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Geographical Information Management and Applications

Creating a user-centric assessment framework to assess Spatial Data Infrastructures for Crisis Management

Master Thesis

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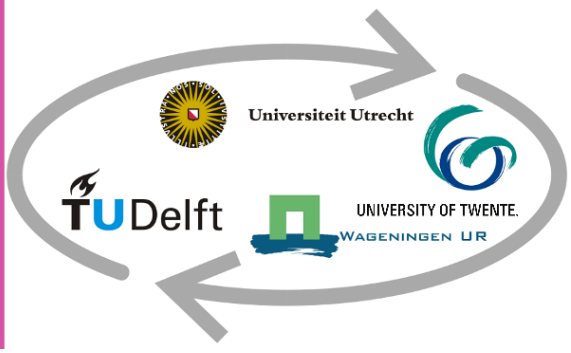

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Content

Abstract

While crisis management and Spatial Data Infrastructure [SDI] assessment are both extensively studied in literature, the link between the two field is uncommon. Assessment frameworks in literature are not focused on crisis management situations, so it is unclear whether they can be applied to this field.

This study combines literature of the two fields to clarify the role of an SDI within crisis management, and to set up a framework for user-centric SDI assessment. Interviews have been conducted to examine whether this framework could be applied to crisis management, while being useful for SDI development that focuses on decision making of the end-user. The World Food Programme SDI has been used as a case study.

It has been found that a conventional SDI assessment framework cannot be copied to a crisis management situation without adjustments and special considerations. Crisis management is a complex and dynamic field which requires a different approach of SDI assessment. The framework has therefore been adjusted to this context. Further research is required to put the framework into practice and to test its potential for SDI development.

Chapter 1: Introduction

1.1: Introduction

In the past decades, the losses of natural disasters have increased (Mechler & Bouwer, 2015). It has been found that this rise varies among different researches, however, in general it can be said that there is a rising trend in the amount of both loss events and economic losses (Mechler & Bouwer, 2015). Banholzer, Kossin & Donner (2014) also state the increased amount of both intensity and frequency of disasters in the past decades.

The trend can also be found in The International Disaster Database, EM-DAT, which is "a global database on natural and technological disasters, containing essential core data on the occurrence and effects of more than 21,000 disasters in the world from 1900 to present" (EM-DAT, 2018). A disaster has been defined as a:

> ...situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance (definition considered in EM-DAT); An unforeseen and often sudden event that causes great damage, destruction and human suffering. Though often caused by nature, disasters can have human origins. (EM-DAT, 2018)

EM-DAT data shows that both the amount of disasters and the number of affected persons has in general been rising in the past decades (EM-DAT, 2018). Mechler & Bouwer (2015) even state that these numbers will still rise in the future. This means that a certain importance to address this topic, and to apply knowledge in the form of disaster management, remains.

The rising amount of disasters and losses demands adequate actions to handle them. Disaster response and disaster recovery are both phases of the disaster management cycle that try to reduce potential losses (Janssen, Lee, Bharosa & Cresswell, 2010). This is not only the case for financial losses, but also reducing the amount of injuries and casualties after a physical event by means of life-saving activities is one of the goals of disaster management (Rode Kruis, n.d.). However, it is crucial that the actions taken after a disaster are well-coordinated. Warren (2010) wrote in his article on news website cleveland.com: "experts say Chile's response to one of history's most powerful earthquakes has been a model for disaster recovery." In contrast, he also states the following about the Haiti event:

> Chaos also [like hurricane Katrina in 2005] reigned initially in Haiti, where in the absence of a functioning government, hundreds of planes landed in the cramped Port-au-Prince airport with no clear plan for getting aid to survivors. Foreign NGOs competed for priority treatment, and badly needed food, water and medicine got stuck. (Warren, 2010)

Warren in fact states that disaster responses can have harming difficulties, which potentially can cause more losses and even casualties. Effective disaster management is therefore essential to overcome issues like these.

1.2: Problem statement

As disasters will continue to occur in the future, arguably with higher frequencies and more intensity (Mechler & Bouwer, 2015; Banholzer et al., 2014), effective disaster management will remain relevant. Geographic information [GI] plays a major role within disaster management (Fuhrmann et al., 2005; Enders & Brandt, 2007; Kerle, 2013; Voigt et al., 2011; Adams & Friedland, 2011; Saito et al., 2010; Zook et al., 2010; Bengtsson et al., 2011). Important challenges not only lie in production of GI, but also in effective distribution of the information (Mansourian, Rajabifard, Valadan Zoej, & Williamson, 2006; Payne, Florance, & Shain, 2012; Bajracharya, 2015; Yulfa, Adity, & Sutanta, 2017). According to Janssen et al. (2010), "A disaster is a continuously unfolding situation, marked by changes in urgency, scope, impact, the types of appropriate responders, and the responders' needs for information and communication." They also state that "...although there is a common body of knowledge, disaster management is still an under-developed area. There is a need to relate practice and theory by using human-centered approaches such that disaster management can realize its full potential." (Janssen et al., 2010) A more human-centric approach is needed for evaluation metric in the field of information systems [IS] for disaster management (Janssen et al., 2010). It has been shown that information sharing is still considered as an important problem in crisis management, despite good systems and information quality (Janssen et al., 2010).

Providing (geographic) information and communication in crisis situations is something that a spatial data infrastructure [SDI] can support. SDIs are "Internet-based mechanisms for the coordinated production, discovery, and use of geospatial information in the digital environment" (Budhathoki & Nedovic-Budic, 2008). An SDI therefore has the potential to facilitate better distribution of GI during disaster responses, which can help make the response and recovery phases more effective, minimizing the losses after a disaster.

However, the research that has been performed regarding SDI for disaster management mostly does not comply with the user-centered approach that Janssen et al. (2010) suggest. Multiple researches focused on the role of SDI in disaster management, but did not specifically focus on the people-component of SDI, or the user (Bajracharya, 2015; Mansourian, Rajabifard, Valadan Zoej & Williams, 2004; Mansourian et al., 2004; Payne et al., 2012; Rajabifard, Mansourian, Williamson & Valadan Zoej, 2004; Scholten, Fruijter, Dilo & Van Borkulo, 2008; Mobaraki, Mansourian, Malek & Mohammadi, 2007). Mansourian, Rajabifard & Valadan Zoej (2005) created an SDI framework for disaster management. While users are briefly mentioned, the research does not cover an extensive user needs analysis.

Snoeren, Zlatanova, Crompvoets & Scholten (2007) did actually focus on user needs for a disaster management SDI, however, they focused on regional-scale disaster management (sub-provincial) coordinated by regional governmental bodies. The scope of that research is therefore not on the scale of large natural disasters. Besides, the research was published in 2007, and with the changing nature of user needs (Hennig & Belgiu, 2011), this could already be outdated. Gyamfi-Aidoo, Schwabe & Govender (2007) conducted research on the user needs for the datasets available through an SDI, and not the other aspects of SDIs. Finally, Manfré et al. (2012) stated in their research that incorporating VGI in a disaster management SDI will be beneficial for users, though an extensive user needs analysis has not been conducted to fully understand why it is beneficial for the users.

In addition, most of the research on SDI for disaster management has been conducted more than a decade ago (Mansourian et al., 2004; Mansourian et al., 2004; Rajabifard et al., 2004; Scholten et al., 2008; Mobaraki et al., 2007; Mansourian et al., 2005; Snoeren et al., 2007; Gyamfi-Aidoo et al., 2007). Meanwhile, SDI practices have been changing towards a new generation: the third generation of SDI. This generation of SDI is less focused on technology like the earlier generations, but more on the user where the development is user-centric (Hennig & Belgiu, 2011). To assess an SDI from a users' perspective, the users' needs have to be well understood (Hennig & Belgiu, 2011). Due to these changes and the outdated literature, the current SDI practices in disaster management cannot be assessed from a user perspective, and it is therefore not clear if these practices contribute to more effective crisis management in its full potential. However, research has been conducted on development and assessment of SDIs in general or in other fields. This can be used as a basis to fill the gap in the field of crisis management.

1.3: Research objectives and research questions

This research tries to contribute to more effective crisis management by clarifying the role of GI and SDI in the context of crisis management and more specifically: how to address the user needs for an SDI used in crisis management. Ultimately, a framework will be designed to address these SDI user needs. When roles of GI and SDI are clarified and when the user needs are better understood, SDI development could benefit from this. With current SDI practices, users normally are the starting point of development (Hennig & Belgiu, 2011). This research will therefore create a framework for clarifying the user needs for the development of SDIs for crisis management in large-scale disasters. The end-users (the decision-makers, see research scope) in this particular kind of SDI may not specifically have a demand for an SDI due to limited knowledge of the concept, however, they have certain demands for GI that support their decisions in crisis management. This research will analyze to what extent these needs for GI can be translated into a user-centric assessment framework for this specific type of SDI, and also how the users themselves play a role in SDI development.

The objective of this research can be divided into 6 sub-objectives. This research aims to:

- Create an overview of decision-making processes during crisis management (after large scale natural disasters, see research scope);
- Describe how GI and SDI could support decision-making in these crisis management processes;
- Develop a user-centric SDI assessment framework;
- Create an overview of the SDI structure of an SDI that is used in crisis management (case study);
- Analyze to what extent the developed user-centric SDI assessment framework could be applied to the SDI used in crisis management (case study);
- Finetune the user-centric SDI assessment framework (case study).

These objectives lead to the following research question:

To what extent can a user-centric SDI assessment framework support decision-making in crisis management during large-scale natural disasters?

Sub question 1: What are the processes of decision-making in crisis during large scale natural disasters?

Sub question 2: To what extent could the use of GI support decision-making in crisis management processes during large scale natural disasters?

Sub question 3: To what extent could the use of SDI support decision-making in crisis management processes during large scale natural disasters?

Sub question 4: Which current user-centric SDI assessment frameworks can be combined for developing a single framework?

Sub question 5: What is the SDI structure of an SDI that is used for decision-making in crisis management during large scale natural disasters?

Sub question 6: To what extent can the user-centric SDI assessment framework be finetuned to an SDI to support decision-making in crisis management during large scale natural disasters?

1.4: Research methodology

The sub questions of the research question will be answered in order throughout the research. The following chapter, crisis management, GI & SDI, will give the theoretical background to answer the first sub questions. The different processes of and activities in crisis management will be explained, and the (potential) use of GI for decision making in crisis management will be explained. The relationship between crisis management and SDI will also be clarified by performing a literature review. Thereafter, the third chapter will address the fourth sub question and goes further into user-centric SDI assessment frameworks. Combining current assessment frameworks from literature, a single user-centric assessment framework will be designed that will be used in the subsequent chapters.

Chapter four clarifies the qualitative methods used further in this research, as from chapter five onwards, a case study will be used for answering the fourth, fifth and sixth sub questions. The case study is the SDI of the World Food Programme (WFP), because it has an SDI in operation, it is well-developed, and development is ongoing in this SDI (WFP, 2018). WFP is a subsidiary of the United Nations. The fourth chapter will briefly introduce the case study, as well as describe how the methods are operationalized for the case study. An overview of the research methodology can be seen in figure 1.4.

Chapter five will go deeper into the SDI components of the case study, which is used for decision-making in crisis management during large-scale natural disasters. The schematic SDI model of Rajabifard & Williamson (2001) will be used to describe the components of this particular SDI, and what their relevance is for the processes of crisis management. The interviews for chapter five will be conducted with people involved in the development, maintenance, and/or coordination of the WFP SDI, to get the picture of the SDI structure. SDI scholars that have knowledge in crisis management will also be interviewed for discussing the relevance of an SDI for crisis management.

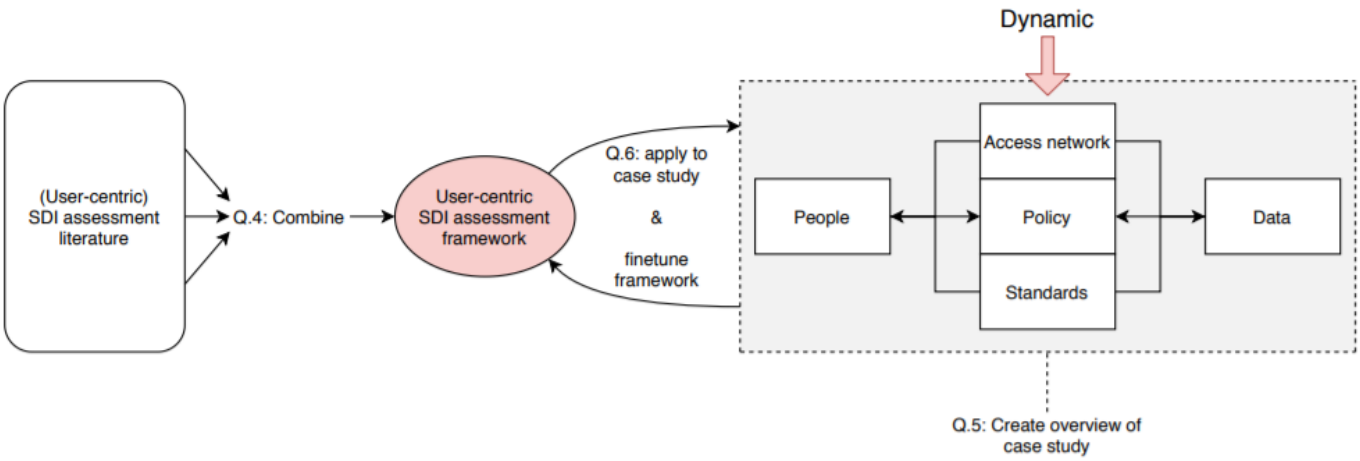

Figure 1.4: research methodology, SDI structure based on Rajabifard & Williamson (2001)

The sixth chapter applies the user-centric SDI assessment framework of chapter three with the SDI structure found in chapter five. By conducting interviews with SDI developers and experts (see chapter four: Methodology), the sixth sub question will be answered: examining to what extent the user-centric SDI assessment framework could be applied to the case study. Experts that have been interviewed for this chapter are scholars from the SDI field that have knowledge about crisis management, as well as people involved in development, maintenance, and/or coordination of the WFP SDI. The information in the results of this chapter will be used to finetune the user-centric SDI assessment framework for the SDI of the case study. Finally, the results will be discussed and a conclusion will be drawn in the last chapter: chapter seven.

1.5: Research scope

It should be noted that this research aims for large-scale disasters only. According to the United Nations Office for Disaster Risk Reduction [UNISDR], a large-scale disaster is "a type of disaster affecting a society which requires national or international assistance" (UNISDR, 2017). As there are many actors that all have their own goals and actions in struck areas, it has to be coordinated which organization is doing what and where. This is a role for the United Nations and its subsidiaries (United Nations, n.d.). With the coordinating role or assisting in the coordination, the UN therefore have the task to coordinate information sharing. The focus of the research is therefore on crisis management during disasters at such a large scale that national and/or international humanitarian aid is given by multiple organizations including the UN (and subsidiaries), while the UN also coordinates the humanitarian aid. In addition, the focus is on sudden-onset disasters, which are disasters triggered by a hazardous event that emerges quickly or unexpectedly (UNISDR, 2017). Examples of such disasters are the 2010 Haiti earthquake (Julmy, 2011), typhoon Haiyan in the Philippines (2013) (Carden & Clements, 2015) and the 2015 Nepal earthquake (The Cash Learning Partnership, n.d.).

Chapter 2 will go further into the disaster management cycle and it will be described how each phase differs from each other. Crisis response encompasses the response and recovery phases of disaster management (Aubrecht, Özceylan Aubrecht, Klerx & Freire, 2013). In this research, the focus will not be on mitigation and preparation phases (both for prevention) due to the different nature of action, compared to the response and recovery phases (Carter, 2008). Besides, SDI development can already be seen as a part of mitigation and preparation for disasters.

The user-perspective plays a major role in the development of the SDI assessment framework, but the users need to be identified in the process. The users that will be taken into account will be limited to certain user groups. As users are not a homogenous group, Van Loenen (2006) distinguishes four types of users:

- Primary user: the user that are the major, experienced users of the data. Often also a member of the organization that has collected the data. They use the dataset for which it is collected.

- Secondary user: Same as the primary user, but on an incidentally base.
- Tertiary user: users that add value to the framework dataset. This means that use the dataset for other purposes than for which the information was created. For example, new applications or more user-friendly extensions.
- End users: citizens, decision-makers and others that use Geographical Information as a map for a certain action. The geographical information is mostly provided by the Tertiary users.

For this research, the focus will be on the perspective of end users, in this case the decision-makers in crisis management. Based on the data that is available through the SDI, they make the decisions for taking action. The user groups will be identified in chapter five, and the perspective of decision-makers will be taken as guidance for the assessment framework. Their actions and decisions have an impact on the effectiveness of crisis management. Incorporating their user needs in SDI development is therefore crucial. In third generation SDIs, the user is also often the creator of data, which will be taken into account with defining and categorizing the users.

Creating an SDI assessment framework from a user-perspective means that it will not incorporate other assessment perspectives, solely the needs of the users will be taken into account. Assessment of the SDI from other perspectives, for instance from an SDI-perspective or a developer-perspective, will not be taken into account for the framework in this research. Other perspectives will therefore remain open for further research. The creation of the assessment framework in chapter three will therefore only incorporate other frameworks that are focused on a user-perspective.

The use of an SDI in an area where a disaster struck might be hampered in different ways because of damage to communication networks. Normally SDIs operate in an online environment, but while sufficient internet connection is not present, other solutions may be required. However, problems like these will not be taken into account in the research as they can be seen as problems that go beyond the SDI itself.

SDI development for crisis management is the goal of this research, however, it does not encompass the entire process of user-centric SDI development as described by Hennig & Belgiu (2011). Figure 1.5 shows this process. This research will only perform the first process in the model. The framework for a requirement analysis, from a user-perspective, will be designed in this research. This requirement analysis has to be actually conducted to give more detailed insights in the user requirements, which is part of further steps in the model but not within the research scope. The application of the assessment framework will therefore not be conducted in this research, this will remain open for future research and/or for SDI developers of SDIs used in crisis management. However, the SDI components will be examined from a user-perspective (without performing the user needs analysis), so preliminary conclusions and recommendations can be given that are part of the next step to the design phase in figure 1.5. The implementation phase is outside of the research scope because this is a task for the SDI developers. Full validation of the SDI over the whole process can therefore also not be applied in this research. This means that this research will be explorative, also because there is a gap in literature in the

combination of SDI assessment and crisis management. It will therefore be difficult to draw final conclusions about the usability of an SDI for crisis management, but the research provides a useful step towards further analysis and research.

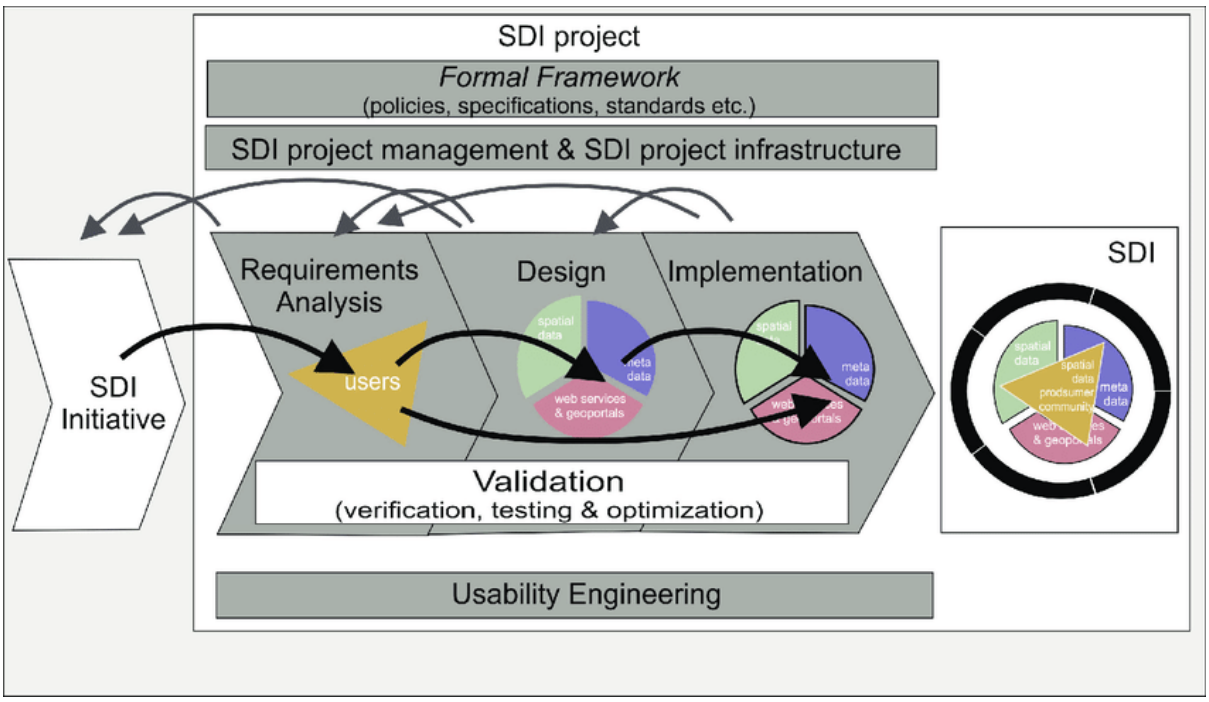

Figure 1.5: Schematic (and simplified) user-centric SDI development process model. (Hennig & Belgiu, 2011)

Chapter 2: Crisis management, GI & SDI

In the first part of this research, the theory behind crisis management, GI and SDI will be explained. It should be made clear where in the process of crisis management GI and SDI play a role, and why they play a role. This chapter will therefore focus on the first three sub questions:

1. *What are the processes of decision-making in crisis management in which GI is used during large scale natural disasters?*
2. *To what extent could the use of GI support decision-making in crisis management processes during large scale natural disasters?*
3. *To what extent could the use of SDI support decision-making in crisis management processes during large scale natural disasters?*

To answer these questions, the chapter will first explain the processes of crisis management and where it stands in the broader process of disaster management, as explained in the introduction (research scope). After that, the role of GI in this process will be explained in the second part. Research explaining why GI is important for crisis management will be summarized and an overview of the different forms of GI will be made. The role of SDI for sharing this GI in the processes of crisis management will be explained in the third part. Finally, the information will be summarized, and this theoretical background is the basis for the following steps in the research.

2.1: Crisis management

Before going deeper into the roles of GI and SDI for crisis management, crisis management itself will be explained. The definition of crisis management will be given and it will be explained why crisis management is so important. Besides, an overview of processes will be given in this part of the chapter, as there are many different processes going on after a disaster occurs.

2.1.1: Natural disasters

This research specifies on SDI for crisis management during large-scale natural disasters, but what is a disaster exactly? UNISDR (2009) determines a disasters as: "A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources." The emergence of a disaster is a combination of three elements: exposure, vulnerability and coping capacity (Khan, Vasilescu, & Khan, 2008; UNISDR, 2009; Christoph, Dilek, Joachim, & Sérgio, 2013).

- *Exposure*: the exposure to a hazard. The hazards can come from "geological, meteorological, hydrological, oceanic, biological, and technological sources, sometimes acting in combination" (UNISDR, 2009). "Natural hazard events can be

characterized by their magnitude or intensity, speed of onset, duration, and area of extent." (UNISDR, 2009). The exposure of the hazard relates to people, property, systems, or other elements.

- *Vulnerability*: "The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard." (UNISDR, 2009). Christoph et al. (2013) also add: "Vulnerability is critically context dependent and variable patterns of vulnerability eventually determine where and when a mere natural event potentially turns into a disaster."
- *Coping capacity*: The UNISDR (2009) describes coping capacity as: "The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters."

If the exposure and vulnerability get higher and the coping capacity lower, the chances are bigger for a disaster to have a large impact. This means that the location of the natural event is very important as different areas have different levels of these three elements. A simple example of a difference in exposure is whether the event happens in a rural area (sparsely populated so less people exposed and less assets like buildings) or an urban area (densely populated to more people exposed and more assets). Vulnerability differences are for instance differences in building stock, where in some places houses are commonly built according to strict building codes, and in some places not. Besides, vulnerability differences could also include socio-economic aspects like differences in the share of insured households. Coping capacity includes awareness of the risks in the society for instance, which could also differ in different areas. This means that disasters do only occur due to the interaction of these elements (Khan et al., 2008). Cristoph et al. (2013) also state that just the incidence of a natural hazard does not necessarily cause negative effects. The greater the coping capacity, the more the impact of the hazard reduces (Khan et al., 2008), which is highlighting the importance of disaster management, which will be explained in the next paragraph.

Disasters have a wide range of impacts that have a negative effect on societies. According to Carter (2008), typical effects of disasters can for example be loss of life and injuries, national economic loss, damages to infrastructure etc. In addition to effects related to the built environment and the population, the United Nations Office for Disaster Risk Reduction (UNISDR, currently known as UNDRR) also states that environmental degradation is a possible negative effect of disasters (UNISDR, 2009).

2.1.2: Disaster management & crisis management

Disaster management can be seen as a means of reducing the chances that hazard events turn into disasters, as it "aims to reduce, or avoid the potential losses from hazards, assure prompt and appropriate assistance to victims of disaster, and achieve rapid and effective recovery" (Khan et al., 2008). This research focuses on large-scale disasters, which call for the international response community. An overview of key characteristics of large-scale disasters can be found in table 2.1.2 below. It should be noted that these characteristics have an impact on the complexity of disaster situations and therefore disaster management, which will also be mentioned in other parts of this research.

Table 2.1.2: Key characteristics of large-scale disasters. (Jiang & Yuan, 2019)

Emergency Characteristic	Description
Large scale impact	May affect wide geographical areas and large groups of population
Severe consequences	May cause huge number of casualties and severe property damages
Multi-agency involvement	May involve multiple parties such as rescue teams, volunteers, and international support teams
Time pressure and emergency	Time is critical for life saving, and there is time pressure for quick decision making and action
Demand surge and resource shortage	Huge demand surge with severe resource shortages
Great uncertainty	Great uncertainty caused by the nature of the disaster which is often unpredicted and unprecedented
Infrastructure damage	Infrastructure is often damaged, becoming inaccessible or unusable

The cooperation of this community with the governments of affected countries is by definition international disaster management (Coppola, 2006). With disasters at this scale, many different kinds of organizations and people participate in the situation (Coppola, 2006):

- Victims
- Local first responders
- The governments of the affected countries
- Governments of other countries
- International organizations
- International financial institutions
- Regional organizations and associations
- Nonprofit organizations
- Private organizations—business and industry
- Local and regional donors

The variety of agencies has influence on disaster management. Janssen et al. (2010) enumerated the importance of information and information sharing in these situations. Disaster situations have, in contrast to stable business environments, diverse and unpredictable information demands, with extra emphasis on the timeliness of information: "If information is delivered too late, it may fail to prevent damages or losses, while if too early, it may be neglected. In addition, too much information results in a huge information overload" (Janssen et al., 2010). Also, collaboration between geographically distributed public and private organizations is required for effective response (Janssen et al., 2010). Effective information sharing of accurate and relevant information in disaster management can prevent disasters from becoming worse (Janssen et al., 2010). The processing of information can be described by the disaster information cycle (Carter, 2008). This cycle is relevant for crisis managers and how they process information, which will be important for the SDI as discussed later in this research.

1. Acquiring information;
2. Assessment or evaluation;
3. Decision making; and
4. Dissemination of information and decisions.

According to Joyce, Wright, Samsonov & Ambrosia (2009), the approach on disaster management has shifted its focus throughout the years, where "the traditional approach to hazard risk and disaster management has been one primarily focused on response to events as they occur", mostly focused on limiting the exposure to a hazard. Recent approaches on disaster management "consider disaster management planning as part of a broader system of planning for sustainable, resilient communities" (Joyce et al., 2009). In other words: the focus used to be on hazard exposure, but nowadays, the focus is on vulnerability and coping capacity of communities as well.

Nonetheless, there are several difficulties regarding disaster management. Disasters are extremely dynamic situations where a lot of changes happen in for instance urgency, scope, impact, type of appropriate responders, and the responders' needs for information and communication (Janssen et al., 2010). This fuels the complexity of disaster management, which is also pointed out by Asghar, Alahakoon, & Churilov (2006), who summarized the characteristics making disaster management complex:

- A large number of activities involved with varying features and functionality
- Changing environmental conditions
- Highly interdisciplinary and its changing nature
- A global perspective
- Dynamic decision support needs
- Data scattered at various sources
- The complexity of the system
- Uncertainty involved in decision-making
- A huge volume of diverse data.

This complexity makes the ability to communicate and share information effectively more crucial, however, disaster management often fails to cope with complexity and uncertainty (Janssen et al., 2010). When looking at geographic information and SDIs used in crisis management, this should be taken into account as it might hamper crisis managers' efficiency.

Since disaster management has shifted from a focus on only hazard exposure to a focus on vulnerability and coping capacity as well, social drivers have changed how disaster planning is considered and undertaken (Joyce et al., 2009). The approach that is mostly applied is a four-phase planning system: the Disaster Management Cycle (Coppola, 2006; Carter, 2008; Joyce et al., 2009; Janssen et al., 2010), which consist of (visualized in figures 2.1.2.1 & 2.1.2.2):

- Reduction / mitigation: "reduction incorporates all measures and planning that reduce the likelihood of a disaster occurring" (Joyce et al., 2009);
- Readiness / preparedness: "readiness planning accepts that some residual risk is present for communities and that measures must be in place to ensure any response to hazards is efficient and reduces hazard impacts" (Joyce et al., 2009);
- Response: "response capability involves the processes of coordinated effort to manage resources, including life essentials and personnel, for activities such as evacuation, relief, search and rescue and needs assessment" (Joyce et al., 2009);
- Recovery: recovery "has traditionally been focussed on restoration of lifeline utilities, and building reconstruction" (Joyce et al., 2009), however, now it also incorporates community recovery in a sustainable manner regarding the social, economic, built and natural environments (Joyce et al., 2009).

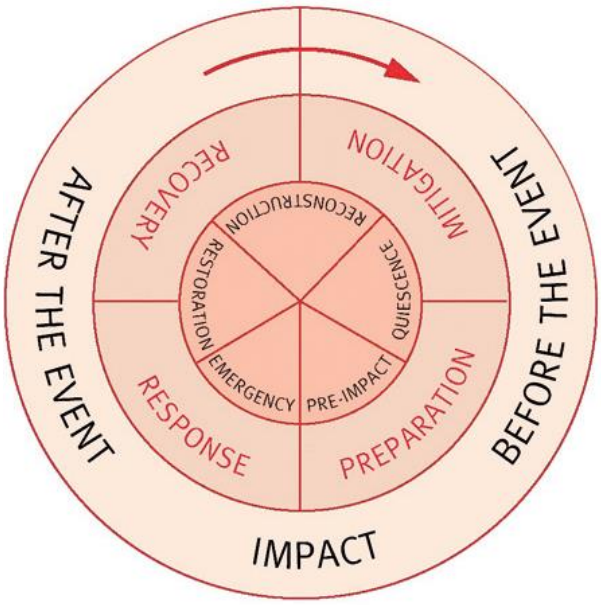

Figure 2.1.2.1: The disaster management cycle (Alexander, 2002)

In this four-phase system, the response and recovery phases start after a disaster happened. Christoph et al. (2013) discuss that the concept can be elaborated by conceptualizing it as an infinite process: the disaster management spiral. This spiral is in fact the same as the disaster management cycle, although it takes into account that it is an infinite process. It is not possible to eliminate all of the risk, so it will keep the spiral in a continuous loop (Christoph et al., 2013).

Even though the four-phase planning system is widely used for disaster management, which describes a different nature of actions in each phase, the phases are not discreet (Joyce et al., 2009). Contreras (2016) reviewed the post-disaster management phases after an earthquake in Italy and found that the phases have fuzzy boundaries. It is stated that it is "defined by the objectives achieved within the affected area than by limiting each phase to a specific time period" (Contreras, 2016). Ideally, the disaster management cycle phases are integrated throughout the planning process, so response and recovery activities will commence at the same time, because information can for instance be used for both

phases and thus at the same time (Joyce et al., 2009). Blackman, Nakanishi, & Benson (2017) describe how post-disaster phases, between short term and long-term phases, have a certain transition phase which is not a clear boundary between short and long term phases, see figure 2.1.2.2. This research will therefore not handle the phases as delimited, but will rather focus on the processes and objectives (of the post-disaster phases) independent of the phase they are in.

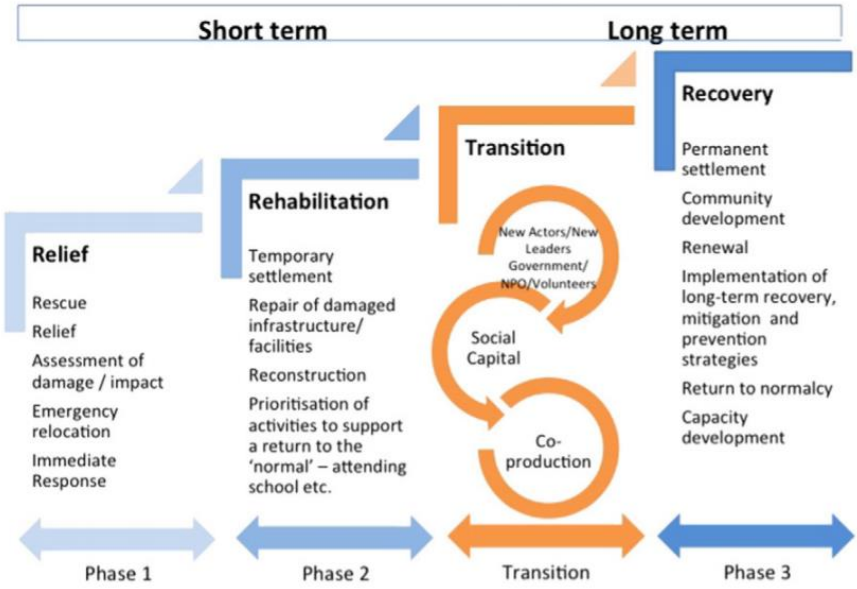

Figure 2.1.2.2: Elements of disaster transition (Blackman et al., 2017)

Extra attention will be given to the phases shortly after the disaster, as the impact of actions is bigger in this period of time. Janssen et al. (2010) illustrate this in figure 2.1.2.3, where the impact in different phases is shown over time. The importance of this phase is also stressed by the WFP because a certain information gap exists early in the response phase (WFP, 2018), hampering decision-making based on required information.

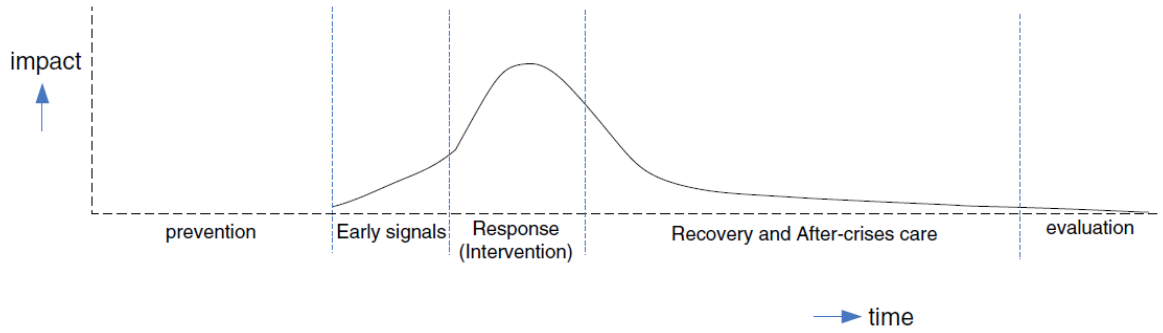

Figure 2.1.2.3: Impact during disaster management phases (Janssen et al., 2010)

2.1.3: Crisis management processes

As explained, crisis management consists of the phases after a disaster strikes. Even though the phases have no clear boundaries, the processes and actors of the response and recovery phases will be given for each of these two phases, as research and documents use this distinction. Further use of these processes in this research will look at the processes themselves and not as parts of a phase. Summaries and explanations of the activities are given in Coppola (2006) and Carter (2008), which will be used for the overview as they contain complete information on both response and recovery activities after disasters within the scope of this research.

