes)**

- How many people were in your group?
- How long have you each live in Marunda village?
- How many floods did you each experience since 2007?
- Based on your experience of flooding in your local area, which areas always get flooded during the monsoon season? Please mark those areas with a blue colour on the map (Appendix 4).
- What is the approximate height of inundation level? Use the measuring tape to show this.

**3. Short Break (Approximately 5 Minutes)**

**4. Session 2 – VGI Experiences (Approximately 20 Minutes)**

- Please use the diagram (Appendix 3) provided to answer this question. In your experience mapping floods in your local area:
    - What kind of information do you try to collect in each disaster management stage?
    - How do you collect it?
- What have you learned from the mapping process?
- What difficulties or issues did you encounter during the mapping process?
- Do you have any ideas of possible ways to improve the mapping process in the near future? If yes, please explain.
- Do you have access to the mapping results (e.g., printed or digital maps)?

- If Yes: Do you think this information is useful for your community to reduce future flood risk? Please explain.
- No: Please explain.

**5. Closing Session (Approximately 5 Minutes)**

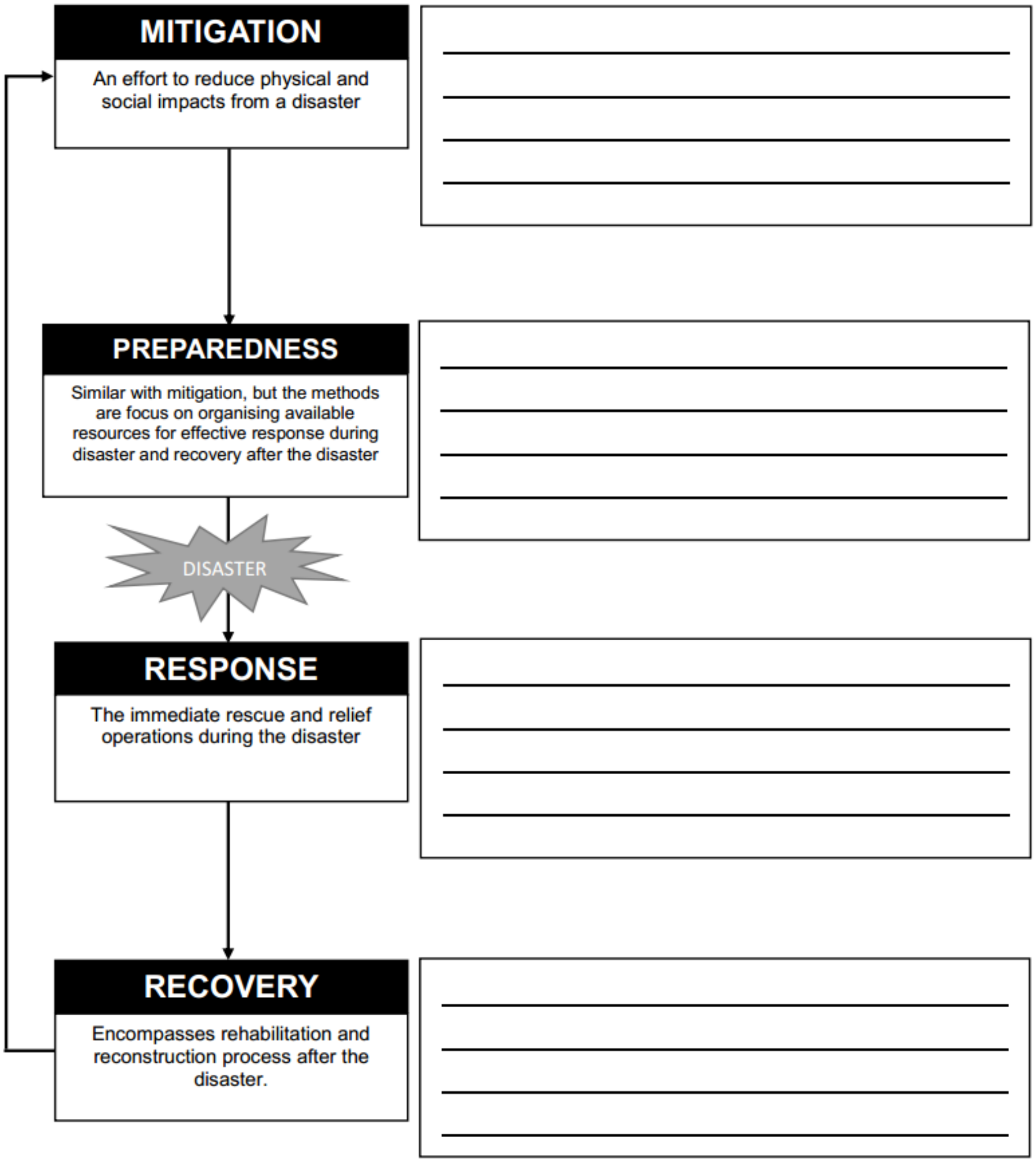
# Appendix 5: Disaster Management Cycle Diagram

## FORM 1

Respondent code :

Date/Time :

DISASTER MANAGEMENT: A set of programmes to minimise the impact of a disaster



# Appendix 6: Focus Group Discussion (FGD) Maps