Disaster response activities

The activities in disaster response are primarily focused on protecting life and property, prior to, during, and immediately after a hazard event (Coppola, 2006; Carter, 2008; Joyce et al., 2009). In addition, limiting damage to the environment (Coppola, 2006) and dealing with the immediate disruption, damage, and other effects caused by the disaster (Carter, 2008) are priorities in disaster response. Carter (2008) describes the goal of disaster response as follows: "Effective response to the impact of disaster is critical mainly to: limit casualties, alleviate hardship and suffering, restore essential life support and community systems, mitigate further damage and loss, and provide the foundation for subsequent recovery." Communities need help through the disaster phase and beyond (Carter, 2008), which is where response (and recovery) comes in. It should be noted that response activities begin as soon as the hazard is recognized as imminent (Coppola, 2006), which is in fact pre-disaster (as this is normally a short amount of time to no time at all before the event, this is not taken into account in the disaster management model, which states that the response phase starts with the impact). Coppola (2006) and Carter (2008) created overviews of activities and tasks that are present during the disaster response phase, which have a wide range of categories as search and rescue, water and power supplies, evacuation etc. However, these activities may not only be limited to the response phase. Kerle (2013) gives an example of rapid structural damage assessment, where "the results provide guidance for rescue forces and other immediate relief efforts, as well as subsequent rehabilitation and reconstruction." The information that is used is therefore useful for the following phases.

The wide range of activities during disaster response that Coppola (2006) and Carter (2008) discuss can be summarized and narrowed to the most important activities:

- implementing plans;
- activating the counter-disaster system;
- search and rescue;
- providing emergency food, shelter, medical assistance, etc.;
- surveying and assessing; and
- evacuating. (Carter, 2008)

Decision-making for each of these processes requires information and a common problem in the response phase is poor information management hampering decision-making, which is due to information issues anywhere in the disaster information cycle (Carter, 2008).

Disaster recovery activities

Disaster recovery activities are the most diverse, as well as the costliest activities of the disaster management cycle, which generates the greatest amount of interest and attention from the world community as a whole (Coppola, 2006). However, "disaster recovery is also the least studied and least organized of all of the disaster management functions, and therefore the most haphazardly performed" (Coppola, 2006). Disaster recovery activities can in short be aggregated into restoration activities, rehabilitation activities and reconstruction activities (Coppola, 2006; Carter, 2008). Common actions during disaster response include for example damage and needs assessments, new construction, social rehabilitation programs etc. (Coppola, 2006; Carter, 2008). According to Carter (2008), "post-disaster review should also be included as part of the recovery process. It should take place as soon as practicable after the disaster."

The information that is required for disaster recovery activities comes from different sources, as distinguished by Carter (2008):

- Information from response operations, for instance:
  - Information from damage surveys and needs assessments;
  - Various forms of operational reports;
  - Departmental and other reports on completion of emergency phase; also, similar reports from NGOs;
  - Information collected by emergency operations centers;
  - Reports from international assistance agencies;
  - Media information; and
  - Various submissions by individuals.
- Post-disaster review
- Information from development programs
- Information from special teams
- Information for program parameters
- Information from previous disasters

The many different sources create extra complexity for information processing during the recovery phase.

Crisis management actors and coordination

Carter (2008) gives a very extensive list of actors that play a role in each phase. However, this list also complies with the summarized view of Coppola (2006), who lists the actors in the following groups:

- Governmental Disaster Management Agencies
  - Fire departments
  - Law enforcement agencies
  - Emergency management (civil protection) agencies
  - Emergency medical services
  - The military
- Nongovernmental organizations
- Private sector
- Academia
- Multilateral organizations and international financial institutions
  - United Nations (and subsidiaries)
  - Regional international organizations (NATO)
  - International financial institutions (World Bank)

In relation to further chapters in this research, this list can be used as making distinctions between data and information providers and users.

The amount of and the high variety of actors requires coordination during crisis management (Salvadó, Lauras, Comes, & Van de Walle, 2015; Balcik et al., 2009; Taynak & Tuğer, 2014). A major challenge for efficient humanitarian disaster management is a lack of coordination (Salvadó et al., 2015), which can create big losses of human and material resources (Taynak & Tuğer, 2014). Also, the amount of produced information by the many actors requires coordination, as actors do not have the capacity to process it, causing a lack of situational awareness (Salvadó et al., 2015). Coordination can be both vertical and horizontal (Balcik et al., 2009; Taynak & Tuğer, 2014). Balcik et al. (2009) distinguish vertical and horizontal coordination as follows:

> Vertical coordination refers to the extent to which an organization coordinates with upstream or downstream activities. For example, if a traditional NGO coordinates with a transportation company, this would be an example of vertical coordination. Horizontal coordination refers to the extent to which an organization coordinates with other organizations at the same level within the chain. An example of horizontal coordination would be if one NGO coordinated with a second NGO to provide relief goods and/ or services.

A clear coordination framework is, according to Salvadó et al. (2015), limited by several elements:

- The large number and diversity of organizations turn the relations to be managed into a complex network;
- The incentives of actors vary as a crisis evolves as well as from one crisis to another;
- Procedures, tools and methods are not interoperable;
- The allocation of costs, benefits and risk is often unbalanced. (Salvadó et al., 2015)

However, the cluster approach of the United Nations has been introduced for humanitarian coordination (Taynak & Tuğer, 2014). The Humanitarian Response (n.d.) platform, a service provided by the UN, describes clusters as follows:

> Clusters are groups of humanitarian organizations, both UN and non-UN, in each of the main sectors of humanitarian action, e.g. water, health and logistics. They are designated by the Inter-Agency Standing Committee (IASC) and have clear responsibilities for coordination.

An overview of humanitarian clusters can be seen in figure 2.1.3.1 below. According to Taynak & Tuğer (2014), the cluster approach improves effectiveness in the following areas:

- Satisfactory global capacity to react to the current and future crisis;
- Trustworthy and predictable leadership at a global and local level;
- Unbreakable alliance between UN bodies, NGOs and local authorities;
- Responsibility, both for the reaction and in relation to receivers; and
- Strategic field-level organization and prioritization. (Taynak & Tuğer, 2014)

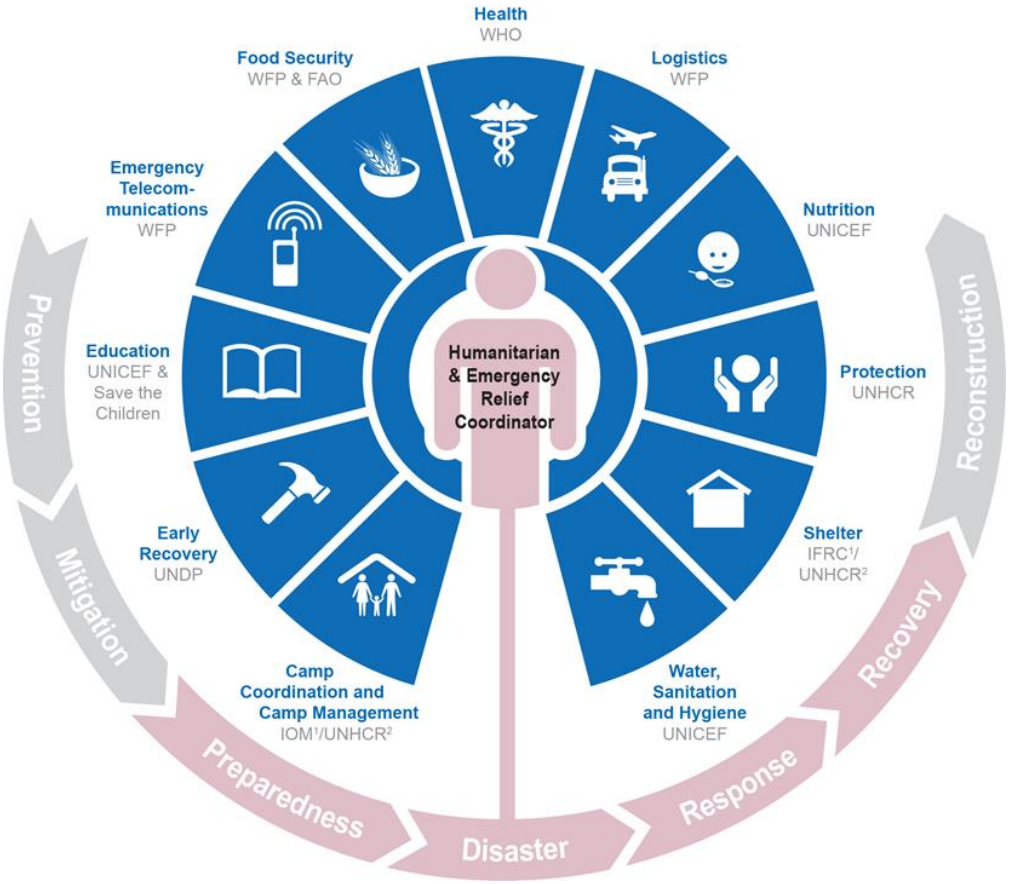

Figure 2.1.3.1: Cluster approach. (Humanitarian Response, n.d.)

The cluster approach works on different scales and both horizontal and vertical, where it gives guidelines for strategic, tactical and operational scales, and for coordination within clusters, among clusters and in the vertical chain (Taynak & Tuğer, 2014). The coordination architecture is shown in figure 2.1.3.2, where different actors are shown in

the context of the cluster approach. This is the current approach of humanitarian response where the United Nations have a coordinating role.

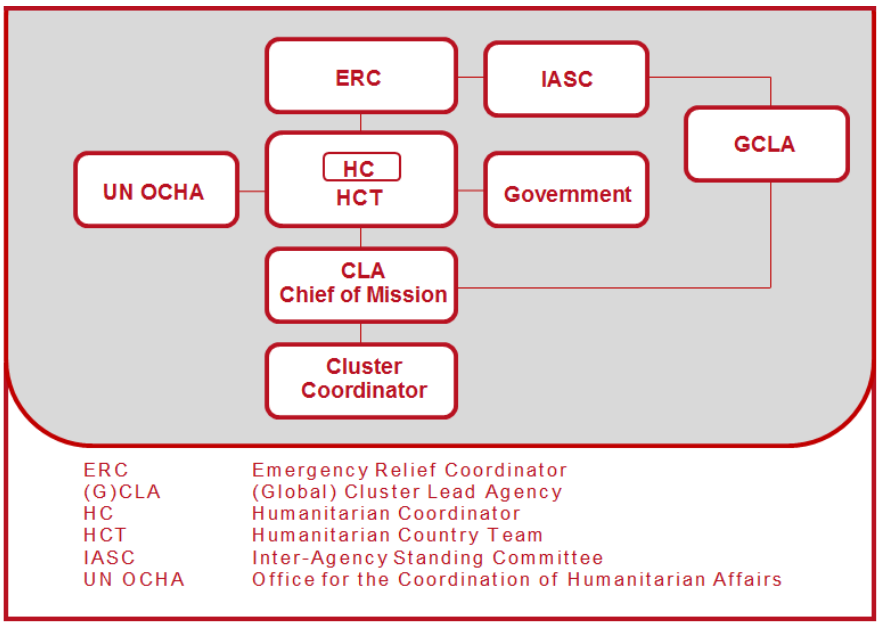

Figure 2.1.3.2: Coordination architecture in the cluster approach. (UNHCR, n.d.)

Challenges for crisis management

There are multiple challenges for executing the activities in crisis management. For instance, development of a model for disaster management faces challenges that can be linked to the information cycle, like slow data and poor updating of the information, data collection challenges, decision support system design challenges and more (Asghar et al., 2006). Bengtsson, Lu, Thorson, Garfield, & Von Schreeb (2011) also state that activities such as relief assistance, needs assessments, and infectious disease surveillance can be severely complicated by population movements. In addition, Carter (2008) explains the importance of logistics for response and recovery operations, which is essential for the fulfillment of operational tasks, procurement and distribution of relief commodities, and international assistance activity. Logistics should also be taken into account during the recovery activities (Carter, 2008). Also, effective operation of the disaster management cycle demands certain organizational facilities and capabilities, such as (Carter, 2008):

- Emergency Operations Center [EOC] (static and mobile);
- good communications;
- capability for survey and assessment;
- facilities to acquire, transmit, receive, display, collate, assess, store, and generally handle information;
- provision for presenting information in such a way that it can facilitate decision making; and

- ❖ trained staff to operate the information management system.

Nojavan, Salehi, & Omidvar (2018) created a comprehensive model of disaster management, which incorporates the disaster management phases and its (summarized) actions. This model (see figure 2.1.3.3) shows the complexity of disaster management, which should be taken into account by anything related to disaster management. What it also shows is that this research does not take the full range of disaster management into account, which is what remains open for further research. Kapucu & Garayev (2011) identified different factors that affect decision-making in emergencies, which are:

- ❖ Complexity arising from severity of situation and involvement of several organizations in response operations (negative impact);
- ❖ Uncertainty caused by limited information about the situation and chaotic atmosphere (negative impact);
- ❖ Time pressure resulting from urgency to make immediate decisions (negative impact);
- ❖ Stress caused by severity and complexity of situation, and urgency to make consequential decision (negative impact);
- ❖ Risk needed to be taken to decide on critical and high-stake issues (negative impact); and
- ❖ Previous experience concerning the case at hand. (positive impact)

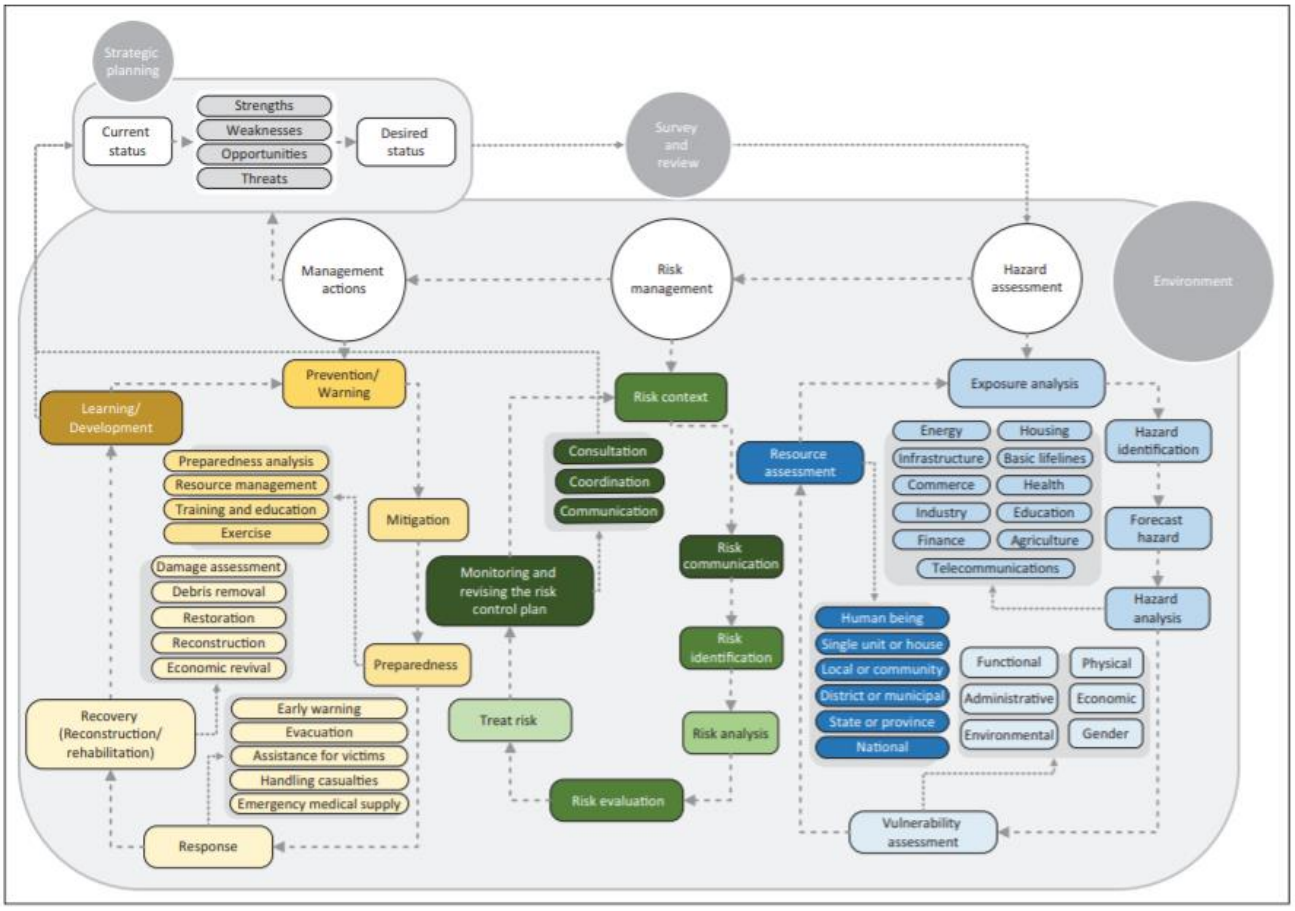

Figure 2.1.3.3: Comprehensive conceptual model of disaster management. (Nojavan et al., 2018)

What conventional disaster management models do normally not extensively incorporate is the role of public participation in providing disaster information. Christoph et al. (2013) state that crisis communication has changed considerably due to increasing public participation on social media platforms, which could provide information in the form of blogs, microblogs, instant messaging services, photo sites and interactive maps. They conclude: "Effective participative inter-communication between stakeholders of various backgrounds as well as external experts and government officials is the key factor in forward-looking activities" (Christoph et al., 2013), where forward-looking activities relate to contemporary views on improved disaster management. The next subchapter, 2.2, will go further on this topic in the section of Volunteered Geographic Information (VGI).

2.2: The role of GI for crisis management

The previous subchapter stressed the importance of crisis management and the need of information for decision-making. This subchapter will explain what geographic information contributes to the crisis management processes, and what types of geographic information are used. An overview of acquisition methods and outputs will be given.

2.2.1: The importance of GI

As most of the required information for disaster management has spatial nature, effective disaster management cannot be expected when spatial data is not available (Mansourian, Rajabifard, Valadan Zoej, & Williamson, 2004). Snoeren et al. (2007) concisely describe the importance of GI and GIS for disaster management:

> GIS allows for an effective visualization of a disaster situation. By placing the accurate physical geography of a disaster event on a computer monitor and then append with other relevant features, events, conditions or threats, people can make decisions based on these GIS data. This visualised information can be of critical relevance to the disaster manager.

However, this barely scratches the surface of why GI and GIS are so important for disaster management. Several technologies related to spatial data have been proven useful for disaster management, like GIS, GPS, remote sensing & photogrammetry (Mansourian et al., 2004). MapAction (2011) also states that "humanitarian emergencies necessitate the fast and effective use and sharing of geographical information". Location information is crucial for disaster management activities and its role is well recognized (Bajracharya, 2015). "Timely, up-to-date and accurate spatial information describing the situation is of utmost importance for successful emergency response" (Bajracharya, 2015). It is nevertheless a challenge to provide availability of and access to reliable, accurate and up-to-date information (Bajracharya, 2015). Many researches state the importance of certain types of GI for phases in disaster management, which will be described in the following subchapter based on the type of data acquisition.

2.2.2: Types of data acquisition

Different types of data acquisition could be distinguished for creating GI that is used in crisis management. A distinction has been made between image-based mapping / remote sensing, volunteered geographic information (VGI), field-based systems / global navigation satellite system (GNSS), & other methods. It should be noted that both image-based mapping / remote sensing and field-based systems / GNSS could be used by both expert mappers and non-experts, but only takes expert mapping into account, as non-expert mapping is incorporated in the VGI method.

Image-based mapping / remote sensing (non-VGI)

The use of remote sensing for disasters has been increased, not only because of an increased awareness, but also increased technologies and the provision of up-to-date imagery to the public (Joyce et al., 2009). Remote sensing is very useful when for instance ground based mapping is too slow, dangerous and difficult to perform (Kerle, 2013), and it provides a valuable and objective data source for each of the disaster management stages (Joyce et al., 2009). According to Eguchi et al. (2008), it could for instance offer an advantage over ground-based survey for building damage assessments. What is important for remote sensing data to be of support, is that it provides data that is spectrally, temporally, and spatially relevant for disaster management (Joyce et al., 2009). Joyce et al. (2009) also stress the importance of close collaborations between the disaster management community and the remote sensing / geospatial community, to tailor the remote sensing information to the disaster manager's needs. There are several types of remote sensing data, where each of the data types has its advantages and disadvantages depending on the circumstances, so it is recommended that multiple data types and/or processing methods are used for disaster management (Joyce et al., 2009). There are different types of sensors that create remotely-sensed images. This results in different types of imagery, each with its own advantages and disadvantages, which can be categorized as:

- Optical imagery
- Thermal imagery
- Active sensing, like Synthetic Aperture Radar (SAR) and Light Detection And Ranging (LiDAR) (Joyce et al., 2009; Boccardo & Tonolo, 2015)

Regarding thematic accuracy, Boccardo & Tonolo (2015) state that designating a level of damage to buildings, based on satellite imagery, creates concerns about the thematic accuracy, because vertical imagery may be limiting the assessment. In addition, Kerle (2013) explains that the accuracy of assessments is not sufficient enough for the information to be used as stand-alone information. The accuracy was, in a situation with perfect input data, only 63% right (Kerle, 2013). It is therefore dependent on the situation or task that the thematic accuracy is sufficient or not. Manfré et al. (2012) therefore state that satellite observations are complementary to traditional in situ measures. Other limitations of remotely sensed data are explained by Kerle (2013):

- Universally accepted damage map nomenclature and style are lacking;
- Instead, damage is depicted on various scales and in different categories using point or line signatures, damage clusters, grid-based damage averages, damage per city block using color ramps, damage aggregated per neighborhood, or as continuous damage density maps;
- The decisions for a given mapping style do not appear to be based on what users have identified as useful or understandable, nor to reflect the needs of specific user groups;
- A growing number of organizations produces damage maps, including non-experts, leading to duplication of mapping efforts and potential disagreement;
- The number of damage map users, and their information needs, have been growing rapidly;
- Traditional charter maps remain static, being distributed as print-optimized pdf documents, not allowing ready mash-ups with other data and map customization; and
- Damage mapping validation rarely takes place.

In the remote sensing community, the most recognition, funding and planning effort goes into the response phase, of the four disaster management phases, with numerous research on the topic (Joyce et al., 2009). However, this data is often not provided in the timeframe requirements for decision makers (Joyce et al., 2009). Besides, Joyce et al. (2009) state that the application of remote sensing is the least developed in the disaster recovery phase, even though there are "clear indicators for recovery that can easily be measured and monitored with remote sensing imagery". For example, time series imagery could be useful for monitoring disaster recovery activities (Joyce et al., 2009).

As solutions for the limitations of remote sensing for disaster management, Boccardo & Tonolo (2015), Adams & Friedland (2011) and Joyce et al. (2009) state that Unmanned aerial vehicles (UAVs) could be used instead of or in conjunction with satellite sensors. The different types of sensors for satellites could as well be used for UAVs, making the processes for creating information from the data comparable. The temporal resolution limitations and weather effects could be tackled by UAVs. Adams & Friedland (2011) discuss that photogrammetry-ready data (with appropriate metadata) acquired by UAVs could map multiple elements of disasters and hazards.

Volunteered Geographic Information (VGI)

Even though information from many different sources is integrated in disaster management, Poser & Dransch (2010) state that the integration of observations of eyewitnesses (other than emergency staff) is rarely taken into account. They explain that VGI is regarded as an opportunity for this problem (Poser & Dransch, 2010). Goodchild (2007) says that VGI is a rising phenomenon, describes VGI as "using the Web to create, assemble, and disseminate geographic information provided voluntarily by individuals." This trend can also be seen in disaster damage mapping, as anyone with a digital media device is likely a map user (Kerle, 2013), and civilians are often 'first responders' during crises (Janssen et al., 2010). According to Kerle (2013), "crowd-sourced projects may

provide new perspectives that do not currently exist in established methods; the hope is that they can provide actionable information that is reliable, time sensitive, and cost sensitive." However, as this article is published in 2013, it should be taken into account that it might be different in 2020.

Crowdsourced mapping can play a key role in the logistics of crisis response, where aggregating, evaluating, and planning via logistical back support is one of the fundamental actions (Zook, Graham, Shelton, & Gorman, 2010). Zook et al. (2010) state that "the greatest benefit to this form of distributed mapping is that a greater number of maps can be produced in a shorter period of time, allowing scarce technical resources to be diverted elsewhere." Emergency responders can therefore focus on actions that are less easily distributed to others (Zook et al., 2010). Also, VGI provides the possibility to add reports on local and specific conditions as an individual. While this information is not cross checked, it can be used as an additional information source for crisis responders (Zook et al., 2010). Another benefit of VGI is that it could produce datasets at a high speed, which is critical for crisis response (Zook et al., 2010).

Even though VGI has advantages, several challenges are present with using VGI for disaster management support. The data quality and the availability of data are uncertain, there might be bias towards severe events, localization issues may arise (although the emergence of mobile phone GPS mostly solves it), and data collection issues could play a role (Poser & Dransch, 2010). Also, an abundance of maps could be harming the ability to quickly find the information disaster responders are requiring, as was the case in Haiti (Kerle, 2013). This suggests that there was a lack of coordination and probably duplication of tasks, besides, the usability of all the maps remains to be assessed (Kerle, 2013). The challenge with many volunteers involved in crisis mapping is that the instructions become very important for the accuracy and consistency in the outcome of the analysis, which is where cognitive task analysis methods could be useful, for analyzing how map users interpret analysis results (Kerle, 2013). Also, crowdsourced mapping can be performed by both experts and non-experts, however, attention must be paid to the role of experts in the process (Kerle, 2013). Zook et al. (2010) also name licensing issues as a potential problem for acquiring the right information, which could hamper combining it with other information. Besides, more practical challenges remain with crowdsources mapping. Regarding collaborative damage mapping (to buildings) for instance, several challenges may play a role (Kerle, 2013):

- "Damage" (to buildings) becomes a concept rather than a physical state due to classification differences and discrepancies;
- Detection of damage indicators is often impossible from direct perception;
- Assumptions are made by the three actors in collaborative mapping: mapping organizers, volunteers, and the damage information users, potentially hampering performance of the tasks.

Zook et al. (2010) state that crowdsourced online mapping is a powerful tool for individuals to contribute to relief work without being present in the area. Nonetheless, even if there is clearly potential for using VGI in disaster management, it will depend on the user's

needs and the business case of the user to what extent VGI will be incorporated (Payne, Florance, & Shain, 2012).

Field-based systems / Global Navigation Satellite System

There is not much research about the use of field-based systems and geotagging for disaster management, however, it shares a lot of features with geotagged VGI. The distinction is made as the creators are in this case professionals, contrary to (mostly) non-professional volunteers. The Global Positioning System (GPS) is by far the most used positioning technology used, which could provide very precise positioning, used in most preventive, management and emergency situations in natural disasters (Manfré et al., 2012). MapAction (2011) gives a few examples of using GPS for disaster management, both waypoints and tracklog information:

- Surveying features along a route
- Village-based assessments
- Flood and damage surveys
- Photographs
- Surveys from aircraft

Other

Besides the data acquisition methods described earlier, other methods may also be applied to provide useful data and information for disaster managers. For instance, the method described by Bengtsson et al. (2011) makes use of SIM card tracking in mobile phones. This method can be used to follow population movements in a rapid and accurate way after disasters. However, the prerequisite is that the area of interest holds high mobile phone use. Besides, social behavior regarding phone use, and technical problems as power loss have not been taken into account in the method. Nevertheless, the method showed high validity in the case of the 2010 Haiti earthquake, and the information is better and especially created quicker than other estimates (Bengtsson et al., 2011). This is therefore a method to tackle the difficulties of population movements for disaster management, as described in the previous subchapter.

In addition to the given methods of data acquisition, hybrid approaches, where multiple methods will be used in conjunction, are preferable according to Payne et al. (2012).

2.2.3: Geographic information types

The previous paragraph discussed different ways to produce data that is used in crisis management. This paragraph will discuss what types of geographic information are used in crisis management. MapAction (2011) gives an overview of common data layers categories that are used in these situations:

- Administrative units
- Elevation / terrain
- Map scans (general-purpose maps)
- Settlements
- Transport infrastructure
- Remotely sensed imagery
- Population
- Human and situation data (post-event)
- Other:
    - Environmental aspects
    - Land use
    - Physical
    - Points of interest

This overview will be taken as a basis for this research, for analyzing if and how these types of information are shared through the SDI for the users. However, the type of geographic information that is required is dependent on the type of disaster. Lewis (2011) provides an overview of uses of remote sensing data for certain actions per disaster type. This overview includes all phases of the disaster management cycle, however, for this research the post-disaster phases are the only ones taken into account, as seen in table 2.2.3. This table shows some of the varieties of information that could be generated for certain types of disasters. Also, only disaster types with sudden-onset character are taken into account in the table. Joyce et al. (2009) also give more specific examples of information that could be used during the response and recovery phases, like: inundation, widespread storm or earthquake induced landslides, volcanic ash and gases, public information during events, ship location, co-seismic and post-seismic deformation for disaster response, and for disaster recovery: rate of recovery (debris removal, vegetation regrowth, reconstruction), infrastructure and facilities locations, revised DEM, status quo.

Action plans are constantly being developed during the response phase, spatial data and maps are key components of these plans (Snoeren et al., 2007). Apart from helping the disaster responders with getting an (frequently updated) overview of the disaster, maps could also be useful as a means of information sharing towards citizens and press (Snoeren et al., 2007).

Table 2.2.3: Ways remote sensing can help disaster management (Adapted from: Lewis, 2011)

Disaster type	Response	Recovery
Cyclone/storm	• Identifying escape routes; • Crisis mapping; • Impact assessment; • Cyclone monitoring' • Storm surge predictions.	• Damage assessment; • Spatial planning.
Earthquake	• Planning routes for search and rescue; • Damage assessment; • Evacuation planning; • Deformation mapping.	• Damage assessment; • Identifying sites for rehabilitation
Fire	• Coordinating firefighting efforts.	• Damage assessment
Flood	• Flood mapping; • Evacuation planning; • Damage assessment.	• Damage assessment; • Spatial planning.
Landslide	• Mapping affected areas.	• Damage assessment; • Spatial planning; • Suggesting management practices.
Volcano	• Mapping lava flows; • Evacuation planning.	• Damage assessment; • Spatial planning.

2.3: The role of SDI for crisis management

It can be concluded that the importance of geographic information in crisis management and also in disaster management as a whole is significant. How can an SDI facilitate the creation and sharing of this information, and why is it important? This subchapter describes the link between geographic information, SDIs, and crisis management.

A spatial data infrastructure can be described as "an initiative intended to create an environment in which all stakeholders can co-operate with each other and interact with technology, to better achieve their objectives at different political and administrative levels. In simple terms SDIs facilitate the sharing of data" (Williamson, 2003). SDIs consist of multiple core components: policy, access network, technical standards, people (including partnerships) and data (Rajabifard & Williamson, 2001). Figure 2.3.1 visualizes these components of the SDI in the dynamic environment. "Considering the important and fundamental role between people and data as one category, a second can be considered consisting of the main technological components: the access network, policy and standards" (Rajabifard & Williamson, 2001).

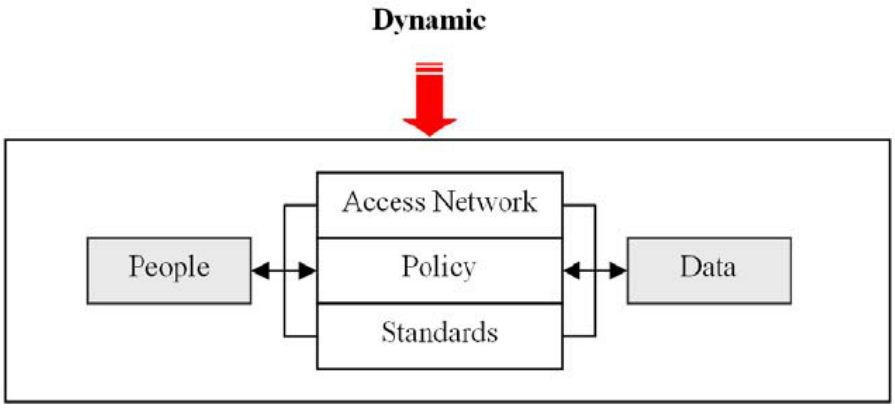

Figure 2.3.1: SDI Nature and Components. (Rajabifard, 2008)

Chapter 2.2 discussed that spatial data can be used for decision-making during crisis management, however, there are problems with collection, access, dissemination and usage of this data, which are especially problematic in the disaster response phase (Mansourian, Rajabifard, Valadan Zoej, & Williams, 2004). SDIs are suggested to be able to serve as a tool for resolving these problems and to facilitate decision-making for disaster management (Mansourian et al., 2004; Manfré et al., 2012). Eguchi et al. (2008) say that opportunities "emerge when time-critical information can be delivered more efficiently to users making critical decisions during the disaster." However, even with good systems and information quality, the sharing of geographic information is still considered as a problem (Janssen et al., 2010), while disaster management institutions need to access and use the data easily and rapidly (Manfré et al., 2012).

What SDIs tend to overcome is the problem of 'isolated islands of technology', which is a result of disaster management agencies' vertical organization (Janssen et al., 2010). During disasters, inter-organizational processes appear next to the single-agency processes that are normally the only processes present during non-disaster circumstances, bringing interoperability problems and "isolated, overlapping in function and content, highly fragmented, and unrelated computerized applications within individual agencies" (Janssen et al., 2010). It is sometimes overlooked that information has to be shared horizontally as well, instead of only within the organization (vertical) (Carter, 2008). This challenge is especially important because disaster management has immense flows of information that require coordination and communication between the organizations and agencies (Asghar et al., 2006), but each organization does not need to try to possess and create all of the data (Snoeren et al., 2007; Bajracharya, 2015). SDIs can be useful for minimizing these duplications of efforts and not wasting resources (Bajracharya, 2015). It "provides a better method for communication and collaboration among the different actors within and among the emergency forces" (Snoeren et al., 2007), so all the data and information "...should be available at all levels and simultaneously through information networks" (Manfré et al., 2012).

Using SDI for emergencies are especially relevant to save time for emergency responders, because time savings will result in less victims and a smaller size of the hazardous areas (Snoeren et al., 2007). Besides, money and effort could be saved with SDI (Snoeren et al.,

2007), as SDIs "...address the issues on coordinated development, access and use of geospatial information" (Bajracharya, 2015). Snoeren et al. (2007) mention that awareness of multidisciplinary SDIs is rising within emergency forces, which is of interest because it is important that people are familiar with the spatial data sets. Furthermore, the benefits of shared data do not only apply to emergency management organizations, it could also benefit citizens and press as produced overviews can be used for informing them (Snoeren et al., 2007).

Payne et al. (2012) explain that there are multiple ways to share geospatial data in all of the disaster management phases, from hard-copy prints to online web mapping or feature services. They discuss that the use of data repositories, as part of a broader SDI, has benefits for sharing geospatial data during disaster management (Payne et al., 2012). Payne et al. (2012) explain that there are many different classes of data portals/repositories. These platforms support disaster management by facilitating, at a minimum, data creation and dissemination (Payne et al., 2012). They are used in both pre-disaster and post-disaster activities by humanitarian information management officers, but especially crisis mappers (Payne et al., 2012). These data repositories and portals need to be managed in order to be used effectively in crisis management. A repository manager has multiple tasks (Payne et al., 2012):

- First, the repository manager needs to take data in by either seeking data and services to publish or by receiving contributions (from users).
- Second, they need to make the data useful by providing value-added data services. However, "these activities are generally too time consuming to be conducted by field-based IM managers actively responding to a crisis", which is why these tasks are traditionally performed by other personnel (e.g. personnel active in the headquarters and not at the disaster site).
- Third, they need to distribute data by making data discoverable. This could for instance be done by providing a search interface for metadata.

These tasks should be accomplished with development of the SDI. Manrourian et al. (2004) created a schematic presentation of a conceptual SDI model for disaster response, as seen in figure 2.3.2. This is an elaborated conceptual model based on the schematic SDI model of Rajabifard & Williamson (2001). The conceptual model shows the links between geographic data and people in the case of disaster responses. Mansourian et al. (2004) stress that it is essential for decision-makers to understand the significance of different factors and issues that may be challenging for designing, building, implementing and maintaining such SDIs, including the conceptual, technical, socio-technical, political, institutional and financial perspectives. "It is note-worthy that these factors and issues should be considered in the long-term in order to achieve sustainable and ongoing development of SDIs for disaster management" (Mansourian et al., 2004). This conceptual SDI model will be used to explain the SDI components in the fifth chapter, where the responsibilities of the people in the SDI will be explained as well, in the context of the case study.

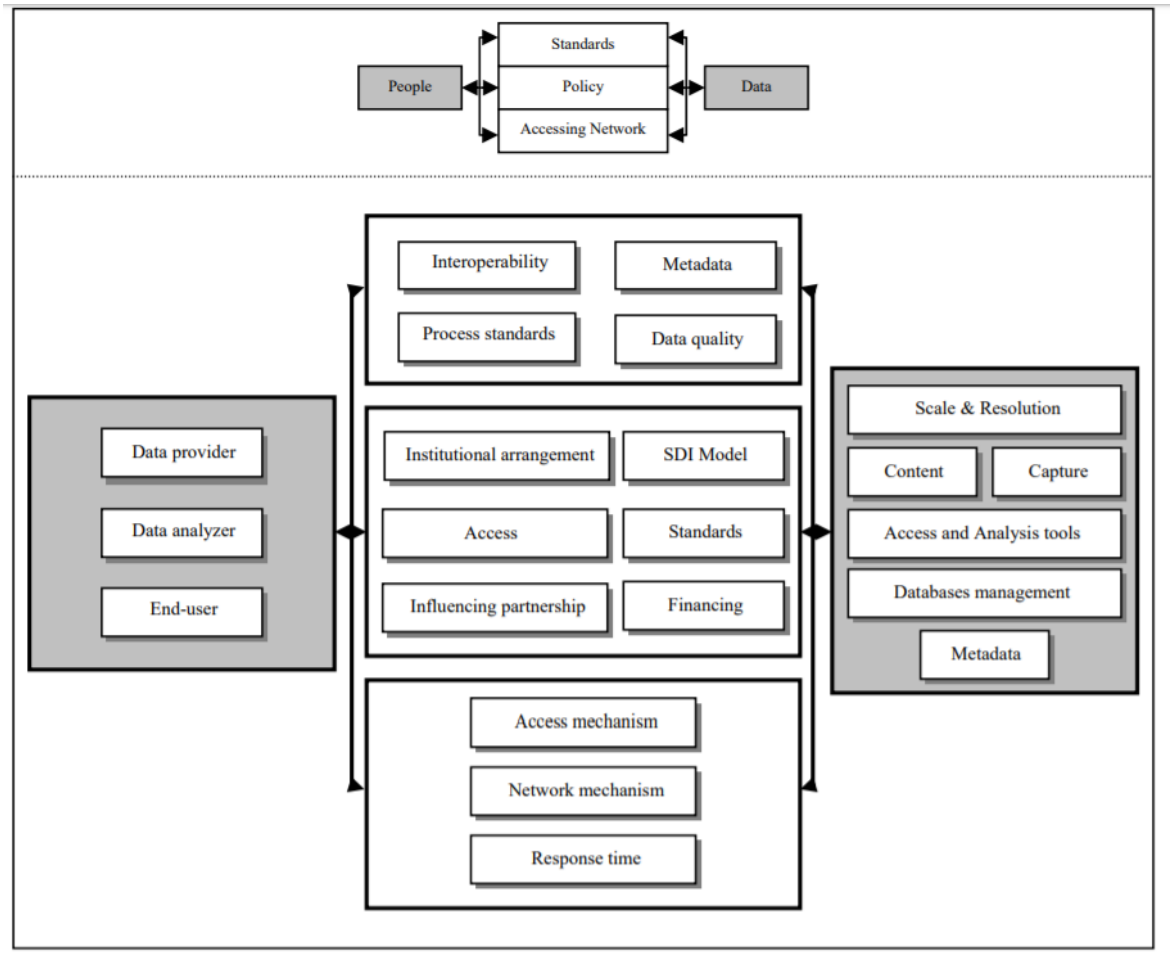

Figure 2.3.2: Schematic presentation of SDI conceptual model for disaster response. (Mansourian et al., 2004)

The datasets that are used in disaster management need to comply with certain standards and specifications, and interoperability models to be of better support for decision-making (Mansourian et al., 2004; Bajracharya, 2015). If the required datasets comply with these, a geospatial portal can facilitate the inter-agency partnerships (Bajracharya, 2015) and the data will be "...easily integratable with each other and interoperable with decision-makers' systems for real-time use" (Mansourian et al., 2004). Metadata is important in the creation of such SDIs, and missing metadata will have a negative impact in trying to enable the best use of the data and information (Manfré et al., 2012). Therefore, Manfré et al. (2012) emphasize the importance of reliable metadata standardization. In addition, semantics, as a part of metadata standardization, are important for data sharing, as not only syntactic equivalence is important, but also equivalence of concepts and meanings (Manfré et al., 2012). Ontology definition therefore facilitates data sharing (Manfré et al., 2012). Other challenges are also present in such SDIs, as Bajracharya (2015) gives a few examples of issues:

- Gap in GIS base layers
- Impossible to download huge satellite images
- Back up plans needed for electricity and internet loss
- In the case of Nepal: loss of crowdsourced information was not geo-coded due to lack of coordination
- Without an automated system for integrating information from various sources, a lot of time is spent (and wasted) on digitalization of data

Bajracharya (2015) therefore also stress that the "preparation of basic information layers needs to be given priority for disaster preparedness in future", which is required for more effective post-disaster relief activities. Another challenge is that there are many or even too many data portals, which results in information managers having to search for the data in more locations and groups that are not sharing their data in central repositories (Payne et al., 2012). This could be an issue unless these portals are linked to each other by other services like a catalog service or search engine (Payne et al., 2012).

What the conceptual model of Mansourian et al. (2004) not specifically exposes is the integration of VGI into the SDI. Bajracharya (2015) states that the relevance of VGI is increasing as an information source that complements authoritative spatial data, and that it contributes to SDI development in areas with poor GIS data coverage. Besides, Payne et al. (2012) discuss that geographic data from crowd-sourced mapping more likely applies to international professional standards. As this chapter discussed earlier, data standards are important for improved data sharing, thus crowd-sourced data will more likely be contributed and maintained in the data repository (Payne et al., 2012).

The process of information synthesis for disaster management, with regard to geographic information that is shared through a geospatial portal, is visualized in a framework by Bajracharya (2015), as seen in figure 2.3.3. This framework gives an overview of the role of SDI in the processes of disaster management. Bajracharya (2015) mentions that it should be possible that all the information could be accessed on a comprehensive platform, visualized through a user-friendly interface. In this way, the geospatial portal for disaster management, which plays a central role in the process according to figure 2.3.3, can make information comprehensible for users (Bajracharya, 2015).

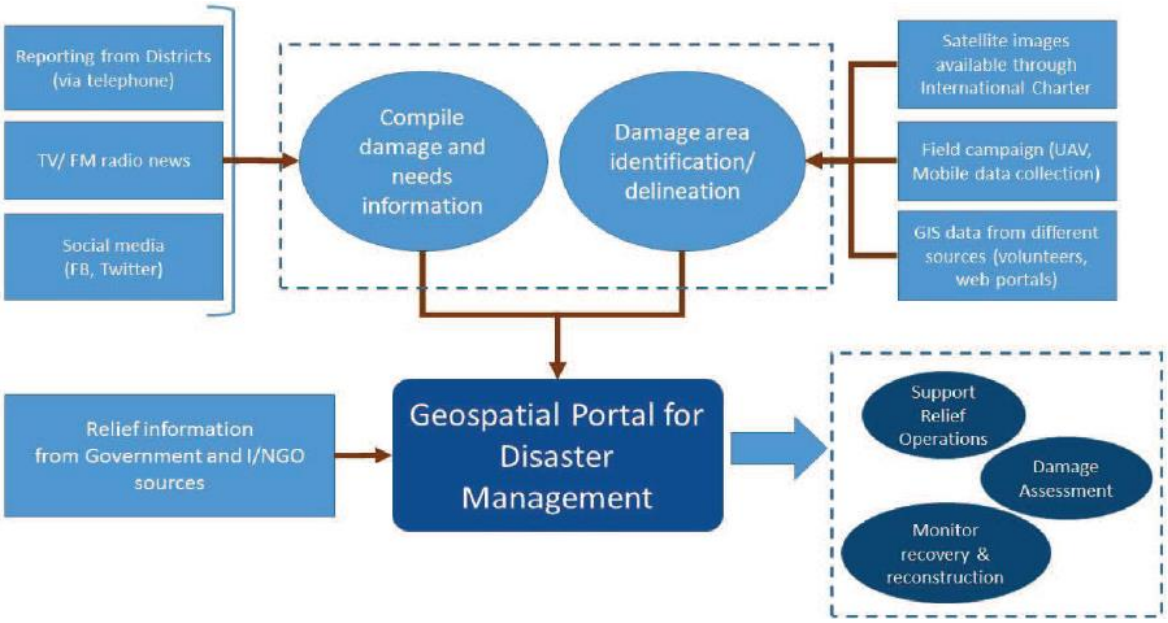

Figure 2.3.3: Framework for information synthesis and use. (Bajracharya, 2015)

2.4: Overview

This chapter discussed literature about both crisis management and the geographic information / SDI field to get a view of the link between the two. First of all, each natural disaster is different and there are the factors of exposure to the hazard, vulnerability and coping capacity that interact with each other, and can lead to a disaster. The management of disaster relief efforts, disaster management, is a complex field with many different actors, activities and other factors. However, with all this complexity, it can be grouped in 4 phases, of which 2 phases are after a disaster struck: response and recovery. The management of these phases is crisis management. Especially the disaster response phase is crucial and important, as there is extra pressure in for instance time that plays a huge role in how the disaster unfolds. Geographic information has been proven to be very useful for crisis management. There are different types of geographic information that are used by crisis managers, however, there are many problems related to information management and usage in the crisis phases. This is where the role of an SDI is important. SDIs can be used during crisis management to disseminate data and information so the decision makers can easily get the data they need. However, there is little literature about the usability of SDIs in the field of crisis management, which is the focus of this research.

Chapter 3: SDI assessment framework

This chapter examines relevant literature on SDI assessment frameworks and creates a new SDI assessment framework for SDIs used in crisis management.

3.1: Overview of SDI assessment

Vandenbroucke et al. (2013) state that "assessments are crucial in order to understand what is working well, how and to what extent the SDI can help in reaching the organisation's goals and objectives, and to improve the processes." In the light of this research, these processes are the processes of crisis management and the goals and objectives those of the actors that are engaging in crisis management. Contrary to the early years of more intuitive SDI development research, recent research on SDI assessment has an increasing demand for more rational assessment approaches. Generic assessment approaches could be useful to measure "the extent to which SDIs programs meet their objectives" (Grus et al., 2011). Another reason to assess SDI performance is "...to show decision makers how policy making and service provision are benefiting from SDI" (Vandenbroucke et al., 2013).

However, an SDI is a complex concept. It is because of the complex and dynamic nature of SDI that it is difficult to assess the benefits and impact of it (Vandenbroucke et al., 2013; Grus et al., 2007). The complexity increases as SDI models go from more data-centric to a more service-centric nature, which also increases complexity in the assessment (Grus et al., 2007). The lack of an agreed definition of SDI, its components and the relationships between them also makes it difficult to define uniform assessment criteria (Grus et al., 2007). Even though there is an extensive body of literature on SDI assessment, "there is a limited number of assessment approaches that are able to demonstrate whether SDIs indeed realize the intended goals" (Grus et al., 2011). Grus et al. (2007) also state that the different SDI assessment approaches present different pictures of SDI.

The view of the user is one of the SDI assessment approaches. Grus et al. (2008) describe this approach as follows:

> The aim of the user's perspective assessment approach is to measure the effectiveness of an SDI from the user's perspective. It derives measures mainly from information systems that are based on concepts such as: usefulness, effective use, information and organizational effectiveness. This assessment approach focuses on identifying its existing and potential users, and also investigating how useful SDI-'products' are for meeting their particular needs.

In this chapter, four different assessment frameworks will be explained and the methods of these researches will be combined to get a combined user-centric SDI assessment framework. These four frameworks have been chosen based on the usefulness (see chapter 3.3) for this research and the fact that they have a focus on user-centric assessment. According to Snoeren et al. (2007), the user point of view can be taken as a starting point

of developing an SDI. The next paragraph discusses the four frameworks that combined will result in the newly created user-centric SDI assessment framework and discusses in more detail why they are relevant for this research.

3.2: User-centric SDI assessment

The first of the four researches is from Hennig & Belgiu (2011): *User-centric SDI: Addressing users requirements in third-generation SDI.* The research focuses on addressing user requirements and the place of these users and their requirements in the SDI development process. A case study has been applied to the EU project Nature-SDIplus. They discuss the evolution of SDIs from product-based models, to process-based models, to current day user-centric models, where usability criteria are used for measuring SDI value. The research discusses a modified approach of SDI models that targets user-centric SDI development, as seen in figure 3.2.1. The user requirements are placed centrally in the model, which determine the nature of the overall SDI. "Thus, for implementing a user-centric SDI, both technological components and the formal framework need to be well-orchestrated and user-centered designed" (Hennig & Belgiu, 2011).

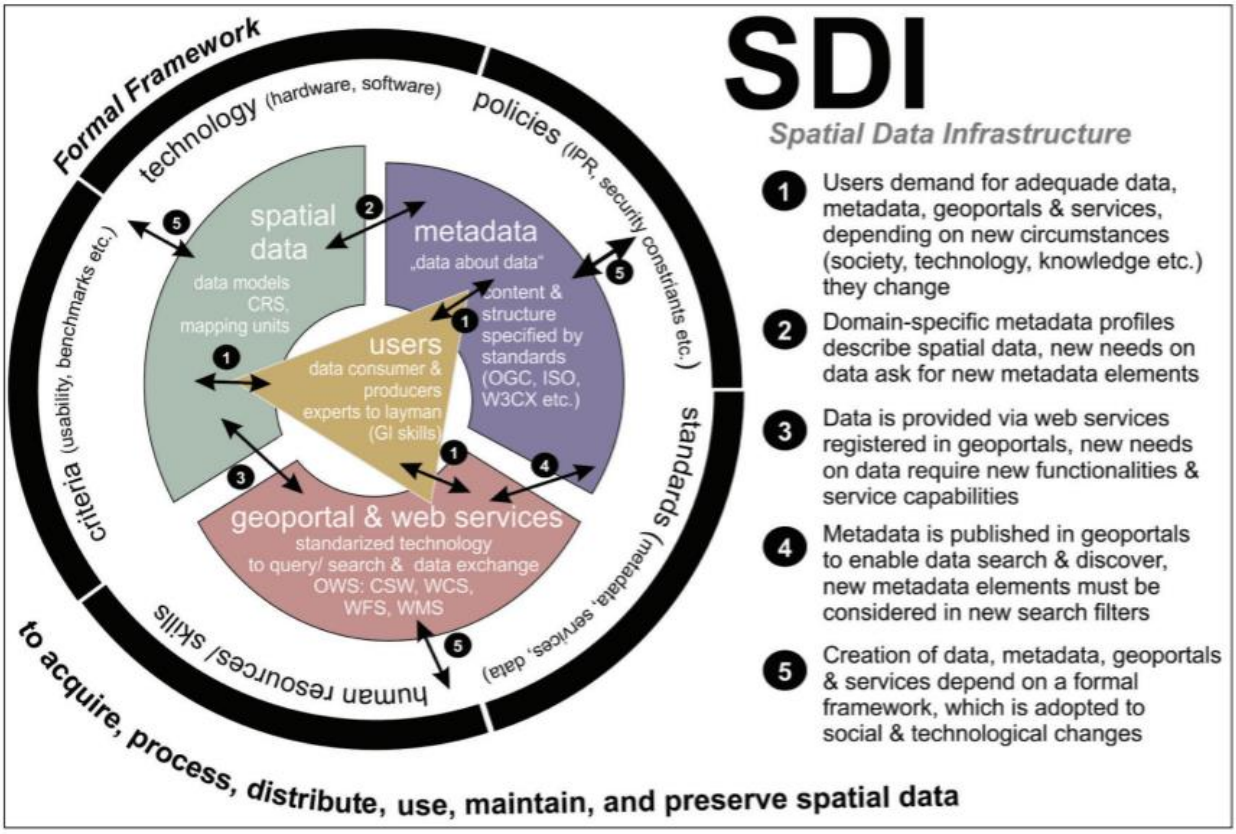

Figure 3.2.1: User-centric SDI development model (Hennig & Belgui, 2011)

Based on this user-centric SDI development model, they discuss the user-centric SDI development process model, which is shown in figure 3.2.2 (also shown in figure 1.5, introduction). The essence of this model is that it shows different development steps that

are guided by a user requirements analysis. These steps are explained as follows (Hennig & Belgiu, 2011):

- Requirements analysis: user survey, interviews, contextual inquiry, target groups, evaluating existing systems, card sorting, scenarios of use, task analysis etc.
- Application design: design guidelines, paper prototyping, heuristic evaluation, parallel design, storyboarding, evaluate prototype, interface design patterns etc.
- Application implementation: style guides, rapid prototyping etc.
- Application validation: diagnostic evaluation, heuristic evaluation, user survey, remote evaluation etc.

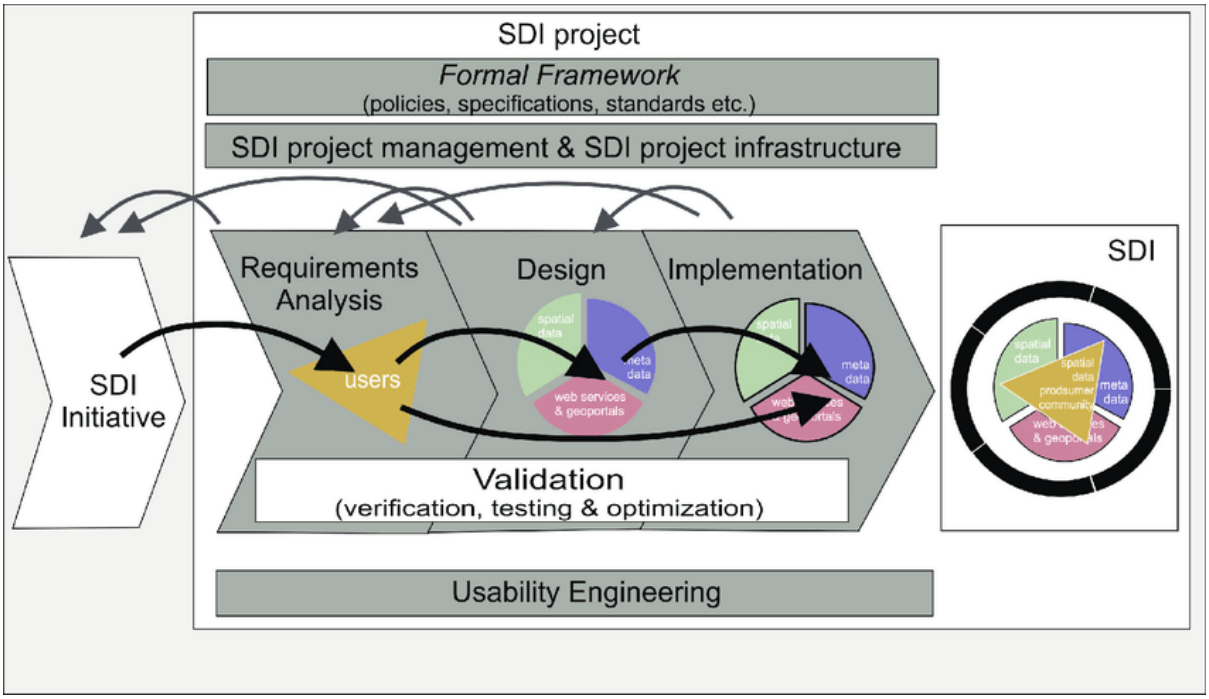

Figure 3.2.2: Schematic (and simplified) user-centric SDI development process model. (Hennig & Belgiu, 2011)

In the case study of Hennig & Belgiu (2011), several methods were used for the user requirements analysis: user survey, interviews, definition of target groups, and task analysis. The user survey was a questionnaire with different sections: the user and the users' company, use and production of the thematic spatial data (with regards to the case study), use of GI software and methods and geoportal use. Besides, interviews have been conducted to which served as information input to describe the context of the case study and to describe the use of spatial data, metadata, GI tool and methods within this context. "Different types of target user groups were distinguished, and user requirements specified" (Hennig & Belgiu, 2011). For analyzing the user requirements, an overview of open recommendations has been created. They conclude from their results that in the specific case study that "...the number of basic and advanced users regarding spatial data handling, GIS and SDI is surprisingly high", thereby stating that "...a user-centric SDI asks for intensive education and capacity building programmes and for simplified approaches following usability criteria" (Hennig & Belgiu, 2011). Finally, they state that the dynamic nature of SDI is still challenging for user-centric SDI development and that

user requirements analyses need to be paralleled by user integration in SDI development (Hennig & Belgiu, 2011). This framework is relevant for this research because it describes how users can be involved in SDI development, and how their needs can be assessed.

The second research is from Welle Donker & Van Loenen (2017). They discussed multiple assessment frameworks for open data ecosystems and found that these only cover parts of the ecosystems. A new multi-dimensional framework has been proposed that builds on these other frameworks. This research is specified for open data ecosystems, but the method proposed builds on the assessment theory and concepts developed in the GI & SDI domain. Since open data ecosystems are very similar to SDIs, the framework can also be used in the context of this research. For their research, they use three output indicators as conditions for a successful open data ecosystem, namely (Welle Donker & Van Loenen, 2017):

1. Data supply: the way in which data are provided as open data;
2. Data governance: the way in which governance aspects are organised;
3. User characteristics: the way in which the user characteristics enable the user to innovate with open data.

The data supply and data governance indicators are subdivided into more detailed indicators. Data supply indicators follow the concentric shell model of Backx (2003), which states that data should be (Welle Donker & Van Loenen, 2017):

1. Known to the user (are the data identifiable and where can data be obtained?)
2. Attainable by the user (can the user obtain the data, and under what conditions?)
3. Usable for the intended purpose of the user (can the user assess the quality of the data)

The model is shown in figure 3.2.3 below. “For a user to be able to reuse data, these three conditions must be satisfied” (Welle Donker & Van Loenen, 2017). Each of these three conditions are further subdivided into indicators.

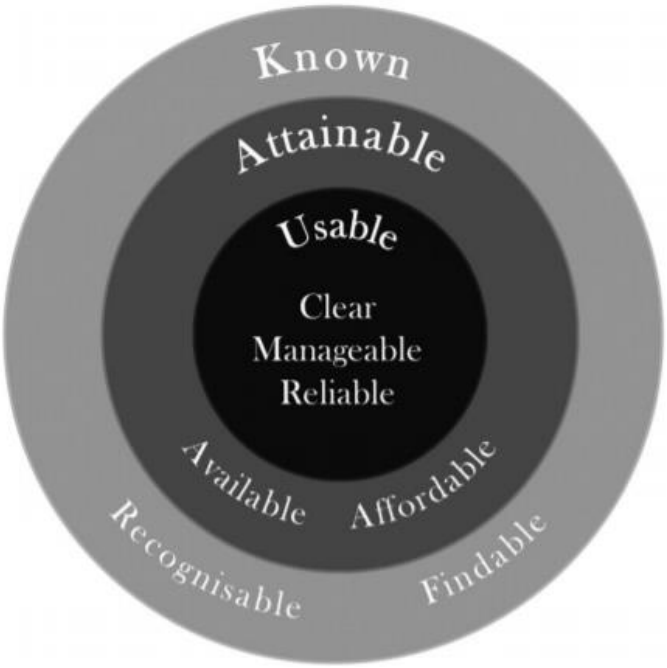

Figure 3.2.3: Concentric shell model (Backx, 2003)

Data governance is also subdivided into several indicators. "Governance of open data not only provides a framework to facilitate the shells of Backx's model but also establishes who will assist the user when he/she stumbles over one of the shells" (Welle Donker & Van Loenen, 2017). The aspects that were used are: vision, leadership, communication, self-organising ability, and sustainable financing.

For each of the data supply indicators, a score on the scale of 1-5 has been given by performing desk research. Scores on the scale of 1-5 (defined stages) have been given to data governance indicators by gathering information from interviews. While Welle Donker & Van Loenen (2017) state that further research is necessary to propose indicators for user characteristics in the context of a holistic assessment framework. No indicators have been proposed for user characteristics as that part of the research was qualitative. However, user characteristics do have an impact on the re-usage of (open) data. They also discuss that the assessment framework needs to be fine-tuned and made more user-friendly. The importance of this framework for the research is the method of assessment, and the use of indicators that are focused on the user-perspective. Chapter 3.3 will go further into the indicators that are taken into account and those that are not taken into account.

The third research is from De Kleijn, Van Manen, Kolen, & Scholten (2014): *Towards a User-centric SDI Framework for Historical and Heritage European Landscape Research.* Although the research is applied to a field not closely related to the field of crisis management, the methods that have been used are nonetheless relevant. The users of the case study in this research have different levels of Geospatial Information literacy (GI-literacy). GI-literacy is defined by Hennig et al. (2013): "knowledge, understanding and expertise to be prepared to use spatial data and associated tools in a competent manner and in an emancipatory way". This definition is also used in the research of De Kleijn et

al. (2014). De Kleijn et al. (2014) state: "...besides the objectives, the requirements for the SDI are also highly dependent on the users´ GI-literacy. We therefore propose to split the users from the objectives and components, and approach them as separate concepts". De Kleijn et al. (2014) distinguish multiple levels of users' objectives, where the levels require more effort as they increase (perception being the lowest level of effort, maintaining the highest). They can be summarized as follows:

- Perception – the knowledge of the nature and characteristics of GI and being able to view and understand it;
- Preparation – the knowledge of capabilities, applications and limitations of GIS, allowing one to know how to make sense and use of GI and to diagnose knowledge and skill gaps;
- Operation – knowing how to use GIS tools and techniques to make the GI meaningful and usable;
- Communication – knowing ways of presenting and communicating solutions spatially to others;
- Maintaining – having knowledge of GI as a dynamic type of data that involves multiple disciplines and various temporal and spatial dimensions for which skills and knowledge need to be constantly updated.

The amount of technological skills of the user affects the amount of effort to be put into each of these objectives. This is shown in figure 3.2.4 below. "Approaching GI-literacy from two angles enables us to clearly identify any gaps between spatial thinking skills and technological skills, which can be solved by implementing or developing the technical components" (De Kleijn et al., 2014).

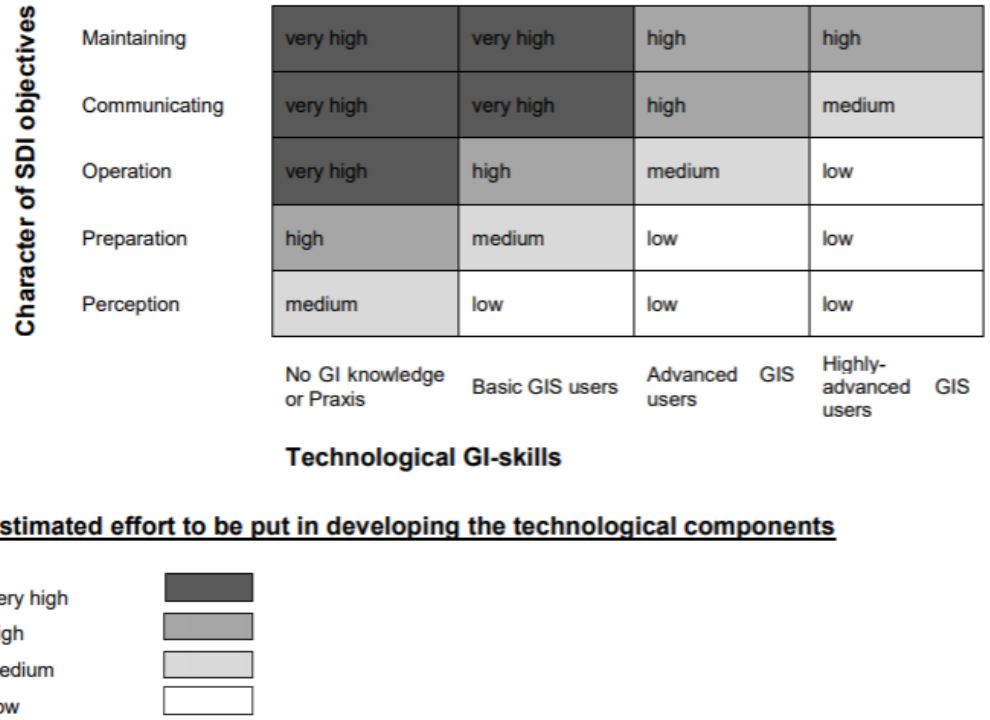

Figure 3.2.4: Overview on the effort to be put into developing tools for different levels of user GI-literacy (De Kleijn et al., 2014)

De Kleijn et al. (2014) discuss that SDI development is both expert-driven / top-down in earlier stages, followed by the iterative process of active user-involvement, which is bottom-up development. They also state that "the developing process needs several iterations in which the users' needs are constantly reviewed" (De Kleijn et al., 2014). The research applies a top-down analysis of the users, with the GI-literacy model applied. A prototype SDI has been proposed to function as a building block for further SDI implementation and development. The importance of this framework, in the light of this research, is in the explanation of the process of user-centric SDI development, and in particular how user characteristics and objectives are taken into account in SDI development.

The fourth research is the paper from Zwirowicz-Rutkowska (2017): *A multi-criteria method for assessment of spatial data infrastructure effectiveness.* This paper makes use of a multi-criteria method to assess the SDI effectiveness from the user perspective, which is applied to the Polish SDI. This framework is focused on the SDI business project view, from a user perspective (Zwirowicz-Rutkowska, 2017). The multi-criteria method is adapted from the multi-view SDI assessment framework, which has been used because it incorporates multiple perspectives and accepts the complexity of SDIs (Zwirowicz-Rutkowska, 2017). In more detail the SDI business project approach has been considered for "measuring SDI effectiveness from the perspective of the users and their organizational performance, as well as the organization undertaking the SDI investment" (Zwirowicz-Rutkowska, 2017). SDI effectiveness refers to the support of the SDI to the users' needs and the performance of the users' duties, as well as to the achievement of business objectives of organizational units utilizing the SDI (Zwirowicz-Rutkowska, 2017).

The methodology in the paper is based on the characteristics of multi-criteria methods, which are (Zwirowicz-Rutkowska, 2017):

1. Pillars, categories or domains of assessment with weighting schemas are identified,
2. Indicators are grouped by each pillar, category or domain,
3. Ranking, weighting or scoring schemas for indicators are assumed,
4. The results of the evaluation process are scores for each indicator, then pillar and also the total score for the project, which is then being interpreted.

Four assessment categories have been used in the research, in which the results have been weighted. The categories are based on SDI effectiveness, which is "manifested by outcomes, benefits (impacts) and business value of using the SDI projects' artifacts (outputs)" (Zwirowicz-Rutkowska, 2017). Each category has multiple indicators, users must give a score on the scale of 0-10 for each indicator. It should be noted that users are also divided in different groups, so different weighing scores could be given to each group, and differences between groups can potentially be discovered. The assessment categories are:

1. Information and support provided; ("the SDI provides some data sources, applications and metadata which can be utilized by users and also supports the users in utilizing the functionality of the SDI")
2. Use process; ("the use of SDI components influence the decision making processes of the users")
3. User organizational performance; ("the use of SDI components influence user organizational performance") and
4. Strategic alignment and business impact on user enterprise ("the SDI might help to achieve users' strategic goals and have an impact on their ability to transform business processes"). (Zwirowicz-Rutkowska, 2017)

Each of the categories have multiple indicators, which were presented to the users as questions in a questionnaire. Zwirowicz-Rutkowska (2017) discusses that the results of this SDI assessment can serve as a basis for improvements of the SDI components and to identify goals for SDI development, which is why this framework is relevant for this research. However, as the view of the framework is on business projects, indicators need to be evaluated in the broader user-centric view (not solely user-centric related to business projects).

3.3: Combined assessment framework

This research combines several elements of these four frameworks to create a user-centric SDI assessment and development framework. This results in a framework for user-centric SDI development, with extra attention to the user requirements, which can be seen as a separate framework within the user-centric SDI development framework. This section describes which elements of the four frameworks have been taken into account and which have not been taken into account. Elements are taken into account when they could be combined with elements of the other frameworks and are also taken into account if they contribute to a feasible method of assessing users' needs. If they seem less feasible for this study, they are not taken into account. Besides, some indicators from the frameworks need to be adjusted to fit in a broader assessment framework. Appendix A shows the table of all indicators and what has been done with them for creating the framework, as well as the statements of the indicators that are included in the end.

Hennig & Belgiu (2011) – taken into account:

- SDI value is measured by usability criteria. This is also done in Welle Donker & Van Loenen (2017) and Zwirowicz-Rutkowska (2017);
- The (conceptual) place of the users in SDI development, which is the starting point according to Hennig & Belgiu (2011);
- Performing a requirements analysis by user surveys and interviews;
- Using the requirements analysis as input for application design (see chapter 3.1). This will be taken into account in the SDI development framework; however, this research does not fully execute this step as it only gives first recommendations based on the interviews, the rest is out of the scope of the research;

- ❖ The structure of the survey, which is structured in the following sections: the user, the user's company, use & production of thematic spatial data, use of GI software and methods, and geoportal use (although this order is not taken into account);
- ❖ The goal of the interviews, which is to describe the context of the case study and describe the use of spatial data, metadata, GI tools and methods in this context;
- ❖ Defining user groups.

Hennig & Belgiu (2011) – **not** taken into account:

- o Application design is taken into account in SDI development, however, the design for other SDI components is outside of the research scope;
- o Idem for application implementation;
- o Later stages of application validation can therefore also not be taken into account in the research.

Welle Donker & Van Loenen (2017) – taken into account:

- ❖ Using indicators / criteria for measuring usability with scores;
- ❖ Data supply indicators, which are grouped as: known, attainable, & usable;
- ❖ Taking user characteristics into account, however, no indicators have been given;
- ❖ Conducting interviews for finetuning the framework, which is not for the requirements analysis, but for creating the framework itself.
- ❖ Data governance indicators, although government to government communication is not taken into account, and open data stimulation is adjusted to stimulation of SDI use.

De Kleijn et al. (2014) – taken into account

- ❖ Users and user objectives are taken as a starting point of the SDI;
- ❖ GI-literacy influences the way that the SDI components are designed around the users;
- ❖ SDI development is bottom-up in later stages, which means that the user drives the development.

De Kleijn et al. (2014) – **not** taken into account

- o It is suggested in the article that the early stages of SDI development need to be top-down. This is not taken into account as the framework only focuses on the user needs for further development of the SDI and not on the early development of the SDI.

Zwirowicz-Rutkowska (2017) – taken into account

- ❖ Using indicators / criteria for measuring usability with scores;
- ❖ Defining user groups;
- ❖ Using a questionnaire for requirements analysis;
- ❖ Most of the used indicators are taken into account, however, some of them are combined to reduce the number of indicators.

Zwirowicz-Rutkowska (2017) – **not** taken into account

- o Some of the indicators are not taken into account, as they are more business-focused and not applicable for crisis management SDI.

First of all, based on the researches of Hennig & Belgiu (2011) and De Kleijn et al. (2014), the user should be the central point of SDI development. The SDI components should be designed around the user requirements analysis, taking the objectives of the users into account. A schematic overview of the SDI development can be seen in figure 3.3.1 below. The requirements analysis will be explained hereafter and is shown in this figure as the starting point of developing SDI components based on the user requirements.

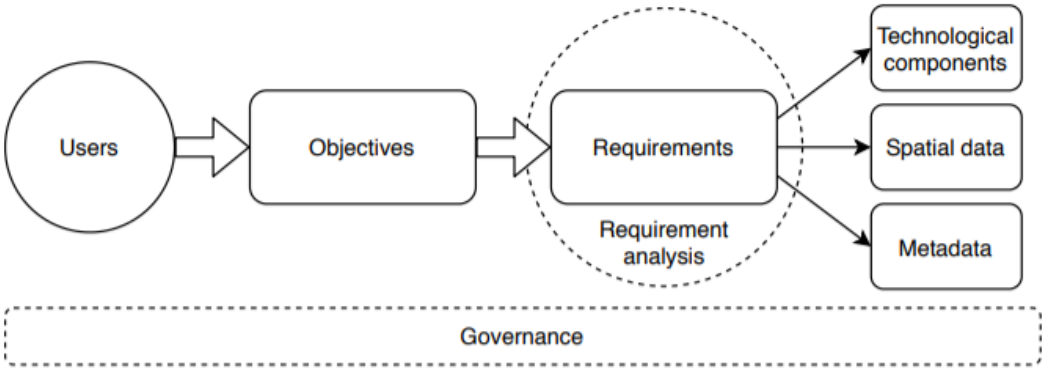

Figure 3.3.1: Proposed SDI development model

The first element that is shown in the SDI development model (figure 3.3.1) is the user. The first step is therefore to identify the users of the SDI. With this step, user groups have to be defined that can be targeted in the requirements analysis. The second step is to clarify the objectives of the users per user group, to place the requirements analysis in context. Based on the requirements analysis, the other components have to be designed in a user-centered way, where technological components, spatial data and metadata of the SDI fulfill the user's requirements. Governance is the component covering the whole SDI, which needs to enable a user-centered SDI design.

For the requirement analysis, a questionnaire is proposed to give insights into the users' requirements, as used in Hennig & Belgiu (2011) and Zwirowicz-Rutkowska (2017). In addition, in-depth interviews can be conducted to give information about the users' objectives, and to give more detailed open recommendations.

It is proposed that users should be grouped based on the type of activity, as used in Zwirowicz-Rutkowska (2017). It is first important to distinguish different user groups because they could have different user requirements, but it is also important to take into account that not every user has the same amount of knowledge about spatial data and SDI. The GI-literacy model of De Kleijn et al. (2014) will therefore also be taken into account, albeit as an element to take into account when designing or evaluating other SDI components. Different levels of GI-literacy may result in different requirements for the design of the SDI components. GI-literacy should therefore be classified in the classes used by De Kleijn et al. (2014): perception, preparation, operation, communicating, and maintaining.

The questions in the questionnaire should be grouped by certain indicator groups as used by Welle Donker & Van Loenen (2017) and Zwirowicz-Rutkowska (2017). The indicators need to be chosen and grouped in the context of the case study, but it is proposed that at

least the indicators for usability are incorporated (from: Welle Donker & Van Loenen, 2017), as well as the indicator group about the provision of information and support (from Zwirowicz-Rutkowska, 2017). In addition, it is proposed that scores are weighted for each group of indicators and each user group, based on the methodology of Zwirowicz-Rutkowska (2017).

The requirements analysis is divided in multiple topics:

- Definition of the user's objectives;
- Definition of the user's GI-literacy, according to the categorization of De Kleijn et al. (2014): perception, preparation, operation, communicating, maintaining;
- Identification of the user's required datasets;
- Data supply indicators, in relation to the required datasets, divided between known, attainable and usable;
- SDI use-related indicators, divided between use process, governance, and organizational impact. This differs from the data supply indicators in a way that it does not apply to the data itself, but the infrastructure around the data to get it, for instance a geoportal.

Figure 3.3.2 shows the proposed user-centric assessment framework, which is based on the description above. This framework is not yet applied to crisis management, which will be done later in this research with the information of the interviews. The indicators are shown in dashed boxes. Appendix A shows how these indicators are created based on the original indicators.

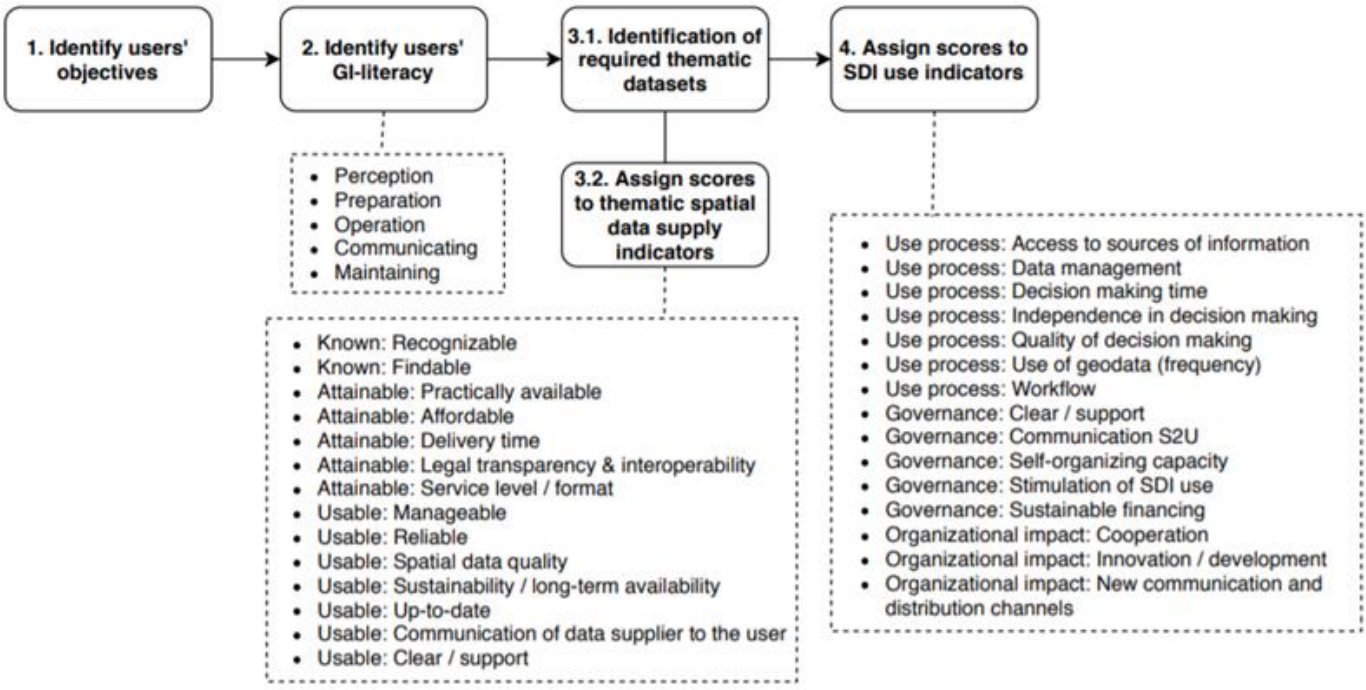

Figure 3.3.2: Proposed user requirements analysis framework.

Chapter 4: Methodology

The previous chapters of this research handled the theoretical background of the research, which is used to answer the first sub questions. The second chapter explained crisis management and its processes, and the relevance of both GI and SDI for crisis management. This information is a useful basis to link SDI practices with the objectives of crisis management and will be used for structuring the interviews. In the third chapter of this research, a user-centric SDI assessment framework has been developed that will be applied to a case study in the following chapters. This methodology chapter will explain how this will be done and how the interviews are structured, to find answers to the remaining sub questions and ultimately the main research question. All interviews are semi-structured, because some structure is required to handle all the elements, but it also gives room to go further on specific answers and/or other topics not included in the interview scheme. The first part of this chapter will explain the case study. The second part, operationalization, explains how the fifth and sixth sub questions will be answered, which are:

5. *What are the current SDI components of an SDI that is used for decision-making in crisis management during large scale natural disasters?*

6. *To what extent can the user-centric SDI assessment framework be applied and finetuned to an SDI that is used for decision-making in crisis management during large scale natural disasters?*

The development and assessment framework of the previous chapter will be finetuned in the context of the case study, which is therefore, so far, not the final framework. The methodology chapter describes how this framework will be finalized in the research, which means that the interview schemes described in this chapter are **not** part of the framework itself.

4.1: Case study overview

The case study of this research is the SDI of the World Food Programme (WFP). The WFP is a subsidiary organization of the United Nations (UN), and is:

> …the leading humanitarian organization saving lives and changing lives, delivering food assistance in emergencies and working with communities to improve nutrition and build resilience … WFP's efforts focus on emergency assistance, relief and rehabilitation, development aid and special operations. (WFP, 2020).

Besides focusing on food security, WFP takes a wide range of other humanitarian responsibilities during all kind of disasters, including natural disasters. WFP is often first on the scene and provides support services for the entire humanitarian community, categorized as (WFP, 2020):

- Procurement of food, relief items, and operational equipment;
- Emergency stockpiling and prepositioning;
- Cargo transportation;
- Telecommunications and IT services;
- Air passenger transport;
- Warehousing and handling;
- Engineering support;
- Medical wellness and accommodation services.

Coordination of humanitarian responses, led by the UN, is done by the cluster approach (Humanitarian Response, n.d.). The Humanitarian Response (n.d.) platform, a service provided by the UN, describes clusters as follows:

> Clusters are groups of humanitarian organizations, both UN and non-UN, in each of the main sectors of humanitarian action, e.g. water, health and logistics. They are designated by the Inter-Agency Standing Committee (IASC) and have clear responsibilities for coordination.

An overview of humanitarian clusters has been shown in figure 4.1.1. It can be seen in the figure that the WFP is present in multiple clusters: food security, logistics, and emergency telecommunications.

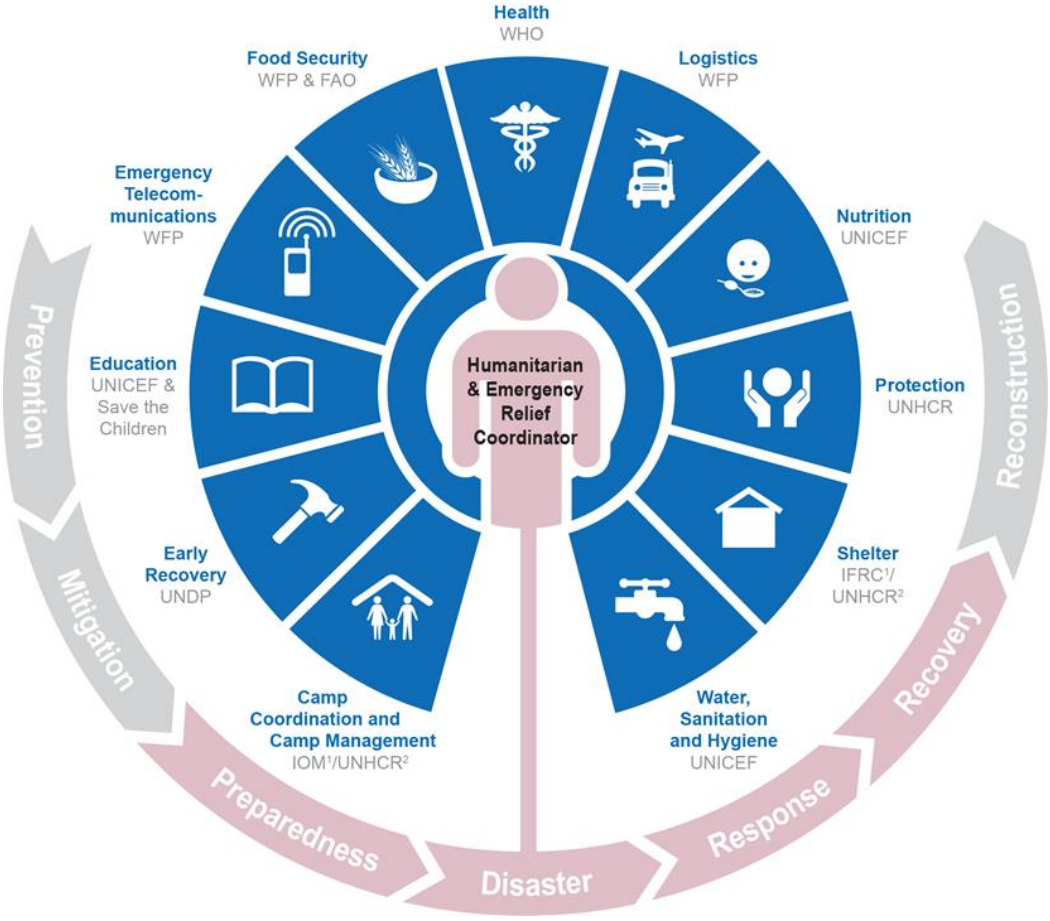

Figure 4.1: Cluster approach. (Humanitarian Response, n.d.)

According to ITHACA (n.d.), "the main aim of the Spatial Data Infrastructure (SDI) project is the development and implementation of a distributed geodatabase solution, to store and efficiently share geospatial data for WFP and other actors in the humanitarian sector." The aim of the SDI is to support all WFP preparedness and response operations by:

- a common data model, shared across all levels of the organization
- synchronization services, supporting information exchange in efficient way
- data analysis tools, to quickly and reliably produce value-added information
- standard symbology rules and automated map templates help in enforcing a brand perception
- and in increasing output quality, timeliness and readability
- conditions for setting up a GIS community (ITHACA, n.d.)

The development in this SDI is supported by the work of the United Nations Spatial Data Infrastructure (UNSDI) initiative, which "…is an institutional and technical mechanism for establishing system coherence for the exchange and applications of geographic data and information for UN activities and related SDI development activities in Member Countries" (UNSDI, n.d.). This initiative has been initiated by the United Nations Geographic Information Working Group (UNGIWG), partially under the leadership of the WFP (UNGIWG, n.d.). Chapter 5 will go deeper into the details of the SDI structure.

4.2: Operationalization

The operationalization is based on the case study of the WFP SDI. The SDI functions within the wider cluster approach, which is the context of the case study related to crisis management. The SDI objectives, the overview of the SDI structure and the involved organizations are taken into account in targeting respondents and structuring the interviews. The fifth sub question goes further into the SDI components of the WFP SDI. The SDI schematic model of Rajabifard & Williamson (2001) will be used to describe the SDI components of the WFP SDI. Mansourian et al. (2004) created a schematic presentation of the SDI conceptual model for disaster response (see figure 2.3.1). This model is based on the standard SDI conceptual model but is further extended and specified for disaster response. This model is therefore useful as a basis for the case study. Each of the components will be discussed in the interviews (appendix B) to create an overview of the structure. In addition, the objectives of the SDI and GI-literacy of the users, as described by De Kleijn et al. (2014), are also topics in the interviews since they have an influence on designing the other SDI components. Special consideration in the interviews is given to how the users should be approached with the assessment. This element returns in all interviews (see appendix B). In addition to the qualitative data, literature will also be used to describe the SDI components. The results will be analyzed, compared, and aggregated to give an answer to the research question. The framework will not be put into practice, this is out of the scope of this research. This research will focus solely on

designing the assessment framework and putting it into the context of the case study and crisis management in general.

The interviewees for this part of the research are people responsible for the development, maintenance, and/or coordination of the WFP SDI. Dimitris Karakostis is a GIS-expert within the WFP and has been involved in development of the WFP SDI at the headquarters in Rome. Francesco Stompanato is also a GIS-expert within WFP and has also been involved with the WFP SDI development. The scheme of the interviews regarding SDI structure can be found in appendix B, which describes both the questions regarding the SDI structure and the assessment framework, targeted at the people responsible for the development, maintenance, and/or coordination of the WFP SDI.

For answering the sixth sub question, applying the SDI assessment framework to the case study and finetune it to fit in this context, the framework created in the third chapter has to be discussed during the interviews. In each of the interviews, the framework guides the topics discussed. Nonetheless, the focus is different for each group of interviewees (see appendix B). In all interviews, it will be discussed how the users' needs can be incorporated in SDI development and how to review to what extent the development supported decision making during crisis management.

In the interviews with SDI scholars, the focus is on the methodology behind the framework itself. The application of the framework to the case study is less of importance, as insight in the case study is required for this. The framework will be discussed in relation to crisis management in general. The goal is to make clear to what extent the framework is applicable for specific cases like the case study at hand, and to what extent it might need to be tweaked (or not) to become useful to support decision-making. It is of less importance to discuss each individual indicator. Ali Mansourian (Associate Professor and Senior Lecturer at Lund University) and Sisi Zlatanova (Professor at The University of New South Wales, Sydney) have been interviewed as SDI experts. Andrea Ajmar (Researcher at the Polytechnic University of Turin) has also been interviewed as an SDI scholar but also for his involvement in the development of the WFP SDI, as a senior researcher at ITHACA.

In the interviews with people responsible for the development, maintenance, and/or coordination of the WFP SDI, the focus is both on the content of and the methodology behind the framework. It is assumed that they have a certain level of knowledge of SDI that is high enough to give insights in how the framework can be applied to the case study, and if adjustments are required. Besides, the indicators will also be discussed. The full transcripts of the interviews can be found in appendices C, D, E, F and G. It should be noted that the indicators of the framework have not been discussed in detail with Karakostis and Stompanato, however, they mentioned that the framework is in general useful (personal communication, April 7, 2020; personal communication, April 9, 2020).

4.3: Overview

The findings from the interviews that discuss the WFP SDI components will be shown in chapter five. The schematic SDI model of Rajabifard & Williamson (2001) is used to describe the components, which includes the identification and grouping of users. The identification of users, including the specification of user groups, will also be given in the fifth chapter.

The results will cover the following:

- The users will be identified in the fifth chapter.
- The overall objectives of different user groups are also clarified in the research, although individual objectives of decision makers are not clarified.
- The requirement analysis framework will be finetuned and finalized in this research.
- The requirements for the other SDI components that come out of the requirement analysis are only partly clarified. The research does not fully perform the analysis in a large user pool, but during the interviews, some requirements may become clear.
- With the limited information of the requirements for the other SDI components, first recommendations could be made for the technological components, spatial data & metadata, and governance. However, these recommendations are based on limited information and it will therefore be required to verify these recommendations when an extensive requirement analysis is performed.

This framework will be finetuned to be of use for improving decision making during crisis management. The application of the finetuned framework is a method for analyzing users' needs and to put them into perspective in SDI development. SDI development relating to the technological components, metadata / spatial data, and governance should, based on this framework, support better decision making as it is based on the users' needs for decision making during crisis management. The final framework includes indications for testing whether SDI development actually supports decision making in crisis management.

Chapter 5: SDI components

This chapter describes the case study of the WFP SDI in detail, identifying the SDI components. The results in this chapter are based on both documentation about the SDI and from information acquired in the interviews, as described in the previous chapter (Chapter 4: Methodology). At first, a detailed background of the WFP SDI will be given. In the second part of this chapter, the technological components, policies, and standards within the SDI will be explained. After that, the available data in the SDI will be discussed, as well as the users of the SDI. Finally, current assessment of the SDI will be discussed. The relevance of these results in relation to the theory and the framework will be discussed throughout the chapter.

5.1: SDI context

As to date, the WFP SDI can be considered as one of the most well-thought SDIs in the humanitarian context (Appendix C). One of the objectives for establishing the WFP SDI was to overcome the real need of efficient data sharing (Appendix E). Data needed to be shared between smaller offices to bigger offices and the headquarters, and the other way around, as Ajmar (Appendix E) states:

> Obviously the request came from the headquarters so it was more related to the fact that they wanted to collect data from the country offices, but then they also realized that it was an important issue also for the country offices to get information from the headquarters, especially during emergencies. So, they really needed to have an updated situation from the headquarters in order to efficiently manage the situation.

Another driver of the WFP SDI development was to unify different units within the WFP organization that use GIS, however, the main focus and main driver came from within the emergency preparedness and response unit (Appendix E). Establishing the WFP SDI was a top-down development, where the initial request came from the headquarters of the WFP (Appendix E). The development included support of the ITHACA (Information Technology for Humanitarian Assistance, Cooperation and Action) organization (Appendix E). Even though the users are seen as the first source of specification (a bottom-up approach), the development comes from a central architecture which is also responsible for capacity building and support (Appendix E).

Stompanato (Appendix D) states that another of the main objectives is to improve the support that GIS can provide to the operations of the WFP, which is mostly done in situational awareness. Using GIS adds spatial intelligence to the operations (Appendix D). Stompanato (Appendix D) gives the following example of the SDI use:

> A typical use case is that there is a cyclone approaching a country, and we are able to identify each warehouse where we have the food, might be on the path of the cyclone, and we need to move the food stock or we need to move staff, so this has been very effective. The SDI has been keen to achieve that.

Also: "When something happens, the GIS officer locally can directly produce a map without struggling with loading data from different sources" (Appendix D). One of the issues with information within the WFP is that they are active in more than 80 countries, with country offices and local offices, who all use geographic information from the headquarter level, but also create information themselves, as well as acquire information from local governments and institutions (Appendix E). Another issue that had to be solved was that there was a lack of human and financial resources for all the GIS related tasks in the country offices of the WFP, while connectivity is sometimes very weak (Appendix D).

5.2: Technological components, policies, and standards

The WFP SDI, including the web applications, the database systems, the maintenance, can be seen as the basis of the whole GIS system, where on top of this basis, maps and analysis is built (Appendix C).

Figure 5.2 shows a conceptual model of the WFP SDI structure. According to the WFP (n.d.), two main systems are in use to store and manage geographic information: "A spatial data infrastructure called SDI, which is based on the ESRI technology, and an open source web platform called GeoNode, which provides easy access to the whole set of GIS data managed by WFP." Each of these systems are synchronized, where the SDI environment is focused on users with access to GIS systems and the GeoNode portal for users with no or little access to GIS systems (WFP, n.d.). The two systems are connected with each other on the database level, as interoperability is important (Appendix C). However, the GeoNode platform is separated in two different modules: a basic user module and an advanced user module.

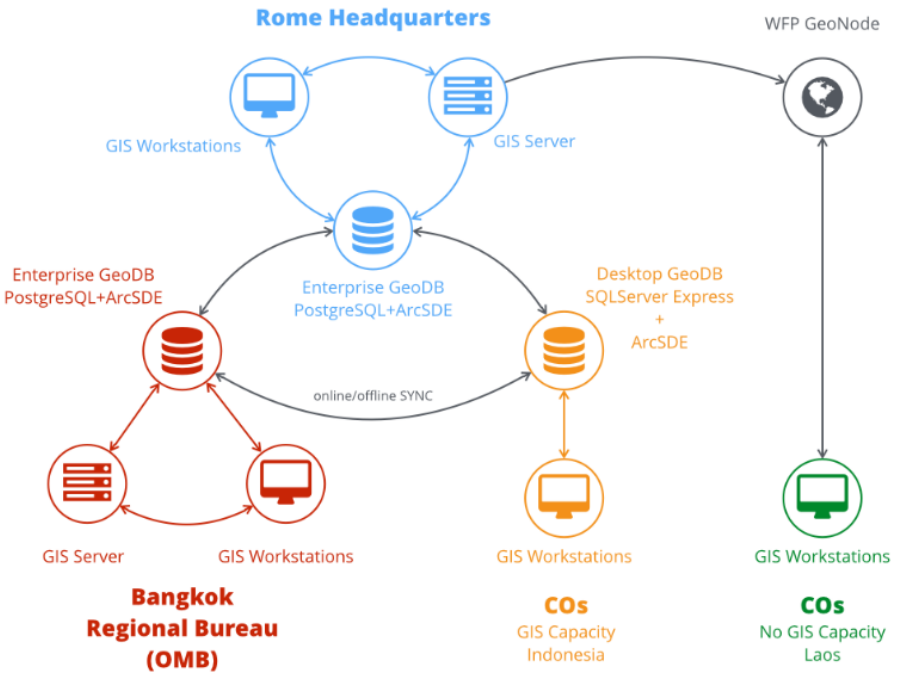

Figure 5.2: WFP SDI structure. (ITHACA, n.d.)

The ESRI part of the SDI is more suitable for users that are not GIS experts, because they can for instance easily create storymaps. However, the flexibility of the GeoNode part is good to have, according to Karakostis (Appendix C). The GeoNode part is an open-source solution which was pushed within the organization, to tackle issues related to licenses and competencies of using complex environments (Appendix E). As more and better ESRI products became available, the organization chose to keep both developments and to connect them (Appendix C). The GeoNode platform is also linked to other platforms within the humanitarian community (outside of the WFP organization), where other platforms take data from the WFP, while the GeoNode platform is also consuming data from other connected platforms (Appendix C), as explained in the next paragraph. The data is also exposed, via GeoNode platform, to web applications, although there are also applications built on top of the ESRI platform (Appendix C). At the moment, the SDI is transitioning to a new setup with a hybrid use of cloud and on-premises services (Appendix D).

With the GeoNode component of the SDI, the WFP is aiming to produce data coupled with updated, standardized metadata (Appendix E). However, Karakostis (Appendix C) mentions that there are users that do not completely fill the required metadata, which is an issue, as the SDI developers had to clean the data in the end. The data is also distributed in the OGC WMS and WFS services, so it could be accessed in applications on the web platform (Appendix C). Within the ESRI platform, the data is mostly standardized, but not all of it, also depending on the user who uploads data (Appendix C). There is a standardized naming convention relating to the name, category and source of the data for sharing it through the SDI (Appendix C).

Related to the governance, Karakostis (Appendix C) mentions that it took lots of effort to reach the level of the SDI that it is today. The management of the WFP organization had to be convinced of the project, however, the SDI is becoming more recognized. Currently,

the WFP finances the SDI project, which means it does not need to rely on the budget of the department of which the SDI project is a part of, but it has a more stable, sustainable funding. Karakostis (Appendix C) states that it is the task of the SDI developers to work for the SDI users, so it can be seen as a support department. However, more information about the policies and governance could not be gathered, which should be done by interviewing people from higher management functions.

In short, the idea behind the SDI implementation was:

> … to enable all these people to create GIS products, and part of this implementation includes buying the server, installing their ArcGIS server, installing all the necessary software, the enterprise database for each country office, and then synchronizing these databases between country offices, the regional bureaus and the headquarters (Appendix C).

The structure consists of 2 main parts, the open-source GeoNode and the ESRI-based system. Applications are made on top of both systems, which should be taken into account in the framework, because it has to be specified what the user uses.

5.3: Data

The data that is incorporated in the SDI can be categorized in a comparable way as in the overview of MapAction (2011), discussed in chapter 2.2.3. First, there are the global reference layers of data that are incorporated in the SDI. A few examples of this data are locations of airports, ports and railway networks, but also the locations of WFP specific locations, such as WFP warehouses and offices (Appendix C). This information is mostly used for creating maps, and the country offices also check whether the data is up-to-date in that region (Appendix C). The global layers also include boundaries, settlements, bridges, border crossing points etc. (Appendix C; Appendix D).

Another type of layers are the road networks, which are incorporated with an automated workflow. The OpenStreetMap database will be acquired twice a day to update the latest information of the road network, because during emergencies, the Humanitarian OpenStreetMap Team will be activated, who update the OpenStreetMap database in areas where a disaster has struck (Appendix C). In this way, VGI is incorporated in the SDI. Also, data that might not be up-to-date will be validated or updated with information from the colleagues in the field (Appendix C). This road network data is very important for logistics mapping, which is one of the operations of WFP during crisis management (Appendix C). What is also incorporated in the SDI is data about borders, which is important in crisis management because it can cause political issues if it is not correct (Appendix C). These borders, where the subdivisions of countries, which is something that the WFP has created with its own team, are being aligned with the official United Nations administrative dataset (Appendix C)

Other data that is included in the SDI is data related to the natural hazards, for instance about earthquakes, tropical cyclones and floods (Appendix C; Appendix D). This data is "…automatically gathered from external sources with python scripts at the headquarters and it is automatically disseminated to all the countries where we have implemented the SDI" (Appendix D). This information is also disseminated through the dashboards built on top of the SDI (Appendix C). The WFP does not create the data about natural hazards but incorporates it from other sources and consumes the data for automated analysis that is visible in the dashboards or other applications (Appendix C). Additionally, the SDI contains data about the places of WFPs activities, and other relevant humanitarian data such as data of refugee camps (Appendix D).

At the moment, there is barely any socio-economic and demographic data available within the SDI, but the SDI is designed to have this information available, as it can be seen that users are uploading some of these layers themselves (Appendix C). However, Karakostis (Appendix C) mentions that categorization of the data will be better in the newer version of the geoportal, so it will be easier to search for data within categories such as socio-economic data and demographics.

On top of the SDI are the applications (which are seen as part of the SDI in this research), such as dashboards and storymaps, that combine layers and information from within and outside of the SDI to create geographic information (Appendix D). Karakostis (Appendix C) mentions that the GeoNode portal, due to its open architecture, acts as an information hub because it is connected to other sources in both directions (it consumes data from other sources, and other platforms consume data from the WFP GeoNode portal).

It is important for the data in the SDI that it is clean, because quality is more important than quantity according to Karakostis (Appendix C). Some users have been uploading their own data to the SDI with incomplete metadata, but they are encouraged not to upload data of their own as the GIS experts maintain most of the datasets in order for it to be clean with complete metadata. The data supply is mostly supplied and maintained centrally from the GIS team.

5.4: Users

This paragraph will explain the users of the WFP SDI, however, there are multiple ways to group users and it will also define on how the SDI is defined. The framework of this research will focus on end-users, but it should be made clear who the users of the SDI are before adjusting the framework. Related to how much the SDI is used, Stompanato (Appendix D) mentions that this will also depend on how the SDI is defined:

> So if we include all the sets of tools that comes with it, not only the geodatabase but also all the tools we built on top of it, there has been a huge increase in use in the past years. The enterprise [ESRI] database technology itself is mostly used now at the WFP HQ, in RBs and in a few countries where we have the biggest GIS capacity.

For the framework of this research, the tools and applications built on top of the SDI will also be taken into account. This means that some users are only using these applications or dashboards, while others consume the raw data within the portal. Stompanato (Appendix D) mentions that the SDI is used daily at the headquarters, but there are also different types of users that can be distinguished (outside of the headquarters):

> There are different types of users. There are direct users, which is mostly the GIS community in the organization, around 100 people. There are the indirect users, which are those that do not have proper GIS expertise, but are able to use data which is in the SDI, because they use ArcGIS online which is much easier to interact with the data. Many layers in ArcGIS online point to our SDI. And then there is the third group of users which are basically the decision makers in the organization, that use the SDI through the applications that we built for them. (Appendix D)

The categorization of users that Karakostis (Appendix C) describes is in line with this categorization. Most of the ca. 50.000 WFP employees do not have any GIS competencies (Appendix C). There are people that are no GIS experts but want to learn, and they learn to use GIS systems to create information for their own needs. The GeoNode system is also designed for simple tasks for non-experts, like uploading layers, visualizing them and making descriptions for them (Appendix C). However, there are also people in the organization without GIS competencies, but who also do not have the time to learn this, so the SDI developers and GIS officers provide services to them, so they do not have to invest time in improving their GIS competencies to get the information that they need out of spatial data (Appendix C). Finally, there are the GIS officers within the organization, that are present in many of the offices around the world, who are being trained for using the latest GIS tools and the latest applications of both platforms of the SDI. These trainings are organized by the people from the headquarters, who go to the other offices for capacity building and raising awareness about GIS and the SDI. During these events, other users with less GIS competences will also be gathered for a simple training. Karakostis (Appendix C) mentions that the trainings in general are separated between training for non-GIS users and for more experienced GIS users.

Besides, Karakostis (Appendix C) suggests not to make a bigger breakdown between the users, categorized in non-GIS expert and GIS-experts, where the non-GIS experts could be logisticians, reporting officers, or people with other types of roles, and the trainings are customized for each of these roles. The SDI development in general is focused on all kind of users (Appendix D)

Not only is the SDI used within the organization, there are also users from outside of the WFP organization that use the SDI, which is mentioned as an advantage of the open-source GeoNode (Appendix C). The use of the data from GeoNode is being tracked by Google Analytics, were downloads of shapefiles are counted (Appendix C). Besides, the ESRI system of within the SDI is also used with external users, however, this is mostly to share visualizations of the data within governments and not for external users to edit any

data (Appendix C). There is no clear overview of all the external users, besides, this is not the aim of the SDI.

5.5: Current SDI assessment

Currently, the assessment of the SDI is not done by formal procedures such as the framework proposed in this research (Appendix C; Appendix D; Appendix E). Mostly, the feedback that is received for SDI development is collected through information communication (Appendix C; Appendix D; Appendix E). Due to good communication network within the organization, it is easy for the SDI users in country offices to contact the SDI developers at the headquarters or regional bureaus to give feedback or request things (Appendix C).

What is going on within the organization related to SDI assessment, is that there are certain workshops where the GIS-experts put effort in capacity building and training for using GIS and the SDI. During these workshops, questionnaires were handed out asking about the training and what users find important (for example whether they find data collection more important, or how to analyze data). In this way, users are incorporated in SDI development. On the infrastructure itself the users have less influence, but it is mostly on the products built on top of the SDI where users have a lot of saying. The basis is laid by organizing the data and making sure it is catalogued, then the products on top are built with feedback of the users (Appendix C).

By means of this capacity building, the GIS-experts try to raise the spatial awareness of the users, so users start to see the potential and can give more feedback and questions to the experts (Appendix C). For the SDI developers, besides building the SDI, the objective is "…building capacity for using the infrastructure, and to foster the partnerships and strike collaborations inside of the organization but also inter-agency" (Appendix C). Karakostis (Appendix C) also mentioned that capacity building can also lead to more feedback for SDI development.

Another form of feedback for the SDI project is a review that happens once every 3 years, focusing on SDI use of the ESRI part of the SDI. However, there is no survey or formal check with the end-users, decision makers. Currently, this is estimated by the number of requests for the thousands of maps produced and hundreds of applications built (Appendix D).

One of the main issues with SDI assessment in crisis management is that many users are not aware about the importance of SDI, the focus is more on other products (built on top of the SDI) that have more visibility for end-users, and they do often not know what an SDI is (Appendix D). This will result in less useful feedback for the SDI itself and that is why there is little feedback and literature about SDI assessment (Appendix D). The lack GI-literacy can for instance also mean that users do not understand the importance of metadata (Appendix C). Normally, the users with more GIS competences can provide more

and better feedback about the SDI and GIS related things in general, where the expert users can also put the feedback into the organizational context (Appendix D). To approach the users, Stompanato (Appendix D) suggests:

> …instead of putting the emphasis on the technology itself, I would ask the end-users how GIS, how geographic information, how locations, are helping them performing their job better. And all the answers we will get, in my opinion will automatically reflect on the SDI. Then it depends a lot on the audience you target. If you target end-users, decision makers, that is the way to phrase the question. So if you then ask the same questions to people like me, people that have much more technical background, you can go more in depth and have more precise questions.

Another problem with the assessment is that it takes time and effort for users to participate and to be involved in the process, which is something that not all users have (Appendix C; Appendix D; Appendix E). To get users involved in the assessment, Stompanato (Appendix D) says that "…the user needs analysis must be a part of the broader GIS strategy of the organization, which goes through constant review of the projects, according to the results of the user needs analysis." Capacity building and improving spatial data management within the organization are challenges for the organization to bring GIS use to a more professional level (Appendix D). The SDI assessment framework therefore needs to be placed in the context of this strategy. It should also be noted that "the SDI is not developed to make profits, it is developed for efficiency within the organization. There will be more interest to test the internal efficiency than to include users from outside the organization" (Appendix E).

5.6 Overview

The figure (5.6) below shows the overview of the SDI structure with relevant points for the proposed framework. The information is derived from the interviews and described earlier in this chapter. SDI users that are not from the WFP but use certain platforms of the SDI are not taken into account, as the development of the SDI focuses on internal use and efficiency (Appendix E). This schematic overview can be used for user-centric SDI development as it can put the answers of the assessment framework into context for further development.

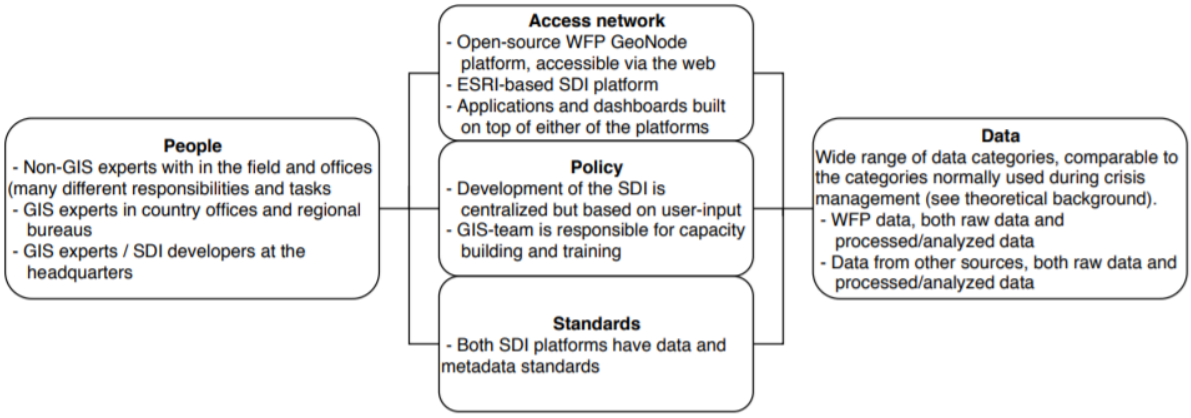

Figure 5.6: schematic SDI overview of the WFP SDI with relevant findings for the assessment framework

Chapter 6: Framework completion

This chapter will discuss the information from the interviews that is related to the proposed SDI assessment framework. First, general comments about the framework and SDI for crisis management will be explained. After that, each individual indicator of the proposed framework will be discussed, to make clear what has to be finetuned to be applicable for the WFP SDI. Finally, the updated framework will be proposed and placed in the context of the theory that has been discussed earlier in the research.

6.1: General remarks

The proposed framework is based on the field of SDI in general and not specified to crisis management. From the literature discussed in this research, it became clear that crisis management is a specific field which makes the SDI use different than the more conventional SDI field. First of all, the role of time is very important in crisis management (Appendix E; Appendix F), and an SDI used in crisis management should also be able to present real time or near-real time data and information (Appendix C; Appendix D). Also, data has to be produced in a short period of time, during the disaster response phase (Appendix F). The factor of time and having up to date data quickly available is very important, and in some cases more important than the quality of data, which means that users might sacrifice some quality in return for timeliness (Appendix E). During the disaster response phase, a huge amount of data is needed quickly and needs to be quickly shared and integrated with other data for analysis. This makes SDI for crisis management different than conventional SDIs, where this level of time constraint is not present (Appendix F). According to Mansourian (2020), "…this time [constraint] influences many other things, including for example communication networks that you need to actually communicate the data and share the data immediately with emergency operation centers and planners."

In the context of crisis management, SDIs have the focus more on general needs for planning and decision-making, rather than a specific application (Appendix F). The goal of such SDIs is to inform communities and disaster managers. (Appendix G). This is where GI-literacy, as described in the theory, plays a role. Within a crisis management SDI, there is a variety of users with different levels of GI-literacy (Appendix C; Appendix D; Appendix E; Appendix F; Appendix G). This has an influence on what is important for them, as Zlatanova (Appendix G) gives the example of that the interface and how the product looks is more important to them. Ajmar (Appendix E) states that for this variety of users, "…we have to provide different levels of products. An efficient system, the SDI in this case, should be able to provide both basic data and final products."
Related to the users, there are other types of users present in a crisis management SDI as opposed to conventional SDIs. There are also users that are already active, but they are facing different tasks when a disaster strikes, as explained by Mansourian (2020):

> If you look at the structure of disaster management, there are governmental organizations who are doing their normal work during daily activities, and then in emergency management. They become activated to work quicker and harder to manage the disaster. A large part of the stakeholders who are involved in disaster management are those organizations who are doing normal work during daily days. So we have the same users in disaster management as in daily activities on normal days. And also on top of these governmental organizations, you will have NGO's, such as Red Cross, which will become activated, or some group of people, citizens, who become activated to give health support to disaster responses. (Appendix F)

This means that the people already active in the region face different tasks, and with that different needs for data. Besides, more coordination is required because of the time constraint of crises (Appendix F).

The role of people and VGI for the SDI is also higher during a disaster response (Appendix F). It is very useful information if people can update dynamic data in a crisis situation, however, this creates a need for a new conceptual model for SDI for disaster management in which technical solutions should be solved to incorporate this information (Appendix F). Besides, there are other technical challenges present specifically for crisis management SDI. Low internet connectivity has been stated as a challenge (Appendix C; Appendix E). This hampers SDI functionality and the functionality of applications within the SDI (Appendix C). So parallel to web applications, ready to print products are still made (Appendix E). Also, the regulations and policies on data use are different during disasters, as the time pressure requires data to be shared quickly and not being hold up by rules or policies (Appendix F). Furthermore, an SDI used for crisis management should be flexible and expandable, as every crisis is different (Appendix C).

There are also some points specific for crisis management and the case study that need to be taken into account related to user-centric SDI assessment. While all respondents agreed that a framework such as the proposed framework could be useful for SDI assessment (Appendix C; Appendix D; Appendix E; Appendix F; Appendix G), the indicators have to be chosen and defined carefully (Appendix F; Appendix G). The proposed framework did not take into account that there could be confusion about certain indicators, and unclarity on what the indicator refers to. It should therefore be defined in the assessment (during interviews with the users) what will be assessed, for instance whether the non-data related indicators are being assessed for an application, or for the GeoNode geoportal.

One of the main discussion points on the framework was that the questions should not be closed (Appendix E; Appendix F). Users should be able to explain why they give a certain score (Appendix E). Besides, valuable information can be extracted from users if you give them more room to talk about the context of their work regarding the SDI, which cannot be done by asking questions in a questionnaire. With this context, the problems regarding the SDI usability can be discussed in detail with the user if you approach them with an interview instead of a questionnaire. This information is more useful for further SDI development (Appendix F). Mansourian (Appendix F) also suggest to interview people

from all levels to get many different experiences. It is therefore proposed to change the context of the framework. Previously it has been proposed to be mainly focused on questionnaires, but to get valuable information for further development, thus potentially for better decision-making, interviews are preferred to be conducted. This could potentially also fit in the informal communication within the WFP that Karakostis (Appendix C) and Stompanato (Appendix D) mention.

GIS competencies / GI-literacy has been named as an important factor for both SDI use and SDI assessment (within the context of crisis management), so this should be taken into account in the framework (Appendix C; Appendix D; Appendix E; Appendix F; Appendix G). This has also been proposed in the assessment framework, however, respondents stated that users can be classified differently than proposed in the framework, as the respondents propose to group users in experts and non-experts (Appendix C; Appendix D; Appendix F). Not all included questions should be asked to people with less GIS competencies, because some of the questions could not be understood (Appendix D; Appendix E; Appendix F; Appendix G). It is also confirmed (as proposed in the framework) that you should check the competencies of the user first, in order to skip less important parts of the assessment and emphasize other more important parts (Appendix E). Besides, classifying the users also needs to be done first for understanding their needs for data, because different users "…need different types of data. The type of the data that they need actually differs in different disasters. The needs have to be assessed case by case, based on different disasters. And also based on the role that an organization plays in that disaster." (Appendix F) According to Stompanato (Appendix D), you should first ask what components of the SDI the users use before going into detail with the questions, which is in line with the proposed framework.

What should be added to the context of the framework is that a feedback loop is required for SDI development (Appendix F). An SDI is dynamic and communication and feedback is required to develop the SDI further (Appendix F). However, SDI users are often too busy with their tasks to get closely involved in the SDI assessment (Appendix C), which has to be taken into account in creating a certain feedback loop. Stompanato (Appendix D) also describes the context of the user needs analysis as part of the SDI assessment:

> "…the user needs analysis must be a part of the broader GIS strategy of the organization. Which goes through constant review of the projects, according to the results of the user needs analysis." (Appendix D)

This means that the assessment must be placed in the context of the strategy and the development. In the end, "without the contribution of the end-users, what is needed in the SDI, you may end up with some kind of SDI that nobody uses or understands. So indeed it should be tested with the users, and after that improved." (Appendix G)

6.2: Indicators

This section discusses the individual indicators and what to do with them to be usable for the case study. The previous section discussed the general comments on the framework, which is translated to actions in tables 6.2.1 and 6.2.2. Table 6.2.1 discusses the indicators related to the data that is available within the SDI. As discussed in the proposal of the framework (3.3.2), this should be specified to the data that the users need and use. The data is also available through applications, dashboards and/or tools built on top of the SDI, so these indicators can also refer to these when the user uses and requires these (Appendix G). As mentioned in chapter 5.5, users have an impact on the development of these applications, so the SDI-specific indicators are also applicable for applications (and therefore not only SDI-specific anymore). Besides, because of its importance within crisis management, extra attention should be given to dynamic data / VGI during the interviews (Appendix G). Apart from the indicators that remain or are altered, three indicators are added: metadata completeness, metadata quality and the usefulness of the standards. The metadata-related indicators replace some of the indicators as they were all related to metadata (see table 6.2.1 below). The usefulness of the standards is added because if the users know the data and its standards, it would be easier to use (Appendix G). The theoretical background also discussed that data standards are important for improved data sharing (Payne et al., 2012). The overview of these indicators is shown in the table below.

Table 6.2.1: overview of required actions related to the data-specific assessment indicators

Category	Indicator	Action
Known	The dataset is recognizable	Keep (Appendix E; Appendix F; Appendix G)
Known	The dataset is findable	Keep (Appendix E; Appendix F; Appendix G)
Attainable	The dataset is practically available	Keep (Appendix E) but combine it with / include it in the indicator of 'service level / format' (Appendix F), and also relate this indicator to interfaces (Appendix G).
Attainable	The dataset is affordable	Remove because it is not relevant for WFP SDI, as the WFP SDI does not price the data for users (Appendix E). It is a relevant indicator (Appendix F), but only if it is applicable for the SDI situation (Appendix G)
Attainable	The dataset can be acquired in time	Keep (Appendix E; Appendix F; Appendix G)
Attainable	The dataset does not have any legal restrictions (and there is transparency about legal restrictions)	Remove because it depends on the SDI structure (Appendix G). It is relevant (Appendix F), but not applicable for the SDI of WFP.
Attainable	The dataset is distributed in a sufficient format or service	Keep (Appendix E; Appendix G) but combine it with practical availability (Appendix F). Include that it depends on the user what 'sufficient' means for the format or service (Appendix E; Appendix F).
Usable	The dataset is manageable	Replace with indicators for metadata because it is related to the metadata (Appendix E; Appendix F). Besides, it can be interpreted in multiple ways (Appendix G). Manageability derives from complete, high-quality metadata.
Usable	The dataset is reliable	Replace with indicators for metadata, because it is related to metadata (Appendix E; Appendix F; Appendix

		G). Reliability can be checked by complete, high-quality metadata.
Usable	The dataset has sufficient spatial data quality	Keep (Appendix F; Appendix G), but it should be included that it is dependent on the user and situation, because delivery time is mostly more important than data quality (Appendix E)
Usable	The dataset has long-term availability / is sustainable	Keep (Appendix E; Appendix G), but it might depend on the type of dataset (Appendix F).
Usable	The dataset is up-to-date	Keep (Appendix E; Appendix G), but also define what up-to-date means for the user (Appendix F)
Usable	There is sufficient communication from the data supplier to the data user	Remove, because it depends on the SDI structure (Appendix F; Appendix G) and it is not applicable for the WFP SDI (see chapter 5)
Usable	The metadata and support are clear	Replace with indicators related to metadata, because it is metadata related (Appendix E; Appendix F; Appendix G). Metadata should be complete and of sufficient quality so support is not required.

Table 6.2.2 shows the actions related to the SDI-specific assessment indicators. One of the remarks for these indicators is that it needs to be specific for each component of the to get useful answers for SDI development (Appendix F). Therefore, these indicators should also be used when the user uses certain products like dashboards within the SDI (without using the rest of the SDI, or the 'basic structure'). Beforehand it should be specified with the user which component is discussed, or whether there are multiple components to be discussed if the user uses more than one within the total WFP SDI. An overview of all actions for the indicators is shown in the table below.

Table 6.2.2: overview of required actions related to the SDI-specific assessment indicators

Category	Indicator	Action
Use process	The SDI increases access to sources of information	Remove, because it is probably always true (Appendix E; Appendix F; Appendix G)
Use process	The SDI improves data management	Remove, because it is probably always true (Appendix E; Appendix G). Replace it with an indicator specified to each component of the SDI (Appendix F)
Use process	The SDI shortens decision-making time	Keep (Appendix E) but take into account that there is only a with and without (SDI) comparison with experienced users (Appendix G).
Use process	The SDI creates independence in decision making	Keep (Appendix G), but this is related to competencies of users (Appendix E).
Use process	The SDI improves the quality of decision making	Remove, because this will be true (Appendix G; Appendix E)
Use process	The SDI increases the use of spatial data	Remove, because this will be true (Appendix E). Besides, it implies that more spatial data is good while too much data is also something to take into account (Appendix G)
Use process	The SDI improves the workflow	Only include it for people with more experience, also without using this SDI, to make it measurable by a comparison. (Appendix G)
Governance	The communication and support regarding the SDI use are sufficient/clear	Keep the indicator, but it is also related to capacity building (Appendix G; Appendix E).
Governance	The SDI stimulates and supports communication from	Due to the structure of the SDI it is not applicable for the WFP SDI.

	the data supplier to the data user	
Governance	The SDI organization stimulates SDI use	Indicator is related to capacity building (Appendix G; Appendix E; Appendix F), rename the indicator as such.
Governance	There is guaranteed (long-term) financing for the SDI	Remove, although it is important (Appendix E), users are not able to answer this
Governance	There is a shared vision about the SDI on all levels of the organization	Remove, although it is important (Appendix E), users are not able to answer this
Organizational impact	The SDI increases cooperation in the organization	Keep indicator (Appendix E; Appendix G), but also apply it to external cooperation (Appendix E)
Organizational impact	The SDI stimulates innovation and development	Keep indicator (Appendix E; Appendix G), but this will mostly be applicable only for users with GIS-knowledge (Appendix G)
Organizational impact	The SDI presents new communication and distribution channels for the organization	Keep indicator (Appendix G), although it is difficult to say what can be done with it for SDI development (Appendix E)

6.3: Finetuned framework

Based on the comments on the indicators and the framework as a whole, a finetuned framework is created to be more applicable to the case study of the WFP SDI. The finetuning is based on the comments that have been gathered in the interviews, and other information from literature that has been described in chapter 5. The framework needs to be placed in the context of SDI development.

First, as mentioned earlier, assessing the SDI needs to be part of the broader strategy of the organization. It is important to fit the framework into this strategy, however, this research does not go further into the overall strategy of the WFP regarding GIS and the SDI. What should be included within the strategy however is that it should include a feedback loop, in which the outcomes of the assessment are validated later. The assessment should also take the objectives of the user into account, as proposed in the framework. As mentioned in chapter 5.5, once every 3 years there is a feedback moment of the SDI, this could be an opportunity to apply this framework as part of that feedback moment.

As discussed in the previous chapter, the breakdown of user categories should be limited to GIS experts and non-GIS experts. When the indicators are discussed with the non-GIS experts, the interviewer should carefully choose words to describe the indicators, to make it clear what is discussed. Not all terms that are common in the GIS community will be understandable for non-GIS experts, however, this will depend on the knowledge of the user about this topic. It might also be that some indicators should be skipped as the users might not give a useful answer because it could be misunderstood due to the lack of GIS knowledge. When talking to GIS experts, this problem does not have to be taken into account. As already proposed in the framework, the GI-literacy should be taken into

account before discussing the indicators. The overview of final indicators is shown in figure 6.3, which is based on tables 6.2.1 and 6.2.2.

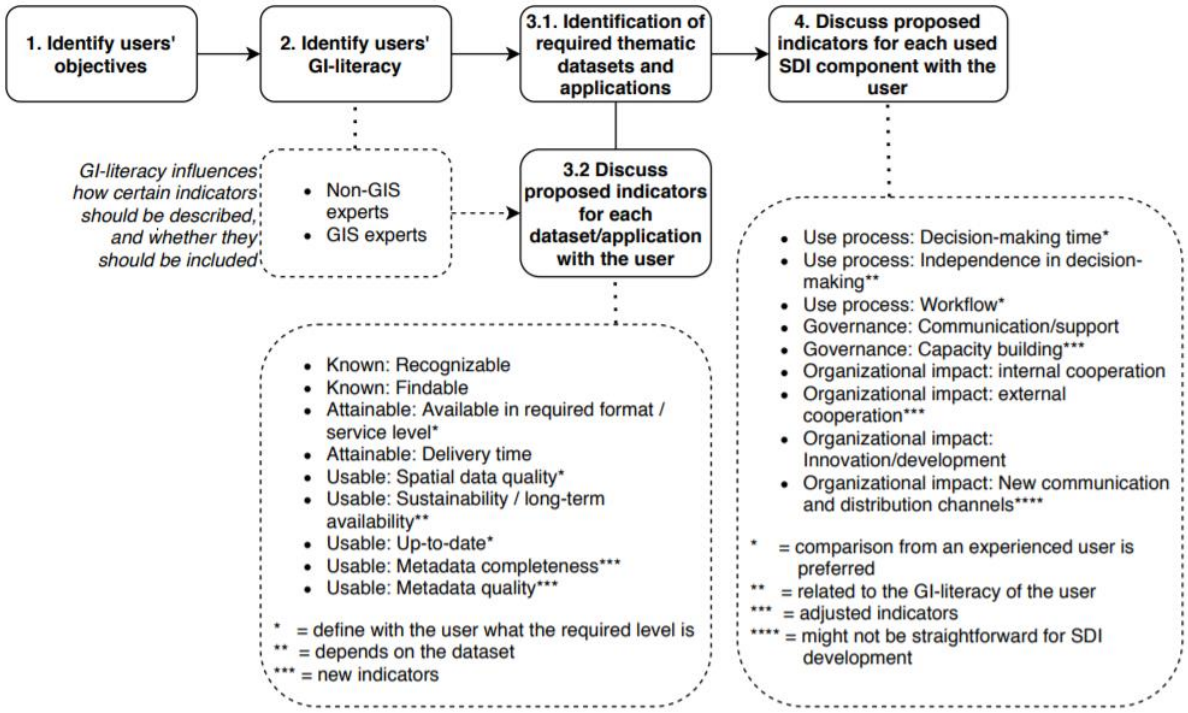

Figure 6.3: indicators of the finetuned SDI assessment framework

There are some points that should be taken into account when assessing an SDI, in this case the WFP SDI, in the context of crisis management. It has been discussed in the theoretical background that it is important for crisis managers that information is delivered exactly in time (not too late but also not too early, as it might be neglected), but it should also not lead to an overload of information (Janssen et al., 2010). The key is to share the information effectively, which is what should be emphasized in the interviews. Therefore, when assessing the objectives of the user, the disaster information cycle should be taken into account (discussed in the theoretical background):

1. Acquiring information;
2. Assessment or evaluation;
3. Decision making; and
4. Dissemination of information and decisions. (Carter, 2008)

This cycle could also be taken into account when developing the SDI further on the basis of user needs. The objectives and tasks of the users can be related to the different kinds of actions that are taken in the response and recovery phases of disaster management, which have been discussed in the theoretical background. An SDI user may for example be active in the field of providing emergency food, which is one of the disaster response tasks described by Carter (2008). During assessment and development of the SDI, it can for instance be checked whether the SDI is useful for this field.

As discussed in the theoretical background, an SDI provides communication and collaboration during crisis management, where the information should be available at all levels (Snoeren et al., 2007; Manfré et al., 2012) The WFP SDI and other SDIs used in crisis management should take this goal into account. The WFP SDI does provide information at all levels, as discussed in the case study description.

What has been shown in literature is that disaster management is very complex (Janssen et al., 2010; Asghar et al., 2006; Kapucu & Garayev, 2011; Salvadó et al., 2015). This complexity makes it even more necessary that a feedback loop is required for the framework, as the user requirements are very dynamic in this dynamic environment. This means that the assessment should be periodically done to make sure the development will be reviewed by users. Janssen et al. (2010) mentioned that disaster management often fails to cope with this complexity, so extra attention should be given to the context of the user needs analysis. What has been stated by Kapucu & Garayev (2011) has been confirmed by all respondents in this research: time pressure has a significant impact in decision making during crisis management. The SDI should therefore provide information for rapid and effective decision making, which need to be emphasized in both the assessment and the development of the SDI.

From an SDI development perspective, less attention should be required to the technical side of SDI, as there are already technical solutions available which are working (Appendix F; Appendix G). The focus should be more on the non-technical issues as these are not always solved, such as the organizational infrastructure (Appendix F).

Finally, Karakostis (Appendix C) states that SDI development is all about the preparedness. This can also be related to the *coping capacity*, one of the factors influencing the severity of a disaster, where a higher coping capacity results in less losses and damages (see chapter 2.1.1). It is "the ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters" (UNISDR, 2009). As the proposed framework might be used for assessing crisis management SDI, it will contribute to better preparedness and coping capacity. As already mentioned in the theoretical background, preparation of basic information layers needs to be prioritized for effective crisis management (Bajracharya, 2015).

Chapter 7: Discussion & conclusion

7.1: Discussion

As there is little literature about the topic of this research, it is mostly an exploratory and theoretical research, and does therefore not include hard conclusions. Literature mainly explains geographic information used for crisis management, with no reference to an SDI or whatsoever. Only a small number of researches explain the link between SDI and crisis management, but none with regard to SDI assessment. However, during the interviews, Mansourian (Appendix F) and Zlatanova (Appendix G) mentioned that the term SDI is somewhat outdated and sometimes replaced by other terms. Zlatanova (Appendix G) gives the example of dashboards, which can be part of the SDI, but with the focus on the front-end. The technical back-end, which is in fact the SDI, is less commonly mentioned. These other terms have not been taken into account in the research as it is merely focusing on SDIs, interfaces built on top of the SDI are seen as part of the SDI. The links between these other terms and crisis management have therefore not been made but remain open for further research. User-centric assessment in the context of crisis management could for instance also be applied to the example of dashboards.

Not only is it difficult to make conclusions due to the lack of scientific literature, but also due to the complexity of the field of crisis management. An overview of the processes and phases in crisis management has been given in the theoretical background, and the most important points are that crisis management is complex due to the amount of (different) actors, the variety of actions that are taken, and the fact that each disaster is different. Besides, this field is also highly dynamic, resulting in even more complexity. Drawing hard conclusions that can be generalized to the wider topic should therefore be avoided. This research might provide useful information for further research, but SDI specific information (in this case specifically the WFP SDI) cannot be copied to other cases (for example: other SDIs in crisis management) because extra attention should be given to the complexity of the field. However, the provided framework does not differentiate between different types of disasters. Nevertheless, each disaster is different and the outcomes of the assessment will therefore not be the same, so when applied, results could not be compared.

This research did not include testing and/or applying the framework, it is outside of the scope because this should be seen as a sequel on this research. The amount of work that needs to be done to apply and test the framework is expected to be enough for it to be a research of its own. Therefore, application and validation of the results remain open for further research and/or SDI developers to do.

Another shortcoming of this research is that it only focused on the disaster management phases that are after a disaster struck. As explained in the theoretical background, the generally used model for disaster management consists of 4 phases. The phases before the disaster, mitigation and preparation, have been left out of the scope of this research.

Further research could also include these phases to give a view of the whole disaster management cycle.

The focus of this research is on the view of the crisis manager, however, there are also other users than only the end-users that need a usable SDI, their needs should also be taken into account. Zlatanova (Appendix G) mentioned data custodians which also play a role in SDI for crisis management. As they create products or interfaces for end-users, they have an influence on the overall usability of the SDI from the view of these end-users. This research did not take their needs for the SDI, nor for other types of users other than end-users, into account.

For this study to be feasible, only one case study has been analyzed. For further research, another case study within the field of crisis management could be analyzed to see whether the results are comparable or different. Besides, the case study of the WFP is part of the cluster approach of the UN, as discussed in chapter 2.1.3. There is no guarantee that this approach is the best approach, nor that it benefits the decision makers. SDI use may be different within another approach, but this should be studied in further research.

Further research could also continue with the user-centric SDI assessment framework that has been created in this research, based on combining several frameworks. As this framework, as proposed in chapter 3, was not yet discussed in the light of crisis management, it could be applied to other fields of SDI where a user-centric assessment is required. This research does not test whether this framework is universally applicable, but this could be analyzed in further research.

This assessment framework focused mainly on the SDI as a source for taking data and information, however, in further research, it should also be taken into account that the SDI can also be used the other way around, where it provides an infrastructure for supplying data and information. This 2-way SDI functionality should be included in further research, where it might be added to the indicators.

7.2: Conclusion

This explorative research tried to clarify the role of an SDI in the context of humanitarian crisis management after large-scale natural disasters. The literature of crisis management and SDI assessment has been combined and together with interviews, an answer has been found for the following research question:

To what extent can a user-centric SDI assessment framework support decision-making in crisis management during large-scale natural disasters?

It can be concluded that the user-centric SDI assessment frameworks reviewed in this research, which have been combined into a single framework, is to some extent relevant for the case study of the WFP SDI, but it needed to be finetuned to be more applicable and

useful for SDI development. The most important changes are that interviews are preferred for the assessment, and that the importance of indicators depends on what the user uses and needs. Besides, indicators that were not relevant for the case study, such as data affordability and supplier to user communication, were deleted, while other indicators have been replaced by another definition to give more clarity, such as data manageability and reliability, which could both be derived from metadata. It has been stated by the respondents that such a framework could be useful for SDI development, also in the case of an SDI used for crisis management during large-scale natural disasters. As the framework remains to be tested, it cannot yet be concluded that it is true whether it supports decision-making in crisis management through user-centric SDI assessment. Besides, due to the dynamic and complex nature of crisis management, it is difficult to get a clear view of the users' needs related to the SDI. This complexity resulted in an assessment framework that is more focused on qualitative information rather than quantitative information, otherwise the results will not be as meaningful for further SDI development. This research can be used as a basis for further research and development where the proposed framework can be put into practice and be reviewed for its usability.

It is recommended for future research that more case studies will be analyzed, and as stated in the discussion, that the framework need to be put into practice. In this way the usefulness of the assessment framework can be tested and it can give input for further finetuning of the framework.

To apply this framework in a real situation, it is recommended to fully understand the contexts of both crisis management and SDIs so the results of the interviews can be useful for further SDI development. The framework does suggest the indicators that need to be discussed with users, however, the interviewer has influence on how the indicators will be discussed, so it is recommended that the interviewer has experience in acquiring the correct information.

References

Literature

Adams, S. M., & Friedland, C. J. (2011). *A survey of unmanned aerial vehicle (UAV) usage for imagery collection in disaster research and management.* publisher not identified.

Asghar, S., Alahakoon, D., & Churilov, L. (2006). A comprehensive conceptual model for disaster management. *Journal of Humanitarian Assistance, 1360*(0222), 1-15

Aubrecht, C., Özceylan Aubrecht, D., Klerx, J. & Freire, S. (2013). Future-oriented activities as a concept for improved disaster risk management. *Disaster Advances*, *6*(12), 1-10.

Backx, M. (2003). *Gebouwen redden levens. Toegankelijkheidseisen van gebouwgegevens in het kader van de openbare orde en veiligheid.[Buildings save lives. Accessibility requirements for buildings in the context of the public order and safety]* (Doctoral dissertation, M. Sc. thesis, Delft University of Technology).

Bajracharya, B. (2015). Geospatial Portal as an important SDI building block for Disaster Response and Recovery. In *FIG-ISPRS workshop, 2015: International Workshop on Role of Land Professionals and SDI in Disaster Risk Reduction: In the Context of Post 2015 Nepal Earthquake*, Kathmandu, Nepal, 25-27 November.

Balcik, B., Beamon, B. M., Krejci, C. C., Muramatsu, K. M., & Ramirez, M. (2010). Coordination in humanitarian relief chains: Practices, challenges and opportunities. *International Journal of production economics*, *126*(1), 22-34.

Banholzer, S., Kossin, J., & Donner, S. (2014). The impact of climate change on natural disasters. In *Reducing disaster: Early warning systems for climate change* (pp. 21-49). Springer, Dordrecht.

Bengtsson, L., Lu, X., Thorson, A., Garfield, R., & Von Schreeb, J. (2011). Improved response to disasters and outbreaks by tracking population movements with mobile phone network data: a post-earthquake geospatial study in Haiti. *PLoS medicine*, *8*(8).

Blackman, D., Nakanishi, H., & Benson, A. M. (2017). Disaster resilience as a complex problem: Why linearity is not applicable for long-term recovery. *Technological Forecasting and Social Change, 121*, 89-98.

Boccardo, P., & Tonolo, F. G. (2015). Remote sensing role in emergency mapping for disaster response. In *Engineering Geology for Society and Territory-Volume 5* (pp. 17-24). Springer, Cham.

Budhathoki, N. R., & Nedovic-Budic, Z. (2008). Reconceptualizing the role of the user of spatial data infrastructure. GeoJournal, 72(3-4), 149-160.

Carden, D., & Clements, A.J. (2015, January). Coordinating the response to Typhoon Haiyan. Retrieved from https://odihpn.org/magazine/coordinating-the-response-to-typhoon-haiyan/

Carter, W. N. (2008). *Disaster management: A disaster manager's handbook*. Manila: Asian Development Bank.

Christoph, A., Dilek, Ö. A., Joachim, K., & Sérgio, F. (2013). Future-oriented activities as a concept for improved disaster risk management. *Disaster Advances, 6*(12), 1-10.

Contreras, D. (2016). Fuzzy boundaries between post-disaster phases: The case of L'Aquila, Italy. *International Journal of Disaster Risk Science, 7*(3), 277-292.

Coppola, D. P. (2006). Introduction to international disaster management. Elsevier.

de Kleijn, M., van Manen, N., Kolen, J., & Scholten, H. J. (2014). Towards a User-centric SDI Framework for Historical and Heritage European Landscape Research. *IJSDIR, 9*, 1-35.

Eguchi, R. T., Huyck, C. K., Ghosh, S., & Adams, B. J. (2008, October). The application of remote sensing technologies for disaster management. In *The 14th World Conference on Earthquake Engineering* (p. 17).

EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.

Enders, A., & Brandt, Z. (2007). Using geographic information system technology to improve emergency management and disaster response for people with disabilities. Journal of Disability Policy Studies, 17(4), 223- 229.

Fuhrmann, S., MacEachren, A., Dou, J., Wang, K., & Cox, A. (2005). Gesture and speech-based maps to support use of GIS for crisis management: A user study. AutoCarto 2005.

Goodchild, M. F. (2007). Citizens as sensors: the world of volunteered geography. *GeoJournal*, *69*(4), 211-221.

Grus, Ł., Castelein, W., Crompvoets, J., Overduin, T., van Loenen, B., van Groenestijn, A., ... & Bregt, A. K. (2011). An assessment view to evaluate whether Spatial Data Infrastructures meet their goals. *Computers, Environment and Urban Systems, 35*(3), 217-229.

Grus, L., Crompvoets, J., & Bregt, A. K. (2007). Multi-view SDI assessment framework. *International Journal of Spatial Data Infrastructures Research, 2*, 33-53.

Grus, L., Crompvoets, J., & Bregt, A. K. (2008). Theoretical introduction to the Multi-view Framework to assess SDIs. *A Multi-View Framework to Assess Spatial Data Infrastructures. Space for Geo-information (RGI), Wageningen University*, 93-113.

Gyamfi-Aidoo, J., Schwabe, C., & Govender, S. (2007). Determination of the Fundamental Geo-spatial Data sets for Africa through a User Needs Analysis.

Hennig, S., Vogler, R., & Gryl, I. (2013). Spatial Education for Different User Groups as a Prerequisite for Creating a Spatially Enabled Society and Leveraging SDI. *International Journal of Spatial Data Infrastructures Research*, *8*, 98-127.

Hennig, S. & Belgiu M. (2011). User-centric SDI: Addressing Users Requirements in Third-generation SDI: The Example of Nature SDIplus, Perspetiv no.20

"Het Rode Kruis helpt wereldwijd" (n.d.). *Rode Kruis*. Retrieved from: http://www.rodekruis.nl/hulpwereldwijd/hulpverlening

Humanitarian Response (n.d.). *What is the Cluster Approach?*. Retrieved from: https://www.humanitarianresponse.info/en/about-clusters/what-is-the-cluster-approach

ITHACA (n.d.). *WFP SDI.* Retrieved from: http://www.ithacaweb.org/projects/wfp-sdi/

Janssen, M., Lee, J., Bharosa, N., & Cresswell, A. (2010). Advances in multi-agency disaster management: Key elements in disaster research. *Information Systems Frontiers*, *12*(1), 1-7.

Julmy, S. (2011, February). *Coordinating the earthquake response: lessons from Leogane, western Haiti*. Retrieved from https://odihpn.org/magazine/coordinating-the-earthquake-response-lessons-from-leogane-western-haiti/

Joyce, K. E., Belliss, S. E., Samsonov, S. V., McNeill, S. J., & Glassey, P. J. (2009). A review of the status of satellite remote sensing and image processing techniques for mapping natural hazards and disasters. *Progress in Physical Geography, 33*(2), 183-207.

Kapucu, N., & Garayev, V. (2011). Collaborative decision-making in emergency and disaster management. *International Journal of Public Administration*, *34*(6), 366-375.

Kerle, N. (2013). Remote sensing based post-disaster damage mapping with collaborative methods. In *Intelligent systems for crisis management* (pp. 121-133). Springer Berlin Heidelberg.

Khan, H., Vasilescu, L. G., & Khan, A. (2008). Disaster management cycle-a theoretical approach. *Journal of Management and Marketing, 6*(1), 43-50.

Lewis, S. (2011) Remote sensing for natural disasters: facts and figures. http://www.scidev.net/global/earth-science/feature/remote-sensing-for-natural-disasters-facts-and-figures.html. Accessed 10 Oct 2018.

Loenen, B. van, (2006), Developing geographic information infrastructures; the role of information policies. Dissertation. Delft University of Technology. Delft: DUP Science.

Manfré, L. A., Hirata, E., Silva, J. B., Shinohara, E. J., Giannotti, M. A., Larocca, A. P. C., & Quintanilha, J. A. (2012). An analysis of geospatial technologies for risk and natural disaster management. *ISPRS International Journal of Geo-Information*, *1*(2), 166-185.

Mansourian, A., Rajabifard, A., Valadan Zoej, M.J. (2005) SDI Conceptual Modeling for Disaster Management. In *Proceedings of the ISPRS Workshop on Service and Application of Spatial Data Infrastructure*, Hangzhou, China, 14–16 October.

Mansourian, A., Rajabifard, A., Valadan Zoej, M. J., & Williams, D. (2004). SDI for disaster management to support sustainable development. *Map Asia, Beijing*.

Mansourian, A., Rajabifard, A., Valadan Zoej, M. J., & Williamson, I. (2004). Facilitating disaster management using SDI.

Mansourian, A., Rajabifard, A., Valadan Zoej, M. J., & Williamson, I. (2006). Using SDI and web-based system to facilitate disaster management. *Computers & Geosciences, 32*(3), 303-315.

MapAction (2011). *Field Guide to Humanitarian Mapping*.

Mechler, R., & Bouwer, L. M. (2015). Understanding trends and projections of disaster losses and climate change: is vulnerability the missing link?. *Climatic Change*, *133*(1), 23-35.

Mobaraki, A., Mansourian, A., Malek, M., & Mohammadi, H. (2007). Application of mobile GIS and SDI for emergency management. *Revue Francaise de Photogrammetric et de Teledetection, 185*, 95-100.

Nojavan, M., Salehi, E., & Omidvar, B. (2018). Conceptual change of disaster management models: A thematic analysis. *Jàmbá: Journal of Disaster Risk Studies, 10*(1), 1-11.

Payne, K., Florance, P., & Shain, S. (2012). The role of data repositories in humanitarian information management and crisis mapping. *Journal of Map & Geography Libraries*, *8*(2), 118-133.

Poser, K., & Dransch, D. (2010). Volunteered geographic information for disaster management with application to rapid flood damage estimation. *Geomatica, 64*(1), 89-98.

Rajabifard, A., Mansourian, A., Williamson, I. P., & Valadan Zoej, M. J. (2004). Developing spatial data infrastructure to facilitate disaster management.

Rajabifard, A., & Williamson, I. P. (2001). Spatial data infrastructures: concept, SDI hierarchy and future directions.

Saito, K., Spence, R., Booth, E., Madabhushi, M., Eguchi, R., & Gill, S. (2010, September). Damage assessment of Port au Prince using Pictometry. In *8th international workshop on remote sensing for disaster management*, Tokyo, Japan, 30 September-1 October 2010.

Salvadó, L. L., Lauras, M., Comes, T., & Van de Walle, B. (2015, May). Towards More Relevant Research on Humanitarian Disaster Management Coordination. In *ISCRAM*.

Scholten, H., Fruijter, S., Dilo, A., & Van Borkulo, E. (2008). Spatial Data Infrastructure for emergency response in Netherlands. In *Remote sensing and GIS technologies for monitoring and prediction of disasters* (pp. 179-197). Springer, Berlin, Heidelberg.

Snoeren, G. F. I., Zlatanova, S., Crompvoets, J. W. H. C., & Scholten, H. (2007). Spatial Data Infrastructure for emergency management: the view of the users.

UNISDR (2017, February 2). Terminology. Retrieved from:
https://www.unisdr.org/we/inform/terminology

UNSDI (n.d.). *UNSDI*. Retrieved from:
http://www.unsdi.nl/about-us/unsdi/

The Cash Learning Partnership (n.d.). 2015 Nepal Earthquake Response. Retrieved from: http://www.cashlearning.org/coordination/nepal-earthquake-response

UNGIWG (n.d.) *United Nations Spatial Data Infrastructure – UNSDI.* Retrieved from: http://www.ungiwg.org/content/united-nations-spatial-data-infrastructure-unsdi

United Nations (n.d.). *Deliver Humanitarian Aid*. Retrieved from https://www.un.org/en/sections/what-we-do/deliver-humanitarian-aid/

Vandenbroucke, D., Dessers, E., Crompvoets, J., Bregt, A. K., & Van Orshoven, J. (2013). A methodology to assess the performance of spatial data infrastructures in the context of work processes. *Computers, Environment and Urban Systems, 38*, 58-66.

Voigt, S., Schneiderhan, T., Twele, A., Gähler, M., Stein, E., & Mehl, H. (2011). Rapid damage assessment and situation mapping: learning from the 2010 Haiti earthquake. *Photogrammetric Engineering and Remote Sensing (PE&RS), 77*(9), 923-931.

Warren, M. (2010, March 10). *Disaster experts praise Chile earthquake response*. Retrieved from http://www.cleveland.com

Welle Donker, F., & van Loenen, B. (2017). How to assess the success of the open data ecosystem?. *International Journal of Digital Earth, 10*(3), 284-306.

WFP (2018). *The 72-hour Assessment Approach: A guide for vulnerability and spatial analysis in sudden-onset disasters.*

WFP (2020). *Humanitarian support and services.* Retrieved from: https://www.wfp.org/humanitarian-support-and-services

Williamson, I. P. (2003). SDIs – Setting the Scene. In Williamson, I. P., Rajabifard, A., & Feeney, M. E. F. (Eds.), *Developing spatial data infrastructures: from concept to reality*. CRC Press.

Yulfa, A., Aditya, T., & Sutanta, H. (2017, August). Towards SDI services for crowdsourcing spatial data in disaster response. In *Engineering Seminar (InAES), 2017 7th International Annual*(pp. 1-6). IEEE.

Zook, M., Graham, M., Shelton, T., & Gorman, S. (2010). Volunteered geographic information and crowdsourcing disaster relief: a case study of the Haitian earthquake. *World Medical & Health Policy*, *2*(2), 7-33.

Zwirowicz-Rutkowska, A. (2017). A multi-criteria method for assessment of spatial data infrastructure effectiveness. *Earth Science Informatics, 10*(3), 369-382.

Figures

Figure 3.2.1: User-centric SDI development model (Hennig & Belgiu, 2011)
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Backx, M. (2003). *Gebouwen redden levens. Toegankelijkheidseisen van gebouwgegevens in het kader van de openbare orde en veiligheid.[Buildings save lives. Accessibility requirements for buildings in the context of the public order and safety]* (Doctoral dissertation, M. Sc. thesis, Delft University of Technology).

Figure 3.2.4: Overview on the effort to be put into developing tools for different levels of user GI-literacy. de Kleijn, M., van Manen, N., Kolen, J., & Scholten, H. J. (2014). Towards a User-centric SDI Framework for Historical and Heritage European Landscape Research. *IJSDIR, 9*, 1-35.

Figure 3.3.1: Proposed SDI development model.
Own work.

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Own work.

Figure 4.1: Cluster approach. (Humanitarian Response, n.d.)
Humanitarian Response (n.d.). *What is the Cluster Approach?*. Retrieved from:
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Figure 5.2: WFP SDI structure. (ITHACA, n.d.)
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Figure 6.3: indicators of the finetuned SDI assessment framework
Own work.

Tables

Appendix A: Proposed indicators

Source	(original) Indicator group	Original indicator	Action	Proposed indicator	Proposed indicator group
Welle Donker & Van Loenen (2017)	Data supply - known	Recognisable	Keep	Recognizable	Thematic spatial data supply - known
		Findable	Keep	Findable	Thematic spatial data supply - known
	Data supply - attainable	Affordable	Keep	Affordable	Thematic spatial data supply - attainable
		Legal transparency & interoperability	Keep	Legal transparency & interoperability	Thematic spatial data supply - attainable
		Practically available	Keep	Practically available	Thematic spatial data supply - attainable
		Service level	Combine	Service level / format	Thematic spatial data supply - attainable
		Delivery time	Keep	Delivery time	Thematic spatial data supply - attainable
	Data supply - usable	Reliable	Keep	Reliable	Thematic spatial data supply - usable
		Clear	Combine	Clear / support	Thematic spatial data supply - usable
		Manageable	Keep	Manageable	Thematic spatial data supply - usable
		Communication	Keep	Communication of data supplier to the user	Thematic spatial data supply - usable
		Up-to-date	Keep	Up-to-date	Thematic spatial data supply - usable
		Sustainability / long-term availability	Keep	Sustainability / long-term availability	Thematic spatial data supply - usable
	Governance	Vision	Not taken into account	-	-
		Leadership & control	Not taken into account	-	-
		Sustainable financing	Combine	Sustainable financing	SDI governance
		Self-organising capacity	Keep	Self-organizing capacity	SDI governance
		Open data stimulation	Adjusted	Stimulation of SDI use	SDI governance

		Communication S2U	Combine	Communication of data supplier to the user	SDI governance
		Communication G2G	Not taken into account	-	-
	User characteristics	- No indicator -	Use GI-literacy (De Kleijn et al., 2014)	GI-literacy	Users' GI-literacy
Zwirowicz-Rutkowska (2017)	Information and support provided - data	Thematic accuracy	Combine	Spatial data quality	Thematic spatial data supply - usable
		Completeness	Combine	Spatial data quality	Thematic spatial data supply - usable
		Spatial resolution	Combine	Spatial data quality	Thematic spatial data supply - usable
		Temporal validity	Combine	Spatial data quality	Thematic spatial data supply - usable
		Positional accuracy	Combine	Spatial data quality	Thematic spatial data supply - usable
		Distribution format	Combine	Service level / format	Thematic spatial data supply - attainable
		Lineage	Combine	Spatial data quality	Thematic spatial data supply - usable
	Information and support provided - support	Help menu - FAQ	Combine	Clear / support	Thematic spatial data supply - usable & SDI governance
		Help menu - video tutorial	Combine	Clear / support	Thematic spatial data supply - usable & SDI governance
		Email contact	Combine	Clear / support	Thematic spatial data supply - usable & SDI governance
		Tel contact	Combine	Clear / support	Thematic spatial data supply - usable & SDI governance
		Forum menu	Combine	Clear / support	Thematic spatial data supply - usable & SDI governance
		User's manual	Combine	Clear / support	Thematic spatial data supply - usable & SDI governance
		Other materials	Combine	Clear / support	Thematic spatial data supply - usable & SDI governance
	Use process - Decision makers	Higher confidence in making decisions	Combine	Quality of decision making	SDI use process

		More independent of suppliers, superior, other employees	Keep	Independence in decision making	SDI use process
		Easier/On-line user authorization	Combine	Quality of decision making	SDI use process
		Better understanding of problems and factors	Combine	Quality of decision making	SDI use process
		Increased comfort at work	Combine	Quality of decision making	SDI use process
		Improved competencies	Combine	Quality of decision making	SDI use process
	Use process - Decision making process	Detecting gaps in problem analysis	Combine	Quality of decision making	SDI use process
		Better information quality	Combine	Quality of decision making	SDI use process
		Faster access to information	Combine	Decision making time	SDI use process
		Access to more sources of information	Keep	Access to sources of information	SDI use process
		Easier task/goal formulation and realization	Combine	Quality of decision making	SDI use process
		Consideration of constraints and alternatives	Combine	Quality of decision making	SDI use process
		Length of time to make decisions	Combine	Decision making time	SDI use process
		Length of time to acquire data	Combine	Decision making time	SDI use process
		Length of time to analyze data	Combine	Decision making time	SDI use process
		Thoroughly studies and analysis	Combine	Quality of decision making	SDI use process
		Better data management	Combine	Data management	SDI use process
		Better quality of decisions	Combine	Quality of decision making	SDI use process
		Better/Easier cooperation with different stakeholders	Combine	Cooperation	SDI organizational impact
		Better/Easier cooperation within an organization	Combine	Cooperation	SDI organizational impact
	Use process - Applications	Accessibility	Not taken into account	-	-
		Usability (intuitiveness, clarity and content presentation)	Not taken into account	-	-

		Usefulness	Not taken into account	-	-
	User organizational performance	Duration of procedure	Combine	Decision making time	SDI use process
		Change of attitude towards some procedures/tasks	Combine	Workflow	SDI use process
		Improved procedures	Combine	Workflow	SDI use process
		More executed plans, decisions, studies	Combine	Use of geodata (frequency)	SDI use process
		Increase in orders	Not taken into account	-	-
		Automates manual calculation, analysis, tasks, realization	Combine	Decision making time	SDI use process
		Automates data acquisition and collection	Combine	Data management	SDI use process
		The prompt completion of work	Combine	Decision making time	SDI use process
		Reduces costs of data acquiring and processing	Combine	Sustainable financing	SDI governance
		Cost displacement (e.g. software, hardware, people)	Combine	Sustainable financing	SDI governance
		Increase in costs of equipment, the infrastructure	Combine	Sustainable financing	SDI governance
	Strategic alignment and business impact	Corporate or brand image/public perception	Not taken into account	-	-
		Improved understanding of competitive landscape	Not taken into account	-	-
		Increase of the competitiveness of the firm	Not taken into account	-	-
		Formalizes innovation	Combine	Innovation / development	SDI organizational impact
		Improved knowledge transfer	Combine	Innovation / development	SDI organizational impact

		Enhance ICT and GIS/CAD knowledge	Combine	Innovation / development	SDI organizational impact
		Development of the firm	Combine	Innovation / development	SDI organizational impact
		Enhances linkages with customers and data suppliers	Combine	Communication of data supplier to the user	SDI governance
		Supports new communication and distribution channels	Keep	New communication and distribution channels	SDI organizational impact
		Ability of ICT to cope with changing business processes	Combine	Innovation / development	SDI organizational impact
		Optimalization of workflow	Combine	Workflow	SDI use process
		Flexibility to reflect new business requirements	Combine	Innovation / development	SDI organizational impact
		Improved coordination in an organization	Combine	Cooperation	SDI organizational impact
		Improved coordination with different participants of the tasks and procedures	Combine	Cooperation	SDI organizational impact
		Increase of tasks/procedures/work supported by ICT	Combine	Use of geodata (frequency)	SDI use process
		ICT impact on the office/company's organizational structures (new positions)	Not taken into account	-	-
		Possibility of ICT inclusion in tasks	Combine	Use of geodata (frequency)	SDI use process
		ICT impact on efficiency increase of the employees and the whole company	Combine	Workflow	SDI use process

Data specific indicators

Known	Recognizable	The dataset is recognizable
Known	Findable	The dataset is findable
Attainable	Practically available	The dataset is practically available
Attainable	Affordable	The dataset is affordable
Attainable	Delivery time	The dataset can be acquired/delivered in time
Attainable	Legal transparency & interoperability	The dataset does not have any legal restrictions (and there is legal transparency)
Attainable	Service level / format	The dataset is distributed in a sufficient format or service
Usable	Manageable	The dataset is manageable
Usable	Reliable	The dataset is reliable
Usable	Spatial data quality	The dataset has sufficient spatial data quality
Usable	Sustainability / long-term availability	The dataset has long-term availability / is sustainable
Usable	Up-to-date	The dataset is up-to-date
Usable	Communication of data supplier to the user	There is sufficient communication from the data supplier to the data user
Usable	Clear / support	The metadata and support are clear

SDI-specific indicators

Use process	Access to sources of information	The SDI increases access to sources of information
Use process	Data management	The SDI improves data management
Use process	Decision making time	The SDI shortens decision-making time
Use process	Independence in decision making	The SDI creates independence in decision making
Use process	Quality of decision making	The SDI improves the quality of decision making
Use process	Use of geodata (frequency)	The SDI increases the use of spatial data
Use process	Workflow	The SDI improves the workflow
Governance	Clear / support	The communication and support regarding the SDI use are sufficient/clear
Governance	Communication supplier to user	The SDI stimulates and supports communication from the data supplier to the data user
Governance	Stimulation of SDI use	The SDI organization stimulates SDI use
Governance	Sustainable financing	There is guaranteed (long-term) financing for the SDI (note: many users can probably not answer the question, but long-term financing is of course essential)
Organizational impact	Cooperation	The SDI increases cooperation in the organization

Organizational impact	Innovation / development	The SDI stimulates innovation and development
Organizational impact	New communication and distribution channels	The SDI presents new communication and distribution channels for the organization

Appendix B: Interview structure

Discussed topics:

SDI scholars

Introduction

- Objectives of the research
- Methodology of the research
- Objective and context of this interview
- The interviewees' expertise on SDI and crisis management

SDI for crisis management

- Characteristics of SDIs for crisis management, in comparison to conventional SDIs
- Objectives of SDIs for crisis management

Defining users

- Defining end-users (decision making)
- Creation of user groups (based on certain characteristics)

Framework indicators and methodology

- Discuss the methodology for the creation of the framework
- Discuss the place of the framework within SDI development
- **Discuss the content of the framework (walk-through with discussion)**

Including user needs in SDI development

- Using the users' needs as input for other SDI components
- Discuss how to get feedback of users to see if it supports decision making

Closing

- Summarize the information of the interview
- Discuss, if applicable, open recommendations for the research and/or the framework
- Ask for any useful connections in his/her network
- Closing of the interview

WFP SDI (development / maintenance / coordination)

Introduction

- Objectives of the research
- Methodology of the research
- Objective and context of this interview
- The interviewees' role for the WFP SDI

SDI structure

- Explanation of SDI structure described by the SDI components:
    - Data (relate to chapter 2.2)

    - Technological components / access network
    - Standards
    - Policy
    - People (see next topic)

Defining users

- Defining end-users (decision making)
- Creation of user groups (based on certain characteristics)

Framework indicators

- Discuss the place of the framework within SDI development
- **Discuss the content of the framework (walk-through with discussion)**
- **Discuss indicators used in the framework**

Including user needs in SDI development

- Using the users' needs as input for other SDI components
- Discuss how to get feedback of users to see if it supports decision making
- Discuss how and to what extent users have or should have influence on SDI components

Closing

- Summarize the information of the interview
- Discuss, if applicable, open recommendations for the research and/or the framework
- Ask for any useful connections in his/her network
- Closing of the interview

Appendix C: Interview Dimitris Karakostis

April 7, 2020

[Opening]
Mick Visser: Well nice to meet you. I'm Mick Visser, a student from The Netherlands. I am doing a master's study in Geographic Information Management and Applications. I do my research, my master's thesis, about the link between crisis management and SDI. I use the WFP SDI as a case study, so that's why we ended up here.
Dimitris Karakostis: Okay, cool. So first of all, how did you hear about this SDI, of the WFP?
M: Well it was just a lot of researching and Googling of course. There is not much to find about the link of crisis management and SDI. I came across the WFP SDI and it seems like the best case study that could be found, because it is well documented and complete.
D: I think the WFP SDI is one of the most well-thought SDIs is the humanitarian context and many others are trying to build some GIS infrastructures. During the last years we have also advised in a way, colleagues from FAO, EFAD, to build similar systems. Another system I could recommend is the OCHA HDX.
M: Yes, I also came across that one. So I will explain a bit about my research. There is not much scientific literature about SDI and crisis management. What I try is to create a framework for a user needs analysis, that can be applied to an SDI that is used in crisis management, like the WFP SDI. Because that is different than conventional SDIs like national SDIs. It has different kinds of users, different objectives. It has not been done before, so I try to take literature about SDI assessment, to apply it to this case study of the WFP SDI.
D: Ah, I see.
M: There are some differences of course between conventional SDIs and this specific case. That is why I conduct interviews, to discuss a bit how it can be changed and finetuned in such a way that it can be applicable to SDIs like the WFP SDI.
D: Okay, well it is a huge topic and I am glad to have this discussion, I hope I can help you. And if things come to my mind later I will share them with you. In general, the scope of the SDI that is used does not really matter, nowadays it is important to have like near real-time or if possible real-time exchange and access to data. So the fastest, the better. Of course, this is not always possible for various reasons, because for instance of the type of data, satellite imagery with a temporal resolution, which is once every week or something. Maybe data cannot be accessed due to low internet connectivity, so if we surveys with mobile data collection, in areas where we have no internet, we need to get the data later. But in many cases, it is important to make sure that the data we have in the SDI is as much as possible automated, and good quality. Because if the SDI does not have good data quality, it is worthless. Because it is not about the SDI, it is about the data in the SDI. People focus a lot on the SDI structure, but they put less effort on the type of data and metadata, but they do always have to be up to data and clean, and this is one of the biggest difficulties we face. On the one hand, we want more users to use the SDI, on the other hand, these users are not GIS officers. They are simple users, reporting officers,

no GIS experts. So they do not really understand the importance of metadata. Maybe I can share a bit with my screen in a minute.
M: Yes that would be nice, take your time. In the meantime, can I ask you some questions? So first of all, what is your role for the WFP SDI and the WFP organization?
D: So I joined WFP in 2016, I was working in the GIS team in WFP, with 50 to 60 GIS officers. Back then, it was split into three pillars. The first one was mapping, they were responsible for all the mapping requests, mostly static maps, PDFs, maps regarding logistics, access constraints maps, road networks, etc. The second one was analysis, they were conducting all the analysis mainly using ArcGIS, also doing automated analysis, so with ArcPy etc. The third pillar, in which I was, was the development of an infrastructure, which was focused on building either web GIS applications. So I'm a web GIS developer. But also focused on the SDI implementation and maintenance in the HQ (Headquarters) in Rome, but also in the RBs (Regional Bureaux) and the COs (Country Offices). So the RBs in Cairo, Bangkok, Johannesburg, Nairobi, Dakar, Panama. And then the COs. So our pillar was responsible for the SDI implementation and the web GIS implementations. So my tasks there were splitter into working a lot with open source technologies, such as GeoNode, so the WFP GeoNode. Which is one of the components of the SDI. And also working quite a lot, and now actually organizing the missions for the SDI implementation in the RB in Cairo, which was actually made and used by ESRI. So the SDI of WFP actually has two components. So the first component is WFP GeoNode. The proprietary ESRI component is the other component.
M: And what exactly is the connection between the GeoNode system and the ESRI system?
D: That is a good question. Interoperability is very important. What we did, is that we managed to connect the two systems in the database level. This means we could actually edit data in GeoNode and this data will also be visualized and accessible in ArcMap. So you would load a layer, you would load it in the ArcMap application and you would see the edit like you had done in your GeoNode environment. We also have the connection in the sense of that the data, as OGC WMS and WFS, could be accessed in the web platform. So the reason we use two SDIs, we started these two projects many years ago. The GeoNode project started in 2012, back then GeoNode was heavily supported by the World Bank, which was funding the full project. Nowadays it is a very solid and stable project that is being used a lot by governments and institutes all around the world. And there was also an agreement with ESRI, an enterprise license agreement. We had two different projects at the same time. Initially, our GeoNode project was covering all our needs, and it replaces other web GIS applications that were envisioned back then. But they were not so complete in terms of metadata cataloging, searching capabilities etc. So GeoNode came to replace this. Back then, the ESRI tools were not so amazing as they are today. Back then, there was no ArcGIS Online, no StoryMaps, all these sets of tools. So anyway, the time was passing by, ESRI products are very good at this point, GeoNode is also a very mature project and we maintained both, because GeoNode gives us freedom, it gives us possibilities to develop new functionalities. I was actually the core developer in WFP GeoNode. We have developed new functionalities. It gives us a good connection with the community, the open source community of GIS. And it also gives possibilities in sharing of data. So our SDI, of GeoNode, shares data and consumes data of different sources. So we have let's say an agreement on the technical level with OCHA, and we actually share data from GeoNode with OCHA on the HDX platform. And on the same time, we consume

all the layers regarding the road networks in GeoNode. This kind of flexibility is not really possible with closed software. And having that kind of solution is always good.
M: So it is also mainly for your own GIS developments that you have this system, and that you do not have to rely on another organization for that?
D: Yes, exactly. Now the situation is getting more and more solid, the agreement with ESRI. Now we also question why we should also still maintain the open source platform, but still, the freedom that you have, customizing the platform the way you want, and adding whatever you like, whatever you want, and also the connectivity and interoperability that there is with other platforms, like the good example of HDX, which is also a huge platform, but you cannot find something like this in the ESRI SDI. What you can find in the ESRI SDI is amazing software which is very fast and very appealing.
M: Also the ease of use I suppose?
D: Exactly. It is more suitable for people that are not really GIS experts. Everyone can build a storymap. After a bit of training for two hours, you can build a storymap, and this is perfect because GIS is also growing a lot, we need more people that are spatially aware that have this understanding. In that sense it is good, but if you have the capacity, like we have in our team, it is also good to have the flexibility and freedom with open source projects.
M: Okay, and what kind of data is incorporated in the SDI of WFP?
D: Well, there is a whole lot of data available.
M: And all of this data, I think it is divided into several categories?
D: So yes we have lots of different data. There are the global layers, which relate to the location data of airports, ports, railway networks. We have data, that we also call global layers, and that is WFP specific, such as locations of warehouses, we have WFP offices, country offices, all the locations of this data. We use this information mostly on the maps we create, we also get updates of this information from country offices, because they can actually inform us the best about how correct the data is. Also another type of data that belongs in the category of global layers are bridges, border crossing points, etc. Then we have data related to road networks, we actually have built workflows. We download and acquire the OSM database, I believe twice a day, we download these road networks from all over, Africa, Asia & South America and we have all the up-to-date road networks. Because when there is like an emergency in the country, the HOT [Humanitarian OpenStreetMap Team] will be activated. Let's say we have concentrated volunteers working on specific countries and that they are actually contributing data. So we use this kind of information quite a lot. So the second category is like road network data. Very important for our logistics mapping. The third one is related to border. There is a very big initiative taking place now, within the UN system, to have like unified borders. In the past we were using the GAUL [Global Administrative Unit Layers] data, maintained by the FAO. Nowadays we are using, more and more, the UN administrative official dataset, which currently have the Admin-0 level. Eventually they also want to provide Admin-1 and Admin-2, so what we do, the WFP has an own team that is working on the admin boundaries. What we do is adjust our Admin-1 and Admin-2 boundaries to the Admin-0 official dataset of the UN. This is quite important because boundaries can actually cause political issues, so it is important to have the correct boundaries. Another category is natural disasters. We have earthquake data and tropical storm data. We are using this data to create the automated maps, that are being disseminated to the users. Like

epicenters, affected population after an earthquake, the trajectory of a tropical storm, the wind speed of a tropical storm etc. This is actually information that we have incorporated with organizations like other institutes, and we take this information, we put it together, and we create the dashboards. We do not produce this information, we consume lots of information for our needs.
M: And combining this data is also automated?
D: Yes this is also automated. There are API's, and we consume these API's and there is automation, in a certain extent. For example, you can search ADAM [Automatic Disaster Analysis & Mapping].. Are you aware of the project ADAM?
M: No, what is it exactly?
D: Okay, so ADAM is Automated Disaster Analysis & Mapping. I have a colleague of mine that is working with this, I can put you in contact if you want. It is actually consuming this kind of data and creating dashboards, that are being disseminated. In the first ten minutes of an earthquake, they are being disseminated to the users. So all this is kind of automated. Then we have data related to topography, for example contour lines, settlement data, location of settlements, cities. For that we used to use GeoNames, which is like the database for the settlements. Now we are also trying to build some kind of custom database with all this information. Then we go to the analysis. There is a project called Integrated Context Analysis, it is actually combining natural disaster data like floods and droughts, together with food security. This is a project that we do for each country individually and we have to cooperate with the government of each country. What we do is cooperating with the governments to get data of food security of the country and combine it with natural hazards, which is in this case that we examine floods and droughts, to see how the drought can affect the food security by looking at historical data. So all this kind of information are in our SDI as well. For all of these projects we have platforms. They are reading data from our GeoNode, so this is another good thing, using GeoNode as a hub of data. What it is, is that there are web applications, satellite applications, that are reading data from GeoNode via the API.
M: So the GeoNode portal really functions as an information hub?
D: Yes exactly.
M: And is there also socio-economic information or data available in the SDI? For example population and population density, but also thing like GDP for instance.
D: No not really. We do not have something like that at this point. But people are uploading data. Inside the GeoNode platform I see that there is a category for population, and I see that there are some population layers for Cambodia and stuff like that. People are uploading data in general. The new GeoNode is going to have a much better categorization of data and we are moving into the direction that we have specific categories, and we do not encourage people too much to upload their data, but we have very clean data by ourselves, we maintain the datasets by ourselves. Because it is not about the quantity, it is about the quality again. And in the SDI, we have seen that people do not correctly upload their data. They upload without metadata, we had to do lots of cleaning in the end.
M: So there are some standards for data and metadata to be included in the SDI?
D: Yes, but this is different for GeoNode than for the ESRI SDI, because that has the whole ESRI part. So the GeoNode platform indeed has some standards. The idea was like that anyone could share very fast with colleagues of WFP all around the world. So I want to

share a certain file instead of putting it into mail or putting it in the cloud, I put it there and people can actually get it, visualize it, and do simple stuff. That was in GeoNode. When it comes to the core of the SDI implementation, there is standardization of the data, there is a process. Let me show you something to understand the structure. This is the actual GIS structure in WFP. What I want to show you is that 'here' we have the GeoNode environment.

[Screenshot provided by Karakostis]
And as you can see, there is a stage in GeoNode, the production in GeoNode, and the production is the one you could access, and all this data is being exposed -you can see the cloud under the GeoNode- they are being exposed to web applications as we said. We use the GeoNode as a hub. On the right side, we have this ADAM earthquake thing, which is kind of independent. So this is like an independent system, it lives in a container in a server and it is producing the automated data, that we then actually share on GeoNode. So in the middle we have the core SDI, which is based on ESRI technology. We have the enterprise databases, which are connected through ArcGIS server, we expose the layers to ArcGIS Online, or we can expose the layers to structures directly by uploading the shapefiles to ArcGIS Online, and then we use ArcGIS Online (as you can see in the middle) to create the StoryMaps, Dashboards, interactive maps and stuff like that. The enterprise database, as you can see, consists of four databases. The ESRI GN, GN stands for GeoNode, is the one that is connected with our GeoNode. So this is the one that could be visualized from both systems, and you can use and edit in both systems. Then we have three other databases, they are only with ESRI geometry. All of them are very important, but the HQS3 is the one that is synced through the procedures of synchronization we have built, with small SDIs that we have implemented in the different countries. As I said before in the regional bureaux of Cairo etc. So the standardization that we use, when we are actually putting data in the databases [DATABASE NAMES] it goes down to the level of standardization in the name. So we have a specific naming convention, which is the first the name, the category, the source of the data. We tried to make sure that the data inside is as clean as possible. But it is not always possible you know, for example global layers of the airports, we do not really keep them up-to-date but if there is a crisis and we need to create maps, in a specific country, then in that case we are going to update them. In that case we are going to talk to the colleagues in the field, and we are going to get the latest information, like if the status of the airport is open or closed. Other data, like the OSM databases, that come from the cloud, from external sources, they are always updated because we have the automated workflows. So we have these small SDIs in different COs and RBs, we have implemented a lot of them. The idea was to enable all these people to create GIS products, and part of this implementation includes buying the server, installing their ArcGIS server, installing all the necessary software, the enterprise database for each country office, and then synchronizing these databases between COs, the RBs and the HQ. In order to do that, we had to make sure that at least part of the data are maintained and that they are with the correct naming convention. To answer the question: yes, the data that we are putting in the SDI platform, not in GeoNode but the ESRI platform, they are actually standardized in a big percentage but not all of them, because in the end, it is how the user decides to use the SDI. For example: we have people in a CO that just keep

uploading data without following the naming convention that we have suggested. These are actually the challenges.
M: And how is this all organized? Like the governance behind this, who is responsible for development and management of the whole SDI and are there certain layers between those responsibilities?
D: Ah that is a good question. I would say that the history of this team in WFP is quite long, it took lots of efforts in order to reach the point in which we are today. Lots of realizations of upper management to the importance of GIS. There is a problem, because the upper management in general are not technical people, so they are not able to understand what GIS is all about, for sure they cannot really realize it that easily that GIS is more than just mapping. It is not just the map that you get in the end of the day, this is the outcome, it is actually very important, one of the most important things in our organization, but it is not only that. This took lots of efforts to convince them. They are very good managers but they are not technical people, so there is a constant effort throughout the last ten years. Thankfully, these efforts are showing results, because we have became more and more necessary, and our work is becoming more recognized, in a sense like the example of the agreement we have with ESRI. This is several hundreds of thousands of Euros on a few years basis. It was decided that this was funded by the organization, not by the division itself, which is a great achievement because the division actually managed to make clear to the organization that GIS is something that we need and that you have to fund for it. When it comes to the open-source technologies, the costs are not so high, there is the server maintenance of course and we actually pay for the servers, but the costs are not very high. So it is like one or two consultants working on these projects, this is part of the team. Let me show you a diagram I built some time ago, it shows where the SDI stands. If the whole GIS system is like a triangle, the SDI is the base of the triangle. It consists of the web applications, the database systems, the maintenance, all of this would be considered as the infrastructure. On top of that you build all your products, like the mapping and the analysis. This is the idea that we have passed to our management. If the maps looks cool, but you do not have the systems behind, it is not actually sustaining. No one is going back to file system, hundreds of shapefiles, no metadata. In order to be efficient, we need to have this. You have preparedness and you have response, the idea is that the SDI belongs to the preparedness. We mean preparedness about the data, having the right data, all the tools, and the people to be trained, so capacity building. Of course you can use the SDI to share data in the emergency when the response is happening.
M: Okay. So what I also want to discuss are the users of the SDI. Because are there different types of users that you can distinguish?
D: There are the people that want to learn. They want to learn something, and they use GIS and they start to do some simple stuff. That was the idea of GeoNode, people that have some GIS background to do some simple stuff, upload layers, visualize it, make description. And then there are the people that do not have the time to learn, are too busy with other tasks, too busy with their jobs, and we actually provide the services to them. And then we have our GIS officers, which are the ones we have all around the world, in the COs and RBs. These are the ones that we train. So all the SDI implementations that we have made in different countries, one of the requirements is that there is GIS capacity there. We need someone there that we have to train. So this is the person we go to there,

we train them to use the enterprise database of ESRI, we train them on GeoNode, how to use ArcGIS Online, how to make StoryMaps, sometimes a bit of remote sensing to calculate NDVIs, stuff like that. So this training takes place there and when we are there, we raise the awareness. So we put people from different units in a room, and we say okay guys, we are here and we are going to have a very simple training on how to make web maps with GeoNode and ArcGIS Online, but nothing too complicated. We are not getting into too many details. So we do some simple seminars and people are getting trained and some of them are using the application software, most of them, well, you know how it is. You get the certificate, you put it on the wall, and that is it. But this is not wrong of course, they are super busy with other stuff and they can always ask, like to the colleague that is doing the GIS. But people are slowly more understanding the importance of maps and more important, the importance of spatial data, when there is not a map. It does not always happen the way we want this to happen, because people are making maps, and are using Tableau, which is not a tool for making maps, it is a business intelligence tool. But at least, they start trying. The problem is however, that the maps are not really correct, in the titles, the legends, things are missing. Maybe they are not using the right border data, but anyway. So regarding user groups, I would say there are like GIS experts, that we train to use the latest technology and latest tools, and then we have non-GIS experts and based on their needs, we have given specific trainings. For example, if we have information management officers that have seen data online that they want to make, we are going to make customized training for them. In the past we have created online Skype trainings for our colleagues in the Panama RB, where we train them how to use the GeoNode platform and other specific tools. I would not make a bigger breakdown on specific types of users. In the end it is GIS experts and non-GIS experts. Non-GIS experts can be many people like logisticians, reporting officers, and we make customized trainings for each of them.

M: And are there also people outside of WFP that make use of the components within the SDI?

D: Yes, definitely. This is one of the advantages of GeoNode. GeoNode is used quite a lot by people outside of WFP. We have established a Google Analytics thing. We have lots of usage of people, we are tracking the downloading of shapefiles, we also track people that are not inside of WFP but actually download data. Their organizations use the platform as well, such as OCHA. The SDI platform, regarding the ESRI component, is being used on a government level, in the governments. This depends on each CO, it is up to them to see how they want to use the data and who they want to work with. There are cases that the COs cooperated with governments and have given access to the online platform of the SDI. Not directly to the database. So they are using ArcGIS Online to visualize, to see the web applications that the CO of WFP has created for them. And they use the SDI in that sense, not to edit, but to see the web applications.

M: All right. So you mentioned that you have used different kinds of approaches for different users, regarding for instance training..

D: Yes there are different modules in training. I would not say that this is something very well organized though. So in the past we have identified two types of trainings: for GIS users and non-GIS users. Of course the second training was much simpler, and according to some expressed needs that they had.

M: So you say that some users had some expressed needs for things that they would like to know or have explained to them. What is the way that these user needs have been addressed?
D: I would say that there is not a straightforward way. WFP has around 50.000 people working around the world. The thing is, most of the people do not know about GIS. They know that GIS is maps, they do not know the capabilities of GIS, the analysis you could do, all the cool stuff you can do with GIS, so how could they ask? The people that work closely with us, we see that they are like 'can you do something for us? Can you do something like that?' But there is not a centralized and standard system, communication system. It is more like on the personal level, and our team at the HQ has developed very good communication. We know almost all GIS officers around our COs through our missions etc. It is easy for them to contact us and they say okay we need that. We work a bit like a family.
M: So there is not some kind of standardized analysis for user needs like a questionnaire or interview structure?
D: Well, there is no questionnaire. But what is happening, and that is quite important to mention, there is lots of work happening from the RBs down to the COs. I have worked a lot with the RB of Cairo, and I know that they cooperate quite a lot with the COs. So the idea is that if the CO does not have GIS capacity, no GIS officer, the RB is supporting them, or the HQ. So there is a map, they send the request to us, and we support them. If they have the capacity, they could do it by themselves. If, for some reason, they cannot do it by themselves because of for instance a heavy workload or because they do not have the technical knowledge, they first contact the RB. And the RB can contact us as well, so there is a chain I would say. It is not a hierarchical chain, it is not like we tell the RB what to do, but this is how the workflow works, it is more like steps in the process. What happens is for example that the RB organizes an amazing workshop, once or twice a year, and in this workshop there are specific trainings. We have organized, last October, a global GIS workshop in Rome and we brought all the GIS people from around the world in Rome. For these kind of things we had questionnaires, we actually sent questionnaires. A bit like: 'so we are doing these kinds of trainings, these kinds of seminars, what do you think and what is more important for you? What do you use? What do you need to learn more?' And we brought experts from different companies. In that sense, there is this kind of thing.
M: And do you have any of these questionnaires still available?
D: Me, not at the moment. I remember sending a questionnaire with questions like what do you find more important, data collection, or how to analyze data?
M: So in that way, the users do have an influence on the development of the SDI?
D: Yes. So for example: maybe the SDI as an infrastructure is quite solid, but when it comes to the products of the SDI, they definitely have a lot of saying. The thing is, technologies like ESRI's, has given lots of flexibility of building products on top of the SDI. So the SDI in the end is like all the data nicely standardized and nicely catalogued. Then the question is like: what kind of cool visualizations can we create with this? And how can we actually help the people in the field? What is important for them? What does it mean for them to be successful? So this is the presentation like we did in Syria, I did the SDI implementation in Syria last year. We put all the people together in the room, people from different units, and we are like 'okay we are here doing our SDI implementation and what is the scope and objective of the SDI.' So three main objectives actually, building the SDI,

building capacity for using the infrastructure, and to foster the partnerships and strike collaborations inside of the organization but also inter-agency. So to the people in the room, we show them some demos. Some applications that we have built in another SDI or back in the HQ. Based on this kind of stuff, they come to us and they tell us: 'okay you know what, this is what I need, this is what makes my job easier. We need this kind of application, we need this kind of data collection platform', and we teach them how to create these tools. The teaching can also take this kind of direction, informally.
M: So first you raise spatial awareness, and the result is that they start to see the potential and come to you with questions and needs?
D: Yes, yes. The problem is that they are very happy, very excited, but as usual they cannot follow up because they are super busy. Especially in offices like in Syria, they are really busy, and in the end they like it, but they cannot always follow up. And then we also have issues with internet connectivity. In South Sudan, the connection is so bad, I was talking to the guy there and he told me 'I am waiting for Saturday to run some analysis, because during the week the internet connection is so heavily used and is so bad that you cannot actually run analyses online, you cannot download data.' So these amazing tools they do not always work perfectly. Lately there was the idea of customizing or changing the SDI a bit, but this is work in progress, but the idea of customizing SDIs based on specific parameters. Because we have to be a bit more flexible in our SDI implementations in the field, what are the parameters that will affect our SDI, the efficiency of the SDI and how it is used. We have identified several of them but the most important is capacity: do we have GIS officers and how many? And infrastructure, like internet connectivity. If we go to a country that does not have internet connectivity and we offer them online solutions.. I am sure there is a good expression for this you know. Like you give a boat to a landlocked country. So that was the way forward and it is probably going to happen soon. But at this point the SDI is very solid, what is less solid are the things that people can build on top of the SDI.
M: Okay understood. Do you think it might be useful to use some kind of questionnaire with indicators to reflect on the SDI, based on certain scores? This is what I have seen in SDI literature, a common way to assess SDI is for users to give certain indicators scores to assess from a user's perspective.
D: I think it is very, very important. We do not do it so much to be honest. We would like to do it more. It is like the most important thing. We work for the users of the SDI. What we have done, and it was really cool, during the global GIS workshop, we put all the SDI users in a room. We had the GIS people from around the world and we put them in the room, and we were like: okay the floor is yours. What are the problems of the SDI? What do you not like? What do you like? And then we created four groups of people because there were around 20 people in total, they had a flipchart, each of them, and they found the positives and the negatives. Lots of things that we saw were actually the source for the use strategy we were building. So it is very important to ask the people, through questionnaires, through meetings, understanding their needs, understanding what is important for them, what success looks like for them, and what are the user needs.
M: Is it an idea that I send you the concept framework for the user needs analysis, and that you could have a look at it and give some comments on that?
D: Sure, yes! I am happy to help.

M: So this was really helpful, thank you very much for that. This was about it for my questions, do you maybe have some recommendations or comments for the research? Like did I miss some important points?
D: From my experience, every crisis is different. It is difficult in the end to have a system that incorporates everything. I think what is important, is to create a system that is flexible, expandable, that is fast, and that it can actually expose the data in different ways, in order to enable people to collect data. Probably I have to think a little bit more about this. You know, one of the things we see for example these days is that there are these amazing platforms that have satellite imagery on it, without having to download the satellite data, but you can run amazing analysis on it without exposing it to your server. So the question is like: how much do we need to invest on building this kind of SDIs that expose these huge raster files, is it necessary? The other question is: what is the role of WFP in developing software? Because in the end, WFP is a humanitarian organization, and not a software company. Who is the entity that should actually build these SDI platforms? Lots of money and funds are going into a direction that we do not know if it is able to provide things that are not already there from other companies. But for the data side of things, it is really important for your SDI to have clean data in it, if it does not have it, the SDI is not going to work, it is not reliable.
M: Well, that is clear.
D: And when you are finished, please send me the results of your research!
M: I definitely will! So thank you very much for your time and all the information.
[Closing]

Appendix D: Interview Francesco Stompanato

April 9, 2020

[Opening]
Mick Visser: Well nice to meet you. I'm Mick Visser, a student from The Netherlands. I am doing a master's study in Geographic Information Management and Applications. I do my research, my master's thesis, about the link between crisis management and SDI. I use the WFP SDI as a case study, so that's why we ended up here. What I try to do is create a framework for assessing an SDI from a crisis managers perspective.
Francesco Stompanato: Ah well it is very nice that we have this chat, because with WFP we have done a lot of work in the SDI. I also did a thesis on SDI, for a PhD. This SDI is a quite unique environment compared to the private sector, in terms of challenges and use cases. I can give you some background on what we have done if you would like?
M: Ah yes, if you could start with some background that would be nice.
F: So I joined the WFP in 2011, one of the first tasks that I worked on was the implementation of corporate web GIS platform, to expand the used geographic information and provide access also to people that did not have GIS expertise. So I got in touch with some partners, to understand what was already available, in order to not reinvent the wheel. I discovered that the World Bank was very active with a project called GeoNode. So what we did was getting in touch with the GeoNode community, hire a developer, and we released the first version of GeoNode in 2012. That was mostly, for a couple of years, the main way we were sharing our data with partners and with other colleagues in the office. Even though at the WFP HQ, since 2009, there was a spatial data infrastructure, a local one, built with ESRI technology. But that was not used for data sharing. So in 2014 we signed an enterprise agreement with ESRI and that gave us a more professional infrastructure. To take into consideration also the needs of the community, around 100 GIS officers that we have. The organization is organized with 6 regional offices, and more than 80 country offices in countries where we operate. First challenge was to find solutions to allow GIS officers, that were in the field, to improve the way that they were managing geographic information that they were using to create GIS products. So we analyzed what the main issues were that they were facing, related to the fact that there is very weak connectivity in many countries, there is a lack of resources, human resources, because in many cases we have only one GIS officer that has to cover all the requirements of the country for WFP, and also lack of financial resources in many cases. So what happened in many cases was that the GIS consultants had built the whole geodatabase on their own laptop, and then they left the organization and we lost all the data. In some cases the laptop broke, and we were not able to get access to the data. So we thought: let us use this agreement that we signed with ESRI to build a SDI which is not only locally at the HQ in Rome, but is distributed in all those offices where there is GIS capacity. In the other offices, where there is no GIS capacity, we use the GeoNode platform as a common repository for spatial information. So in order to tackle this issue we started working in our RB in Bangkok, where in 2015 we hosted a regional GIS workshop, to show them with the practitioners in the region the GIS technology, related to the enterprise databases and data sharing workflows made available by ESRI. So what we did after the workshop was

having some missions, in 3 countries, Bangladesh, Indonesia and Philippines, to test mostly the networking. How the replica transmission was performing, connecting to remote databases, because one of the first things we discovered working also with our IT department, is that because the way that ESRI technology is built, the access to the geodatabases is very shocky. There are many messages shared between the client and the server, I opened a connection where there were 90 messages, so we installed something on the server to discover that that was a huge bottleneck. Not really in terms of bandwidth, but in terms of latency, because there is a relatively big latency between our offices, 100 ms, and if you multiply that for each single message, it makes a big change. It makes it not easy to connect to our centralized systems. So we said okay, let us build a network of geodatabases, but it cannot really happen real-time because the test with the synchronization failed. What we did was to create scripts, to schedule the synchronization overnight, when the network was not very busy. So we started the project in these 3 countries, and then throughout the year it was expanded in Bangkok and all the countries that are connected to Bangkok, and later on all the other RBs.
M: So was Bangkok then the pilot for the rest of the offices?
F: Yes kind of, because in the meantime the limited financial and human resources remained, so consider that I have been working alone on this project for 5 years, supporting the implementation in all the countries, managing the replicas, doing the trainings, it is really a lot of work if you want to make it happen. In some countries we managed to get some support from the IT department, but the IT department is in general very weak in our country offices. In some RBs we have GIS capacity, in Cairo for instance, so we hand over the management of those countries to the RBs, but that is a unique case. In all the other RBs there was not that much GIS capacity. So you can imagine that at the same time we also started talking with ESRI, because having a quite advanced use case, quite unique in the humanitarian community, we reported our experiences with using the technology to ESRI. All the issues that we had, there were many issues related to the management of replica synchronization procedures, for instance it is not very scalable, so this was very limiting for us. So we ended up having 100 replicas to manage at the HQ. In the long-term, this is not really feasible. When we reported our experiences to ESRI, we encountered some resistance from their side, because at the same time they do not have a lot of customers with the same issue, and they mostly focus on the market, the US market, which provides them more revenues. Despite all the support we have from ESRI on other projects, on this part ESRI is not really keen to improve the technology. So they are moving to a completely different setup using ArcGIS online, that proposed a different use of workflows. Replica synchronization procedure against webservices instead of direct connections, systems to access in ArcGIS desktop, instead of having databases in the countries, putting central nodes in place that you access through virtualized instead of connecting to the database, using a virtual remote desktop connection. So you also move the client of the server, which can be either on a physical server or on the cloud. We are now in the moment where we are kind of transitioning to a new setup, which makes a hybrid use of cloud and on-premises services. It is quite slow because in the meantime, the organization is going through an additional transformation, and it is also strengthening security constraints in the organization. So we are facing some issues in this regard, but we have managed to expand the use of GIS technology a lot in the organization. We brought GIS to the next level, supporting several departments and operations in the

organization, logistics, program planning, communication, IT also in some cases, so the SDI at the HQ and some that are in COs, have been used a lot to build products in support of the response to emergencies for instance. We have standard templates made in ArcGIS desktop and ArcGIS Pro, that point directly to the geodatabase, where we have some layers, like the ones with natural hazard information: earthquakes, tropical cyclones, floods. That is automatically gathered from external sources with python scripts at the HQ and it is automatically disseminated to all the countries where we have implemented the SDI. So these countries have templates in ArcGIS desktop and Pro, that point to the database. When something happens, the GIS officer locally can directly produce a map without struggling with loading data from different sources, and so on. On top of this, we also started building a lot of applications, like dashboards, storymaps, use of GIS analysis to bring different layers of information together and apply some geospatial intelligence.
M: So there is some automation in GIS analysis right now?
F: Yes. So this is more or less what we have done and where we are heading now.
M: And what do you think that the main objective is of the WFP SDI?
F: The main objectives that we have is to basically improve the support that GIS can provide to our operations. This is mostly done in situational awareness. And as we were saying, some intelligence, spatial intelligence to our operations. A typical use case is that there is a cyclone approaching a country, and we are able to identify each warehouse where we have the food, might be on the path of the cyclone, and we need to move the food stock or we need to move staff, so this has been very effective. The SDI has been keen to achieve that.
M: And is the SDI used much, and is there an increase in SDI use over time?
F: It depends on what we mean with the SDI. So if we include all the sets of tools that comes with it, not only the geodatabase but also all the tools we built on top of it, there has been a huge increase in use in the past years. The enterprise database technology itself is mostly used now at the WFP HQ, in RBs and in a few countries where we have the biggest GIS capacity.
M: Okay, and can you tell me a bit more about the users of the SDI?
F: At the HQ, we use it daily. In the enterprise database, we store all the data that we use for mapping purposes. At the same time we have some applications that automatically produce maps, that point to the SDI basically. And some others for advocacy and reporting our operations that are also linked directly with the SDI to have real-time feeds.
M: And who is using the SDI, are there certain types of users you can distinguish?
F: There are different types of users. There are direct users, which is mostly the GIS community in the organization, around 100 people. There are the indirect users, which are those that do not have proper GIS expertise, but are able to use data which is in the SDI, because they use ArcGIS online which is much easier to interact with the data. Many layers in ArcGIS online point to our SDI. And then there is the third group of users which are basically the decision makers in the organization, that use the SDI through the applications that we built for them.
M: Okay, and the development of the SDI, is that focused on a specific kind of user, or does it incorporate all types of users?
F: It is all kind of users.
M: So what I have read is that this is mostly focused on the preparedness in crisis management, is that correct?

F: It depends, because GIS in the organization is managed by 2 different groups. One is within the division of emergencies, so they focus more on emergency response and crisis management. And then there is another one that supports the typical operations of WFP more, like food assistance, for feeding, and others. So in general it is used for both.
M: Okay, clear. What kind of data is available in the SDI? I can imagine that it incorporates a lot.
F: Yes there are thousands of layers, from reference layers, boundaries and settlements, to logistic information, ports, airports, roads, border crossing points, WFP points of interest, offices, warehouses, facilities, refugee camps, natural hazard related information, tropical cyclones, earthquakes, floods, landslides, droughts, and then some other operational information about our beneficiaries, places where we have our activities, and so on.
M: And for the whole SDI, is there a way that the usefulness could be tested, like from the perspective of different users?
F: Well, every 3 years, we have a review of the SDI project. So what we do is assessments with the countries on the SDI use, and get feedback from them. But we have not done any survey or check with the final end users, which are the decision makers, but our proxy that we can use for that is the number of requests that we receive, that keep increasing year by year. So considering now we produce an average of 2000-3000 maps, and on top of that there are hundreds of GIS applications that we build.
M: And do you think that it would benefit the SDI if you would implement some sort of standardized user needs analysis?
F: We do it, it is more than one office with a constant needs analysis. Because together with the SDI project, we are running other projects to build the GIS community in the organization. We maintain the internal social network, in which we constantly get in touch with all the users in the field and in the HQ, to have them share their experience and ask questions, make up requests and others. So there has not been a formal needs analysis with the decision makers recently, the last one was in 2016 when we did the first review of the project. But I think we have a quite clear understanding of what is needed in the organization, a needs analysis would be needed, but the main the problem that we have in the organization is that there are many requests going to countries and going to the users for different reasons. To request information for operations. So recently, we tend to contact other people in the organization as little as possible, with surveys and asking questions, because they are really bothered. That is done extensively in the organization for other means.
M: Okay, so mostly the feedback is through informal communication if I understood correctly?
F: Yes!
M: Clear. So you told me that there were some formal moments of feedback, can you tell me a bit about how that goes?
F: A standard review goes through the RBs mostly. Every 3 years, we have to renew the enterprise license agreement we have with ESRI. So we take that opportunity to do a kind of assessment of the use that is done on both on our project, so SDI and others, as well as of the licenses that we provide to our colleagues, ArcGIS desktop server and others. So what we do is we send to our RBs, a set of questions that they have to answer, to the countries, in order to then collect this information, gather it, aggregate it and share it with

us. We use that information to create a report for ESRI, and to then modify and align our projects.
M: And do you have an example of the questions that are shared?
F: Yes, I will share it with you.
M: So I guess you could say that the users do have an influence on the development of the SDI?
F: Yes, correct. Recently we are putting less effort in the use of enterprise databases in countries, in COs and RBs, and more in the online tools. So we are transitioning from supporting the COs and installing their own geodatabases, with Postgres and the enterprise system, to using basically a file geodatabase, where they store all the information, and then the use of ArcGIS Online or GeoNode, to produce online map products.
M: So what I found in my research is that there is not much literature about the link between SDI, especially SDI assessment, and crisis management. So there is literature about SDI assessment not related to crisis management, and I try to link that with this field by the case study of the WFP SDI, where SDI assessment will be viewed from the perspective of the decision maker. What they mostly do in conventional SDI assessment is create certain indicators where users can assign a score, for instance by using a questionnaire. Do you think that such a formal assessment could be useful for the WFP SDI?
F: I believe that the main issue is that there is very little awareness of the importance of the SDI, more on the other products that have more visibility for end-users. This is also why there is little feedback and literature, because usually our decision maker does not even know what an SDI is. And that is an issue that we also have within the organization. Because our managers do not really know and do not really understand that an application that we built for them, is only the tip of the iceberg, there is much more required to update information, have real-time systems and so on. If you go to the end-user and ask: is an SDI useful for you? Then they will say: no. Because they do not even know what it is.
M: So you say that the lack of spatial awareness and the lack of knowledge of SDI makes it difficult for assessment?
F: Yes. I also think that the name itself does not help. The term SDI is too technical. You know what I mean? As a community of practitioners we should find an alternative way to make it more sexy.
M: Yes and the technical stuff is only a part of an SDI of course.
F: Yes exactly.
M: How do you think that those users, that lack the awareness, could be approached for assessment of their needs?
F: First of all I believe that the SDI is behind all the work that has been done in GIS in general. In any form, an SDI -also a file geodatabase can be considered as kind of an SDI- instead of putting the emphasis on the technology itself, I would ask the end-users how GIS, how geographic information, how locations, are helping them performing their job better. And all the answers we will get, in my opinion will automatically reflect on the SDI. Then it depends a lot on the audience you target. If you target end-users, decision makers, that is the way to phrase the question. So if you then ask the same questions to people like me, people that have much more technical background, you can go more in depth and have more precise questions.

M: So you would think that if you would do such an analysis, you would do that differently for different kind of users?
F: Yes. So the first question I would ask is whether their organization has a GIS team. Then, go to the GIS team and ask if they use the SDI somehow, and then all the questions that you will ask to the end-users about the use of the products, GIS products, automatically created by the SDI.
M: And if you would do such an analysis, for different groups, how could the end-users actually benefit from the analysis? So let us say that they cooperate in an interview or by a questionnaire, how can you make sure that it is actually beneficial for them to cooperate?
F: At first, user needs analysis helps end-users to have more awareness in general. So what is available? What can be done? And also to report what their requirement are in general, that are not strictly related to GIS, but a GIS expert can then find ways to use GIS to answer those questions. So our user needs analysis would help the end-users to get more advantage on the use of GIS, to respond to problem that they have in performing their job.
M: If you address the user needs, the people responsible for SDI and GIS development have to do something with it.
F: Yes, that is why the user needs analysis must be a part of the broader GIS strategy of the organization. Which goes through constant review of the projects, according to the results of the user needs analysis.
M: Because I can imagine that some sort of feedback loop is required to test if the needs of the users have been incorporated in development and is beneficial for them?
F: Yes.
M: So how do you think that such a feedback loop could work in this case?
F: I believe that if we do a user needs analysis in the organization, you will get different results. There is still a huge part of the organization that does not know what GIS in general means, they need GIS for the static maps they receive for use in the meeting. So they see the value of those maps, the feedback will be positive, but they will not be able to provide a lot of feedback to prove it because there is not the knowledge about what GIS can provide at the moment. So there is another group of users that are being more exposed to GIS, also at the decision making level, for instance people working in the logistics department or people dealing with the emergency and emergency response, or with climate change for instance, those are more aware of what GIS can provide. Apart from reporting good feedback about GIS in general, they are also able to provide constructive feedback on how to improve things that are done at the moment. And then there is the other group of GIS experts, that also have the knowledge to tell you: okay this makes sense in this organization for this reason, or if it is not really feasible, or if there is a lack of resources to implement it. So they report typical examples of the organization. The organization is going through a digital transformation, and they believe that Tableau will resolve all their issues, I do not know if you are aware with Tableau?
M: Yes I have used it a couple of times yes.
F: Okay, so they believe that that is the solution for all of their problems, because they do not have the knowledge of GIS analysis for instance, spatial intelligence. So for them, GIS is at the moment mostly used for reporting. In that case Tableau is enough, because it allows the creation of global maps by countries, country maps with administrative boundaries. But Tableau is not enough to aggregate different layers, derive other

information and apply intelligence to the data, data science basically, to the geographic component. That is one of the biggest issues I personally have in the organization at the moment. So I have been responsible to improve spatial data management in the organization, but also to identify how GIS can provide that added value for the organization to the decision makers. And I struggled a lot to convince people in the IT department for instance, and people in other divisions that are not really involved with the logistics for instance, on what can be done with GIS in order to justify the investment to have a more professional way to use GIS. At February I was at the HQ, first of all I was really busy with many things, so the management of the SDI, several other projects where we were involved, and then never really had the time to stop and say: okay, before proceeding with some project, let us create 1, 2, 3 pilot applications to show the value of GIS in terms of using the spatial intelligence and the spatial component to solve problems. And this is something that I am trying to do now in Panama, where I have time to focus on some specific activities. I think that this would be very beneficial for the future GIS strategy in the organization, to get some buying from the managers.
M: So I like to make another link to my research. I have created a framework to do a user needs analysis, however, this is entirely based on SDI literature not related to crisis management. It has certain indicators to test the usefulness of an SDI. Would you like to comment on that if I send it to you by mail?
F: Unfortunately now I do not have more time, but I can have a look at it later.
M: That is no problem, you do not have to answer straight away of course, I will just send it by mail so you can have a view at it when you have time, if that is okay?
F: Okay then I will provide my feedback by mail.
M: Well thank you very much. It is not a long list, there are about 25 indicators. It is quite compact, because a user needs analysis in this case must not take too much time. So if you could do that, that would be really great. This already was a whole lot of useful information, thank you very much for that.
[Closing]

Appendix E: Interview Andrea Ajmar

April 9, 2020

[Opening]
Mick Visser: so I am doing research on the link between SDI and crisis management. I am using the WFP as a case study. So that is why I asked you for an interview, because I have seen that you have been involved with the WFP SDI. Can you tell me maybe a bit more about your work? Are you still working for ITHACA?
Andrea Ajmar: No I am not anymore involved with ITHACA, but I have strong contact with them anyhow, because I recently moved to Politecnico di Torino, where I am a researcher. But I have been in ITHACA since the beginning of ITHACA, so since 2006. It is a non-profit association that was born in the framework of an agreement with WFP. And one of the major tasks that had to be accomplished is to develop a solution for the SDI. We were mostly in contact with the emergency preparedness and response unit, but I am not sure if that exists anymore, or maybe it has changed name, it is a very dynamic environment. In generally the UN environment, especially of WFP. The issue there is that they are present in more than 80 countries around the world, with country offices and local offices, and all these offices have both users of geographic information produced on the HQ level, but they also generating information or harvesting information from local governments, local institutions, local NGOs etc. Therefore there was a real need of looking for an efficient way for sharing data. At the time, especially at the beginning, it was clearly that the most used software for geographic data was ESRI. So we focused initially to develop something compatible to this kind of infrastructure because that was the most used. Therefore we structured both the geodatabase to manage the information and both ways of synchronization and replica management at various levels, with hierarchical organizations, HQ as the main spot, then they have the RB, and then the national offices. This was organized in order to allow two-way communication and exchange of data in an efficient way, considering also the problems with connection and allowing offline synchronization, even physically exchanging data on media etc. So we considered various different aspects. Then at a certain point, more or less around 2010, there was a big push within WFP to use an open-source solution, because they realized that there were issues with licenses, especially in local offices, and also competencies of using complex environments could be critical, therefore they started contributing a lot in the development of GeoNode as a platform of sharing data. And obviously connected to that the exploitation with open-source desktop GIS such as QGIS. At a certain point we also started developing a mixed architecture were we had a common physical database that was accessed by both closed software and open-source software. So one physical database where ESRI software could be used to access the database and perform the most complex analysis, but at the same time information of this data is also published and shared on GeoNode and accessible on open-source software. This solution has been implemented with ITHACA support at the Bangkok RB, the RB that controls SE-Asian offices, and all the countries that are connected to the Bangkok RB, through physical training and also missions for the installation. I know that is has been installed also in the Cairo RB, but ITHACA was not heavily involved.

M: So the case of Bangkok was some sort of pilot? And the rest followed?
A: Exactly, the SE-Asia situation was used as a test site, a pilot. But I am not really aware of the current situation, but the last update I can give to you is from around 2015/2016, after that I have no knowledge of the current situation at WFP.
M: That is no problem, I also speak to some people from WFP as well so they could give me updates on the recent years.
A: Ah, it would be really interesting to have some updated information, so please let me know!
M: Yes, I will do that.
A: So this is more or less the overall situation, if you want some more specific details there are a couple of publications, especially on the last part of the changes in the architecture to the open-source solution.
M: So you said that one of the objectives was to improve data sharing from different levels in both ways, do you think that that is considered as the main objective of the WFP SDI?
A: It was for sure the driver of all the activity, it was the initial request of WFP. Obviously the request came from the HQ so it was more related to the fact that they wanted to collect data from the COs, but then they also realized that it was an important issue also for the COs to get information from the HQ especially during emergencies. So they really needed to have an updated situation from the HQ in order to efficiently manage the situation. So yes, for sure this was the driver. The second driver was a sort of unification of the platform used by other units, because there was also the vulnerability assessment, the mapping unit, that was using a lot of GIS systems for their activity. There was also the logistic unit that has a lot to do with logistics, and at that time there were the classical issues of not really sufficient communication among the units and not beneficial sharing of the data. That was partially achieved during the project, but that was not the main scope, the activity was really driven by the emergency preparedness and response unit. The other units were involved but with less engagement.
M: So the focus is mainly on the disaster response unit?
A: Yes.
M: And has the SDI environment been tested in terms of usefulness for the disaster responders?
A: No, there were no formal benchmarks to test this. There was a clear interest during the trainings, I have got some informal feedback from the users of the system, but it is clearly not homogeneous, so that is a lot related to the actual person using the system. Some people are more willing to participate in this sort of collaborative activities, and some people less because it involves many updates in day-to-day work. But in general I have no formal feedback systems for usefulness, but there were places, people, that were highly involved and contributed. But I do not have any figures or formal statements on this.
M: So regarding the feedback, it is mostly through informal communication?
A: Exactly.
M: OK, because that is something I try to do in my research, as there is no literature on assessing usefulness of a crisis management SDI. So what I have read, is that normal SDIs are mostly assessed through certain indicators that together give a view of usefulness, then a user can give certain scores to these indicators. Do you think that such a method can be applied to crisis management, to get the view of users, the crisis managers?

A: Okay so there is another service in which I was involved when working with ITHACA. That is the Copernicus emergency management service rapid mapping, which is a service that generates crisis layers in the aftermath of major events. This could be considered as another SDI, as it has data provided in standard formats and through standard channels to the actual users, that are normally civil protection officers. This is more formalized because at the end of each single activation, the users are required to fill in a form, with satisfaction, and criticality in using the service, so other aspects and not specifically the access to the data, but it does include the access to the data, and also JOC, that is the institution that manages the service that organizes yearly meetings with all the users, where again they are trying to collect criticalities and strong points of the service. So somehow it is the way to have some sort of feedback of the users, in terms of accessing relevant geographic information during crises. I am not sure if all that data is public. So, WFP was more of an informal activity, this one is much more formal, so maybe there is also more formal information about the usability of the service.
M: All right, that makes sense. Do you think that you must also approach different users differently? Like more basic and more advanced users, or perhaps another way to categorize users?
A: Different users may have different needs in an approach about the SDI. This is for sure yes. This is very clear, also it was evident both in the experience with the WFP SDI and also with the Copernicus emergency service, so it's very clear that different competencies and knowledge of GIS systems bring to the different necessities of various data in various formats. This is very clear. Then, with my experience with the WFP SDI, most of the users were GIS analysts, with competencies of using geodata. For example with the Copernicus service, it was not said that they had that, in most cases they were civil protection authorities, for that reason for example the results of the Copernicus service are both provided in terms of vector data and ready to print maps. It was assumed that there were some users that really need the final product ready to use, and not basic GIS data to assemble and for further analysis. So maybe also statistics, total numbers of people affected, total number of disrupted roads etc.
M: Okay. How do you think that SDI user needs could be addressed, what do you think is the best method for that?
A: You mean during an emergency?
M: Well not specifically during the emergency itself, however, relating to the emergency period. So it could be both during and after an event.
A: As we mentioned, we may have very different users, so we have to provide different levels of products. An efficient system, the SDI in this case, should be able to provide both basic data and final products. You should consider the issues specifically related to the emergency. Be able to provide data in a critical situation with low connectivity, those are very critical aspects. There is for sure increased interest in accessing the information through web applications. So this is also another aspect that is more and more relevant and tries to replace some of the products, producing parallel to ready to print products. An efficient web application makes use of most up to date data. For the final users in this kind of field, especially during responses, also the timing and the delivery of the data is important. Imagine for example very fast changing situations such as fires, it's really critical to have a high rate of updates of the data.

M: So it is one of the most important things for a crisis manager, that the data is up to date?
A: Yes exactly.
M: Do you think that it is more important than the quality of the data itself, especially in the earlier phases?
A: Yes, yes, exactly.
M: So you do think that the competencies of SDI users should be taken into account when addressing user needs?
A: Yes for sure. Based on that you can give priorities or target certain products more against others. If all your users have GIS capabilities, you might skip more high-level, ready, products, because you can imagine that an advanced user can produce them easily and tailor it to their needs. For sure this assessment of the level of competencies of the users is something that has to be done as a first step, especially because it may allow you to reduce the resources spent to the assessment, and skip things that are not really needed, because the users for instance might prefer to realize the product by themselves.
M: Yes, understood. So what I did in my research so far, is creating some sort of framework which is based on SDI literature about SDI assessment. This literature is not specified to crisis management, but has certain indicators that as a whole create a view of the usefulness of the SDI, from a user's perspective. So maybe we could go over this framework and discuss the indicators?
A: Yes!
M: Okay, so in this framework, it is the first step, for users, to describe the datasets that they require the most, and then there are some indicators related to each dataset. After that, also indicators for the SDI as the whole system, so not really dataset-specific but the whole system around the datasets. So I have the indicators here, and the first of the data-specific indicators is about finding the dataset. The first indicator is whether the required dataset is recognizable. And also whether this dataset is findable.
A: Yes, that makes sense to me.
M: All right, and then is the category of attainable. So first, that the dataset is practically available, so that there is actually data and not only metadata for instance.
A: Yes, yes.
M: And also another point, do you know if the data in the WFP SDI is free to use?
A: Not all the data, so basically the information is a mix of public domain datasets and datasets generated by WFP. Among the datasets generated by WFP there is data that can be shared with the public, and data that is confidential and is managed only by WFP. So they have to manage the level of confidentiality of the data. For instance food distribution, they have to stock food which is critical information especially in certain environments, it should not be in the public domain. So there is a mix of public and confidential data.
M: And is there a way for other organizations to access or perhaps buy the confidential data, with legal restrictions?
A: In my experience with WFP, no. If it is not public, it is really confidential.
M: So that is also related to another indicator, that the required dataset is affordable, but I suppose that this is not the case for people inside of WFP, and not relevant for people outside of WFP if I am correct?
A: Yes, exactly.

M: Another indicator is that the data could be acquired in time, and I think that that is related to your comments about that time is very important in acquiring data.
A: Yes, this is especially important during the response phase yes, in other phases maybe not so much. Users would accept limited lower quality of the data in exchange for timeliness.
M: All right. And another one: whether there are legal restrictions that have a negative impact on using the data. Is that applicable for the data in WFP SDI?
A: I am not sure, most probably data that is used should be cited. But I am not really aware of the current policies of data they are producing. For sure they have a policy but I imagine that it is the classical policy of open access data with some sort of open license.
M: Okay. And another: whether the dataset is distributed in a sufficient format or service. I think this might also be dependent on the level of GIS competencies as you mentioned, that some people require static final products instead of vector data, correct?
A: Exactly. As far as I know, WFP is very much engaged in producing very nice and complete maps including infographics and so on. But at the same time, they are also delivering raw data for expert users. It could be very relevant to talk to them and understand which kind of user requirements they have for this point.
M: All right. And also still related to the data: whether datasets are manageable and reliable. Do you think that it is relevant or important in this case?
A: It depends. In some cases I have the feeling that users can sacrifice a little bit of data quality for the availability and timeliness. Nevertheless, this kind of information that you are mentioning so far should be included in the metadata. So another big aspect is that all the information produced which is shared, should be coupled with updated metadata, standardized metadata. The WFP GeoNode is also aiming to do that, so I am sure that everything produced and shared is also well documented.
M: Okay, clear. And another indicator is whether the dataset is available on a long-term, so sustainable availability. Do you think that it also applies to these cases, or perhaps less important because it is a dynamic environment?
A: No I think it is relevant. Because normally the data that you produce during an emergency is then used for recovery or other further risk analysis. So the persistency of those datasets, the availability of that data during time is generally speaking, for the risk and emergency management, very important still.
M: Okay. And the last ones about the datasets: is whether there is clear metadata, and clear support for using the data. Do you know if there is a certain connection between data suppliers and data users in the SDI?
A: I would say that the tendency is to have reliable metadata and reliable system for distributing the data, and minimizing the possible physical interaction between the users and suppliers. In my opinion it is better to invest in the first two components: be sure that metadata is well filled and available, and that the systems are reliable. More than having contact with someone that manages the data, it is not really important if the two components are sufficiently developed.
M: So the other indicators are more focused on the SDI as a whole. So the first category is the use process of SDI use. The first indicator is a score for whether the SDI gives access to more sources of information. I could imagine that in essence this is true of course, but maybe it is perceived in different levels?

A: So your question is that the users has the perception that the SDI increases the availability of the data? In general terms I would say the SDI is considered for that so you could expect that that is something that is completely true. There is of course a big difference between for instance FTP sites and SDIs, so I would say that the perception of increased data sources is always true.
M: Okay. So the next one is that the SDI improves the data management of the user, the crisis manager.
A: Yes I think that this is about the same story as the previous one, it can be assumed that it improves.
M: Okay, that makes sense yes. So the next one: whether the SDI shortens decision making time for the user.
A: That is a very good question. In my opinion, if you ask this, you may get interesting answers on this. It may also add some complexity in the workflows, maybe, someone could perceive a more complex environment that is less efficient. But this is really a question where you could have very different answers according to different persons you ask it to.
M: So this framework is built on the idea of assigning scores to indicators, do you maybe think that more important questions, like this one, should be open questions?
A: Well, yes, at least if you make a closed question, couple this question with some sort of description, where users can say why they consider yes or no.
M: All right, good one. And also another indicator: whether the SDI creates independence in decision making.
A: Well, it is most probably not the SDI itself, or alone, but you should couple the SDI with specific competencies. So again, the SDI is a mix of physical architecture and human behavior, so for sure you cannot be efficient with having just one of the two components.
M: Okay. And then another: whether the SDI improves the quality of decision making.
A: For sure the efficiency in my opinion, the quality derives from the efficiency.
M: And also whether the SDI increases the use of spatial data.
A: This is also related to the goals of an SDI, so in my opinion this is most probably always true.
M: All right. And then other indicators more focused on the governance: whether the support regarding the SDI use is clear and sufficient.
A: Yes this is really important. In my knowledge this is very different country to country, for example in Europe we have the INSIPRE directive that is a strong push of central governments to the implementation of this kind of solutions, I am not sure if for other countries this is the same. But it is a critical part, because it is true that an SDI should be built with a bottom-up approach, so considering the users as the first source of specification, but it is nevertheless a central architecture so some authorities that then are in charge of promoting descriptions and support is very important. And that is more or less the same in the case of WFP, so the WFP is the central authority and the initiative was started by the HQ and not by the COs or RBs.
M: So the initial development was not bottom-up?
A: Yes. The initiation of the process was top-down, and then the realization in terms of needs must be bottom-up.
M: All right. So another point is, something we discussed briefly earlier, whether the SDI stimulates and supports communication from suppliers to users, but as you said that is maybe less relevant for this case?

A: Yes, again more or less what we have mentioned earlier, yes.
M: Okay. And also: whether the organization behind the SDI, so in this case WFP, stimulates use of the SDI.
A: Yes this is important again, an issue related to the promotion and coordination. The central authority that started the initiative is also responsible for providing documentation, training and so on. So basically stimulating the usage.
M: Okay. And another one is, this is more relevant for developers to answer as the users might not be aware, but: whether there is long-term financing for the SDI.
A: Of course this is very relevant, but it is as you say not up to the user to give an answer to this. But the long-term availability of the initiative is a very critical point.
M: Okay, that might also be the case for the next one then: whether there is a shared vision of SDI development among the organization.
A: Yes, true, but also very important.
M: Yes, and the last one: whether the SDI increases cooperation in the organization, this could be both for WFP itself but also users of other organizations.
A: In my opinion this is very relevant, for example in the case of WFP, the community of users of the data does not only include WFP staff, but also NGOs and so on. This should be an objective with the implementation of this kind of infrastructure.
M: So you would say both within the organization and among other organizations?
A: Yes.
M: And whether the SDI stimulates development, do you think that that is relevant for the case of the WFP SDI?
A: Yes, in my opinion yes.
M: And the actual last one: whether the SDI presents new communication and distribution channels for the organization.
A: This is in my opinion also quite true, open possibilities to have new ways of communicating. There is innovation also in that field.
M: And do you maybe have some points for SDI assessment that I did not mention but are relevant?
A: No in my opinion, what we have discussed so far is complete.
M: And do you think that such a framework, if it theoretically speaking has been used by WFP, do you think that that helps developing the SDI in favor of the user and how can they do that?
A: That really depends on the users. In the case of WFP SDI the users are mainly their own WFP staff, so addressing their needs is a way of improving efficiency directly, of the organization. Most probably, WFP would be highly interested in addressing the request of the users. With requests that are coming from users outside of the organization, that really depends. It is not an infrastructure developed to make profits, so there is more interest in testing the internal efficiency and less interest in requirements from outside.
M: So that was about it, those were all my questions. This was really a lot of information, useful information, so thank you very much.
A: Well I am very much interested also in some results and further information, so if it's possible I would like to keep in touch with you and the progress of your activities.
[Closing]

Appendix F: Interview Ali Mansourian

April 17, 2020

Interview Ali Mansourian
[Opening]
Mick Visser: I do a research for my thesis on SDI for crisis management after natural disasters, as I wanted to combine my GIMA study with my interest in natural disasters. So this is my research topic, I do this under supervision of Bastiaan van Loenen. So what I have seen in literature, the link between SDI and crisis management, is that most of the research was quite a while ago, and after that period of like 10 years ago, not much can be found on this topic. Do you have an idea why it seems not such a hot topic as some time ago?
Ali Mansourian: The issue is that SDI itself is not a hot topic these days, maybe you have heard from Bastiaan, there are many issues with SDI frameworks or SDI as it was defined 15-20 years ago. It was not really successful, the problem was in the hand of governments, it could produce and share the data, but the government did not want to do it, to really share the data, because they are paying for the data and also in many cases, the data are not really reliable and accurate so they do not want to share it, not wanting to show they have produced data with errors. But there are also many other issues, more specifically INSPIRE in Europe. The organization behind this became too heavy, lots of bureaucracy. Such issues actually impede the development and successful implementation of SDI. And when you do not have a successful SDI, then you cannot apply it in other domains, including disaster management. That is why, I think, research in that area has stopped. In line with that, which is what I also discussed with Bastiaan, maybe it is time to revise the definition of SDI and try to open some new gates, some new doors in SDI to create a space for growth of SDI. Then we came up with this idea of open SDI initiative that Bastiaan had worked with it before. We have received some EU fund for it, to research more seriously and have more focus on this topic. So maybe open SDI is an opening for the SDI topic to grow up again and then its applications in other areas such as disaster management will show up and become interesting. But related to disaster management and SDI, if we look at SDI from technical and non-technical perspectives, the story I said to you were mainly focusing on non-technical issues of SDI, the cultural and organizational infrastructure needed for data-sharing in disaster management, this part is not successful. But the technical infrastructure and technical solutions, that is a topic, an area, that is still progressing and you can see publications even linked to disaster management for that. For example how you can use automatic web-service composition to facilitate disaster management planning. I had a PhD student who has published 3 papers on this and 1 publication, which was in 2018, how you can use the semantic web to facilitate integration and harmonization of data, coming from different sources, to be useful for disaster management. That is a topic which is also related to SDI, that is data harmonization, but mainly technical focus. So you can say that research on technical aspects of SDI is still ongoing and you can see publications on that. But the issue is that you cannot use those technical solutions in practice because organizations, government organizations, are not

willing to share the data. So if they do not share the data, there is no platform to implement these technical solutions on.
M: Okay yes that makes sense. So I will shortly tell a bit about my research. My main focus is on disaster management in the humanitarian domain, on a large scale like for instance after big earthquakes and hurricanes. I have used the SDI of the WFP as a case study, this organization is a UN organization with their own geoportal and SDI structure behind it. They create data themselves, they take data from other places and all share it on their SDI, they have quite a developed system for facilitating data and information for crisis managers, both in the field and in offices. So what I wanted to ask is: what is the difference between SDIs specifically used for crisis management as opposed more conventional SDIs? Also relating to the objectives.
A: One big difference between an SDI for disaster management and conventional SDI, is the role of time, and the data that you have to produce in a short period of time, which is the disaster response period. I would say that is one of the differences, if you want to focus on disaster responses. Another difference is that when you are talking about conventional SDIs, the data framework that you define is focusing on general needs for planning and decision-making, not a specific application. Or if you consider INSPIRE, which is an SDI to facilitate environmental management in Europe. So the data framework that they have defined is mainly environmental related data. When you want to use the SDI for disaster management, such as volcano eruption, earthquake etc., you need other types of data that needs to be produced and shared for all phases of disaster management: mitigation, preparation, response and recovery phases. So the datasets that you define, I think that is one of the most important issues or differences. The role of time is very important, because during the disaster response phase, you need a huge amount of data quickly and also share it and integrate it with other data, and then analyze is and use it. But in conventional SDI you do not have that time constraint, maybe you have one year time to produce or update a map of the city. But after an earthquake, you have maybe 2 days, maximum, to update the data for the city. So that is an important issue. And this time influences many other things, including for example communication networks that you need to actually communicate the data and share the data immediately with emergency operation centers and planners. And also during disaster response, the role of people, or VGI, is also much higher than normal SDIs. Maybe in normal SDIs you do not use VGI data, for example in the Netherlands people are not allowed to upload their data to geoportals. Or in Sweden it has not been decided at all if companies can upload the data, so VGI data is at a lower level. But in disaster management, if people can update information of a disaster, for example buildings that have been destroyed, these people are in problem, this area is burning, it is very useful information that should been included. So these are special criteria that need a new conceptual model for SDI for disaster management, in comparison to normal SDIs.
M: Okay, and if anyone can upload data, if VGI is heavily incorporated in an SDI, does that not give an overwhelming amount of data?
A: Yes, there is a risk, but I do not say that we should cross this opportunity because of the possible issues. Actually, it could be something to study, a research gap, to consider and define the problem, and then find solutions for that. Of course when you give the possibility to people to upload the data, one advantage is that you get real-time data that has been updated by citizens, but you might face several problems like the one you

mentioned. For example many people may report similar or same type of issues in an area, or you may receive a huge amount of data that the management of the data is difficult. But there are solutions for that, for example you can use some algorithms that can filter the data, or for instance artificial intelligence, and reports may be aggregated. And also you can use big data processing capability to handle a huge amount of data which are coming in. You have to find technical solutions to solve the issue, but I do not believe that we should cross the option.
M: So you would say that research gaps and then solutions have to be found?
A: Yes.
M: All right. So what I did for my research is trying to view crisis management SDI from a user's perspective, so decision-makers during crises, and how to assess the SDI from the perspective of these end-users. How would you say that users of these SDIs differ from conventional SDIs?
A: If you look at the structure of disaster management, there are governmental organizations who are doing their normal work during daily activities, and then in emergency management. They become activated to work quicker and harder to manage the disaster. A large part of the stakeholders who are involved in disaster management are those organizations who are doing normal work during daily days. So we have the same users in disaster management as in daily activities on normal days. And also on top of these governmental organizations, you will have NGO's, such as Red Cross, which will become activated, or some group of people, citizens, who become activated to give health support to disaster responses. So if you want to have a look at the organizational perspective, users of the data are the same, but in normal situations, you use this data for daily planning, activities, long-term planning, if you consider for example a city as a case study. In normal days you have the municipality, you have the water organization, you have the electricity organization, they are managing the city in a normal situation. But when a disaster hits, then they work harder and they need more coordination to manage the disaster, and shift from response phase to recovery phase, to save the city. So you have the same user groups, but they need to work harder and faster, and also they need to work with new types of data. This new types of data are damages, malfunctioning systems, which has happened in a larger scale, and they have to manage it very quickly. So if I understand your question correctly, you have the same type of users, but they need a different kind of data and they need to be faster and more clever to be able to manage disaster. And of course, in a disaster situation, you also need some rules and regulations, if you consider the policy component of SDI, that facilitates the data sharing of organizations in an efficient way. In normal situations, in order to get the data, there may be an mechanism that you send a request to an organization, and then the organization has the right to review your request for example in 2 days, and then give you an answer if you can get the data or not, and if you cannot get the data they have to justify why, otherwise they have to share the data to you. But such a mechanism, which is very efficient in daily works, if you can get the data in 2 days, that is very good. But it does not work in an emergency situation, you cannot wait 2 days, you need the data immediately. So what types of policies you should watch, what type of organizational arrangements do we need. We have the same actors, we have the same organizations, but you need another type of regulations and rules.

M: That is clear, yes. And how would you think that you could address the user needs in such a situation, the situation of the response and recovery phase?
A: If you look at my paper, and also my thesis, I have discussed it there. First you have to classify your users, like I said, some part of the users are companies or organizations that are doing daily works, and then you have NGO's, and also you have volunteer communities. They need different types of data. The type of the data that they need actually differs in different disasters. If you have flooding, the type of damages, the type of disaster is different with for example an earthquake. The needs have to be assessed case by case, based on different disasters. And also based on the role that an organization plays in that disaster.
M: So the objectives of each organization, for each disaster, have to be taken into account?
A: Yes, definitely.
M: And do you think that a user needs analysis, after a disaster, could be done by a questionnaire or interviews?
A: So you have experienced the disaster and then you want to know what their needs are?
M: Yes.
A: Yes, of course. A questionnaire could be an approach, but I always also prefer interviews, because when you interview people, they start telling the stories where you can extract a lot of information from those stories. You cannot receive that information by just asking certain questions in a questionnaire. So I prefer to interview at least 20 persons of the people who have been heavily involved in disaster management, and also I prefer to interview people at all levels. You have some people that stay in an emergency operation center, their task is planning, some people are heading each organization or group, they receive comments from emergency operation centers and then they have to implement the plans, and some people are in the field, operational people. So you have different types of people with different responsibilities and different experiences and also different types of data needs. So if I want to do that, I prefer to interview key people in all these categories. When you want to collect experiences for disaster management, you need the experiences, you need to listen to stories, so you have to interview people.
M: And how would you think that information from those interviews could be used for further development of an SDI?
A: When you interview people, that is an art, to direct your interview. If you tell them "just tell me the story", they may start talk nonsense for days, you get nothing out of it. But if you start to manage your interview, I do it like that, I create a questionnaire for myself and I put some, maybe 5, questions on it to ask from the persons and also give space for myself and to them to tell stories linked to those questions. For example one question could be "how did you manage the disaster? Can you give me some general view?" And then he starts to tell some general experiences, then you have to be clever and pick those points that are data related or data need related, and ask more specific questions linked to data. But give space to let them tell the stories. Based on this, you always need to be clever to extract some more questions, get the mental orientation of that person, how he thinks, what he understands, what he needs, and based on that, you ask more specific questions related to data. For example: what type of information was good, if he had access to it, in which form did he need to get this information, could he get the information easily or not, if no, what type of problems etc. So if you start asking these types of questions more specific later, this is what you need to design your SDI. A data-sharing issue, you need to know

about that and you can realize if it had been an organizational issue or if has been a technical issue, and what type of issue it is, then you start working on that and then give solutions for that. With what type of data they need, and based on those needs, you can start to complete or curate your data framework. Or in terms of access networks, did they have any web-GIS system, did they have any geoportal, were they using local systems or not, what problems with communication systems they had, and based on them, you can curate your access network component of your SDI. So of course, based on interviews, which is a mixture of general stories you listen to and the specific questions you ask, then you can improve your SDI framework.
M: So you told that you need to create solutions based on the user's problems or needs..
A: Yes, but I did not actually create solutions in what I did. What I did was revising a conceptual model, so I interviewed people, I created a conceptual model, I created a web-GIS system, and then I was successful enough to establish something for disaster management, and then I could gather and keep layers there. Then they started data sharing and using my system, and then I interviewed them again and listened to their experiences, and then improve my conceptual model. So if you look at my conceptual model, which is 15 years old today, it introduces different places that need more research or different aspects that are already solutions for them, and then I have suggested to have those solutions, and different suggestions on how it can be solved. So my conceptual model does not give a solution from a user perspective, it is just bringing up those aspects that need to be considered.
M: So you mean that there is a feedback loop required to re-assess the user needs?
A: Yes, for sure. It is always needed, SDI is a dynamic thing so you always need to communicate with the users and get feedback to improve your SDI.
M: All right. So what I did in my research is that I have looked into some user-centric SDI assessment frameworks, and I am looking at whether those frameworks, which have indicators for usefulness, could be applied in the context of disaster management SDI. So is it an idea to discuss the indicators that I found?
A: Yes.
M: Those indicators are of course based on the conventional SDI context, but it might be different for SDI use in crisis management. As you mentioned, it is of course important to get to know what the required datasets are that the users require.
A: Yes.
M: And with these indicators, users could give scores to them, for example on a 5-point scale, to get a view of the current state of the SDI. Would you say that that is useful for assessing user needs?
A: How do they give the score, do they give a score for each dataset or in general?
M: Well, in fact, both. At first for required datasets, but also about the SDI in general.
A: So you give them a list, you want them to score 1 to 5 on the whole list?
M: Yes and some of them are also more specified to the SDI as a whole, the concept, which is not directly pointing to certain datasets. For example how a geoportal is used. But for their most required datasets, for each of the dataset, they could then assign scores to the indicators.
A: Okay, I think that if they do it for each dataset, then you can analyze it better. But if you have a list of for example 100 datasets, and then they give you a score 3, then what does it mean? Was it dataset number 1, or database number 15? You cannot understand

the answers, so it will be useless. But when they start to give the scores to the indicators for each dataset individually, then you can interpret it to the level of importance of that dataset, for that specific user.
M: So that is related to the stories that you like to hear in interviews, where you can extract information requirements.
A: Yes, I think so.
M: So for each dataset there are some indicators. The first ones are that the dataset is recognizable and findable, within the SDI. So would you think that makes sense?
A: Yes, yes.
M: And then that the data is practically available. For instance: sometimes you will see that data seems there because there is metadata available, but there is no viewing service or download link.
A: Yes, if the data itself is not there you cannot get it, this is relevant.
M: And that the data is affordable, in terms of costs.
A: Yes, yes.
M: And that data is required in time. You have already mentioned that time is a very important factor in crisis management.
A: Yes exactly.
M: And then: legal restrictions of data use.
A: Also, yes.
M: And that data is distributed in the sufficient format or service.
A: What do you mean with that?
M: For instance that some dataset is shared by WMS, but you need to do analysis on it and actually require shapefiles or WFS.
A: Of course, that is relevant yes. But based on the example of that, is it not related to the other indicator, if it is practically available? I mean, if the data is there and if it is published by WFS, but not in practice. I think that there is an overlap between these two questions.
M: All right, yes, they might be combined into 1 indicator then I suppose, that the lowest score means that it is not available and that the higher score means available in the required format or service.
A: Yes.
M: Okay. And then: that the dataset is manageable and reliable. So that might also be linked to the completeness of the metadata.
A: Yes. Do you also consider accuracy etc. as reliability?
M: Well, I have the indicator of "spatial data quality", which goes into the spatial qualities of the data and not the metadata.
A: So you have separated them, that is fine, yes.
M: And that the dataset has a long-term availability, so sustainability.
A: For some data you will need long-term availability, but maybe for some of them you do not need it. For example extent of a flood, I do not know whether you need long-term availability or not. Or information of burnings, why do you need this information forever? This building have been destructed, but it has been reconstructed in the recovery phase. Just think about it. Maybe for conventional SDI this is needed, but for disaster management, think about it. Maybe some datasets, maybe some not. But you have to ask

that: do they really need long-term availability, what is the purpose? If that is the need, then it is of course okay.
M: Okay clear, it will of course depend on the situation and crisis then.
A: Yes, that is fine, you can ask that.
M: And then a bit related to this: whether the dataset is up to date.
A: Yes. And to add on that, up to date here is different than up to date in conventional SDIs. In conventional SDIs, if the data is 5 days old, that is still very good, but in disaster management, it is useless. The time sequence needed to update the data is very tight in disaster management, it might be up to 30 minutes for each update.
M: So it might also be good to discuss with the user, to define up to date in that situation?
A: Exactly.
M: Another one is whether there is sufficient communication from the data supplier to the data user. I have discussed this earlier with someone from the WFP, the case study, and this might be more dependent on the type of data in the SDI. In the example of the case study, the WFP collects data from external sources, and they handle the communication with their users. This indicator might be different depending on the SDI.
A: I also think so, yes.
M: And then: that the metadata is clear. I think this is quite related to the reliability of the data.
A: Yes, and also something that is good to think about: how much metadata can we create during disaster management? Imagine that someone is in the field and he is collecting information about victims, burning areas, flooded areas, destroyed buildings, and then for each point he digitizes it and can you expect him to fill in a list of metadata according to ISO19115? I do not think that it will work.
M: And also taking the time pressure into account, this might be difficult.
A: Yes, you should think about it. Maybe you should use other mechanisms to collect some metadata automatically, for example the name of producers can be collected based on the login information and then the time can be collected automatically from the device he is using, accuracy maybe the accuracy of the GPS, so maybe some metadata components can be collected automatically, but you cannot expect the person to fill in a list of metadata.
M: Okay, and do you maybe have other suggestions, relating to the datasets that users need during crises, that I have not mentioned but are important for addressing user needs?
A: I think the list that you mentioned is good, at the moment I do not have anything else to add yeah.
M: So I have also included some indicators that are related to the SDI as a whole, not specified to a single dataset. The first one is: whether the SDI increases access to more sources of information for the user.
A: Yes, well, probably it should.
M: Do you think that it might be useful to ask that to a user?
A: Maybe you can ask how much the SDI that they use is efficient, and satisfies this requirement, maybe that could be a better question. Because in theory, we should know that this should have, but it may not in practice. So maybe you should ask how much they think they have increased efficiency and what they think that are the problems and obstacles. So you gather some information in that respect, listening to the user.
M: All right. The next one is: that the SDI improves data management.

A: If you have this focus on assessing the SDI, then you can ask if it improves it. But you should be clear in which aspects you are thinking about, is it obstacles in terms of regulations, or in terms of network, or user interface, what type of issue are you focusing on?
M: The indicators of SDI use are related to the use of it in the context of the decision making.
A: Well that is very wide actually. You cannot know what answer you will get. Maybe as a final question, orally, you could ask why you think that the SDI is important. Then he could say "it is good, it is bad, it does not work", such information. But if you want to have detailed analysis, you have to break down your SDI components, and then ask more specific questions. If you for instance ask if he has problems with the SDI in terms of policies for data sharing, if that may create problems, if that is yes or no, it will be more meaningful. Is your SDI for example efficient in accessing networks, in terms of bandwidth? Then you can understand the issue. Or: can you use your geoportal as a functional user interface? Then you can understand the issue. A general does not give this information to you.
M: There is no useful input for SDI development if the questions are too general.
A: No, it will not help. Like I said, maybe you could have some last questions as an indicator of overall satisfaction, but it does not give you information to improve the SDI model or whatever.
M: And if you break that down, also asking these questions maybe to people without much GIS knowledge, how would you break that down so user needs of such people can be incorporated and useful for development?
A: If they are using a geoportal, you can ask them geoportal related questions. If they use it, they probably understand the basics and the icon bars etc. Can they find data easily? Can they find the data that they search? So relating to the user interface, you can ask questions about that to non-GIS expert users, that is an important thing. I do not know where is your case study area, but in the Netherlands, you have very good bandwidth to exchange and download the data. But if you do that in Indonesia, I do not know what the situation is. So bandwidth, communication through the infrastructure, that is something you can ask, but with an easier language. For example: can you download information with a good speed? Or: how much data can you download easily in a reasonable time? Maybe this type of questions can give you an insight in the suitability of the IT infrastructure for exchanging data. So I think you should ask these kind of questions, get this kind of data, from non-GIS experts. Then, you can also of course ask data about policies. For example, a non-GIS expert, he understands if he cannot get to the data because of organizational issues. So it is not a very technical question that you cannot ask. But from a non-GIS expert, you cannot ask: what do you think about OGC standards?
M: Yes, clear.
A: You should think about it, and filter your questions for different types of users. SDI experts, non-experts.
M: Would you say that you would break that down to those 2 categories, experts and non-experts, or maybe in other categories as well?
A: Yes.
M: Okay. So another indicator, asking people if the SDI use, or geoportal use, depending on how it is broken down, improves the quality of decision making.

A: Yes, I think it is important to ask these general types of questions. But also break it to 2 or 3 questions. For example: have they been able to integrate the data? Have they been able to make a decision based on the data that they have received? Have they been able to analyze the data that they have received? Make it more specific, and based on them, do your analysis. Like I said, they may be able to get the data, but if they cannot integrate it because of heterogeneity issues, then still the SDI is not helping them to do real disaster management. If you ask the question in general, you do not understand where the bottleneck is. But if you ask some specific questions, you will understand the bottleneck.
M: That is clear. What came up in an earlier interview was that capacity building is very important for SDI use and efficiency. Do you think that also should be broken down for non-experts and experts?
A: Yes I think so, because you need different types of capacity building for both groups. To my experience, your non-GIS expert groups, are those people who are experts in the field, they are more involved in disaster management. They need different kind of capacity building, they need to be trained on how to use GIS, how to integrate the data etc. Then you have the GIS experts, who look at the data but they do not know about disaster management. You also need some disaster management related capacity building for GIS experts. These 2 different capacity building programs can help these 2 groups of people to better understand each other and have better cooperation during disaster management and disaster response.
M: As the SDI of course has the people component, do you think that this also should be included?
A: Yes, that is a good idea.
M: All right, that were the indicators that I have suggested. Do you have any other suggestions as indicators for the SDI in general?
A: No, I think we already discussed what needs to be added or changed. The general comment is: try to break it down into more specific questions, to be able to analyze them and explain something out of it.
M: That is clear. I think that I have a lot of useful information, which is really helpful.
[Closing]

Appendix G: Interview Sisi Zlatanova

April 16, 2020

[Opening]
Mick Visser: What I do with this research is try to combine the SDI literature with disaster management. I have seen that there is not much of recent research on the topic, most of it is from several years ago.
Sisi Zlatanova: Yes, that is true.
M: So I am trying to revive some of the topic from the perspective of current SDIs, like the third generation SDI from the user-perspective. I try to create a framework to assess an SDI from the user-perspective, a crisis managers' perspective, for an SDI that is used in crisis management. I have used the SDI of the WFP as a case study, have you seen this SDI?
S: No I have not seen this one. Is it some kind of dashboard with access to data, or how is it organized?
M: They have an internal SDI structure based on ESRI software, and they also have a geoportal online based on open-source technology, more specified to basic SDI users. For example for crisis managers in the field. This is all synced together and that is in short their SDI structure. So it is not only a dashboard of some sort.
S: Okay. And do they hold the data somewhere, or do they fetch them from all kind of repositories? How is it organized?
M: It is both. Both their own information and data, and from other sources. They also combine it in the SDI to make automated maps, so there is quite a lot going on within the whole SDI structure. According to them, it is one of the most developed in the field of humanitarian crisis management. That is why I used it as a case study.
S: So how does it differ from this dashboard, like what they use now for Covid-19, do they have much more data available?
M: Yes, it is much more data. And it is for many disasters that are going on, where they are involved. They are active in more than 80 countries, and for all these countries they have offices that require information, but also generate information, so it is also for communication between all the offices to the headquarters and in between.
S: Okay.
M: So what I want to ask: do you perhaps know why the topic of SDI for crisis management is not so active anymore in scientific literature? It was quite a hot topic some years ago, but it seems that it is not anymore.
S: I think that it is not because there is no research, but I think they do not call it SDI anymore. This term is somehow not used anymore. I also do not have a very clear information for what the reason of this is. You know, sometimes new terms are popping up now, everybody talks about dashboards, and usually to provide the information on a dashboard, you have to have an SDI, the background. But this term, dashboard, somehow became more 'fashion', and SDI is considered an 'oldish' kind of term. In The Netherlands, when we were working on this SDI, we are still calling it SDI. And what we were developing for the firefighters, and the veiligheidsregio's, it was a system that can combine all the information from different sources, also collect dynamic information during the

crisis, and after that getting everything together and create an operational picture. Somehow, just the term SDI sort of disappeared, although a lot of systems are developed in this direction, with more focus on the interface, and not that much on what is behind the interface.
M: So it is more a product based on the information of the SDI?
S: Exactly, yes. The other thing that probably pushed the SDI a little to the background was that, specifically in Europe, there were a lot of initiatives for building an SDI. INSPIRE is one example. And it works, so the research on SDIs is not that prominent anymore because a lot works now. There is not that much to investigate there.
M: Perhaps you could say that many goals have already been reached in research?
S: Yes, yes.
M: And when we look at SDI initiatives aimed for large-scale disasters, how do you think that SDIs differ from more conventional SDIs?
S: Well, as I said, these terms as dashboards are coming, and internet of things. Anywhere, in addition to the map layers and all the spatial information that is there, is some information from sensors included. Somehow it starts going into the direction of Internet of Things, or dashboards. This term dashboard is now everywhere, even in Covid. This interface of ESRI, they call it a dashboard, while for me, it is just some map with an interface. But it is also used to visualize something else, to visualize graphs, some kind of charts. This already changes the visual representation to dashboards, but what is behind, nobody cares. Behind is the SDI that you have to have. But related to disaster management, it is about disasters, about informing communities, disaster managers, they are not the spatial specialists, they also do not know that this is an SDI. For them it is more important that the interface is right, the product, how it looks.
M: And how do you think that you could make the SDI, including those dashboards, user friendly?
S: Dashboards are already quite user friendly and are going more in this direction. I would say probably building these applications. So if you have the SDI, something between the interface and SDI should be more user friendly. So not only the specialists in spatial data to be able to read, connect and use the SDI, but also all kind of companies and people. Before we were trying to make a lot of applications that use web GIS services, OGC services [WMS and WFS], but now there are all new types of interfaces. You can use JSON and Geo JSON for instance. Again, if you could make this part more user friendly and more standardized, so everybody can access it in a better way, get the information that is needed, this will be in the direction of making the SDI user friendly. Not the end-user, but the people that are developing the applications for the end-users.
M: So you would say there is a level in-between SDI developers and end-users?
S: Yes, data custodians. They need to prepare the data of the SDI for the application.
M: So I suppose that those people need to have contact with end-users for development of those applications?
S: Yes, I think so yes.
M: And how would you think that those end-users could have an influence on the development of applications and indirectly on the SDI?
S: This is a very nice research question. Without the contribution of the end-users, what is needed in the SDI, you may end up with some kind of SDI that nobody uses or understands. So indeed it should be tested with the users, and after that improved. Users

do not care at all about the types of data that are there. You have to go through the users, via the applications, through the users.
M: That is also more or less the topic of my research, because what I did is looking at SDI literature and how SDI could be assessed from a user perspective. I combined some frameworks to address user needs for an SDI, resulting in a framework with indicator to which users can assign scores, to give an indication about the usability. Would you think that such a framework is useful for SDI development?
S: Yes, yes, that is very useful. You have to be careful with indicators. I remember in the beginning of GIMA there were a lot of students evaluating SDIs. And there were also quite a lot of indicators that were already developed, probably you can think of new indicators. That time there were not that many indicators estimating functionality which an application can offer, based on available data. So you can have some data and different applications, and applications develop functionality on top of this data. It is very difficult to estimate the functionality with respect to the available SDI. But some observations can be made, for example if you do not have something in the SDI, you can also not use in it in the application. If the user cannot see it, it cannot be achieved. So what is in the SDI, what can be provided through the application, and whether the user needs it, I think it is important to add these kind of indicators as well. That somehow you can estimate what can be done. Not only what is there, how it is organized, how it is accessible, but also what can be done with this data.
M: So what I did is select some indicators from those researches, and then discuss whether they are useful or not for crisis management. They are from a non-crisis management perspective so there might be differences in approach, it has to be finetuned to be applicable for crisis management.
S: And who are your contacts in the field of crisis management?
M: I do the case study of the World Food Programme, where I have made contact with several key people. Is it an idea to go through these indicators that I have selected?
S: Yes!
M: So it is of course focused on the user, they have to assign scores to indicators. I suppose that scores from 1 to 5 is the most useful in this situation.
S: Yes, it should not be that complex.
M: I have divided it into data specific indicators, the data that users require, and indicators that relate more to the SDI in general. So for the data specific indicators, I have divided it into the categories of known, attainable and usable. So first that the data is known to the user, and findable. That users could find the data within an SDI. I would say that is relevant for every type of user.
S: Yes, definitely, yes.
M: And then in the category of attainable: whether a dataset is practically available. Sometimes you have an SDI with data in it, well, it looks like it has but when you click it there is only metadata for instance.
S: Yes, okay, and maybe also that the interface is not there. When there is no way to see the data. Yes, this is relevant.
M: And also that the data is affordable, but that might be less relevant for an SDI that does not offer paid data because it is in a closed environment.
S: Ah yes.

M: So I would say that that is more specific for each SDI, so I would say that that is something to discuss with developers from the WFP whether that is relevant or not?
S: Yes exactly, I agree.
M: And then that the dataset can be acquired in time, so the time spent between requesting the data and receiving the data.
S: Yes it is relevant from a crisis managers perspective, especially if you do not possess this data but you want to get it from some institution, and it might happen that the institution only delivers on working hours, that they do not have an emergency 24/7 portal for getting data. So this is very important, especially in the kind of datasets that are maintained by private institutions and companies.
M: And the next one: legal restrictions, whether the data has legal restrictions or not, including the transparency about these restrictions.
S: You should also pay attention to.. If the WFP has some agreement to receive some data from somebody, they probably signed some agreement for access to the data and which data are available to them. Probably you have to consider this, to specify what kind of SDI they have, how many levels they have, data that they have in possession and is accessible, data that they have agreements for with some other organizations, and any other data. That is also part of the SDI, but then with some limitations. And related to the transparency about the legality, this has to be really defined, what it is for and what not. But is legal the good term? It could also be on the basis of some agreement, mutual agreements or some kind of statements, could be noting the legislation. But anyhow, if you want to use just legal, it is fine.
M: And then whether the dataset is distributed in a sufficient format or service.
S: Yes, yes this is also very much relevant. Specifically related to web mapping services, web feature services are not that common.
M: The next category is about the usability of the data. First: whether the data is manageable. So easy to be integrated in your workflow.
S: This could be interpreted in different ways I suppose, it can be broken down in several categories but it is better to keep it simple and clear of course for users.
M: And then: whether the dataset is reliable.
S: Yes, yes.
M: Reliability is also related to metadata of course.
S: Exactly, yes that is important.
M: And then if data has sufficient spatial data quality. Level of detail, resolution, projection etc.
S: But this kind of information should already be in the metadata, otherwise you do not know how to guess it. If you have coordinates but do not know in which projection it is, you cannot do anything useful.
M: And the next one is whether the dataset has long-term availability, so sustainability.
S: Okay, that is okay, but it should somehow be related to how often the dataset is updated. So how up to date the dataset is. It is supposed to be in the metadata when the data is created, but the more important thing is how often it is updated.
M: Well that was exactly my next indicator so I think we can agree on that one already. So you say that those are related to each other?
S: Yes I think so.

M: All right. Another indicator is whether there is sufficient communication from the data supplier to the data. In my opinion this might be somewhat SDI specific. In the case of my case study, the SDI developers are responsible for the communication and users do not directly get in contact with the suppliers.
S: Well yeah, in many cases the data first goes to the application and then to the end-user. This is the same story as before, where the data custodians prepare data for the end-users.
M: And that the metadata and support are clear. We have already discussed metadata, but support might also be relevant.
S: Yes, this is what we have talked before about the communication, you have to have someone that explains to you what it is if you need it.
M: And then I also have some indicators for the SDI in general. First one: that the SDI increases access to more sources of information, from a user perspective.
S: That is probably true, an SDI should give easier access to more sources of information, so it is kind of always true.
M: Okay. And whether the SDI improves the users' data management.
S: It is related somehow, because if the SDI is properly organized, and you know the data, the spatial schema of the data provided, of course it helps for the user.
M: All right, and then whether the SDI shortens decision-making time.
S: But are you going to ask the people to answer yes or no?
M: Well also with these indicators, users should give a score of 1-5. So it is more of a statement where users can agree or disagree on a certain level.
S: But they have to have experience working without an SDI, it is a little bit tricky. I do not know how the people will look at it and how the people will react on it.
M: So maybe it is a suggestion to focus more on the perception of usefulness, in this case the perception that it shortens decision-making time?
S: Yes that could be..
M: So you think that it is a little bit too tricky to ask these types of questions?
S: Well if you discuss with more experienced people, they will be able to make these estimates because they have other experiences. Then they are able to say something useful. I actually did not yet hear anything about the standards, the data standards.
M: Yes I have not included this one because it did not show up in the assessment frameworks that I have used for this research, but it could of course be added to this framework. That is also what I wanted to ask as a final question, if there were some missing indicators on the list so we can discuss why it should be included. I also thought that standards might be relevant, but I cannot add it without some source.
S: Like INSPIRE, this is a very good example of standardized data, in the SDI. All on the basis of standards, what the structure of the data should be, what kind of metadata should be included. By the directive also pushing countries to maintain the data this way. So I think this is an important aspect, if you have the standards, and you know the data, it is easier for users.
M: It is in the end of course relevant for users, but do they have an influence on the development of standards? Because otherwise it should probably be more of an indicator for the developers of the SDI.
S: They have influence, because.. Especially the developers that prepare the applications for the users, if they consider that some data are too difficult to include in the application, they are not going to use it. I think it is very important.

M: Another indicator then: whether the SDI creates independence in decision-making. So that they are less dependent on other people, companies or organizations for their own decision-making tasks. Do you think that this is relevant?
S: Yes it makes sense. If it is the case that the WFP acquires some data, the users are not dependent anymore on getting these data from other organizations or governments.
M: And another one: whether the SDI improves the quality of decision-making.
S: Yes, but these kind of questions.. Do you expect somebody to say no? These are kind of questions that are difficult to collect information from them. You could also make the conclusion by yourself that if everything works, it will improve the decision-making for sure. Do you plan to compare SDIs?
M: No, just evaluating one case study.
S: Okay then it is probably not good to put it this way, you can assume that it is good for decision-making.
M: Okay and this might also be the case for the next indicator: whether the SDI increases the use of spatial data in their decision-making. But this might also be a little suggestive because it implies that more spatial data use is something good.
S: Yes, but this is also the case of what they want to do with this. This is quite subjective. What I usually see is that people want to have data, even if they do not use it. What can also be seen is that too much data can also confuse decision-making.
M: Okay. And another one is whether the SDI improves the workflow of the user. But I think this can also be related to your comment that there is no comparison with another situation without the SDI.
S: Yes, exactly. This would be useful if you talk with somebody that has done it in both ways, before and after SDI implementation.
M: Okay all right. Another indicator: that there is clear communication and support for using the SDI. This is different to the communication of the data suppliers but more for the SDI itself, so how to use it and communication about that.
S: That is very important, yes.
M: And whether the SDI organization stimulates SDI use, so some sort of capacity building.
S: Yes that is also a very important point. Trainings, education and capacity building is very important. Especially with people that do not have a spatial background.
M: Another indicator: whether the SDI increases cooperation within the organization, but this might also be difficult with the before and after situation, or would you think it is still relevant?
S: Hm yes it is okay.
M: And whether the SDI stimulates innovation and development.
S: Yes, that should be true but how can a user judge this? It is easy for us to say because we have the experience, but people that are not really spatially aware can only look at the data.
M: So it might perhaps be better to approach some users different, people that are more spatially aware and people that are not?
S: Yes exactly, that would be better. I can imagine that the WFP will also have some groups where they do something about capacity building.
M: All right and then the last one: whether the SDI presents new communication and distribution channels for the organization.

S: Hm yes.
M: You can think of the example that an SDI is used as a communication tool for external communication..
S: Yes, yes. But in general in this SDI, how does it go with crowdsourced data or other dynamic data that are created during the crisis? Is it not interesting, specifically in the context of disaster management, to have a few indicators on this kind of information? For instance, you can start receiving Twitter data, or you can receive some sensor information.
M: So you say that it should include some indicators on dynamic and/or crowdsourced data?
S: Yes definitely, because for crises this is the most important information. Even phone calls, this is also information. So think about this. This changing data, this dynamic data is very important information.
M: Okay yes, that is clear.
[Closing]